Beef Cattle Manual

Eighth Edition Revised

2023

The Oklahoma *Beef Cattle Manual* has been available since 1983. Since that time, the manual has become a key resource for beef cattle producers, Extension professionals, veterinarians and many others associated with the beef cattle industry.

The development of this comprehensive resource for beef production in Oklahoma is the result of a team effort by faculty and staff in the Division of Agricultural Sciences and Natural Resources and Extension Area Specialists. Authors who contributed to the manual are listed below along with their departmental or agency affiliation. The authors would like to express their gratitude to Hayley Eberle in Agricultural Communications Services for formatting and editing this updated manual.

Agricultural Economics
Courtney Bir
Damona Doye
Amy Hagerman
J C. Hobbs
Derrell Peel
Kellie Curry Raper
Roger Sahs

Animal and Food Science
Paul Beck
Amanda Holder
Mark Johnson
David Lalman
Bob LeValley
Gretchen Mafi
Jazmin Markey
Alexi Moehlenpah
Joao G. N. Moraes
Brian Pugh
Chris Richards
Jeff Robe
Ryan Reuter
Glenn Selk (emeritus)
Daniel Stein

Area Specialists, Oklahoma Cooperative Extension Service
Scott Clawson
Brian Freking
Greg Highfill
JJ Jones
Earl Ward
Barry Whitworth, DVM
Dana Zook

Biosystems and Agricultural Engineering
Douglas W. Hamilton
Ray Huhnke

College of Veterinary Medicine
Rosslyn Biggs, DVM
John Gilliam, DVM

Entomology and Plant Pathology
Justin Talley

Natural Resource Ecology and Management
John Weir

Plant and Soils Sciences
Jeff Edwards
Alex Rocateli

Along with the *Oklahoma Beef Cattle Manual*, OSU Extension personnel offer a comprehensive educational program for beef producers, the Oklahoma Master Cattleman program. The Master Cattleman program uses the *Oklahoma Beef Cattle Manual* as its educational guide. The objective of this program is to enhance the profitability of beef operations and the quality of life of beef cattle producers by equipping them with vital information on all aspects of beef production, business planning, risk management and marketing. Components of the Master Cattleman program include an educational curriculum and a producer certification process. See https://extension.okstate.edu/programs/master-cattleman/ for more information.

We hope that you will find the *Oklahoma Beef Cattle Manual* to be a vital component in your beef production enterprise.

David Lalman
Extension Beef Cattle Specialist

Kellie Curry Raper
Extension Livestock Marketing Specialist

EXTENSION

The information given herein is for educational purposes only. Reference to commercial products or trade names is made with the understanding that no discrimination is intended and no endorsement by the Cooperative Extension Service is implied.

Products mentioned are current at the time of printing.

Oklahoma State University, as an equal opportunity employer, complies with all applicable federal and state laws regarding non-discrimination and affirmative action. Oklahoma State University is committed to a policy of equal opportunity for all individuals and does not discriminate based on race, religion, age, sex, color, national origin, marital status, sexual orientation, gender identity/expression, disability, or veteran status with regard to employment, educational programs and activities, and/or admissions. For more information, visit https://eeo.okstate.edu.

Issued in furtherance of Cooperative Extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Director of Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. This publication is printed and issued by Oklahoma State University as authorized by the Vice President for Agricultural Programs and has been prepared and distributed at a cost of $24,075 for 750 copies. Revised 03/2023 HE.

Table of Contents

Introduction to the Industry and Beef Production

Chapter 1. Beef Industry Overview for Oklahoma 1
Chapter 2. Beef Industry Issues and the Future 9

Economic Issues

Chapter 3. Ranch Business Planning and Management 15
Chapter 4. Analyzing Financial and Production Performance 21
Chapter 5. Leasing Arrangements in a Beef Cattle Enterprise 33
Chapter 6. Business Organization and Tax Considerations 51
Chapter 7. Economic Considerations in Disaster Management 63
Chapter 8. Livestock and Forage Insurance Options 71
Chapter 9. Beef Cow-Calf Marketing 79
Chapter 10. Value-Added Marketing Opportunities 89

Forage

Chapter 11. Grazing Management 103
Chapter 12. Hay Production, Storage and Feeding 109
Chapter 13. Small Grain Forage Management 117
Chapter 14. Fire and Livestock Production 123

Nutrition

Chapter 15. The Ruminant Animal 127
Chapter 16. Nutrient Requirements of Beef Cattle 131
Chapter 17. Nutritive Value of Feeds 149
Chapter 18. Alternative Feeds 159
Chapter 19. Vitamin and Mineral Nutrition of Grazing Cattle 171
Chapter 20. Body Condition Scoring of Cows 185
Chapter 21. Supplementing Beef Cows 189
Chapter 22. Supplementing and Feeding Calves and Stocker Cattle 197
Chapter 23. Supplementation of Stocker Cattle on Small Grain Forage 207
Chapter 24. Preconditioning Nutrition and Management 219

Breeding

Chapter 25. Performance Recording Guidelines 227
Chapter 26 Expected Progeny Differences 243
Chapter 27. Management of Effective Mating and Crossbreeding Systems 253
Chapter 28. Genetics in the Genomics Era 261
Chapter 29. Development of Replacement Beef Heifers 267
Chapter 30. Management Considerations for Bulls 279
Chapter 31. Synchronizing Heats in Beef Cows and Heifers 285
Chapter 32. Artificial Insemination 293
Chapter 33. Available Options for Embryo Production in Cattle 301
Chapter 34. Choosing a Calving Season 309
Chapter 35. Calving Time Management for Beef Cows and Heifers 315

Herd Health

Chapter 36. Herd Health 325
Chapter 37. Internal Parasite Control 335
Chapter 38. External Parasites on Beef Cattle 343
Chapter 39. Implants and Their Use in Beef Cattle Production 349

Environment for Raising Cattle

Chapter 40. Cattle Handling and Working Facilities Design 357
Chapter 41. Waste Management 363
Chapter 42. Biosecurity 369
Chapter 43. Livestock Mortality Management 375

Beef Industry Issues

Chapter 44. Beef Grading Standards 379
Chapter 45. Beef Quality Assurance 385
Appendix 1. Gestation Table 407

Index 409

1 Beef Industry Overview for Oklahoma

Derrell Peel, Kellie Curry Raper and David Lalman

Objectives

- **Review demographic statistics for beef production in Oklahoma.**
- **Introduce financial performance statistics for cow-calf producers.**
- **Describe current management practices of Oklahoma beef producers.**

By the U.S. Department of Agriculture's definition, a farm is an operation with the potential to sell $1,000 of agricultural products, so it includes many small non-commercial operations. The Census of Agriculture provides benchmarks for production agriculture (USDA/NASS) every five years. The 2017 Census lists 78,531 farms in Oklahoma, the 4th largest in the U.S., accounting for approximately 3.8% of the U.S. total. The National Agricultural Statistics Service (NASS) conducts additional annual surveys that supplement census information.

In 2017, Oklahoma ranked 22nd in total cash receipts from farm marketing, accounting for approximately $7.5 billion of the $388.5 billion in sales nationally. In 2019, Oklahoma livestock and products sales were $4.5 billion, and crop sales were $1.7 billion, for a total of $6.2 billion in farm marketing (NASS). The 2017 data shows 52,048 cattle operations in Oklahoma with 46,080 beef cow operations, the third largest in the nation in both categories (Table 1.1).

Needless to say, beef production is big business in Oklahoma. Cattle and calves are consistently the first ranked commodity within the state based on value of production, accounting for more than 40% of the state's agricultural production in recent years. In 2017, Oklahoma had the sixth highest value of cattle and calves sales of $3.7 billion. Numbers for cattle and calves include cow-calf enterprises on farms, stockers on pasture and cattle in feedlots. The state ranks in the top 10 states for all cattle and calves, beef cows, feeder supply and cattle on feed (Table 1.2). Figure 1.1 shows the value of production for all cattle and calves has been more than $2.6 billion in recent years.

The record high number of cattle and calves was 6.5 million in 1975 with the record low of 82,000 head in 1867, when the data series was first initiated. Since 1975, the number of cattle and calves in Oklahoma has generally followed the industry trend downward though cattle numbers recovered sharply following severe drought in 2011-2012 (Figure 1.2).

The number of beef cows in Oklahoma has trended higher since the late 1980sv (Figure 1.3). While numbers

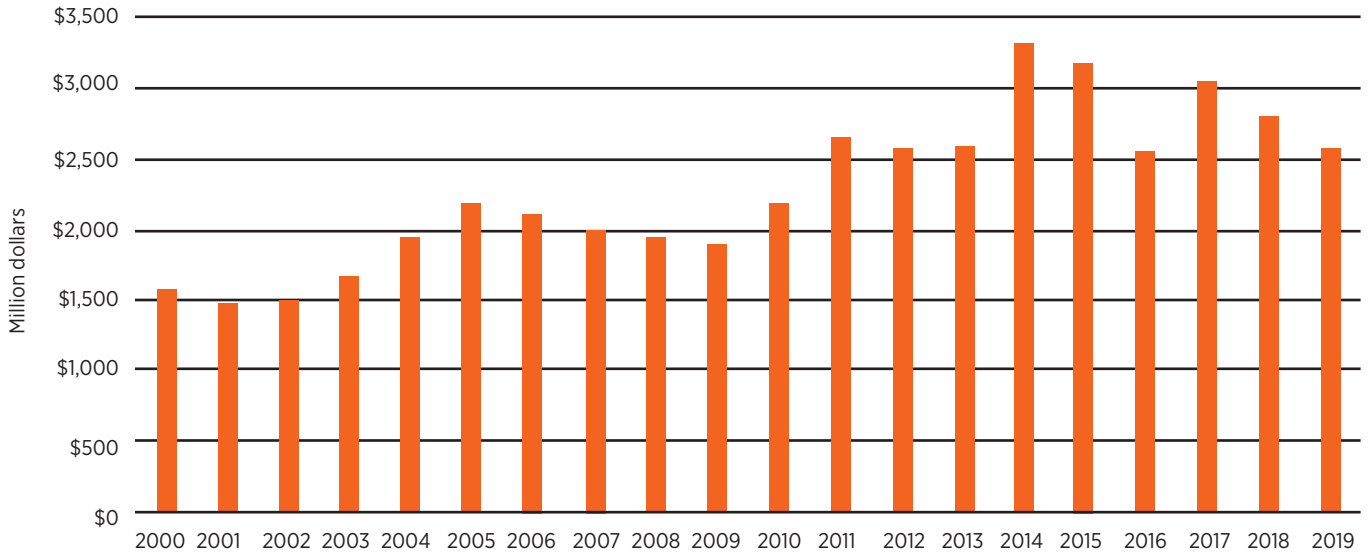


Figure 1.1. Value of production of all cattle and calves, Oklahoma. Source: USDA-NASS.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 1.1. Oklahoma cattle operations and percent of cattle Inventory by size group.*

	Total		*1 - 49 Head*		*50 - 99 Head*		*100 - 199 Head*		*200 - 499 Head*		*500 - 999 Head*		*1,000 - 2,499 Head*		*2,500+ Head*	
Year	*# of cattle operations*	*cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*	*# of cattle operations*	*% of cattle inventory*
1997	63,439	5,378,950	41,459	15	10,574	13	6,300	16	3,666	20	976	12	367	9	97	14
2002	59,155	5,324,240	38,205	14	9,550	12	6,171	16	3,699	21	1,002	13	430	11	98	13
2007	55,105	5,391,337	35,167	12	8,382	11	5,733	14	3,979	22	1,348	17	397	11	99	13
2012	51,043	4,245,970	35,181	15	7,139	12	4,439	14	2,949	21	1,007	16	255	9	73	14
2017	52,048	5,090,919	33,040	12	7,851	11	5,466	15	4,141	24	1,068	14	382	11	100	14

*Census of Agriculture, USDA-NASS.

Table 1.2. Top 10 Inventory for all cattle and calves, beef cows, feeder supply and cattle on feed, 2020

Rank	All Cattle and Calves		Beef Cows		Feeder Supply*		Cattle on Feed	
	State	Head (1,000)	State	Head (1,000)	State	Head (1,000)	State	Head (1,000)
1	TX	13,000	TX	4,570	TX	3,480	TX	2,980
2	NE	6,800	OK	2,099	OK	2,160	NE	2,600
3	KS	6,450	MO	2,083	KS	1,795	KS	2,580
4	CA (T)	5,400	NE	1,922	NE	1,700	IA	1,290
5	OK (T)	5,400	SD	1,733	MO	1,590	CO	1,120
6	MO	4,350	KS	1,433	CA	1,340	CA	540
7	IA (T)	3,900	MT	1,428	IA	1,170	SD	440
8	SD (T)	3,900	KY	1,021	SD	1,045	MN	400
9	WI	3,450	ND	995	WI	820	OK	340
10	CO	2,800	AR	915	KY	808	ID	310

* Calculated from inventory categories such as: (Steers >550 lb. + other heifers > 500 pounds + calves < 500 pounds) - cattle on feed = estimated feeder suuply, USDA-NASS.

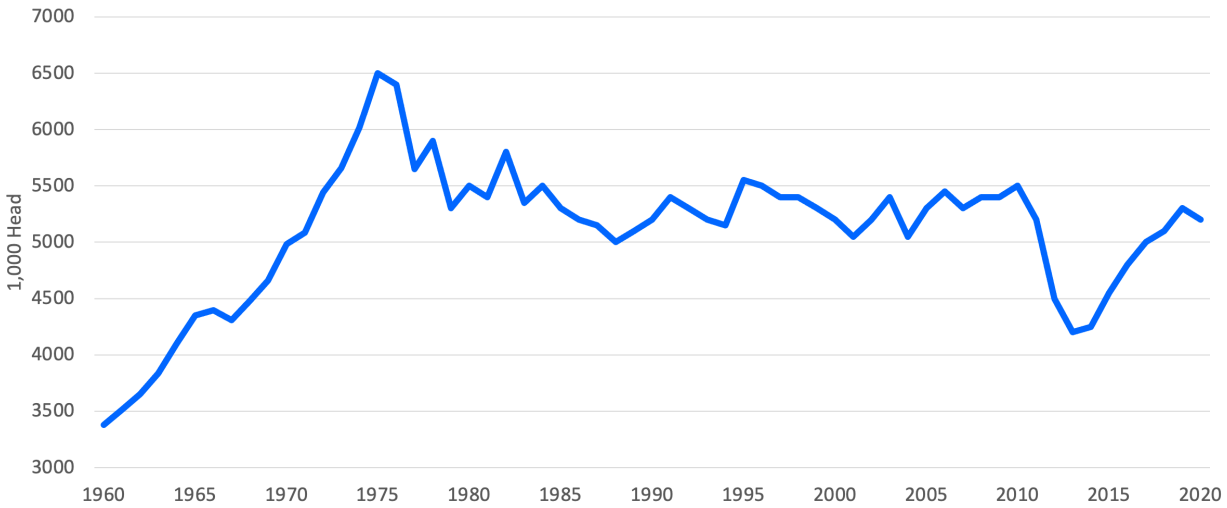


Figure 1.2. All cattle and calves in Oklahoma, 1960-2020. Source: USDA-NASS

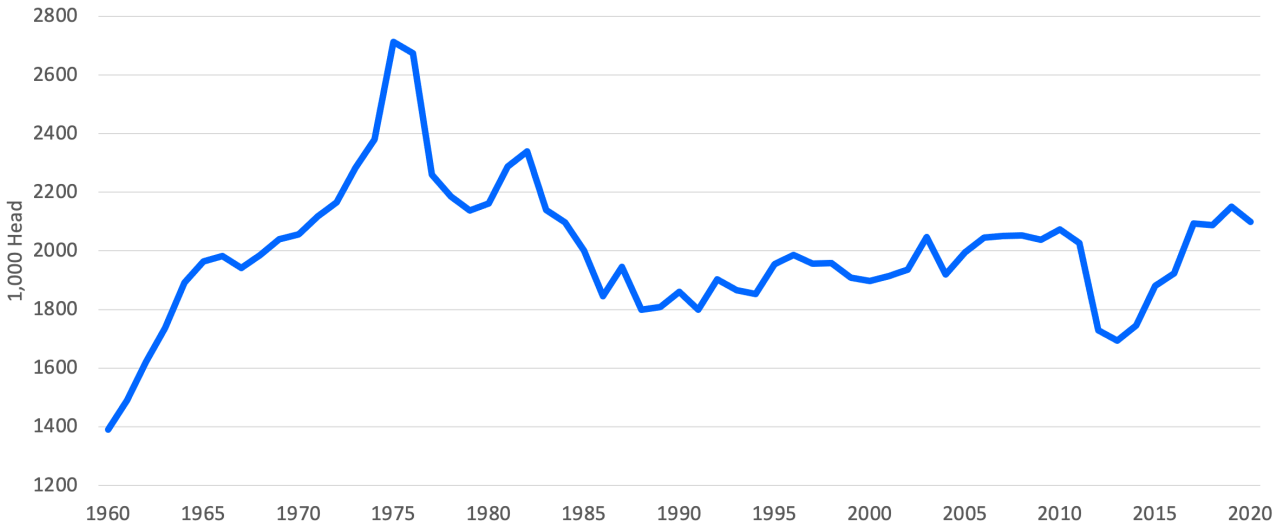


Figure 1.3. Beef cow inventory, Oklahoma, 1960-2020. Source: USDA-NASS

are down from the mid-1970s, the state averaged about 1.9 million beef cows on hand as of Jan. 1 for the past decade, recovering from the drought low of 1.7 million head in 2013 to 2.1 million head in 2020.

While beef production is big business, it also includes many small businesses, as there are many Oklahoma farms and ranches with fewer than 50 head of cattle (Table 1.1). Two-thirds of the state's 78,531 farms have some cattle. Figures 1.4 and 1.5 show the number of operations with cattle by size of operation and percent of cattle inventory by size of operation for 2017, respectively.

Statistics for farms with beef cows (as opposed to all cattle and calves) are shown in Figures 1.6 and 1.7. Most farms (74%) have fewer than 50 cows. Only 11.5% of farms have more than 100 cows. Cow numbers are more concentrated in the larger herds, with 52.3% of the cows in herds of more than 100 cows.

Financial Performance Statistics

In 2019, the Kansas Farm Management Association data listed total variable costs per cow at approximately $748 annually, with total costs at $1,088 per cow on average. Just as herd sizes vary widely, so do costs of production. Cost of production calculated by the Kansas Farm Management Association's data is sorted using profit categories. The difference between the high- and low-profit category producers is approximately $428 per cow. Differences in major cost components are highlighted in

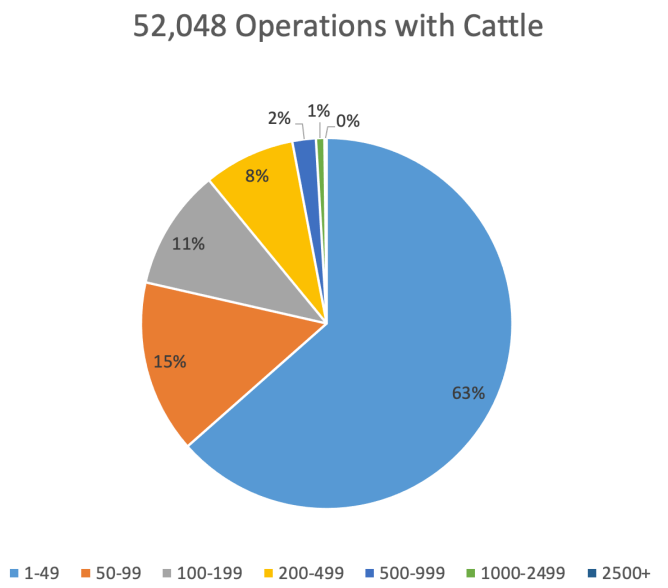


Figure 1.4. Number of Oklahoma farms and ranches with cattle by size of operation. Source: 2017 Census of Agriculture, USDA-NASS.

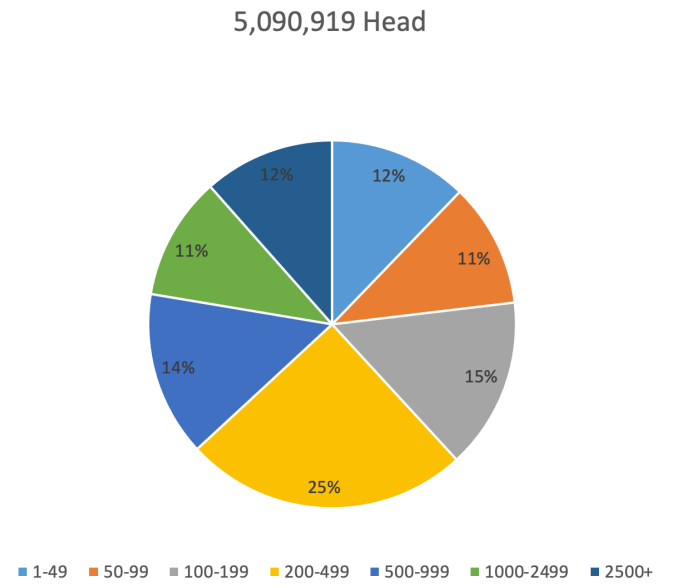


Figure 1.5. Percent of Oklahoma cattle inventory by size of operation. Source: 2017 Census of Agriculture, USDA-NASS.

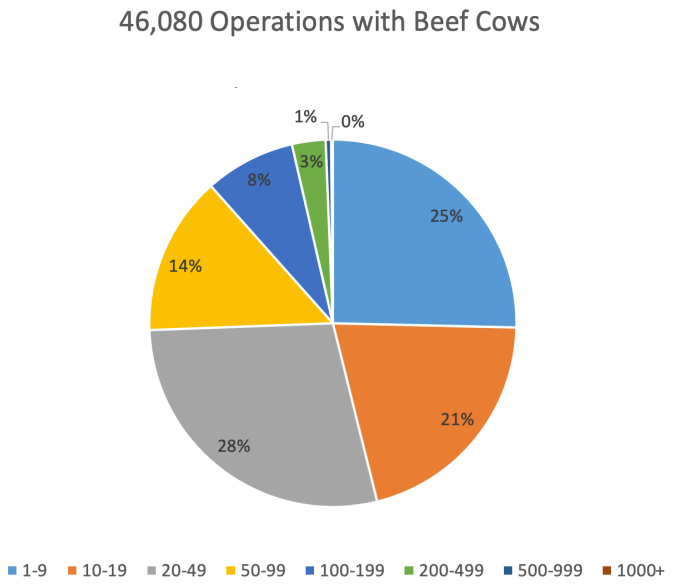


Figure 1.6. Percent of Oklahoma farms and ranches with beef cows by size of operation. Source: 2017 Census of Agriculture, USDA-NASS.

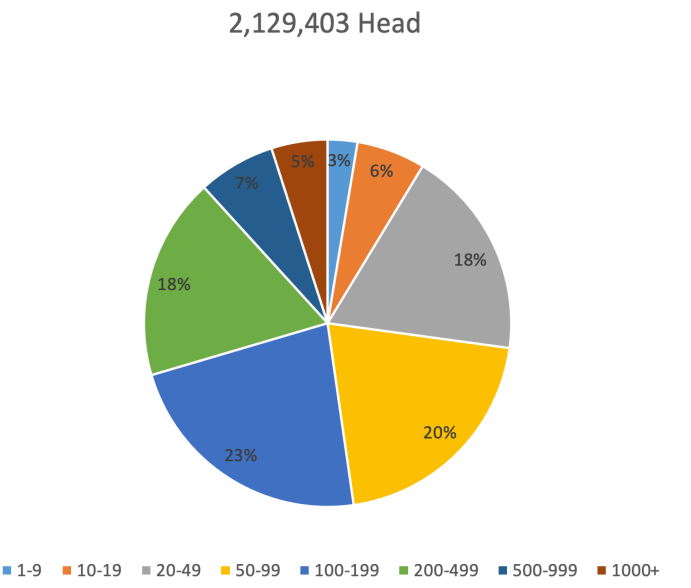


Figure 1.7. Percent of Oklahoma beef cow inventory by size of operation. Source: 2017 Census of Agriculture, USDA-NASS.

Figure 1.8. Producers with above-average net income spend significantly less in maintaining a cow and producing a calf crop than those with lower-than-average income. Producers with high profits tend to have larger herds and generate more gross income per cow.

Cost of production for small herds can be high on average. For example, as fixed costs for a vehicle and other machinery and equipment are borne by a few cows, the cost is high. However, there are many profitable herds in this group. Thus, while it may be more difficult to be profitable with a small herd, it is not impossible. Production must be monitored closely, costs must be controlled carefully and smart choices must be made with respect to investments in capital assets.

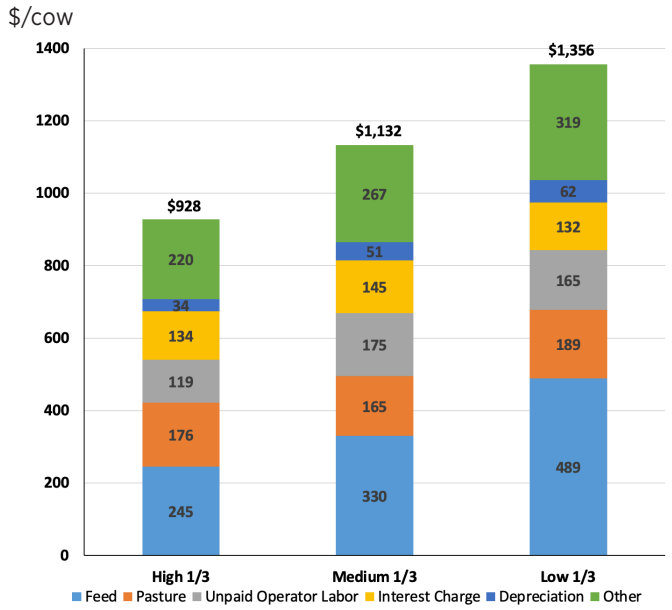


Figure 1.8. Cost of production by profit category ($/cow). Source: Kansas Farm Management Association, 2019

Management Practices

Beef production operations vary considerably in size, available resources, profitability and use of technology. Strategies to increase profitability of small and medium-sized beef cow enterprises like those most prevalent in Oklahoma are crucial to increasing the overall profitability

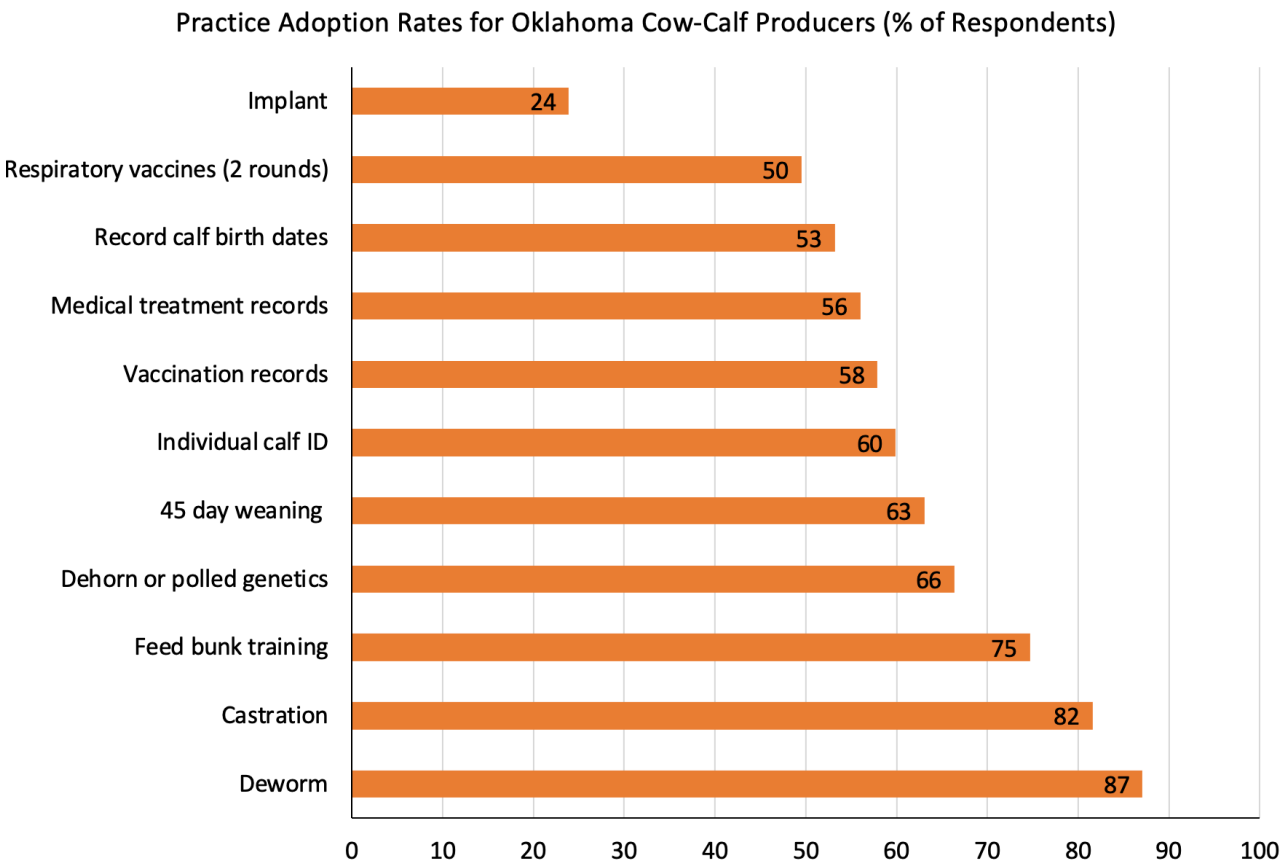


Figure 1.9. Rate of adoption by management practice. Source: Raper, Oklahoma Beef Management and Marketing Survey (2017).

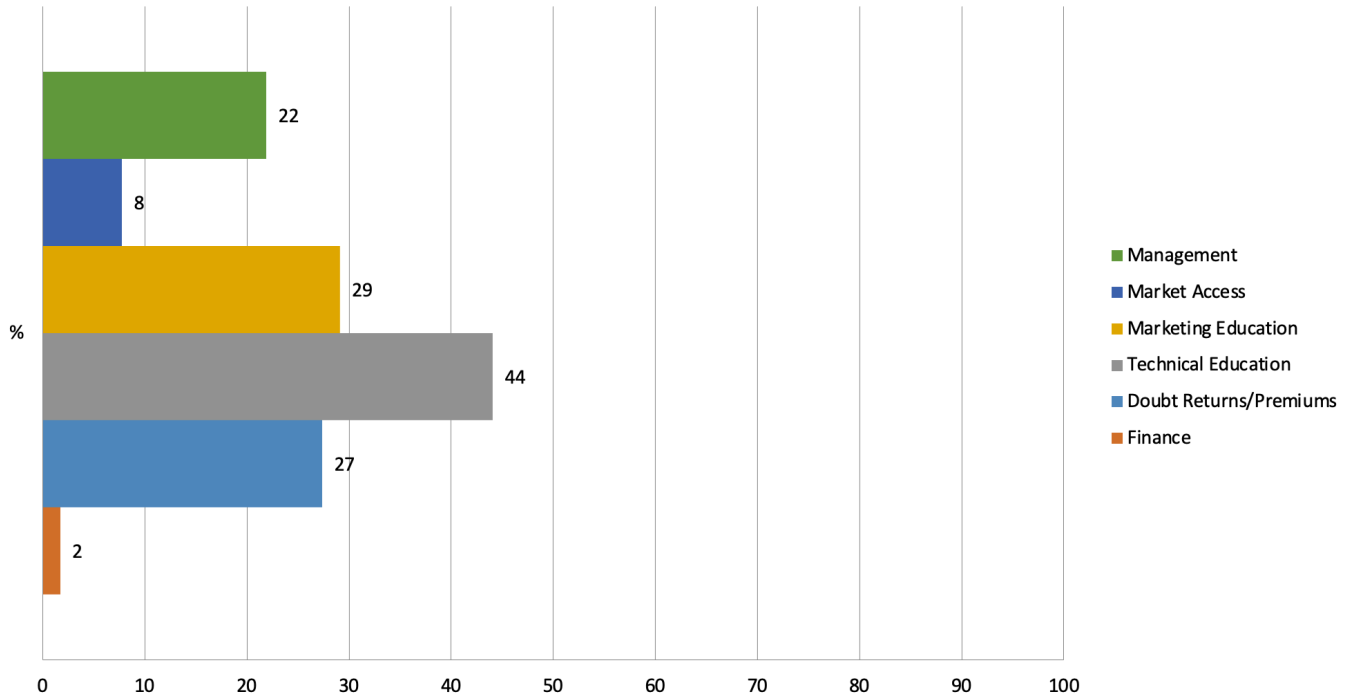


Figure 1.10. Constraints to castration (%) as identified by non-adopters. Source: Raper (2015), Oklahoma Beef Management and Marketing Survey.

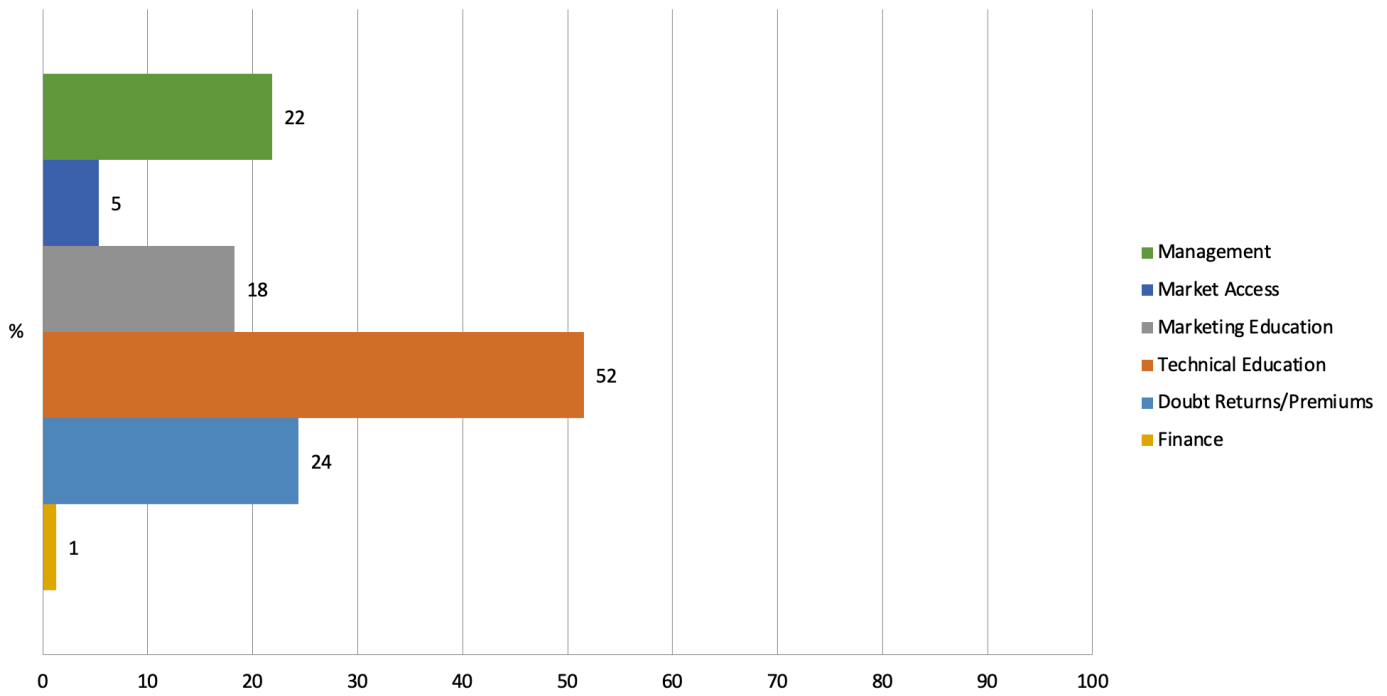


Figure 1.11. Constraints to dehorning (%) as identified by non-adopters. Source: Raper (2015), Oklahoma Beef Management and Marketing Survey.

of the industry. Following recommended best management practices as encouraged by research-based OSU Extension educational programming can help producers both manage costs and generate more gross income per cow. Recommended management practices are based on scientific analysis. According to Ward et al. (2008), cow herd management practices, such as a limited period breeding season and limited use of harvested forages, are generally more cost-effective than alternative strategies and enhance profitability, but adoption among Oklahoma cow-calf producers is inconsistent at best. For example, data provided by Oklahoma producers indicated that only 34% effectively have a defined breeding season (OBBM Survey). Examples of recommended management practices for calves include retention of calves on the ranch for a significant period after weaning and respiratory and other vaccinations, with ample on-farm time post-vaccination prior to marketing – practices that, when bundled together, are known as preconditioning. Science indicates calf health and calf performance is improved by these practices as calves move through the supply chain.

Economic studies have shown that buyers value these practices enough to pay higher market prices for such calves, relative to similar calves without these backgrounds (Williams et al., 2014). However, producers do not always adopt recommended management practices. Figure 1.9 indicates that non-adoption among Oklahoma producers is high across many recommended practices for calf health management and marketing (Williams et al., 2013).

Schumacher, Peel and Raper (2017) reported producer-identified constraints to adoption often includes a lack of technical knowledge or doubt in the returns for practice adoption. For example, producers with herds of 50 to 99 head are more likely to doubt returns from a 45-day weaning period than other herd sizes. Recently, survey and marketing data has identified adoption of castration and implantation, two very specific management practices proven to add value at relatively low cost and to increase efficiency in cow/calf operations, have been on the decline. Raper (2015) reports 44% of respondents who did not castrate bull calves prior to marketing indicated a lack of technical education was a constraint to implementing castration in their cow-calf operation (Figure 1.10). For producers who do not dehorn calves prior to marketing, 52% indicated technical education was a constraint (Figure 1.11).

Increasing adoption rates of basic recommended management practices in beef production increases market access for small- and medium-sized farms, particularly as producers begin to bundle various management practices together, such as the bundle of on-farm calf health management practices known as preconditioning. The implications for future calf health and quality make those calves more attractive to buyers and increase the probability of premiums (Williams et al., 2014). Adoption of basic recommended production and management practices for cow herds can decrease input costs and increase the economic viability of Oklahoma's beef industry.

References

Kansas Farm Management Association, 2019. Enterprise Reports. agmanager.info/KFMA/ Accessed August 13, 2020.

Raper, Kellie Curry. "Producer-Identified Constraints to Preconditioning Feeder Calves." State-wide Livestock Economics In-Service, Stillwater, Oklahoma. February 11, 2015.

Schumacher, Stephanie, Derrell S. Peel and Kellie Curry Raper. ""Demographic Influences on Nonadoption of Calf Management and Marketing Practices for Cow-Calf Operations." *Journal of Applied Farm Economics* 1(2), Article 3. 2017. Available at docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1012&context=jafe.

USDA, National Agricultural Statistics Service, (2012). Census of Agriculture. Table 28: Beef Cow Herd size by Inventory and Sales. nass.usda.gov/Census/

USDA, National Agricultural Statistics Service, Oklahoma Department of Agriculture. Oklahoma Agricultural Statistics Bulletin. (Various Years) nass.usda.gov/Statistics_by_State/Oklahoma/Publications/Annual_Statistical_Bulletin/index.asp

Ward, C.E., M. K. Vestal, D.G. Doye, and D.L. Lalman. 2008. "Factors Affecting Adoption of Cow-Calf Production Practices in Oklahoma." *Journal of Agricultural and Applied Economics*, 40(3):851-863.

Williams, Brian R., Eric A. DeVuyst, Derrell S. Peel and Kellie Curry Raper. "The Likelihood of Positive Returns from Value-Added Calf Management Practices." *Journal of Agricultural and Applied Economics* 46(1):125-138. February 2014

Williams, Brian R., Kellie Curry Raper, Eric A. DeVuyst, Derrell Peel, David Lalman, Chris Richards, and Damona Doye. "Demographic Factors Affecting the Adoption of Multiple Value-Added Practices by Oklahoma Cow-Calf Producers." *Journal of Extension*, Volume 51-6 (December 2013): Article 6FEA7. Accessible at joe.org/joe/2013december/pdf/JOE_v51_6a7.pdf

2 Beef Industry Issues and the Future

Derrell Peel

Objectives

- **Identify a set of broad, fundamental issues likely to be the foundation of the majority of industry discussions.**

Any industry as large and diverse as the U.S. beef industry has a constantly changing stream of issues occupying industry attention at any point in time. It is impossible to anticipate the array of short-term issues that will preoccupy the industry in the coming years. This chapter will identify a set of broad, fundamental issues likely to be at the root of the majority of industry discussions in one fashion or another for the foreseeable future. Such a discussion of fundamental industry issues is particularly appropriate at the time of printing. The U.S. beef industry seems to be at a crossroads with respect to the future, and the next five to 10 years are likely to be a time of rapid change, as much as the last five years have been.

The U.S. Cattle and Beef Industry is Extremely Complex

Considering changes that are occurring or will occur in the coming years, it is important to keep in mind the economic challenges inherent in the beef industry. The U.S. beef cattle industry ranks as one of the most, if not the most, complex industries in the world. Recognition of this reality is important to help producers, industry leaders and policy makers understand the need for, as well as the difficulty of, the changes facing the industry.

Disassembly and Product Diversity

The beef industry produces thousands of different products, all of which originate from a diverse set of individual animals. Many of these products are part of related sets of markets from which value must be determined and in which value depends not only on the product, but also the entire set of products in the market at a given point in time. Thus, the value of an individual animal depends both on its quality characteristics and competing sets of products at the time it is marketed, including all other animals marketed at that time. This is made more complex by the joint product nature of beef production. Every animal represents a basic set of products produced simultaneously. Although fabricating styles and further processing can modify the set of beef products from an animal somewhat, it is fundamentally impossible to produce a loin without also producing a chuck and a round. Many beef products are highly substitutable for other beef products, so the market must simultaneously optimize value over the entire set of beef animal products.

Perishability

Most of the products described previously are highly perishable, which further increases the industry's challenge to provide a stable supply of the set of products desired by consumers. Perishability is most obvious with meat products, but animals are constantly growing and changing in quality, which means live animals, as well as meat products, are appropriately viewed as perishable throughout the production and marketing period.

Geographic Diversity of Production

Beef cattle are produced in all regions of the country, in a wide variety of physical and climatic environments and using a wide variety of feed and production resources. This production diversity promotes additional quality variation in animals and increases the spatial complexity of beef markets. The right way to produce beef and production in each region must balance the economic forces of location, climate and resource availability.

Seasonality of Production and Consumption

Beef cattle production is inherently tied to annual cycles of feed and forage production, thus the market must contend with seasonal patterns of animal availability and age/size demographics influencing animal and meat quality. Moreover, consumer demand is seasonal as well, with climatic- and calendar-influenced variations in quantity and types of meat demanded. Production and consumption seasonality combine to form a complex set of seasonal price patterns

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

with different effects on various cattle and meat markets.

Dairy Industry Influence on Beef Production

Dairy product markets dictate the structure and management of the dairy industry. However, production of meat is a co-product of dairy production, and this has a significant influence on beef markets. Roughly half of annual cow slaughter and about 20% of total beef production is derived from dairy animals. Often, the economic signals for dairy and beef markets are different, causing the two beef meat sources to influence meat markets in conflicting ways. In some instances, the beef cattle industry will have to compensate for dairy industry influences that are contrary to meat market conditions, thereby adding more variability and complexity to beef industry adjustments.

Many Final Markets

The vast array of beef products produced by the industry is a complex set of final markets. The three major beef markets are retail grocery; food service, also known as hotel, restaurant and institution (HRI); and exports. Each of these market types represents a different set of market characteristics and therefore, demands for different profiles of the total set of products.

Biological Influence

Cattle production, like much of agriculture, is dependent on the interaction of the biological process and climate to ultimately determine the quantity and quality of production. The biological realities of cattle production also represent additional complexities for the industry. Long production lags (16 months to 20 months to sexual maturity; nine months gestation; eight months to weaning; six months to 12 months growing and finishing) result in pronounced market dynamics as producers attempt to adjust production to changing market conditions. Biology dictates the stock of breeding animals from which production is made and the level of production must both come from the same inventory of animals. Because there is a one-to-one relationship between changes in breeding animal inventory and changes in production, attempts to expand production in the future first require a direct reduction in beef meat supply to increase future productive capacity. Likewise, desires to reduce production result in an immediate increase in beef meat supply as breeding animals are liquidated and the meat becomes part of commercial supply. This is one of the reasons the beef industry tends to exhibit cycles of prices and production through time.

Multiple Stages of Production and Marketing

The beef industry is somewhat unique in having multiple stages of production to produce a single product—a finished animal ready for slaughter. Cow-calf, stocker and feedlot stages often are done in different locations and with changes in ownership. This means the beef industry historically has relied to a great extent on market prices to coordinate the level, timing and quality of animal production. This is a huge burden on a single price signal. Moreover, the stocker and feedlot stages represent a combination of basic production values plus marketing values, including much of the market's need for assembly, storage and transportation of animals.

Variable Production Systems

The ruminant physiology of cattle makes them uniquely suited to utilize a wide variety of feed resources for production. Cattle are less efficient at utilizing grain for meat production than swine and poultry. This makes beef inherently more expensive than pork or poultry meat. The beef industry maintains relative cost competitiveness because cheaper forage is utilized in early animal production stages to offset higher grain cost for finishing cattle. This use of forage is central to the economic viability of the beef industry. However, some use of grain in cattle production is vital to produce the quality of meat demanded by consumers in the U.S. market. Thus, the beef industry has considerable flexibility to use varying combinations of grain and forage and therefore is able to adjust production systems according to variable market conditions. This represents both an opportunity and a challenge. Changes in the relative values of grain and forages give beef more ability to maintain competitiveness by adjusting production systems. However, doing so requires complex market signals to simultaneously coordinate the activities of multiple stages of production and marketing.

From Commodity Industry to Product Industry

Today's U.S. beef industry really emerged after the Civil War. For most of this 150-year history, the beef industry primarily has operated as a commodity industry, especially at the live animal production level. Producers mostly were focused on production and only indirectly concerned themselves with market demand forces. Although the industry has marketed an increasingly diverse set of products for many years, for the most part, the marketing system primarily was concerned with maximizing the value of the products presented by producers and producers received only crude price signals that did more to change production levels than to change the quality profile of the set of products. Everyone produced what they wanted, when they wanted and the marketing system attempted to find value for those products.

The industry has made great progress in improving production and marketing efficiency, especially during the last 40 years. The industry today is producing more pounds of beef per cow than any other previous time. This is a result of enhanced production efficiency in each of the production subsectors. Better genetics, better management and new technology in the form of growth promotants, feed additives and new drugs and vaccines all have contributed to productivity improvements. However, these gains in productivity have resulted from optimizing within a subsector. For example, producers have utilized better genetics to increase animal size and growth rates with relatively little consideration, at least until recently, of the meat quality or market composition of resulting products. The result has been a tendency

to overemphasize production characteristics relative to consumption characteristics. Producers have responded very well to incentives. Unfortunately, those incentives have been focused largely on pounds of production rather than meeting consumer demand for particular sets of products with specific qualities. The industry's inability to incorporate consumer qualitative and quantitative preferences into beef production systems was a major contributor to the 20-year erosion of beef demand from the late 1970s to the late 1990s.

Since 1999, there has been evidence the erosion of beef demand has reversed. Rapid change has generated much discussion and, in some cases, concern among producers. It appears the cattle and beef industry is dealing with a variety of issues simultaneously, impacting the entire production and marketing system. Economic forces are directing the industry to behave as a unified industry, instead of a set of related but independent subsectors. Optimizing the industry as a single system requires modifications in production and marketing systems compared to practices that optimize individual subsectors of the industry. These questions go beyond what an individual firm in the industry can do alone and imply the need for individuals in the industry to participate in changes sweeping the industry. In short, these changes imply more market coordination in the industry. These changes clearly have been underway for several years and the evolution likely will accelerate for another five to 10 years.

To realize the market potential for an increasing array of differentiated beef products and marketing channels in domestic and international markets, the industry must develop and utilize more precise value signals. These signals must not only influence beef product marketing, but also must focus production to provide the correct set of animals to increase the total market value of the resulting products. For example, to the extent that consumers prefer Choice quality over Select quality, the market must provide incentives not only to produce more Choice, but also to produce fewer Select animals so Select meat is not occupying a spot at the retail counter where Choice is really preferred. Increases in Choice and Prime beef percentages in recent years indicates the industry has responded to value signals in beef markets.

The move from a commodity orientation to a differentiated product orientation for producers carries with it a host of changes and implications and perhaps the loss of cultural elements and traditional comfort zones. For many producers, these changes represent a threat to cherished lifestyles or, at least, considerable frustration as they try to adapt to new ways of thinking and doing business. Whether or not the industry is comfortable with some of the changes, the alternative to moving forward is declining consumer demand and erosion of market share that would continue to reduce the size of the industry. Continued changes in consumer lifestyles and economic status with both domestic and global markets, combined with increased competition and innovation within protein markets, strongly suggest that maintaining the status quo is not a viable option. A differentiated, product-oriented beef industry presents new opportunities and increased potential like no other time in the history of the industry.

Industry Issues

The sections that follow discuss three broadly defined drivers of change that likely will play a major role in the industry in the coming decade:

- Value-based production and marketing of differentiated products.
- Food safety and food quality assurance.
- Global markets and international trade.

These are not new issues; indeed, they have been at work in the industry for several years. The industry has changed considerably, especially in the last five years, but it seems clear more change is ahead. In addition, this chapter includes discussions of two topics that, while not the sources of change themselves, will be critical in shaping how the industry reacts to and evolves in the face of the changes confronting the industry. These two areas include 1) the idea of traceability, which will broaden to eventually encompass things such as animal ID and country-of-origin labeling (COOL) and 2) the power struggles, legal wrangling and political maneuverings that currently divide and undermine the industry.

Value-Based Production and Marketing

There seems to be little doubt beef markets will continue to increase value by targeting products to increasingly specialized markets and developing an increasing array of differentiated products. Beef markets represent a wide variety of products of varying quality for a multitude of different uses. Maximizing value to consumers means producing the proper set of products that serve the intended uses at the lowest cost. This implies a continued and growing need for value signals to reach producers earlier and for production to be targeted to specific final markets. Producers will receive price signals and perhaps non-price signals that are ever more specific to produce certain products and not produce certain products.

Several other trends can be inferred from the growth of differentiated product markets. Product uniformity will take on an enhanced role in the future. Value is not only a matter of the quality of individual animals, but also the predictability and consistency of quality in sets of animals. Additionally, the role of commodity grades and standards will change. With less reliance on the rather coarse system of value distinction that worked well in the past, there will be a need for more detailed determination of value characteristics. Firms will augment commodity grades with proprietary systems of quality grading and product standards. In some markets, it is likely private product brands largely may replace government grades as consumer indicators of value.

The enhanced value of differentiated products consists of providing specific and consistent product quality, plus achieving and maintaining a high level of quality assurance for consumers. Added value occurs when consumers find products that meet specific needs. That value increases over time as consumers develop trust in the reliability and consistency of the

products. In many cases, such quality assurance may require additional information about the production process such as source and process verification. Firms in the production and marketing chain may require such information internally and in some cases, this information is communicated directly to consumers. In an increasing number of instances, consumers are demanding information beyond what is readily apparent in the product characteristics such as assurances about the source or process by which products are produced. Production and marketing systems will include or exclude specific practices as dictated by the particular market. These will include the use or non-use of certain production technologies, production practices, such as animal welfare standards and production systems, such as natural or grassfed. Markets such as natural beef or organic beef likely will grow, but will remain niche markets. Major restaurants and institutional buyers will increasingly require certification of things such as humane animal production and processing standards.

The tendencies identified above have a number of implications for cattle producers. In general, producers need to better understand the market and identify their role in a differentiated product market. Unlike commodity markets, identifying and targeting beef production to specific markets will be important. The change from commodity to differentiated products implies two very important changes for producers: loss of anonymity and commitment. Historically, producers have been able to produce what they want, in the manner they want and market such production anonymously in a vast commodity system. Consumer preferences were felt only indirectly and often with long delays. In a world of differentiated products, there is not only less value in such production systems, there is less and less opportunity for such to remain economically viable. Many producers feel shackled and/or threatened by the growing need to form business relationships or alliances that commit them to specific production where consequences of failure to meet those commitments will be directed back toward them.

The evolution to a differentiated product market will continue to influence market structure in the beef industry. Value-added production and marketing implies increased use of non-price coordination. In many instances, arms-length transactions based on a single price signal are simply not sufficient to provide the quantitative and qualitative information needed. This is not to say that market signals in the form of prices will not be used. Price signals will continue to play an important role and will discriminate product values to an increasing degree. Increased coordination may occur in a variety of ways, including vertical integration by ownership, contractual arrangements or alliances based on a system of information sharing. Economic forces that have pushed the industry to fewer and larger units will continue and will impact the industry at all levels of production and marketing to various degrees. Simultaneously, there will continue to be concern over the potential negative consequences of changing market structure and a need to monitor industry performance.

Food Safety and Food Quality Assurance

More basic than the marketing considerations described in the previous section are the underlying food safety and food quality assurances critical to any food industry. Quality assurance is used here to refer to the system of regulations that maintain consumer belief food is produced and marketed in a fundamentally safe manner. Although related to the previous section, food quality assurance here is concerned primarily with the role of government regulatory systems and inspections to assure the basic safety of food products. The marketing considerations of the previous section depend and build on the underlying consumer confidence in food safety.

The industry faces several challenges related to health and safety in the coming years including ongoing issues of *E. coli* and Bovine Spongiform Encephalopathy (BSE). There is growing evidence that pathogenic *E. coli* levels can be influenced by management systems. While past systems have relied on processing protocols and sanitation to reduce contamination, management systems to reduce the occurrence of *E. coli* are likely to be needed in the future. This will require a determined and coordinated effort by all industry sectors to reduce the presence of *E. coli* in beef products.

BSE clearly is an issue for the global beef industry and a loss of consumer confidence could have enormous impacts. Human and animal health issues are not one-time events, but rather part of the ongoing market environment. It is imperative both government and industry work proactively to identify, quantify and manage human health issues in a forthright manner. In the case of BSE, where the scientific knowledge of the disease is limited, it is critical to commit additional resources to understanding the disease. As understanding of the disease increases, the industry must adapt and adjust production, marketing and the regulations guiding those activities.

The U.S. beef industry is one of the largest in the world, and the U.S. is one of the largest beef importers and exporters. The U.S. beef industry has much at stake in a world where rapid global transportation means human and animal disease threats can travel the globe at unprecedented rates. More intensive and concentrated production and processing facilities handling large volumes make the potential impacts of disease outbreaks more devastating. Biosecurity needs in production and processing facilities will grow in order to maintain food safety and manage human and animal health risks.

The threat of bioterrorism further increases the risk to the industry and to cattle and beef markets. Animal industries are inherently vulnerable to deliberate introduction of animal disease agents that could cause economic havoc in the

U.S. beef market. Political terrorism resulting from global geopolitical sources may evolve from activities using violence targeted toward people to pure economic terrorism, which systematically targets specific components of the economy. The U.S. food supply is clearly a strategic economic target. Moreover, a number of domestic and international groups opposed to animal production in general or to modern intensive production systems constitute a potential threat of economic sabotage and terrorism.

Global Markets and International Trade

International markets for beef products have grown sharply in recent years and have considerable potential for further growth. Several fundamental forces are behind the growing global potential for meat in general and beef specifically. In part, this potential is the result of a natural tendency for agricultural markets toward trade in value-added products rather than basic commodities. Trade in beef products represents value-added trade relative to trade in bulk grains. Each pound of beef exported is equivalent to exporting several pounds of grain.

A second basis for growing beef trade is that much of the potential growth in global beef demand resides in developing countries and is strongly tied to economic growth in those markets. Domestic agriculture in developing countries usually is preoccupied with meeting basic nutritional needs and often is focused on production of basic commodities. As economic resources grow, consumer demand commonly includes higher proportions of high-density animal proteins to replace lower-quality vegetable proteins.

Finally, trade in beef products is economically based on comparative advantages in production and different relative demands for beef products in different countries. Vast differences in the quantity and quality of beef production in different countries imply tremendous opportunities for gain as countries trade beef products to meet different relative demands for specific products.

The coming years likely will see considerable change in both demand, as market potential develops in countries such as China and supply as production potential grows in countries such as Brazil. Growing international trade offers considerable potential for the U.S. beef industry. However, it also implies greater market dynamics and increased risk of volatility as the market is increasingly subject to diverse economic and political shocks in various countries. The U.S. cattle and beef industry must develop agility to quickly understand and adapt to rapidly changing global market conditions.

One final important point should be recognized with regard to international trade of beef products. It was noted earlier the value of beef production in the domestic market depends on matching products to the specific demands of consumers. International trade is a significant means of enhancing domestic demand for beef by exporting those products less desired in the U.S. and importing those products where there is a relative shortage in U.S. international trade. Therefore, it is not only a means of augmenting total demand for U.S. beef products with additional export demand, but also a means of increasing domestic demand by optimizing the product mix in the domestic market.

Traceability and Animal Identification

One of the fundamental differences in value-added markets compared to commodity markets is product differentiation. Although beef animals vary considerably in quality, the lack of ability to trace those differences through the production and marketing system has forced the industry to operate as a commodity industry and establish values based on system averages. This has been a principal limitation of the industry throughout its history. Differentiating products requires changing the entire production and marketing system simultaneously and has not been feasible in the past. However, it appears very likely the industry will continue to move quickly in the coming years toward full traceability of all animals and products.

Virtually all of the issues previously discussed have implications for traceability. Increased need for animal health and food safety assurance has provided the thrust for a regulatory role in implementing an animal identification (ID) system to trace beef production and marketing. Both likely will be encompassed in an information system that facilitates enhanced animal health management, product source verification and identifies other value attributes.

Development of a system of animal and product traceability represents the principal hurdle for the beef industry to realize the values and needs for value-added production and marketing, food safety and quality assurance, and global market potentials described above. A fully traceable beef industry represents the leap from the historically commodity-based industry to a differentiated value-added product industry. Also, it represents a major crossroads in the evolution of the beef industry.

As a key component in the development of a value-added beef industry, traceability also implies major changes in the way producers must think and act in the industry. Traceability means producers no longer have the anonymity characteristic of commodity industries. Traceability implies not only more regulatory oversight, but more importantly, more economic oversight as the market directs value signals much more precisely and specifically back to producers. Traceability means that once and for all the illusion of a producer's independence to produce what they want, how they want and when they want is gone. The market will demand more commitment from producers and will force more accountability on producers. For many producers, this prospect is a frightening change in an industry characterized by many cherished traditions and a culture that has historically valued the lifestyle at least as much as, and sometimes more than, the business of cattle and beef production. Many producers currently feel considerable frustration and helplessness in the face of these changes. These producers face much soul-searching as they grapple with whether or how to embrace these changes and adjust to them.

Internal Disputes and Industry Politics

The changes the industry will continue to face in coming years have led to a great deal of controversy and animosity. The longstanding suspicion and mistrust between vertical sectors of the industry have boiled over into political and legal wranglings between subsectors and among producers within various sectors. In recent years, factions within the industry have launched political agendas and lawsuits, representing a significant threat to the industry. Many producers, feeling frustrated and threatened by the changes in the industry, have been drawn into a variety of simplistic but unrealistically narrow agendas and proposed solutions to industry issues. Many volatile issues characterized by emotion-laden charges of economic conspiracy, rampant monopoly power and breakdown of competitive markets are really symptoms of underlying economic forces pushing the industry to evolve into a modern food industry.

The industry has undergone tremendous change since the late 1990s and inevitably faces more structural change in the coming years. As the industry stabilizes, it is likely to emerge with a very different look and feel than what exists today. The temptation to preserve the status quo with political and legal solutions carries with it the significant threat to cause even greater damage from which the industry must ultimately rebuild. The damage, if not permanent, may certainly be long-lived. One-size-fits-all political or legal solutions are unlikely to be appropriate in an industry so vast and complex and, in many cases, will impede the industry's ability to compete in domestic and international markets and needlessly delay inevitable industry adjustments. It may be asking too much for producers to ever trust packers but it is absolutely critical that the two industry segments recognize the common interests they have and the need for each other to survive.

Conclusion

The industry faces unprecedented opportunities in the next decade with the potential for the first time to truly emerge as a modern food industry. Such opportunities, however, carry with them significant implications for changes in the way the industry is organized and in the way business is conducted. Many producers will continue to feel frustrated and threatened until they are able to decide exactly how they will participate in the beef industry.

3 Ranch Business Planning and Management

Courtney Bir

Objectives

- **Review ranch business plan components: mission and goals; key planning assumptions; operations;organization and management; financial plan; control and records.**
- **Review components of the financial plan.**
- **Identify key business planning and management resources for producers.**

Investing in a ranch is an expensive undertaking and can be financially stressful, particularly for beginning operations. Land ownership in particular is costly. Historically, rates of return to agricultural assets average 4% to 5%, making it difficult to make principal and interest payments on land notes with farm income only. Hence, business planning is especially important in ranching operations, even if the decision to produce beef is a lifestyle choice rather than strictly an economic one.

Few people leave home on a trip to an unfamiliar destination without a plan. They want to know where food, gas and lodging might be available and when they will arrive at their destination. Business planning provides that type of guidance for the ranch. A well-developed plan for the ranch business includes defining goals, understanding limitations and having sound production and financial plans. A comprehensive plan matches livestock to the land resources; identifies appropriate markets for products; and anticipates daily, monthly and annual operations.

Business planning helps the beginning rancher evaluate the feasibility of a proposed venture and helps established producers identify areas for improvement. It identifies financial resources needed for both the ranch investment and annual operating costs. Financial planning and analysis may uncover previously unconsidered opportunities or limitations. It helps ensure investors make decisions based on realistic data, rather than emotions. In addition, the business plan is an important reference for individuals seeking financing and provides the background needed by advisers to assist with problems. The business plan should include:

- Mission or vision statement and goals.
- List of key planning assumptions.
- Market analysis and marketing plan (more in chapters 9 and 10).
- Description of operations, organization and management.
- Financial plan.

Written plans are recommended because writing forces serious thought in the planning process and provides a reference for periodically checking for progress. Business planning is not a one-time event, but rather an ongoing process. Producers may think, "But I just want to own a few cows." If savings are used to finance an investment in a ranch, or the ranch is expected to support a family, completing a business plan helps ensure financial expectations are realistic.

Developing a mission statement and setting goals helps identify why the business exists and what it will achieve (even if it primarily is to serve as a hobby). The mission statement should reflect values and describe what the business will be and what it will accomplish. The mission statement should describe the business purpose (products and services provided) and qualities. This statement provides the basis for developing long-run plans, building from goals and objectives.

Goals can be tangible and intangible; short-term and long-term; and monetary and non-monetary. Because achieving goals often requires the cooperation of family, goal setting should involve discussion and compromise among family members. Goal setting may be used to both anticipate problems and plan strategies for overcoming them. Do not ignore potential conflicts or restrictions that might prevent goals from being reached. Identifying possible problems in the planning stage will allow time to either resolve conflicts or refocus on feasible objectives. Be reasonable in setting goals, use the best information available and include all decision makers in the process. List the family and ranch resources (land, labor, financial capital, other capital assets and management) available for the ranch. Identify planning restrictions and constraints, if any. Spell out what will be produced and where the product will be marketed.

Once the vision, mission and goals of the operation are clearly defined, the next step is to determine how to manage operations efficiently and effectively to move the business in the desired direction. The plan for operations

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

requires the manager to have a good understanding of beef and forage production, marketing, finances and risks facing the business, all of which are addressed in more detail in other chapters in this manual. OSU Extension fact sheet AFS-3261 *Beef Cow Herd Calendar* may be a helpful guide in building a yearly plan for operations and anticipating monthly needs for decision making. The herd calendar highlights differences in timing for decisions relative to fall and spring calving herds.

If more than one person will be contributing labor, management or other resources, it is important to define the roles of each individual in the business. If the ranch is a large operation, an organizational chart should be developed indicating where decisions will be made along with a list of duties and responsibilities of personnel. In addition, identify the most appropriate legal arrangement: sole proprietorship, partnership, corporation, etc. and develop plans for compensation and allocation of profits.

Records provide the means to measure business performance. It has been said, you can't manage what you haven't measured. Records provide facts about the business, forcing plans to be grounded in reality. Records also allow producers to meet legal obligations, support loan applications and arrange for insurance coverage. A complete recordkeeping system includes both financial and production records.

Records also form the basis for the financial plan. The financial plan should include initial financial requirements, historical and projected financial statements, enterprise analysis, risk assessment and break-even analysis. To complete the financial plan, well-formulated ideas about goals, operations and expected markets are needed. Potential investors, including lenders, will be concerned about both financial feasibility and profitability. In other words, will the cash flow from the operation be sufficient to repay loans and pay bills in the short run? Will returns earned in the long run be sufficient to replace breeding livestock, machinery, equipment and other depreciable assets, while also contributing to family living or otherwise rewarding the manager?

Components of the Financial Plan

Initial Financial Requirements

Cow-calf investment costs depend on the size of the herd, whether land and livestock are being leased or purchased, how many acres per cow are required, what type of cattle are purchased (commercial or purebred) and whether supplemental feed and hay are raised or purchased. Table 3.1 summarizes sample costs of establishing a 100-cow herd, assuming no improvements such as fences, roads and watering facilities must be added. If land is purchased along with a minimum set of machinery and equipment to care for the cow herd, the investment may exceed $20,000 per cow. If land is rented rather than purchased, the investment may be dramatically reduced to $3,000 per cow (the annual operating costs would increase to include pasture rental costs). Please note that ownership in hay equipment is financially feasible only for large-scale hay producers or producers doing custom work.

Table 3.1. Ranch investment cost summary.

	No.	*Units*	*$/unit*	*% to cow-calf*	*$/cow*
Cows	100	Head	2,400	100	2,400
Bulls	3	Head	3,600	100	108
Pickup	1		28,000	50	140
Tractor with bale fork	1		30,000	25	75
Equipment			1,500	100	150
Native pasture	1,000	Acres	1,750	100	17,500
Barn	1		40,000	75	300
Total					**$20,673**

Source: Doye.

It is unlikely returns to a cow-calf operation will pay principal and interest on land purchased with borrowed money. This is why: Say 100 acres of grass purchased for $2,000 per acre will support 10 cows. If the buyer can make a 20% down payment and a lender is willing to loan the remaining balance ($1,600 per acre) at 6% interest with repayment taking 20 years in annual installments, the annual principal and interest payment will be approximately $140 per acre.

Table 3.2 shows annual payments for alternative interest rates and loan amounts, assuming repayment will take 20 years. Increases in interest rates or reductions in the repayment timetable would increase the annual loan payment. Since the cow needs 10 acres of forage (it may be more or less depending on geographic region), it means $140 per acre x 10 acres = $1,400 per cow devoted to loan repayment. That is a hefty task, given other production costs and potential income limited to the sale of one calf per year.

Enterprise Analysis

Analysis of ranch financial data suggests that for nearly half of producers, the cow-calf enterprise is a drain on equity rather than an income-generating enterprise. In an enterprise with seasonal and cyclical price changes, sensitivity to variable grain and hay prices and vulnerability to drought, it is important to do both of the following:

1. Adopt appropriate management practices.
2. Do things right, in particular controlling costs.

Circumstances with which the producer has no control can wreak havoc in the short term if a producer neglects strategic planning and risk management.

Table 3.2. Annual loan payments with alternative loan amounts ($/acre), interest rates, a 20-year repayment period and a 20% down payment.

Land price ($/a)	*Loan amount ($/a)*	*Interest rate*		
		5%	*6%*	*7%*
1,000	800	64	70	76
1,500	1,300	96	105	113
2,000	1,600	128	140	151
2,500	2,000	161	174	189

Source: Doye.

Budgets help identify production and financial risks and opportunities for risk management. Budgeting allows producers to evaluate options before committing resources. Budgets also can be used to estimate potential income and the farm size needed to earn a specified return or to compare the profitability of two or more systems of production. Budgets provide the documentation necessary to project cash flows and obtain/maintain credit-worthiness. Budgets can be used to estimate the amount of rent that can be paid for land or machinery.

A cow-calf enterprise budget is a statement of what generally is expected from a set of particular production practices, listing the expected revenue and expenses incurred. It is designed to show profitability, not cash flow. The enterprise budget shown in Table 3.3 lists anticipated costs of operating inputs plus fixed costs (interest, depreciation, taxes and insurance) on machinery, equipment and livestock, along with expected production per cow. Since the budget documents variable and fixed costs, it is useful in calculating profitability and break-even values and the potential return on an investment.

Two general types of costs make up the total cost of producing any farm commodity: variable costs and fixed costs. Variable costs change with the decision about how

Table 3.3. Cow-calf budget, 100 cows raised, Payne County in central Oklahoma, 1,000 acres, rented at $17.50 per acre. Used machinery complement, 25% heifer replacement rate and primary forages – native and 120 days of hay and supplement.

	Wt.	*Unit*	*Price/cwt. ($)*	*Quantity*	*$/Head*	*Total $*
PRODUCTION						
Steer calves	524	lbs	$163.00	41.82 hd	$357.37	$35,737
Heifer calves	514	lbs	$148.00	16.82 hd	$128.10	$12,810
Cull cows	1,150	lbs	$60.00	20.00 hd	$138.00	$13,800
Cull replacement heifers	825	lbs	$135.00	5.00 hd	$55.69	$5,569
Cull bulls*	1,750	lbs	—	1.00 hd	—	—
Total receipts					**$679.16**	**$67,916**
OPERATING INPUTS						
Pasture		hd	$260.00	1	$260.00	$26,000
Hay		hd	$63.17	1	$63.17	$6,317
Protein supplement		hd	$60.78	1	$60.78	$6,078
Minerals and salt		hd	$12.26	1	$12.26	$1,226
Vet services/medicine		hd	$13.62	1	$13.62	$1,362
Vet supplies		hd	$6.84	1	$6.84	$684
Marketing		hd	$8.36	1	$8.36	$836
Mach/equip fuel, lube, repairs		hd	$30.30	1	$30.30	$3,030
Machinery/equipment labor		hrs	$15.00	3.35	$50.25	$5,025
Other labor		hrs	$15.00	5.90	$88.50	$8,850
Other expenses		hd	$5.00	1	$5.00	$500
Annual operating capital		$	7.00%	417.74	$29.24	$2,924
Total operating costs					**$628.32**	**$62,832**
Returns above total operating costs					**$50.84**	**$5,084**
FIXED COSTS						
Average value of machinery/equipment complement				$35,000		
Proportion charged				40%		
Machinery/equipment						
Interest at		$	7.00%		$9.31	$931
Taxes at		$	1.00%		$2.44	$244
Insurance		$	0.85%		$1.13	$113
Depreciation		$			$21.79	$2,179
Livestock						
Interest at		$	7.00%		$85.53	$8,553
Taxes at		$	1.00%		$14.33	$1,433
Insurance		$	0.85%		$10.39	$1,039
Depreciation		$			$15.95	$1,595
Land		$/acre	$1,500.00			
Interest at		$	0.00%		—	—
Taxes at		$	0.00%		—	—
Total fixed costs					**$160.87**	**$16,087**
Total costs (operating + fixed)					**$789.19**	**$78,919**
Returns above all specified costs					**$(110.03)**	**$(11,003)**

* Three purchased bulls per 100 cows are assumed with a 20% culling rate and cull sales income from one bull assumed to equal to its salvage value. March calving, 87.3 %; calf death loss; 4.2%.

Source: OSU Enterprise Budget Software, 2019.

many units of the enterprise to include in the operation. Variable costs are the costs of inputs used in a production period. Examples include feed, fuel, seed and supplies. Fixed costs are those expenses that will be incurred regardless of whether the enterprise is produced. Examples include depreciation, interest, insurance and taxes on buildings and machinery. Fixed costs are associated with breeding livestock, buildings, machinery and equipment and should be prorated throughout the useful life of the asset. Fixed costs are not affected by short-term enterprise decisions and do not vary with the level of production.

Costs that are difficult to allocate to individual enterprises (telephone, tax and accounting services, electricity, etc.), some of which may be variable and others fixed, are called overhead costs. Overhead costs are included in whole farm/ranch budgets, but are sometimes excluded from enterprise budgets.

In the budget in Table 3.3, the return above total operating costs is positive and indicates the operation is able to contribute to fixed costs associated with capital asset ownership. Returns above all specified costs represents residual earnings to land, management and risk. Each individual must decide whether a positive return is sufficient reward for management skills, risk exposure and land devoted to the enterprise. If the return above all costs is negative, supplemental income will be needed. Software at OSU is available to develop a budget customized for an operation (agecon.okstate.edu/budgets).

Building on budgets to determine break-even prices or yields and view sensitivity analysis is helpful in evaluating the financial risk associated with an enterprise. The break-even price is the price at which all costs will be covered, given average production; the break-even yield is the level of production needed to cover all costs, given average market prices. Break-even prices and yields above variable costs and above all costs provide useful information. With sensitivity analysis, income variability due to price and production risk is demonstrated, typically with tables of numbers showing returns under different price and yield scenarios. This information helps the managers assess their willingness to assume the risk of these variations.

Historical and Projected Financial Statements

Financial statements are used for determining business financial performance and planning future financial strategies. Farm records are the basis for developing these statements. Historical financial statements document what has happened in the past; projected financial statements are forward looking and reflect expectations for the future. Although financial statements serve as references for outside investors such as lenders, their greatest value is to the owner/manager in documenting both financial performance and position. Measures showing the ability of the business to pay bills as they come due (liquidity), the value of assets relative to debt (solvency), efficiency, debt repayment capacity and the ability of the business to survive in the long term (profitability) all are important. OSU offers a series of fact sheets (available at extension.okstate.edu) to explain and demonstrate financial statement development, so only brief overviews are provided here.

A **cash flow statement** shows whether there is a surplus or deficiency of cash in an accounting period, typically one year. Historical cash flow statements document seasonal patterns for cash flow and suggest when cash may be available for debt payment. While past cash flows are a good reference for building spending plans, they may be supplemented with information from enterprise budget projections. Reviewing the cash flow plan relative to actual cash flow during a year provides feedback as to whether the business is on track to achieve financial goals. Noticing expenditures in excess of the plan provides an opportunity to make management changes before problems get out of hand. The cash flow plan also is an excellent communication tool for use with a lender.

A **balance sheet** (or net worth statement) is a summary of asset and liability valuations and is one of the most used measures of business financial position. The value of what is owned (assets) less what is owed (liabilities) is the owner's equity or net worth. In other words, it is what is left after satisfying the claims of others to assets. If owner equity increases each year due to profits being reinvested (and not just appreciation in asset values), wealth is increasing and financial progress is positive. Lenders are particularly interested in balance sheet documentation of the market value of assets that serve as collateral for loans.

A **farm inventory** lists all physical assets at a specified date, including the values of all assets or property and the value of all debts or liabilities. A list in a notebook or simple spreadsheet can be used to maintain an inventory of assets and liabilities. A beginning and ending inventory for the accounting year are needed for accurate calculations of net farm income. Taking an inventory involves two processes: examining physical assets and assigning values to the assets. OSU Extension offers two fact sheets that can assist in the process of recording asset and liability information, AGEC-791 *Schedule of Assets* and AGEC-792 *Schedule of Liabilities.*

An **income statement** combines information from the cash flow statement with changes in inventory and valuation of assets and liabilities from the balance sheet. The income (profit or loss) statement evaluates whether the business is profitable. Net farm income shown on the income statement is a measure of the return to equity and unpaid labor and management.

Analysis of financial statements and calculation of financial ratios reveal the strengths and weaknesses of the operation. With this information, the farm manager is able to identify ways to enhance financial performance.

Financial Records

Records are the foundation for accurate budgets, financial statements and tax reports. While tax reporting is the primary motivation for recordkeeping for many producers, research has shown positive returns to investments in recordkeeping and analysis in support of farm and ranch decisions. A variety of tools are available to assist producers in keeping financial records. Computerized recordkeeping systems are affordable and especially useful for manipulating data for different types

of reports. Although a computerized system may not reduce the amount of time spent keeping records, computerized records make financial summaries simple, more efficient and effective for management needs. For instance, an annual or monthly cash flow statement based on actual income and expenses can be generated in a matter of seconds. Income and expenses can be sorted by enterprise so that farm managers know where profit centers are on the farm. Whole farm or enterprise budgets can be prepared and compared to actual transactions so financial progress can be monitored at regular intervals. Graphs prepared with a few keystrokes can show where cash is coming from and where it is going and are valuable in getting a quick feel for the farm's financial situation.

A number of user-friendly commercial software products are now available that can be adapted for farm use. One such software program appropriate for farms and ranches requiring only cash records is Quicken®. Quicken® is user-friendly, widely available and inexpensive. More information on using Quicken® for farm financial recordkeeping is available from the OSU Department of Agricultural Economics at agecon.okstate.edu/quicken. Producers who need a payroll system plus the ability to invoice and maintain accounts payable and receivable may want to use QuickBooks®, or a comparable small business double-entry accounting system. Family expense cash-flow features and investment tracking are lacking in QuickBooks®.

Hand recordbooks are available through the OSU Extension and from many lenders. The OSU Agricultural Economics website agecon.okstate.edu/farmbook offers a book from which individual pages are available to be printed as needed.

Records show that the best decision-making occurs when financial measures are developed annually from the records and care is taken to be consistent in how the measures are developed. Managers will want to note reasons for unusual measures, such as drought and use the information to identify areas for improvement.

Using the Business Plan

The business plan only will be useful if it is used routinely throughout the year. Part of the manager's control process and feedback on performance will be through comparisons of the plan to actual income and expenses. A good practice is to develop a spending plan and compare the spending plan to actual cash flows at least twice per year. This means cash records must be kept on an ongoing basis. Asset and liability inventories should be updated at least annually and more frequently for some types of operations. Finally, at the end of the year, an **accrual-adjusted income statement** should be developed to assess profitability (as opposed to cash flow or net income for tax purposes). For a more well-rounded view of the financial position and performance of the operation, conduct an annual **farm financial stress test** consisting of 16 performance measures recommended by the Farm Financial Standards Council. Some of the performance measures are described in chapter 4, "Analyzing Financial and Production Performance."

Conclusion

The business plan serves as a road map for the ranch. Development of a realistic and complete plan helps ensure managers make informed decisions and unpleasant surprises are minimized.

If outside financing is required, the business plan will go a long way to help secure the funds needed. Business management requires producers to focus on financial management as much as production performance.

Developing and maintaining a current business plan ensures that the focus is on business. Nonfarm small businesses maintain cash records on an ongoing basis, develop inventories of assets and liabilities and update them annually, maintain a spending plan, compare the spending plan to actual cash flows regularly and develop accrual-adjusted income statements at least annually. Ranchers interested in being profitable should expect to do no less.

References

DiGiacomo, G., R. King and D. Nordquist (2003) Building a Sustainable Business: A Guide to Developing a Business Plan for Farms and Rural Businesses. Minnesota Institute for Sustainable Agriculture and The Sustainable Agriculture Network. sare.org/Learning-Center/Books/Building-a-Sustainable-Business

Doye, D. (2013) From Cash Records to Cost of Production. Extension Fact Sheet AGEC-242, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. (2013) Budgets: Their Use in Farm Management. Extension Fact Sheet AGEC-139, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. (2013) Farm and Ranch Stress Test. Extension Fact Sheet AGEC-237, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. (2013) Farmers in Transition: Evaluating Options for Change. Extension Fact Sheet AGEC-208, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. (2014) Quicken for Farm Financial Records. Extension Current Report CR-324, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. and R. Sahs (2015) Ownership of Machinery versus Custom Harvest. Extension Fact Sheet AGEC-240, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. and R. Sahs (2013) Using Enterprise Budgets in Farm Financial Planning. Extension Fact Sheet AGEC-243, Oklahoma Cooperative Exten-sion Service, Oklahoma State University.

Doye, D. (2013) Information Systems for Oklahoma Farmers. Extension Fact Sheet AGEC-302, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. and R. True (2015) Liabilities Schedule. Extension Fact Sheet AGEC-792, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. and R. True (2013) Schedules of Assets. OSU Extension Fact Sheet AGEC-791, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. (2013) Evaluating Financial Performance and Position. Extension Fact Sheet AGEC-790, Oklahoma Cooperative Extension Service, Oklahoma State University.

Doye, D. and R. True (2013) Developing a Balance Sheet. Extension Fact Sheet AGEC-752, Oklahoma Cooperative Extension Service, Oklahoma State University.

OSU Enterprise Budget Software. agecon.okstate.edu/budgets/

Shipman, L., D. Doye and R. True (2013) Developing an Income Statement. Extension Fact Sheet AGEC-753, Oklahoma Cooperative Extension Service, Oklahoma State University.

4 Analyzing Financial and Production Performance

Kellie Curry Raper, Scott Clawson and David Lalman

Objectives

- **Discuss important production and financial benchmarks.**
- **Identify tools available to facilitate performance analysis.**
- **Discuss strategies for improving operations.**

Ranchers often get caught up in day-to-day activities and spend little time assessing overall performance. They may even rely on tax returns for information about how the business is doing financially, though tax returns are seldom a reliable indicator of overall financial performance. In fact, disastrous profitability problems can go undetected for years if Schedule F tax forms serve as the sole source of information about ranch financial performance. Even simple ranch activities like retaining additional heifers or backgrounding a set of calves past the end of the year could distort the Schedule F and misrepresent the financial picture of the operation. Regular and consistent performance analysis can help the ranch manager:

1. Identify areas where the ranch business has excelled as well as opportunities for improvement.
2. Make more informed decisions relative to marketing, investment, production and risk management.
3. Formulate goals and monitor progress toward goals.
4. Compare the ranch investment performance to other alternatives.
5. Develop employee incentive programs.
6. Monitor and control costs.
7. Establish the competitiveness and profitability of the total business as well as individual enterprises.
8. Evaluate present resource use and identify areas for change.
9. Meet information needs of multiple owners, lenders and/or advisers, so their knowledge and skills are used more effectively.

Analyzing performance for only one year will not allow the producer to do all of the above. Regular analysis through time helps producers build a base for better management decisions and improved profitability, as well as develop new ideas for recordkeeping. With several years of analyses, producers can monitor improvement in financial and production statistics to verify progress made and get a truer picture of the ranch's performance and potential. In addition, a great deal of personal satisfaction and reward is gained by the increased understanding of the business. Accurate financial and production records are essential for meaningful analyses.

The Kansas Farm Management Association data referenced in chapter 1 is a source of cow-calf finance benchmark data (agmanager.info/kfma). A second source of information about performance in cow-calf enterprises is the Southwest Standardized Performance Analysis (SPA) database (agecoext.tamu.edu/programs/management-programs/beef-cattle-standard-performance-analysis-spa/). Cow-calf SPA software was developed by producers, Extension staff and National Cattlemen's Beef Association Integrated Resource Management Committees to analyze production and financial performance jointly. A third source is FINBIN, a farm financial database housed at the Center for Farm Financial Management at the University of Minnesota (finbin.umn.edu). FINBIN provides analysis for multiple states and for multiple agricultural and livestock enterprises, including beef cow-calf, stockers, replacement heifers, feeding, backgrounding and others. For cow-calf producers, the most important use of benchmark data is in monitoring key statistics through time, such as cost per breeding cow and pounds weaned per exposed female. Average financial statistics for 2012-2016 in dollars per cow and dollars per cwt ($ per cwt) of weaned calves for cow-calf producers in Oklahoma, Texas and New Mexico who participated in SPA analysis and for Nebraska and Missouri producers who participated in FINBIN analysis for those periods are summarized in Table 4.1 and Figure 4.1. At time of printing, these dates represented the most recent SPA analysis, though more should be available soon. More recent years for comparison to Nebraska and Missouri producers are available in FINBIN and Oklahoma herds are now being added. Comparisons also can be made across herd sizes within the FINBIN tool.

Less recent data from SPA analysis compared high-profit producers and low-profit producers. Data from the 2009-13 SPA (not shown here) found high-profit producers' (producers whose profit per cow ranks in the top one-third) average cost of production was $588 per cow compared to $998 per cow for low-profit producers during that time period—a difference of about 40%. The high-profit producers' average cost of production was $117 per cwt. compared to $243 per cwt. for low-profit producers for

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 4.1. Cow-calf producer financial and production performances for Texas, Oklahoma and New Mexico producers, 2012-2016 and Missouri and Nebraska producers, 2019

Performance Measure	SPA Analysis TX, OK & NM 2012-2016	FINBIN Analysis MO & NE 2019
Percent return on enterprise assets	(ROA)	
Cost Basis	7.49%	
Market Value	5.79%	
Break-even economic cost of weaned calf ($/cwt)	191	148
Total investment per breeding cow (cost basis, $/cow)	270	327
Total grazing cost ($/cow)	130	86
Total pre-tax costs ($/cow)	906	877
Net pre-tax income, after withdrawals ($/cow)	110	-16
Pregnancy percentage (based on pregnancy tested herds)	89.8	94.2
Calving percentage	87.8	89.7
Calf death loss	3.2	3.9
Weaning percentage	84.4	84.9
Average weaning weight (lbs)	447.9	490
Pounds weaned per exposed female	444.3	416

Source: SPA Data, TX-OK-NM, 2012-2016 (agecoext.tamu.edu/wp-content/uploads/2013/08/SW-KeyMeasuresSummary.pdf)
FINBIN Data, Missouri & Nebraska, 2019, Generated 8/12/2020 (finbin.umn.edu)

Figure 4.1. Cow-calf production costs, NM/OK/TX, 2012-2016 annual average and MO/NE 2019 average, ($/cow)

that same period. The break-even cost figures ($ per cwt) indicate that even with relatively low calf prices, high-profit producers are positioned to make money (or lose very little). On the other hand, low-profit producers may need to draw on other income sources to support the cow-calf enterprise even when cattle prices are high. The rate of return on assets on a market basis for high-profit producers at 5.9% is comparable to returns that might be earned in an off-farm investment such as a stock market index fund. Negative returns on assets for lower profit, producers suggest that funds invested in the cow-calf operation could be more profitably invested elsewhere.

Historically, analysis of SPA data has shown costs of production are highest on average for herds with fewer than 50 cows and lowest for herds with more than 1,000 cows. This is evidenced in the FINBIN data as well. While small herds can be profitable, it requires superior management and diligence to control costs. Low-profit producers typically have more debt per cow than high-profit producers.

Historically, the most profitable producers have had higher pregnancy, calving and weaning percentages plus higher weaning weights, leading to more pounds weaned per exposed female than low-profit producers. From 2009-2013, the average weaning weight in the most profitable herds was 555 pounds compared to 499 pounds in the low-profit herds for ranches who participated in SPA data analysis. This pattern also is evident when reproductive success is accounted for at weaning. Average pounds weaned per exposed female are were 465 pounds for the more profitable herds compared to 413 pounds for low-profit operations. From 2009-2013, average weaning weights as well as pounds weaned per exposed female, were higher for high-profit producers than low-profit producers, suggesting high-profit producers do a good job with production while controlling costs.

Some producers assume increasing calf weaning weights ensures increased profitability for the cow herd. The cow-calf manager must determine the appropriate level of mature size, milk, muscle and growth for an individual herd. Matching these traits to the available production resources as well as striving for uniformity of size has favorable management consequences. Beef producers must use information on genetic relationships between mature size, milk, muscle and growth traits to select replacement heifers and control cow costs. For example, selecting for increased yearling weight and muscularity to an extreme may result in mature cows that are too large. With limited forage and feed resources, this cow type may not have acceptable reproductive success. This result impacts earnings as well as cost per breeding cow. To be a sustainable operation, breeding stock selection must consider resource limitations that impact the optimal genetic characteristics. Other production and marketing practices also are important in generating high gross income and, ultimately, profitability. For instance, selling larger lots of calves rather than individual calves and castrating bull calves help generate higher prices. Best marketing practices are discussed in more detail in chapters 9 and 10.

Beef Production and Reproduction Measures

Accurate cattle inventory records for the fiscal year or other time period are essential for analysis. Inventory

items are necessary for the breeding, pregnancy testing (if applicable), calving and weaning measures. A key figure needed for production and reproduction measures is the number of females exposed for breeding. The number of exposed females is adjusted for various transfers of females throughout the production cycle. The adjusted number of females exposed is used for many performance measures. Death loss and replacement rate information also are needed. A count of all calves weaned (steers, heifers and bulls) is required. Beginning and ending dates for the various production seasons are needed (breeding, pregnancy testing, if conducted, and calving and weaning).

The evaluation of reproductive efficiency requires analysis through an entire production cycle. The cycle begins when the females are exposed at the start of the breeding season. It ends when the calves conceived during the breeding season are weaned. Production cycles will overlap, since females are exposed prior to weaning a calf from the previous cycle. When reporting reproductive efficiency measures, the analysis applies to the year the calves are weaned. For example, the data for a herd calving in spring 2020 would be based on the number of females actually exposed in 2019.

Pregnancy Percentage

Pregnancy percentage is an indicator of breeding performance in the herd. This measure has more meaning if it is kept by female age group, since rebreeding may be a problem for certain age groups.

$$\text{Pregnancy percentage} = \frac{\text{Number of females exposed diagnosed as pregnant}}{\text{Number of females exposed}} \times 100$$

Accurate computations require the following adjustments to the number of females actually exposed during the breeding season:

1. Subtract the number of exposed pregnant females sold or transferred out between breeding and pregnancy diagnosis.
2. Add the number of exposed females or pairs purchased for the herd between breeding and pregnancy diagnosis. Include purchased females (pairs) diagnosed as pregnant or exposed. Do not count purchased females (pairs) that are open.
3. Keep death losses of exposed females in the exposed female numbers. Females intended to be culled and sold but remain in the exposed female herd during the breeding season are subtracted from the exposed number when sold.

Some cautions about the pregnancy percentage measure are:

1. Use this value only in comparisons of similar operations.
2. A low value may indicate a problem, but it does not explain the cause of the problem.
3. Environmental stresses will cause year-to-year variation in the pregnancy percentages.
4. This value applies only to production systems that routinely diagnose pregnancy.
5. Adding exposed females may influence the pregnancy percentage.

Calving Percentage

Calving percentage is a good indicator of breeding performance and gestational management in the herd. Percentages may have more meaning when computed by female age group, such as first-calf heifers.

$$\text{Calving percentage} = \frac{\text{Number of calves born}}{\text{Number of females exposed}} \times 100$$

Accurate computations require deriving the number of females exposed and the following two adjustments:

1. Subtract the number of exposed pregnant females sold or transferred out between breeding and calving.
2. Add the number of exposed females or pairs purchased between breeding and calving.

Note: *All term calves born should be included in the number of calves born, even if they are stillborn.*

Again, the calving percentage only should be used in comparing similar operations. The measure may indicate an existing problem, but it does not pinpoint the cause. Environmental influences may cause a year-to-year variation in calving percentage. Also, the percentage does not describe the distribution of calving birth dates during the calving season.

Calf Death Loss

Calf death loss statistics can shed light on the herd health, nutrition and breeding programs and calving environment.

$$\text{Calf death loss based on exposed females} = \frac{\text{Number of calves that died}}{\text{Number of females exposed}} \times 100$$

$$\text{Calf death loss based on calves born} = \frac{\text{Number of calves that died}}{\text{Number of calves born}} \times 100$$

Calf death loss should include any calves lost at birth plus any calves that died prior to weaning. Again, deriving the number of females exposed is critical.

The type of operation—extensive versus intensive—should be considered when comparing calf death losses across herds. Likewise, the age make-up of the cow herd should be considered in any across-herd comparison. Finally, the calculations do not distinguish between calf death loss at birth versus death loss during the suckling period. More detailed records may be justified in cases of high calf death loss to determine the cause of premature deaths.

Calf Crop or Weaning Percentage

Calf crop percentage is one of the most important measures of production performance because it measures the reproductive rate of the herd. Calf crop percentage also may indicate the adequacy of the nutritional program, since reproduction is influenced by nutrition. In addition, this percentage may provide some insight on how well cows are matched to their production resources. The computation for calf crop percentage is:

$$\text{Calf crop weaning percentage} = \frac{\text{Number of calves weaned}}{\text{Number of females exposed}} \times 100$$

To accurately compute calf crop percentage, adjust the number of females exposed during the breeding season:

1. Subtract the number of exposed pregnant females sold or transferred out of the herd between breeding and weaning.
2. Add the number of exposed females or pairs purchased between breeding and weaning.
3. Subtract the number of calves purchased and grafted on females from the number of calves weaned.

Additional points to note:

1. All death losses of exposed females should remain in the number of exposed females.
2. Females intended to be culled and sold but remain in the exposed female herd during the breeding season should be subtracted from the exposed number when sold.
3. The exposed females intended to be bred, but are later culled when diagnosed as open must remain in the exposed number.
4. Do not include purchased grafted calves that are nursing cows in the number of weaned calves.

As with other performance measures, comparisons are valid only between herds with similar calving season management systems and environments. While the calf crop percentage is a good indicator of total herd output, nutritional adequacy and husbandry practices, it does not account for excessive use of inputs (feed and nonfeed).

Calving Distribution

Monitoring calving distribution within the calving season can provide insights into the reproductive performance of the herd. Tracking calving distribution is simply keeping track of when in the calving season a cow calves. Typically, this is done by splitting the calving season into thirds and tracking which cows calve in each third. For example, in a 90-day calving season, track how many total and which individual cows calve in days one through 30, 31 through 60 and 61 through 90. Ideally, a large portion of the herd would calve in the first third of the calving season. This would indicate strong management and reproductive performance. The calves from cows that calve early tend to provide benefits to everyone in the supply chain, from heavier calf crops to increased carcass and maternal performance. For more information, see beef.unl.edu/calves-born-first-21-days-of-calving-season.

Actual Weaning Weights

Actual weaning weights are usually evaluated by individual management or contemporary groups, such as steers, bulls, heifers or creep fed and non-creep fed calves. Actual weaning weights are not standardized to a given age. The influence of production environment and feed resources may be evident in long-term trends. In addition, comparisons between operations are difficult, as pasture availability and management choices such as age of calves at weaning influence weaning weights. Fall and spring calving seasons, in particular, should be evaluated separately for an operation.

Making improvements to weaning weights is certainly an area producers seek out to improve ranch revenues. The list of methods to increase weaning weights is extensive and, as stated previously, high-profit operations tend to have higher weaning weights. However, the method to accomplish it needs to be done in a cost-effective manner. Short-term methods to improve weaning weights would include creep feeding or use of calfhood implants. Creep feeding, as an example, is a high-input method to increase weaning weights. Close attention must be paid to price slides and feed conversion if this route is selected. More long-term approaches can be taken as well. Capitalizing on hybrid vigor via strategic crossbreeding and altering calving distribution can make impacts as well. Regardless of method, an accurate estimation of cost and benefit should determine the approach to higher weaning weights.

Pounds Weaned per Exposed Female

Pounds weaned per exposed female is one of the key production figures every cow-calf operator should assess for each calf crop. By evaluating weaning performance on an exposed female basis, this measure becomes a tool to help producers optimize growth rate and reproductive rate.

The value reflects herd reproductive rate, calf death loss and the genetics for growth and maternal performance. Age at weaning and the calving distribution impact pounds weaned per exposed female, making the measures more valuable for the individual operation and year-to-year comparisons. Comparisons between farms or ranches are less meaningful if production systems vary widely.

$$\text{Pounds per exposed female} = \frac{\text{Total pounds of calves weaned}}{\text{Total number of females exposed}}$$

Financial Measures

The overall financial performance and position of a business or a single enterprise within a business is evaluated through measures of liquidity, solvency, profitability, financial efficiency and repayment capacity. Just as baseball game records are used to derive statistics such as runs batted in, earned run averages, saves and wins/losses in baseball, information from financial statements is used in calculating

business benchmarks. No single measure is sufficient for evaluating a business' financial position and performance. Several measures must be tracked through time to provide a true perspective.

- **Liquidity** measures the ability of the business to pay bills in a timely fashion and provide for unanticipated events. The current ratio is a liquidity measure.
- **Solvency** measures the ability of the firm to retire debts if all of the business assets are sold. The equity/asset ratio or percent equity is one measure of solvency.
- **Profitability** measures the financial performance of the farm or enterprise over a period of time, which is generally one year. Net income and the rate of return on assets are measures of profitability.
- **Financial efficiency** relates physical output to input. The asset turnover ratio is a measure of efficiency.
- **Repayment capacity** is the ability of the ranch to pay debts as they come due. Debt coverage ratios are measures of repayment capacity.

Most of the detailed information required for financial analysis comes from financial statements, including balance sheets, cash flow statements and income statements.

- **Balance sheets** document the financial position at a point in time.
- **Cash flow statements** show cash inflows and outflows for a time period. A monthly cash flow statement is useful in highlighting seasonal surpluses and shortfalls. Shortfalls suggest when savings or a line of credit may be needed.
- **Income statements** combine information from the balance sheet and cash flow to determine profitability.

Balance sheets listing all that is owned and all that is owed are required, one for the beginning of the accounting period and one for the end. Another way of thinking of this would be to have a balance sheet prepared annually at close to the same date. Completing a balance sheet on January 1, 2020 would serve as a beginning balance sheet and completing another balance sheet on January 1, 2021 would serve as the ending balance sheet for the previous year and the beginning balance sheet for the upcoming year. Ideally, both cost and market values are identified for all assets listed in the balance sheet. The cost basis of assets is the book value (original cost minus accumulated depreciation); market value is the value of the asset at the time the balance sheet is developed. Most lenders use a balance sheet based on the current market value of assets. The balance sheet provides information on the ranch's current financial situation. Also, it can be used with comparisons from year to year. This provides insight on the farm or ranch operation's trend with respect to changes in assets and debt over time. Market-based balance sheets, of course, will fluctuate with changes to land and commodity prices. The assets of most agriculture enterprises are heavily weighted in these two areas. Extra attention must be paid to market value balance sheets in times of volatile commodity prices.

Asset values that move drastically can mislead or cover up strengths and weaknesses on the balance sheet. It is important to spend the time necessary to accurately update the balance sheet. Adding assets without the corresponding liability and vice versa or not updating livestock inventories also can keep the balance sheet from accurately representing the operation.

A cash flow statement maps all the cash moving in and out of the operation during a certain time interval. Many lenders will develop an annual cash flow to determine if the new debt load can be managed. But many operations can benefit from a monthly cash flow projection for the upcoming year as a standard management practice. Highlighting the inflow and outflow of cash each month can reveal cash deficiencies or surpluses. The cash flow statement also is beneficial in making management changes. For example, if an operation wanted to plant or manage a winter grazing crop, it would require seed, additional fertilizer and other operating expenses. Developing an expected monthly cash flow statement could help dictate budgeting to ensure enough cash or credit on our operating line is available. This financial statement is simple to develop and easy to adapt to the specific farm or ranch.

An accrual income statement also is needed. This can be developed by using a cash flow statement and accrual adjustment information, including gains and losses on sales of breeding livestock (purchased and raised), changes in inventories (livestock, feed, etc.), updated depreciation schedules (machinery, livestock, buildings and improvements), summaries of cattle sales and transfers for the fiscal year, loan repayment schedule (principal and interest payments) and IRS tax forms. For analysis of the cow/calf enterprise within diversified operation, both the balance sheet and the income statement entries must be prorated to the cow-calf enterprise.

The most important attribute of data used in the financial statement is that it is as accurate and complete as possible. Any assumptions that must be made should be documented so future analyses can be compared appropriately. Review of the financial statements is a useful first step in business analysis.

Financial ratios condense large amounts of financial information into meaningful benchmarks. They provide insight into sources of farm financial stress and the extent of stress. Ideally, the numbers used in the ratios come from current financial statements (cash flow statement, balance sheet and income statement) developed in a manner consistent with Farm Financial Standards guidelines (ffsc.org/). Table 4.2 provides a visual interpretation for the financial benchmarks that follow.

Current Ratio

The **current ratio** indicates the extent to which current assets, if liquidated, would cover current farm liabilities. Current assets are those expected to be sold or used up in the coming year; current liabilities are those due in the coming year, including scheduled principal and interest payments on long-term debt. The higher the ratio, the greater the business liquidity. Lower ratios indicate the potential for cash flow problems. The ratio can vary significantly during

Table 4.2. Financial measures.

			Low stress			High stress
Current ratio	=	Current farm assets / Current farm debt		2.0	1.0	
Debt to asset ratio	=	Total farm debt / Total farm assets		40%	70%	
Net farm income	=	Gross cash farm income - total cash farm expense - depreciation +/- Inventory changes		+	-	
Rate of return on farm assets	=	(Net farm income + farm interest expense - value of operator's labor and management) / Average farm assets		5%	1%	
Rate of return on farm equity	=	(Net farm income - value of operator's labor and management) / Average farm equity		10%	5%	
Debt coverage ratio	=	(Net farm operating income + net nonfarm income + depreciation + interest on term debt - income and social security taxes - family living expenses) / Scheduled principal and interest on term debt		135%	110%	
Operating expense ratio	=	(Gross farm expense - farm interest expense - depreciation expense) / Gross farm revenue		60%	80%	
Interest expense ratio	=	Interest expense / Gross farm revenue		10%	20%	
Asset turnover ratio	=	Current farm assets / Current farm debt		40%	20%	

the year—for instance, if a crop has been harvested but not yet sold. Dairies and other businesses with steady inflows of cash can support a lower current ratio than other types of farms.

$$\text{Current ratio} = \frac{\text{Current farm assets}}{\text{Current farm debt}}$$

Debt-to-Asset Ratio

The **debt-to-asset ratio** indicates the proportion of total assets owed to creditors. The higher the ratio, the greater financial risk the business faces.

$$\text{Debt to asset ratio} = \frac{\text{Total farm debt}}{\text{Total farm assets}}$$

Net Farm Income

The **net farm income value** represents the return to unpaid labor, management and owner equity. There is no single standard for farms of different sizes with different enterprises. Net cash income is adjusted for changes in inventory and depreciation. Changes in inventory (accrual adjustments) may add to income (increases in accounts receivable, prepaid expenses, cash investments in growing crops, supplies on hand) or decrease income (increases in accounts payable, taxes due or other liabilities). Net cash income is calculated by subtracting all operating expenses from gross farm revenues. Because accrual accounting procedures are used, net farm income also reflects the gain/loss resulting from the sale of assets, as well as changes in the values of inventories. In a profitable operation, net farm income is positive and, hopefully, sufficiently large to compensate the owner for family labor and management and use of equity. Profits are needed over time to replace assets such as breeding livestock, machinery and equipment and to pay family living expenses.

	Gross cash farm income
-	Total cash farm expense
-	Depreciation
+/-	Inventory changes
=	Net farm income

Rate of Return on Farm Assets

Rate of return on farm assets (ROA) serves as an index of profitability. The higher the value, the more profitable the business. ROA is most meaningful in year-to-year comparisons if assets are valued using their cost basis. ROA for agricultural assets is typically low compared to nonfarm investments. The measure has some limitations. For instance, if two farms have the same net farm income but one leases land or other assets, those assets' values are not included in owned assets. The ROA for the operation with leased assets will be significantly higher simply because of the way the assets are controlled. If the ROA exceeds the cost of debt financing or average interest rate, then borrowed capital is being used profitably in the business. If the ROA is less than the interest rate on the loan (the cost of debt financing), then increasing debt will further decrease equity. If a value for family labor is not included in the expenses or a portion of family living expenses is not assigned to the cow-calf operation, the ROA is inflated.

$$\text{Rate of return on farm assets} = \frac{\begin{array}{ll}(\text{Net farm income} \\ + & \text{Farm interest expense} \\ - & \text{Value of operator's labor and management})\end{array}}{\text{Average farm assets}}$$

Rate of Return on Farm Equity

Rate of return on farm equity (ROE) also serves as an index of profitability. Like ROA, the higher the value, the more profitable the business. ROE is most meaningful in year-to-year comparisons if assets are valued using their cost basis. If debt is being used advantageously, ROE will be greater than ROA. ROE can be compared to the return that could be earned in alternative investments, such as certificates of deposits, bonds or stock mutual funds.

$$\text{Rate of return on farm equity} = \frac{\begin{array}{ll}(\text{Net farm income} \\ - & \text{Value of operator's labor and management})\end{array}}{\text{Average farm equity}}$$

Debt Coverage Ratio

The **debt coverage ratio** indicates the ability of the business to cover term debt. The higher the ratio, the greater the cushion to cover all payments. Capital lease payments should be included as part of term debt. What is a reasonable value varies with farm enterprises, diversification, management abilities and stability of nonfarm income.

$$\text{Debt coverage ratio} = \frac{\begin{array}{ll}(\text{Net farm operating income} \\ + & \text{Net nonfarm income} \\ + & \text{Depreciation} \\ + & \text{Interest on term debt} \\ - & \text{Income and social security taxes} \\ - & \text{Family living expenses})\end{array}}{\begin{array}{l}\text{Scheduled principal} \\ \text{and interest on term debt}\end{array}}$$

Operating Expense Ratio

The **operating expense ratio** indicates the proportion of total income used to pay expenses. The higher the ratio, the greater the financial risk in periods of low market prices.

$$\text{Operating expense ratio} = \frac{\begin{array}{ll}(\text{Gross farm expense} \\ - & \text{Farm interest expense} \\ - & \text{Depreciation expense})\end{array}}{\text{Gross farm revenue}}$$

Interest Expense Ratio

The **interest expense ratio** indicates the proportion of total income committed to interest payments. Financing costs are highly variable between operations, depending on the debt structure and loan repayment terms. Operators who finance their operation through retained earnings and do not borrow money will have total financing costs of zero and an

interest expense ratio of zero. Farm operations are considered vulnerable once the ratio is 15%.

$$\text{Interest expense ratio} = \frac{\text{Interest expense}}{\text{Gross farm revenue}}$$

Asset Turnover Ratio

Profitable and efficient operations generate more revenue with a given set of resources. The **asset turnover ratio** can vary substantially between farms of different types, but the higher the ratio, the more efficiently farm assets are being used.

$$\text{Asset turnover ratio} = \frac{\text{Gross farm revenue}}{\text{Average farm assets}}$$

Financial ratios vary considerably among farms of different types, for instance, dairy operations and stocker operations. What may be critical for one farm might be tolerable for another. For more information on farm financial statements and analysis, see OSU Extension fact sheets AGEC-751, *Developing a Cash Flow Plan;* AGEC-752, *Developing a Balance Sheet:* AGEC-753, *Developing an Income Statement;* and AGEC-790, *Evaluating Financial Performance and Position* (extension.okstate.edu/fact-sheets).

Any financial measure is only as good as the information used in calculating it. The most important attribute of all data used is that it be as accurate and complete as possible. Any assumptions that must be made should be documented so future analyses can be compared appropriately. Honest insights require honest data. Consecutive years of financial measures developed in a consistent manner provide the best information about changes in financial performance and position of a business.

Contact the local county agricultural OSU Extension educator to inquire about assistance with farm business planning.

Using Analysis to Improve Ranch Performance

Measure, then manage. Performance measures condense a large amount of production and financial information into convenient summaries and ratios for analysis. Results are most useful when annual results are available for year-to-year comparisons. They can be used to identify areas of concern, then management strategies implemented to correct problems. Performance measures are most useful in directing managers to ask the right questions to solve problems. Results also may be used to identify other management tools needed. The tools may include financial and production records, financial statements (cash flow statement, income statement, balance sheets), budgets (cash flow and enterprise), reports comparing actual to budgeted values and other software, such as spreadsheets designed to analyze a specific decision.

A first step in analyzing ranch financial performance is to identify high-cost categories. Where are costs high relative to other producers who are profitable? Comparing individual results to benchmarks such as the Kansas Farm Management Association (KFMA), SPA or FINBIN averages may indicate that a specific cost component is high. The following notes are intended to stimulate thinking about potential causes of problems. No one idea is appropriate for all cases. Review the ideas given in a situation and follow up with specialists who have the appropriate expertise.

High Feed Costs

- Buy purchased feed in bulk rather than in sacks.
- Reduce dependence on feed (reduce stocking rate, consider grazing rotations, overseeding or limit-grazing cool season forages).
- Save money buying feed rather than raising it (or vice versa). Is marketing raised hay or feed through the cows the best use for it? If hay is high quality, could it be sold in a specialty market and an adequate replacement purchased at a lower cost?
- Renegotiate rental rates (cash or share rent) if they are higher than average rental rates for comparable tracts in the region.
- Consider dramatically improving a planned crossbreeding program—to increase fertility, longevity and pounds per weaned cow exposed—without dramatically increasing costs.
- Use chemicals on raised feeds only when it is economically advantageous.
- Shop around for the best supplemental feed values. Consider alternative supplement sources.
- Try to anticipate needs and buy hay early in the season when prices are low.
- Avoid extremes in cattle size and milk production.
- Match the cattle production cycle to forage resources, both in terms of availability and nutritive quality.
- Use a systematic approach in evaluating a herd nutrition program.
- Sort cows based on nutritional needs and feed accordingly.
- Minimize feed wastes through storage and feeding practices (for example, feed hay in racks or rings with enclosed sides).
- Evaluate purchasing rather than raising replacement females.
- Analyze cost of owning versus renting land.

High Grazing Costs

- Match the cattle production cycle to forage resources (availability and nutritive quality).
- Renegotiate rental rates (cash or share rent) if they are higher than average rental rates for comparable tracts in the region.
- If the forage base includes annual pasture, use chemicals only when it is economically advantageous.
- Soil test improved pastures to determine when fertilizer is needed.
- Search for weed control methods that cost the least.
- Improve grazing management. Is the stocking rate optimal?

- Renovate and improve pastures.
- For improved pastures, evaluate the relative cost of higher levels of fertility and reduced stocking rate versus renting or purchasing more pasture land.
- Analyze cost of owning versus renting land.

High Investment Costs per Cow

- Sell unnecessary machinery, vehicles, cows and other assets that do not contribute to profits.
- Emotional attachments to assets, cows for instance, can be costly. Is machinery and equipment justified? Is the bull-to-cow ratio close to the optimum or are there too many bulls?
- Consider leasing rather than owning assets. Could grass be rented for less than it costs to own? Leasing rather than owning may increase flexibility.
- Custom-hire work if it is cheaper than owning machinery (or hiring labor).
- Weigh carefully or defer new investments and consider buying used rather than new machinery, equipment or vehicles.
- If the enterprise is profitable and resources are available, consider increasing the size of the herd to spread fixed investment costs over more cows. Manage heifers so they will have longevity in the herd. Replacing cows can be expensive.

Other Cattle Costs

- Use preventative medicine and practices to reduce emergency costs or losses.
- Plan vehicle use to minimize mileage and other equipment costs.
- Shorten breeding/calving seasons.

High Interest Costs

- Shop around for the best deal on financing.
- Lock in low interest rates for long-term loans when the opportunity arises.
- Use cash surpluses to pay down debt.
- Schedule loan repayments at times when crop and/or livestock sales are expected.
- Negotiate for lower rates if you have a good recordkeeping system and can provide financial statements for the lender.
- Minimize new borrowing.

High Overhead Costs

- Consider increasing the size of the herd to spread overhead costs over more cows (if the enterprise is profitable).

Low Pregnancy Percentage

- Make sure cows have an adequate forage and/or nutritional base.
- Select seedstock to match available forage resources and design management programs minimize to expensive inputs.
- Increase surveillance during breeding to ensure bulls are functional and cows are cycling.
- Build cattle with high fertility through systematic selection, culling and grouping.
- Control the breeding season. Sell cows that do not become pregnant and wean a calf. With continuous calving systems, a cow that does not calve in a given year may go unnoticed, meaning unproductive cows typically stay in the herd longer than is desirable.
- Maintain effective herd health program.
- Conduct annual breeding soundness exams (BSE) on all bulls.
- Work with a veterinarian to ensure the herd remains free of reproductive diseases.

Low Calving Percentage

- Dead calves that are carried to term are included in the numerator for this calculation. A calving percentage significantly lower than the pregnancy percentage suggests reproductive disease.
- Low pregnancy percentages contribute to a low weaning percentage (also see items under that heading).
- Be sure cows have an adequate forage and/or nutritional base for a strong immune system throughout gestation.

Low Weaning Percentage

- A weaning percentage lower than the calving percent suggests dystocia, scours, clostridial diseases, respiratory disease or losses due to theft or predators.
- Practice systematic breeding and culling to increase calving ease and consider grouping females to monitor difficult births.
- Use preventative medicine and practices to reduce death losses.
- Low pregnancy and calving percentages contribute to a low weaning percentage (also see items under those headings).
- Target a minimum body condition score (BCS) of 5 for cows prior to calving to ensure optimal calf vigor and colostrum quality.

Low Weaning Weights

- Consider the cost of increasing weaning weight. If weaning weights are moderate to above average for the region, there may be financial opportunities by reducing production costs. On the other hand, if weaning weights are low, adopting different management practices may increase weaning weight for little additional cost.
- Use genetic selection and crossbreeding to improve uniformity of the cow herd/calf crop.
- Increase quality of grazed and harvested forage by utilizing forage tests and harvesting in a timely fashion.
- Be sure cows have an adequate forage and/or nutritional base.
- Shorten the breeding season.
- Set calving dates to capitalize on high-quality forage production.
- Evaluate balance between forage production capacity and stocking rate.

Again, consider changes in costs and returns to make sure a decision is the right one. The local county OSU Extension office is a good source of information on all of the

above subjects. Annual analysis may raise red flags, signaling a decline in the financial performance of the business. The first red flag to appear is typically a negative cash flow. This may be a temporary problem, for instance, if the operation is being expanded and/or new assets purchased. If negative cash flows persist, it can lead to economic losses. If the ranch does not generate an economic profit, then the assets could be earning more somewhere else. For example, if cows selling at market value cannot pay for raised feed, the land on which the feed is raised could be rented out for more than it is earning in the cow-calf enterprise.

An even more serious red flag is raised if the financial net income is negative, as it signals that equity capital is being consumed. In other words, each year that production continues with financial losses, equity is being consumed, leading to increasingly lower values for net worth. For ranches to survive in the long term, a positive return to labor and management as evidenced by a positive net income and rate of return on assets is essential. Equity increases in a viable business should result from retained earnings rather than capital contributed from off-farm jobs, inheritances and appreciation in asset values.

Being aware of these signals and monitoring performance on an ongoing basis allows producers to correct problems before they get out of hand. Analysis requires a commitment of time and energy, but provides better information for management than either financial or production records can do alone.

Additional Notes

Cost of production is only one part of the profit equation. Producers also should study marketing practices and alternative marketing options. Can an above break-even price be locked in using contracts or futures markets? Will profits increase by retaining ownership through a stocker or feedlot phase? Are there specialized markets? For instance, could natural beef be targeted? Are there other possible sources of revenue, such as hunting leases?

Cash shortfalls can occur even if an enterprise is profitable. Cash shortfalls in a given year can be a temporary problem associated with debt servicing, building of inventories, etc. Negative net cash flows over time are likely to be signals of more serious problems including lack of profitability. Negative values for accrual net income indicate the enterprise is currently not profitable. In this case, changes are needed in operations. Look at altering production practices, marketing, feeding, land management, cost control or all of the above. Risk management also is important in building a sustainable business.

Completing an Analysis for Your Herd

FINBIN or SPA analysis focuses on financial results from a fiscal or accounting year and production records associated with the calf crop weaned in that year. For most producers, the fiscal year coincides with a calendar year. A set of farm financial statements supplemented by tax records and a depreciation schedule will supply the financial information needed to complete the analysis. Whole farm analysis also is available in FINBIN.

Reproductive measures are based on a full production cycle, beginning when all breeding-age females are exposed to the bulls (or artificially inseminated). The cycle ends when the calves are weaned. To make accurate comparisons from one calf crop to the next or between management groups or herds, these performance values are based on the number of exposed females (cows and first-calf heifers). Thus, cow numbers are needed for the period when the mothers of calves being weaned were exposed. Individual calf weights are not required. More information on the production and financial data required is found in OSU Extension fact sheet AGEC-222, *Cow-Calf Standardized Performance Analysis*.

The initial analysis will require some time and effort. Collecting the production and financial data may require four hours to eight hours the first time an analysis is completed, if records are in poor shape. However, a commitment to improving management practices and using standardized performance analysis brings great rewards.

Producers interested in a workshop or assistance in completing a financial performance analysis or the FINBIN package should contact the local agriculture Extension educator, area agricultural economics specialist or the state farm management specialist at (405) 744-9836 to express interest.

Conclusion

Analyzing ranch performance should be a process, not an event, for producers. Change has to take place for an analysis to be useful to producers. Many cow-calf producers can reduce production costs by addressing these issues:

- Minimize investment in depreciable assets such as machinery and vehicles.
- Monitor and control purchased feed expenses.
- Match cows to forage resources.
- In small operations, buy replacements and use terminal cross bulls.
- Consider using crossbred cows to benefit from heterosis.
- Avoid expensive seedstock production.
- Minimize investment in horses if the cows are expected to pay their expense.
- Do not overstock grazing land.
- Develop and integrate a total resource management plan including wildlife.
- Have a controlled breeding season that will optimize grazing land use, minimize purchased feed and result in high reproduction.
- Use proper health practices to ensure sound herd health and allow participation in marketing alternatives.
- Avoid industry fads that are not cost effective.
- Do not spend money to reduce IRS taxes if the investment is not a sound one which will increase after tax profits. It does not make sense to spend a dollar to save 30 cents.
- Have a bank account for the ranch separate from the

personal account so business income and expenses are not masked by personal income and expenses.

Location and other amenities are important in acquiring land to realize appreciation in value. If a goal of land ownership is to monetize expected increases in value, focus on attributes beyond grazing potential.

The large differences in performance between herds observed by OSU research and Extension specialists help validate the need to measure and manage for performance. Ranchers can begin the process by completing an analysis such as selected annual performance measures, SPA or FINBIN if a more complete analysis is sought. Making a commitment to business management can be a significant step. Focused managers measure and monitor progress toward specific written goals, use the analysis to identify areas for change, then implement the changes. Measuring performance motivates managing for performance.

The following Extension publications include more information:

Extension publications with more information are available at extension.okstate.edu/fact-sheets where OSU Fact Sheets can be searched by number, name or topic:

AFS-3162, Expected Progeny Difference: Use of EPDs
AFS-3010, Supplementing Beef Cows
AFS-3018, Nutritive Value of Feeds for Beef Cattle
AFS-3028, Limit Feeding Concentrate Diets to Beef Cows as an Alternative to Feeding Hay
AFS-3260, Planning Calendar for Beef Cattle Herd Health
CR-3279, Cow-Calf Production Record Software
AFS-3280, OSU Cowculator v2.0 Beef Cow Nutrition Evaluation Software
PSS-2570, Reducing Winter Feeding Costs
PSS-2584, Forage Budgeting Guidelines
PSS-2585, Forage Legumes for Oklahoma
PSS-2869, Management Strategies for Rangeland and Introduced Pastures
PSS-2871, Stocking Rate: The Key to Successful Livestock
PSS-2901, OSU Agronomic Services Procedures for Soil, Forage and Water Testing
NREM-2869, Management Strategies for Rangeland and Introduced Pastures
NREM-2870, Drought Management Strategies
NREM-2875, Intensive Early Stocking
NREM-2876, Eastern Redcedar Control and Management Best Management Practices to Restore Oklahoma's Ecosystems

References

Bevers, S. (January 2017) Southwest Cow-Calf SPA Key Measures Summary (Last 5 Years), 2012-2016. Texas A&M Agrilife Extension. Available at agecoext.tamu.edu/wp-content/uploads/2013/08/SW-KeyMeasuresSummary.pdf

Raper, K. (August 2020) AGEC-222, Cow-Calf Standardized Performance Analysis (Revised). Cooperative Extension Service, Oklahoma State University. extension.okstate.edu/fact-sheets/cow-calf-standardized-performance-analysis-spa-1.html

5 Leasing Arrangements in a Beef Cattle Enterprise

Roger Sahs

Objectives

- **Point out terms that should be discussed in developing a livestock lease agreement.**
- **Show example calculations for cost and returns.**
- **Provide overview of farmland lease agreements.**

Beef Cow Rental Arrangements for Your Farm

Managing risk is required for many farm enterprises to be profitable and sustainable. Leasing assets, rather than purchasing them, is a form of risk management because it typically requires less capital. Leasing or sharing arrangements between farm operators and property owners have long been used to acquire control of land. In recent years, leasing has become more common for machinery and livestock. Contractual arrangements—such as livestock leases—can be crafted to lend or transfer capital while also sharing risk. The terms of the agreement depend on the contributions of the owner and operator, as well as the motivation for the lease. A lease agreement may be part of a plan to transfer livestock ownership to a second generation, the means for an older owner to compensate a livestock operator or simply an alternative form of accessing capital. A pasture owner also may use a livestock lease agreement to generate income without committing labor or additional capital.

Through share lease arrangements, the livestock owner typically shares the production risks, expenses and returns with an operator. While the owners may give up some of the risk, they also may give up some of the decision-making power. In developing a lease, owners and operators generally want an arrangement that is equitable to both parties. For a successful relationship between the owner and operator, the following elements should be present:

- The owner and operator both must be willing to risk some capital.
- The owner and operator should demonstrate mutual trust and confidence in each other.
- The operator must convince the owner they have the managerial ability, honesty and integrity to capably manage the livestock enterprise.
- The operator must be confident the owner will deal fairly and honor the contract arrangements for shared returns.

The cow owner may want to check references of the operator, and the operator may want to investigate the owner's reputation to assess if this is someone with whom they want to do business. The owner should compare the return on investment in livestock, fences and buildings with alternative investments to make an informed decision relative to business and personal goals.

A key principal to remember when developing a cow herd lease is to **keep it simple**. It is recommended that a beef cow lease only involve beef cows and bulls. While leasing other items such as pasture, hay land and machinery can be part of a cow herd lease, leasing them in a separate agreement provides better flexibility to deal with changing conditions over time. The time and effort spent developing a simple, straightforward and equitable arrangement in the beginning will be rewarded with better relations between owner and operator and a more efficient beef cow enterprise.

Livestock Lease Terms

The owner and operator should communicate clearly their expectations for the arrangement. The lease should be a written contract agreed upon by both parties and should note, for instance, whether a partnership is intended because of legal implications. A sample lease form is available online at aglease101.org. The arrangement can be simple, but it should cover all the important points. The agreement should include the names and addresses of participants and should answer the following questions:

- When does the agreement start? How long does it run?
- Is it automatically renewable? Note that while an automatic renewal may seem appealing, it should not substitute for ongoing communication between parties.
- When and how is termination notice given?
- What are grounds for termination?
- When will the agreement be annually reviewed?

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

- Which party provides for and pays for feed, water, care, veterinary services, medicine, fencing, etc. What share does each provide? Fencing may not be an issue if pasture is leased separately, but it should be discussed so all parties know their obligations.
- What is the share of the output for each party? How are calves priced if one party buys calves from the other?
- When and where is the share of output divided?
- How are cull animals disposed of and when does culling occur? Who receives the income from culls?
- Who provides replacement breeding livestock? Is there a separate agreement for growing replacement heifers?
- What determines the acceptable amount of death loss for each party? How is death loss documented?
- Who provides bulls? What type and quality of bulls (or semen) are used?
- Are cows insured? Who carries the insurance?
- What facilities are used?
- Are there special requirements or needs regarding feeding and handling of cows or calves?
- Are incentives provided for doing a good job? Are penalties assessed for doing a poor job?
- What records are kept? How are animals identified?
- How are extenuating circumstances (such as drought, blizzard or major health problems) that are not the fault of the operator handled?
- What limits, if any, are placed on the activities of the operator? For example, can the operator add other cattle to the owner's herd?
- How are disagreements settled? Is there a way for either party to get out of the agreement?
- If the owner terminates the agreement prior to the agreed upon end point, how is the operator compensated for expenses up to the date the cows are removed from the producer's premises?

If land is part of the agreement, these additional questions should be addressed:

- How many acres of land and what type of pastures and crops are included? (Include legal descriptions, if possible.)
- What is the expected stocking rate?
- Who is responsible for pasture maintenance and upkeep expenses (e.g., fences, noxious weed control, water systems)?
- Are improvements needed in buildings or facilities? If so, who will pay for them?

Share versus Cash Lease Agreements

Leasing beef cows on a share basis can have advantages for both parties (Table 5.1). Some of the factors that need to be determined for a share-leasing arrangement to be equitable are:

- Costs to be included.
- Cost of resources contributed by each party and costs to be shared.
- Percent of costs contributed by each party.
- Quality of cattle furnished.
- Methods for valuing inputs and products.
- How death losses or other adverse outcomes will be shared.

As a rule, share arrangements are considered equitable for the parties involved if the value of the shares received (i.e., income) reflects a similar share of the value of contributions made (i.e., costs). That is, income is shared in the same proportion as costs are contributed. It is best if an owner and operator can work together in determining their respective contributions. They might work independently at first, then meet to share their estimates and negotiate final terms of the agreement.

Additional details need to be agreed upon before a lease is signed. Some of these are the condition of the cows when returned, the breeding program to be followed, death loss allowed and vaccination program/veterinary cost for the cows. If the lease is for one year only, the cow owner would typically furnish the bull(s) because the operator would not have any benefit from the next year's calf crop. If the lease is for more than one year, the operator is more likely to provide the bull(s) to control the genetics of the next calf crop.

Table 5.1. Advantages of share and cash lease agreements to different parties.

Share lease advantages to livestock operator:	***Share lease advantages to livestock Oowner:***
• Makes use of working capital without tying up capital for breeding stock. • Shares the risk of the operation with the owner. • Obtains capital over and above the limits of credit agencies. • Allows borrowing of capital at a fair rate of interest. (This assumes the lease is equitable!) • Permits an increase in the volume of business. • Helps the beginning operator get started in livestock production. • Provides more efficient utilization of labor if the operator is underemployed.	• Allows an owner to maintain a breeding herd, even though labor is not provided. • Provides a source of rental income. • Provides an opportunity for returns on capital investment. • Provides a means of transferring ownership over a period of time. • Has possible income tax and social security advantages.
Cash lease advantages to livestock operator:	***Cash lease advantages to livestock owner:***
• Generally provides the operator full control and responsibility for management. • Allows the operator to benefit from above average prices and production.	• Provides a fixed income without any operating expenses.

Table 5.1 highlights some of the advantages to the livestock operator and owner of the different types of leases. Tax considerations also may play a role. If the cow owner leases the cows and receives a base cash rate, they will not be subject to self-employment tax on that income. However, a cow owner who shares a portion of the production risk will be subject to self-employment tax on the income received. Production risk occurs if the owner's returns are a portion of the calf crop or if the owner shares a role in the management of the cow herd. The IRS defines the management role as material participation and considers the cow owner to have "materially participated" if:

1. The producer does any three of the following activities:
   a) Inspects production activities (e.g., calving or feeding). Inspecting property or improvements does not count.
   b) Consults with the operator about production of the cow enterprise.
   c) Furnishes at least half of the tools, equipment and livestock used in the enterprise.
   d) Shares at least half of the production expenses.
2. The cow owner regularly and frequently makes decisions that significantly affect the success of the farm operation.
3. The cow owner works at least 100 hours spread over five or more weeks on activities connected to the cow enterprise.
4. Even if the cow owner does not meet 1, 2 or 3, when considered together, their activities may be enough for a ruling of material participation.

Because material participation is somewhat difficult to define, the cow owner should consult with a tax adviser if tax consequences are important for their situation.

Developing Equitable Share Arrangements

Generally, the percentage of profits each party receives is based on their contributions to the enterprise. If the income is divided in a way that does not match each party's contribution to the enterprise, for instance, in a generational transfer of assets, it is essential the owner and operator agree upon the terms. Because of the differences in individual farms and items furnished, the contributions in these arrangements may appear similar when, in reality, they may vary a great deal. Some of the differences may include one or more of the following:

1. **Quality of cattle furnished.** A party who furnishes a cow valued at $2,000 contributes twice as much per cow as one who furnishes a $1,000 cow. Selling a 6-month-old bull calf for $1,500 contributes much more to the receipts than selling a steer for $750.
2. **Labor.** A party who furnishes the labor for growing all the feed and providing the temporary pasture furnishes much more than one who just feeds protein supplements to a cowherd. This can be accounted for by valuing contributed raised feed at market value. The labor requirements on timber pasture are higher than open pasture.
3. **Pasture.** The value per acre of pasture varies widely. What is important is the pasture cost per cow (which also can vary).
4. **Machinery and equipment.** The value of the machinery and equipment depends on the acres of hay and pasture produced; the amount of roughage harvested and transported; and the quality of handling facilities contributed. As with feed, if hay is valued at market price, it presumably covers cost of production, including machinery and equipment costs as well as labor and management. Machinery costs for feeding cattle also can vary considerably based upon type of feed, number of cows fed with equipment and age/quality (i.e., value) of equipment.

Some production expenses, such as veterinary care and drugs, may be shared. Because these costs affect cash flow and profitability analyses, they should still be considered in the overall analysis of enterprise profitability (even though they do not affect the relative contributions of either party when shared in the same proportion as income).

The leasing agreement should be evaluated occasionally to assure an equitable arrangement over time. Fluctuating prices can cause the proportion of contributions to shift. This could be caused by changes in interest rates, feed costs, value of breeding stock or labor and management costs.

An infinite number of possible arrangements for sharing the income generated from the contributions of livestock, land and the other resources are possible. Therefore, it is important both parties itemize their contributions and the expected values associated with those contributions.

Determining Costs to be Included

Actual farm records are an excellent place to start when determining the basic input items and costs that should be considered when developing a beef cow lease. Standard budget worksheets (Worksheets 1 and 2, pages 43 and 44) or computer programs can be used to help identify relevant costs and organize the costs for the required calculations. Many state Extension services offer budgets that may serve as a resource (see agecon.okstate.edu/budgets or agrisk.umn.edu/budgets for links to other state sites). Standard Performance Analysis (SPA) summaries offer benchmarks for production as well, particularly representing the southern Plains states (agecoext.tamu.edu/programs/management-programs/beef-cattle-standard-performance-analysis-spa/). These are especially helpful when working out a lease agreement for the first time.

Cow herd costs can be calculated either for the whole herd or on a per cow basis. Total herd figures are sometimes easier to obtain from farm records, but the parties must be sure cost items are based on the same number of cows as will be in the lease. For this reason, it often is recommended costs be calculated on a per cow unit basis. A cow unit is the cow, her calf, her share of the bull and her share of a replacement heifer when replacements are raised within the lease. For example, if there are 100 cows in the herd and both the owner and operator agree that 15 heifers need to be retained each year, then the development costs for the heifers should be

entered into the cow unit-cost budget, where the per-heifer cost is multiplied by 15% (i.e., 15 heifers divided by 100 cows). Likewise, the costs associated with bull ownership and care should be adjusted by the bull-to-cow ratio.

Estimates of annual fixed costs for assets such as breeding stock, buildings, machinery and equipment can be approximated using the following steps:

Average investment = (original cost + salvage value) ÷ 2

Annual depreciation = (original cost – salvage value) ÷ years of useful life.

Annual interest = average investment x interest rate.

Annual insurance = average investment x insurance rate.

Annual taxes = average investment x personal property tax rate.

Depreciation is not based on tax depreciation as tax laws change with time and often allow complete "expensing" of items. Used machinery or equipment would have a shorter useful life than new items. In some cases, it may be more appropriate to use a replacement cost or current market value as opposed to original cost in the above formulas. What is important is that the useful life is consistent with the value used. For example, the useful life of a new building will be much longer than one associated with an older building.

A short explanation of each cost item listed in Worksheet 1 on page 43 may help in arriving at an equitable arrangement.

Livestock Ownership

Interest on the average value of cows represents the investment contribution of the owner. The interest rate used should be between the rate that could be earned if money were invested in other alternatives (opportunity cost) and the current rate for borrowed capital.

Depreciation on cows is a contribution of the owner if they are responsible for purchasing or raising the replacements outside of the lease. Total depreciation is the difference between the market value of the cow when she is placed in the herd and her salvage or cull value when she is removed from the herd. To arrive at the annual depreciation, total depreciation is divided by the number of years the cow is expected to remain in the herd. When replacement heifers are raised within the lease, these costs are included in the production inputs, so depreciation is not a factor.

Interest and depreciation on bulls are computed in the same way as for cows. The annual cost of the bull is divided by the number of cows served each year to determine the cost to be allocated against each cow. Schedule A later in this chapter can be used to estimate the depreciation and average investment for both cows and bulls.

Taxes on livestock are the amount of personal property tax (if any) on the cows and bulls.

Cow insurance or death loss could be shared if, for example, the operator guarantees a maximum death loss. The cost of insuring the cow is typically used, but death loss can be substituted when the contributing party "self-insures" (i.e., does not buy insurance). Do not include both if death loss is reimbursed by insurance. Cow insurance or death loss is usually computed at 0.5% to 1.0% of the average value of the cow.

Machinery, Equipment and Buildings Used in the Livestock Enterprise

Interest and depreciation on buildings, machinery and equipment used in the livestock operation is a contribution of the party who owns the property. One alternative for valuing the contribution is to use the rental rate (for example, cost per hour to rent a tractor), which may work well where markets are established and rental rate information is available. In other cases, it may be appropriate or necessary to calculate annual interest, economic depreciation, interest and taxes on the contributed assets. Assigning a proportion of the value of an asset to the livestock enterprise also is required, if for instance, a tractor or trailer is used for other purposes in addition to the cow enterprise.

The value of buildings, machinery and equipment used in the beef cow enterprise at the end of this chapter varies from operation to operation.

Schedules B and C can be used to estimate the machinery, equipment and building investment used in livestock production. Livestock machinery and equipment would include tractors, wagons, trucks, trailers, loaders, manure spreaders, bale spears, hay feeders, feed bunks, mineral feeders and handling facilities used in feeding, handling and observing livestock. Livestock machinery and equipment does not include hay or silage harvesting equipment if crop or hay contributions are valued using market prices.

Taxes and insurance on buildings and equipment are the costs for taxes and insurance incurred against property used for livestock during the year. These costs typically range from 1% to 2% of the current value of buildings and equipment.

Repairs on buildings and equipment are the costs of maintaining buildings, equipment and fences used for livestock production. Repairs typically average 2.5% to 4% of new costs on an annual basis.

Pasture

The land charge for pasture can be calculated two ways: a) landowner's ownership costs or b) cash rental value. Ownership costs include a return on land investment plus real estate taxes. The cost of fencing, gates and watering systems may be included in the land investment when being used in the livestock enterprise. A fair market value for agricultural purposes is placed on the land and multiplied by the long-range rate of return to land (typically 1% to 4%) to calculate the annual contribution. Real estate taxes are actual costs; however, they may be accounted for in the rate of return, thus it is important to not double count them. The rental value for the landowner is the amount for which the property could be rented to someone else. If the land is being rented by the party providing it, then the contribution is the actual cost of rent. Rental rates may be quicker and easier to use if there is an established market for pasture in

the area. Schedule D can be used to calculate the number of acres of pasture needed per cow unit. (For more information on pasture leases, see aglease101.org and NCFMEC-03, "Pasture Rental Arrangements for Your Farm." [North Central Farm Management Extension Committee])

Feed and Other Expenses

Software tools may be useful in determining appropriate combinations of forage, hay and feed to meet the cow's nutritional needs under different pasture situations and feed/hay pricing environments (for example, see beef.okstate.edu/files/cowculator-2020). Hay, silage and other raised feed should be valued at long-run market prices when estimating contributions for a multiple year lease. However, if the lease will only be for one year, then it may be more appropriate to use current market prices. Market value is the price that could be received if the product is sold instead of used on the farm. Cost of production can be used in a whole farm lease agreement; however, market values are generally used because they are simpler to calculate. It is recommended that long-run market values be used for all raised feed for the beef cow herd share agreement. **Note:** If hay, silage and/or grain raised under a separate crop-share lease arrangement is fed, the landowner needs to receive credit for their share. If both parties contribute to the cost of producing feed, each party should receive credit for their contribution. For example, one party may furnish land for hay production and the other party may furnish machinery and labor. However, as stated previously, the cow herd lease arrangement will be much more straightforward with fewer potential complications if other leased assets (e.g., pasture, hay ground, crop land) are handled with a separate agreement.

Protein and mineral supplements should be valued at cost. It is generally recommended that protein and minerals be furnished by the same party providing the hay and forage, so there will be no conflict concerning winter rations.

Veterinary and drug expenses may be contributed by either party, or they may be shared the same as the income is shared. When shared, they are not factored into calculations for determining the equitable shares. (See section on shared and unexpected expenses.)

Fuel and oil costs would be for feeding, hauling and observing livestock.

Truck expenses, including repairs, license, insurance, interest and depreciation, should be prorated to the cow herd if the truck is not included in the livestock machinery and equipment. Hired trucking and marketing generally are shared, because they are often deducted from sales.

Utilities and miscellaneous costs should include water charges, electricity, telephone, postage, dues and registration fees that are chargeable to the cow herd.

Labor is a contribution of the party providing it. If labor is hired, the expense is the actual cost to the party who pays for it. If labor is furnished by one or both parties, then labor should be valued at the going rate as though it had been hired. Labor required per cow per year will vary with the size of the herd. Large herds will require around six hours per cow per year, while per cow requirements for smaller herds may be substantially higher (see Figure 5.1). An additional allowance would be required if replacements are raised within the lease rather than purchased. Management of the cow herd typically will be the responsibility of both parties. The owner of the cows should decide, in consultation with the operator, which cows to cull and which heifers to keep for replacements. The owner, along with the operator, should decide on bulls to use that will maintain or improve the herd quality. The operator should be responsible for the day-to-day decisions involved in managing the cow herd to produce maximum returns. Management can be valued at 0.5% to 1.0% of capital managed or 5% to 10% of value of annual production. Schedule E at the end of this chapter can be used to calculate a management charge. Because management is difficult to define, and because both parties provide management, this contribution often is excluded from the calculations in determining equitable shares.

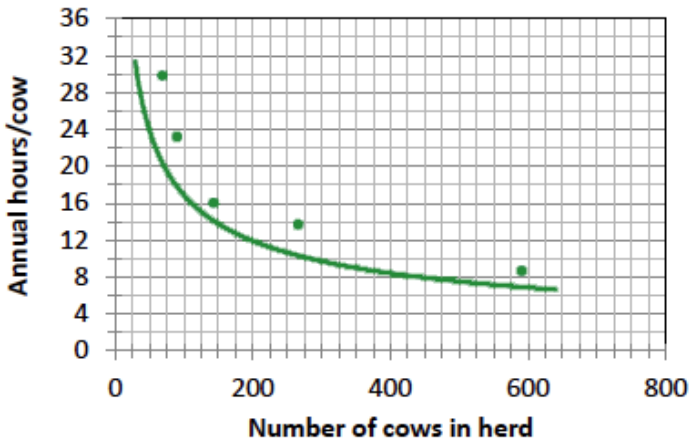


Figure 5.1. Estimated labor requirements for beef cow herds. Source: USDA ERS, EIB #73, McBride and Mathews, March 2011.

Shared and Unexpected Expenses

Sharing the cost of production-increasing inputs in the same percentage as the value of production encourages the parties to use the optimal amount of the input to maximize net returns to the total business operation. Examples of production-increasing expenses include, but are not limited to, antibiotics, implants and creep feed. Even though shared expenses do not affect relative contributions, they should be calculated for a total cost estimate that can be used for cash flow and profitability analysis. These costs can be entered on Worksheet 1.

Unexpected expenses such as additional feed during a blizzard or drought, catastrophic health problems and other irregular items should be shared, because they are periodic and hard to predict. If shared, unexpected expenses do not change the percent contribution of either party when they occur.

Total Costs

Total costs reflect the combined contributions of both parties. The number may lead to concern by lease parties about the profitability of the cow herd operation,

which is a risk each party assumes. If gross returns per cow exceed total costs per cow, each party will get full value for all costs plus a "profit." If gross returns are less than total costs, then each party will not receive full value for their contribution. However, this does not necessarily mean that each party does not benefit from the operation. Livestock owners may realize benefits such as capital gain advantages and pride of ownership. Livestock operators may be able to use hard-to-market feed and off-season labor.

Determining Contributions of Each Party and Percent Contributed

After the annual contribution for all production inputs is determined (Worksheet 1, total column), costs are allocated to the party who contributes each particular input (owner and operator columns). If a certain input factor is provided by both parties, it is divided between them. Worksheet 1 can be expanded to include more than two parties if needed. As noted earlier, the value of homegrown grains and forages raised on land owned by one party and farmed by the other party are prorated based on the crop-share agreement. When the allocations are completed, the inputs are added to determine the total contribution by each party.

To determine the percent contributed by each party, divide the amount contributed for each individual party by the total contribution of all parties. Expenses to be shared should be shared in these same percentages.

Determining Income

Value of production is shared in the same proportion as costs are contributed. Value of production may or may not be the same as sales. When replacement heifers or cows are purchased or provided from other sources outside the lease, value of production equals total calf sales. Calf sales are shared based on the percent contribution. However, when replacement heifers are retained and not sold, their estimated value plus calf sales equals value of production. Total value of production is shared based on the percentage of contribution.

The method of providing replacement cows or heifers has a major impact on items that are considered as contributions and on how cash income is shared. In all cases, the cull bull income would go to the party that provided the bull(s). When replacement females are provided by the owner and not raised as part of the lease, depreciation and death loss are part of the owner's contribution; when replacements are raised as part of the lease, depreciation and death loss are not part of the owner's contributions, leading to a smaller share of contributions unless other adjustments are made. Table 5.2 highlights several ways of calculating contributions and sharing income for alternative ways of how replacements are handled in the lease (described in more detail in notes that follow).

1. Replacements are purchased by the owner. All calves are sold and proceeds are split based on contributions. Cull cow sales go to the owner and the owner provides replacements. This is the simplest and most clear-cut method.
2. Replacements are kept but raised in a separate operation. A market value is placed on the replacement heifers as if they were sold. When the remaining calves are sold, 1) the operator and owner share all calf sales and the owner purchases the operator's share of the replacement heifers; or 2) the operator receives a higher percentage of cash sales because the cow owner receives the replacement heifers as a share of income. In either case, the operator's income equals operator percentage share times the sum of cash sales and the value of replacement heifers. The cow owner would receive all cull cow income, would own the replacement heifers and be responsible for the cost of growing them to maturity.
3. Share value of production of calves (calf sales plus value of replacement heifers). This method is the same as method 2, except the cow owner's share of contribution and receipts would be smaller. Owner's cost would be lower because the cost of growing the replacement heifers is included in contributions. The cow owner would own the replacement heifers and would receive all cull cow sales.
4. Share all sales. All calf and cull cow sales would be shared based on percentage of contribution. Cow sales are substituted for the value of replacement heifers. This method is simpler and works well when cull cows are about equal in value to heifers and the size of the herd stays the same. The owner has less capital gain sales and more ordinary income for tax purposes.

A beef cow share-leasing arrangement that is ***fair, equitable*** and ***simple*** can be very satisfactory for all parties. The worksheets in this chapter and supporting schedules can be used to determine the value of contributions and percentages for sharing income. Blank worksheets are available in the livestock leasing bulletin on AgLease101.org, from which much of this chapter was reprinted. A companion computer spreadsheet (Beef Cow Lease worksheets.xlsx) also is available that can be used to estimate the equitable share rent and cash rents. The Excel spreadsheet is available atagmanager.info/livestock-meat/production-economics/ksu-beef-cow-lease-simple or the aglease101.org/ website.

Cash Leasing Beef Cows

With certain conditions, renting cows for cash might be preferable to a share arrangement. For example, a farmer/rancher contemplating retirement might be interested in renting out their cows. A young farmer who may be limited on capital might be interested in renting extra cows to utilize pasture. In either case, neither party may be interested in renting for long periods of time. The same information used to determine the value of contributions under a share arrangement is used to determine cash rent desired and an ability to pay rent. Compensation is expected for a return on investment, depreciation, taxes and death losses. The prospective renter should estimate the returns from a cow (or herd) to determine how much rent could be paid.

Table 5.2. Income sharing arrangements with alternative ways of handling replacements.

	Replacements purchased by owner (from outside source)		*Replacements retained but raised in a separate operation*	
	Operator	*Owner*	*Operator*	*Owner*
Contribution to lease (costs)				
Cow depreciation	0%	100%	0%	100%
Cow interest	0%	100%	0%	100%
Cow death loss	0%	100%	0%	100%
Replacements	0%	100%	0%	100%
Income from herd				
Calf sales	% based on contributions	% based on contributions	% based on contributions	% based on contributions
Cull cow sales	0%	100%	0%	100%
Heifers retained for replacement	N/A	N/A	% based on contributions[1]	% based on contributions[1]

	Replacements raised within lease with value of production shared		*Replacements raised within lease with value of cash sales shared[3]*	
	Operator	*Owner*	*Operator*	*Owner*
Contribution to lease (costs)				
Cow depreciation[2]	0%	0%	0%	0%
Cow interest	0%	100%	0%	100%
Cow death loss	0%	100%	0%	100%
Replacements	% based on contributions	% based on contributions	% based on contributions	% based on contributions
Income from herd				
Calf sales	% based on contributions	% based on contributions	% based on contributions	% based on contributions
Cull cow sales	0%	100%	% based on contributions	% based on contributions
Replacement heifers	% based on contributions[1]	% based on contributions[1]	N/A	N/A

1 Heifers retained for replacement would be valued at the time of other calf sales with the owner purchasing the operator's share. The owner is responsible for the costs of growing replacement heifers to maturity.
2 There is no depreciation on cows in a cowherd that includes the costs of raising replacement heifers (i.e., the average age of the cowherd is constant through time).
3 This arrangement works best when the value of a cull cow is approximately the same as a heifer calf.

Determining the Cash Rental Rate

Cash rental rates can be determined three ways:

1. Livestock ownership costs. Ownership costs are the same as discussed in the share lease section. They are depreciation, interest on investment, insurance or death loss and personal property taxes, if any. Section 1 of Worksheet 2 can be used to calculate ownership costs.
2. Livestock owner net share rent. Net share rent for the livestock owner is the owner's share of value of production less shared expenses and a risk adjustment. The net share rent is adjusted for risk because the owner no longer has any production or price risk (Worksheet 2, Section 2).
3. Operator's net return to livestock. Operator's net return to livestock is the value of production minus the operator's production expenses. The net return to livestock represents the most an operator could pay given the estimated costs. Worksheet 2, Section 3, can be used to calculate the operator's costs and net return to livestock.

Evaluation of the three rates can provide an opportunity for discussion and negotiation to determine an acceptable cash rental rate. Cash rental rates need to be reevaluated on a regular basis. Cattle prices can change significantly from year to year, changing the return to fixed assets. Because risk is not shared between owner and operator, the lease may need to be re-evaluated or changed to a share arrangement.

Leasing Bulls

Another way for the cow owner to reduce expenses is to lease, rather than own, a bull. The producer must compare the costs and benefits of leasing a bull with owning a bull. Leasing eliminates the capital expenditure of purchasing a bull. The cost of purchasing a bull depends on the cattle market and quality of the bull. Most bull owners in the leasing business charge $700 or more per breeding season.

A leased bull is generally only kept during the breeding season, so operating costs are reduced. For example, the cost of feeding a bull is estimated at $350 per year. The costs of veterinary and medicine, marketing and death loss (1%) approximate $35. Labor is estimated at about $45 per year, resulting in total cash costs of $430 per bull per year.

Another cost of owning a bull is depreciation and interest. Table 5.3 gives an example of the costs of depreciation and interest on average investment for a bull depreciated for three and four years using a 5% interest rate and $1,500 salvage value with different purchase prices.

The cow owner also must consider how leasing a bull could affect the health of their herd. Leasing virgin bulls is ideal to ensure that a venereal disease such as vibriosis or trichomoniasis is not introduced into the herd. This may not be an option, so owners should consult a veterinarian to ensure leased bulls are healthy.

If they have adequate capital and a large cowherd over which to spread operating costs, producers may want to own one or more bulls to ensure they have a quality bull for use each season. There also is the benefit of the salvage value when the bull is sold.

Table 5.3. Annual cost of depreciation and interest on investment for alternative bull purchase prices and years of use ($1,500 salvage value and 5% interest rate).

	Bull purchase price			
	$3,000	*$5,000*	*$7,000*	*$9,000*
Own for three years				
Depreciation	$500	$1,167	$1,833	$2,500
Interest	$113	$163	$213	$263
Total	$613	$1,329	$2,046	$2,763
Own for four years				
Depreciation	$375	$875	$1,375	$1,875
Interest	$113	$163	$213	$263
Total	$488	$1,038	$1,588	$2,138

Farmland Lease Agreements

Leasing land often is a cost-effective means of acquiring forage. Cash leases and share leases are common rental arrangements for land in Oklahoma. Cash leases may require a fixed payment, either cash or a specified yield, for instance, 10 bushels of wheat or one ton of hay. In share leases, income and certain costs are shared between tenant and landlord and management decisions may be made jointly. Rental agreements and rates are influenced by many factors including:

- The location and quality of land.
- Improvements on the land.
- The landowner's costs.
- The tenant's expected earnings.
- Previous rates charged.
- Competition for the land.
- Government programs.
- Tax laws.
- The general economy.
- The party's willingness and ability to bear risks.
- Desired land management practices.
- The personal relationship between tenant and landlord.

Landowners and tenants must choose a type of lease agreement such as fixed or flexible cash arrangements, share arrangements or some combination. Each type of arrangement has advantages and disadvantages. Some of these advantages and disadvantages are discussed in Table 5.1.

Landowners and tenants should each consider the following questions when choosing a type of lease arrangement:

- What portion of the income do I receive?
- What portion of the costs do I contribute?
- What portion of the risk do I bear?
- What crop and land management practices will be followed?
- What will be the condition of the land after the term of the lease?

As most pasture leases in Oklahoma are cash leases, the focus of the remainder of the chapter will be on cash lease agreements for farmland.

Determining a Fair Rent for the Cash Lease

The market approach provides a good starting point for negotiations. With the market approach, the going cash rental rate for the area is used as a guideline. Although this method appears simple on the surface, many questions must be answered.

- What land in the area is of the same quality with respect to productivity?
- How much is a neighbor paying their landlord?
- If this land is of superior quality, how much more is the additional quality worth?

Published results of surveys conducted by OSU and the Oklahoma office of the USDA Natural Agricultural Statistics Service provide information on rental rates. See OSU Extension current report CR-216 *Oklahoma Pasture Rental Rates* at extension.okstate.edu/fact-sheets/ and Cash Rents by County at nass.usda.gov/ for more information.

A second approach is to calculate the cost of land ownership and add an appropriate return on equity. Land ownership costs include:

1. Property taxes on the land.
2. Repairs, depreciation, taxes and insurance on any improvements on the land used by the tenant in the farming operation.
3. A suitable return on the landowner's investment.

A third approach, the residual income method, estimates the fair cash rent using the tenant's expected net return. The expected total income is the sum of expected price times yield plus other income such as wheat pasture rental or government program payments. The time period for the life of the agreement should be considered when estimating prices. The tenant's total costs are:

1. Variable production expenses such as seed, fertilizer, planting and harvest costs.

2. Fixed production expenses including depreciation, taxes, insurance and interest on equipment and machinery investments.
3. Return to management and labor.

The expected net return (income less total costs and the return to management and labor) is the maximum rent the tenant can afford to pay.

The tenant and the landlord may want to estimate cash rents using more than one method, compare the results and negotiate a final figure. By using several different methods, the parties have a chance to see a range of estimated rents, reflecting different points of view. Careful negotiations will provide a balanced agreement that encourages honesty and cooperation between both parties.

A fair rental agreement must be reviewed and adjusted regularly to remain equitable. Changes in prices, costs and yields can make a fair agreement lopsided in a short period of time. A flexible cash arrangement can reduce the frequency of necessary adjustments and distribute more of the risk between the parties.

However, flexibility does change some of the risks and opportunities faced by the parties. Adding flexibility for price and yield risks shifts more risk to the landowner, but will allow them to reap the advantages in good years. In accordance, the tenant will face less risk, but lose some of the benefits of exceptional price and/or yield years. Parties should keep this in mind before adding flexibility to their agreement.

For more detailed information, including example calculations and worksheets, refer to NCFMEC-03, Pasture Rental Arrangements For Your Farm. This publication, leasing forms and other publications are free to download at aglease101.org/.

Putting the Agreement in Writing

A written agreement offers a number of advantages:

- It encourages a detailed statement of the agreement that assures a better understanding by both parties.
- It serves as a reminder of the terms originally agreed upon.
- It provides a valuable guide for the heirs if either the operator or livestock owner dies. The agreement should be carefully reviewed each year to ensure the terms of the agreement are still applicable and desirable.
- It serves as documentation for tax purposes.

Every lease should include certain items. These are the names of the parties involved, an accurate description of the property being rented, the livestock lease terms described earlier and the signatures of the parties. Absent a statutory or constitutional limitation, the duration of the lease can be any length of time agreed upon by the parties. Most leases are for at least one full year. Operators sometimes request leases for more than one year, particularly if they must invest more capital in equipment or improvements needed.

The lease also needs to clearly specify ownership of the cattle. Sometimes, a lessee may have a loan secured by their cattle. However, the definitions of "cattle" in the loan documents may be so broad as to include all cattle possessed by the rancher. As a result, the owner of leased cattle runs the risk of their cattle being seized and sold if the lessee defaults on their loan obligations. To minimize this risk, the lease document needs to be very clear that:

1. Title to the leased cattle remains with the lessor.
2. The lessee will take whatever steps are necessary to prevent the leased cattle from becoming "collateral" for any of the lessee's debts.
3. The lessee will reimburse the lessor in the event of any seizure and sale of the lessor's cattle.
4. The lessee will not brand, mark or identify the leased cattle in any way that could cause them to be mistaken for the lessee's own cattle. The lessor also should take care to brand, tag or otherwise identify the cattle with their own marks before turning over possession of the cattle to minimize these risks.

In general, most transactions involving real estate require a contract in writing to be enforceable. In most states, oral leases for not more than a year are enforceable. Because specific legal terms surrounding leasing vary from state to state, livestock owners and operators are encouraged to check with their local Extension service or a knowledgeable lawyer as to the specific laws for their state. As a practical matter though, it is always a good idea to put the agreement in writing regardless of its duration. Putting an agreement in writing helps both parties understand their rights and duties and can help resolve many disagreements before they even start.

Livestock owners, as well as operators, should enter long-term leases only after very careful consideration — a lease contract "marries" parties to undesirable and desirable provisions alike. Often, it is better to include a provision for buy-out terms or compensation for unexhausted improvements made by one party rather than to have a long-term lease that fixes terms for an extended time period. One of the functions of a written lease is to anticipate possible developments and to state how to handle such problems if they actually do develop.

Conclusion

A livestock lease is an excellent way for cattle owners, landowners and caretakers to pool their livestock and land resources. If the arrangement is properly laid out ahead of time, the lease can help each party share production risk. The lease should cover all parameters of production and possible situations that could arise over the duration of the contract. The parties entering into the arrangement should clearly define their expectations with respect to sharing of costs and receipts. The owner and caretaker should choose an arrangement that best matches their resources and desired returns.

Cash leasing agreements have advantages and disadvantages to both landowners and tenants. Both parties need to recognize the risks and opportunities they face under a cash agreement. By working together to determine a fair rental charge, the parties will have a greater understanding

of the other's position. This understanding should lead to better landowner and tenant relations and keep the agreement fair to both parties.

Arriving at a fair agreement is more likely if several of the methods discussed are used in negotiating the final rental charge. Each method views the agreement from a different perspective and further clarifies each party's position.

Developing an equitable lease agreement requires both the parties to provide estimates of their contributions to production costs (both fixed and variable expenses). The share lease worksheets or spreadsheets can be a helpful tool in drafting an equitable agreement. Although customs in the area may dictate some terms of lease, other terms can be used to tailor the individual situation.

References

Sahs, R., "Oklahoma Pasture Rental Rates," CR-216, extension.okstate.edu/fact-sheets/.

Sahs, R., "Oklahoma Cropland Rental Rates," CR-230, extension.okstate.edu/fact-sheets/.

North Central Farm Management Extension Committee, "Beef Cow Rental Arrangements For Your Farm." NCFMEC-06, February 2013. aglease101.org/.

North Central Farm Management Extension Committee, "Pasture Rental Arrangements For Your Farm." NCFMEC-03, December 2011. aglease101.org/.

North Central Farm Management Extension Committee, "Pasture Lease Form." NCFMEC-03A. aglease101.org.

USDA National Agricultural Statistics Service, "Oklahoma Cash Rent" nass.usda.gov/Statistics_by_State/Oklahoma/Publications/Oklahoma_Farm_Statistics/index.php.

Worksheet 1. Beef Cow Share Lease Agreement Worksheet – Per Cow*

☒ **Replacements Purchased or Raised Outside of Lease** ☐ **Replacements Raised within Lease**

Livestock Investment (Schedule A)	**Contribution** Total	Operator	Owner
Depreciation[A] (do not include cow depreciation if replacements are raised within the lease):			
Cow	$ 44	$	$ 44
Bull	$ 13	$	$ 13
Interest:			
Cow $ 825 average investment × 6 % interest =	$ 50	$	$ 50
Bull $ 86 average investment × 6 % interest =	$ 5	$	$ 5
Taxes and Insurance:			
Cow $ 825 average investment × 1 % rate =	$ 8	$	$ 8
Bull $ 86 average investment × 1 % rate =	$ 1	$	$ 1
Cow Death Loss:			
$ 825 average investment × 1 % rate =	$ 8	$	$ 8
Subtotal	$ 129	$	$ 129
Livestock Machinery, Equipment and Building Investment (Beef Cow Share) (Schedules B & C)			
Depreciation on machinery[B]	$ 31	$ 31	$
Interest on machinery:			
$ 214 average investment/cow[B] × 6 % interest =	$ 13	$ 13	$
Taxes and insurance on machinery:			
$ 214 average investment/cow[B] × 0.5 % rate =	$ 1	$ 1	$
Depreciation on buildings[C]	$ 36	$ 36	$
Interest on buildings:			
$ 362 average investment/cow[C] × 6 % interest =	$ 22	$ 22	$
Taxes and insurance on buildings:			
$ 362 average investment/cow[C] × 0.5 % rate =	$ 2	$ 2	$
Subtotal	$ 105	$ 105	$

(Worksheet 1 continued on next page)

*All values are rounded to the nearest dollar in the example presented in this worksheet.

Worksheet 1. Beef Cow Share Lease Agreement Worksheet – Per Cow* (Cont.)

Pasture, Feed and Other Expenses (List only if not shared the same as income)

	Total	Contribution Operator	Contribution Owner
a. ☐ Return to Land Investment (1% to 4%)			
Pasture:			
$ ____ per acre × ___ acre/cow unit[D] × __% return =	$	$	$
b. ☒ Cash Rental Value			
Pasture[D] 10.4 acres/cow unit @ 20 /acre =	$ 208	$ 208	$
Hay[D] .763 tons/cow unit @ 70 /ton =	$ 53	$ 53	$
Silage[D] ____ tons/cow unit @ ____ /ton =	$	$	$
Crop residue[D] ____ tons/cow unit @ ____ /ton =	$	$	$
Grain[D] ____ lbs/cow unit @ ____ /lb =	$	$	$
Protein[D] 374 lbs/cow unit @ 0.17 /lb =	$ 64	$ 64	$
Salt and minerals 55 lbs/cow unit @ 0.24 lb =	$ 13	$ 13	$
Veterinary, drug, etc.	$ 42	$ 42	$
Breeding costs (AI, breeding soundness exam)	$ 1	$ 1	$
Fuel and oil for feeding, hauling, and observing	$ 26	$ 26	$
Utilities and miscellaneous	$ 47	$ 47	$
Repairs on machinery and equipment	$ 36	$ 36	$
Repairs on buildings and fences	$ 11	$ 11	$
Hauling	$	$	$
Marketing	$ 8	$ 8	$
Insurance	$	$	$
Taxes	$	$	$
Labor: 9.25 hours @ $15.00 /hour =	$ 139	$ 139	$
Operating interest: ($ 324 / 2) @ 5 % =	$ 16	$ 16	$
(sum of all other costs excluding management)			
Management[E]	$ 92	$ 72	$ 20
Subtotal	$ 756	$ 736	$ 20
TOTAL CONTRIBUTION	990	841	149
PERCENT	100	84.9	15.1
Shared Expenses			
_____	$	$	$
_____	$	$	$
TOTAL SHARED EXPENSES	$	$	$
Total Contribution + Total Shared Expenses = TOTAL EXPENSE	$	$	$

*All values are rounded to the nearest dollar in the example presented in this worksheet.

[A-E] Lettered superscript designated the supplemental detail schedule that can be used to calculate the input value.

Worksheet 2. Beef Cow Share Lease Agreement Worksheet – Per Cow

1. Livestock Ownership Cost (Schedule A)

Depreciation[A] (do not include cow depreciation if replacements are raised within the lease):	
Cow	$ 44
Bull	$ 13
Interest:	
Cow $ 825 average investment × 6 % interest =	$ 50
Bull $ 86 average investment × 6 % interest =	$ 5
Taxes and Insurance:	
Cow $ 825 average investment × 1 % rate =	$ 8
Bull $ 86 average investment × 1 % rate =	$ 1
Cow Death Loss:	
$ 825 average investment × 1 % rate =	$ 8
OWNERSHIP COST PER COW UNIT PER YEAR	$ 129

2. Livestock Owner's Net Share Rent

Value of production[E] $ 726 × 15.1 % owner share (from Worksheet 1)	$ 109
Less equitably shared expenses per head	$
EQUALS NET SHARE RENT	$ 109
Reduction for risk, net share rent $ 109 × 10 % risk (5 to 10%)	$ 11
NET SHARE RENT REDUCED FOR RISK	$ 98

3. Operator Net Return to Livestock

Value of production[E]		$ 726
Costs:		
Pasture[D]	10.4 acres/cow unit @ $20 /acre =	$ 208
Hay[D]	.763 tons/cow unit @ $70 /ton =	$ 53
Silage[D]	_____ tons/cow unit @ _____ /ton =	$
Crop residue[D]	_____ tons/cow unit @ _____ /ton =	$
Grain[D]	_____ lbs/cow unit @ _____ /lb =	$
Protein[D]	374 lbs/cow unit @ $0.17 /lb =	$ 64
Salt and minerals	55 lbs/cow unit @ $0.24 /lb =	$ 13
Veterinary, drug, etc.		$ 42
Breeding costs (AI, breeding soundness exam)		$ 1
Fuel and oil for feeding, hauling, and observing		$ 26
Utilities and miscellaneous		$ 47
Repairs on machinery and equipment		$ 36
Repairs on buildings and fences		$ 11
Hauling		$
Marketing		$ 8
Insurance		$
Taxes		$

(Worksheet 2 continued on next page)

Worksheet 2. Beef Cow Share Lease Agreement Worksheet – Per Cow (Cont.)

Labor: 9.25 hours @ $ 15.00/hour =	$ 139
Operating interest: ($ 324 / 2) @ 5 % =	$ 16
(sum of all other costs excluding management)	
Management[E]	$ 72
Depreciation on machinery[B]	$ 31
Interest on machinery:	
$ 214 average investment/cow × 6 % interest =	$ 13
Taxes and insurance on machinery:	
$ 214 average investment/cow × 0.5 % rate =	$ 1
Depreciation on buildings[C]	$ 36
Interest on buildings:	
$ 362 average investment/cow × 6 % interest =	$ 22
Taxes and insurance on buildings:	
$ 362 average investment/cow × 0.5 % rate =	$ 2
TOTAL COST	$ 841
AVAILABLE FOR RENT	$ -115

[A-E] Lettered superscript designated the supplemental detail schedule that can be used to calculate the input value.

Schedule A. Breeding Herd Investment Cost Per Cow

Number of cows 50 Number of cows per bull 25

	Beginning Value, $/hd	Salvage Value, $/hd	Years	% to Beef Cows	Depreciation[1]	Average Investment[2]
Cows	$ 1,000	$ 650	8	100 %	$ 44	$ 825
Bulls	$ 2,800	$ 1,500	4	100 %	$ 325	$ 2,150
Bull depreciation and investment per cow[3]					$ 13	$ 86
TOTAL PER COW[4]					$ 57	$ 911

[1] Depreciation per Cow = (beginning value − salvage value) / years × % to beef cows

[2] Average Investment per Cow = (beginning value + salvage value) / 2 × % to beef cows. Market value may be used to represent the beginning value.

[3] Divide bull average investment and depreciation by number of cows per bull.

[4] Sum of the cows and bull per cow values for depreciation and average investment

Schedule B. Livestock Machinery and Equipment Investment Per Cow

Machine	Beginning Value, $/hd	Salvage Value, $/hd	Years	% to Beef Cows	Depreciation[1]	Average Investment[2]
Tractor	$ 35,000	$ 20,000	10	12 %	$ 180	$ 3,300
Pickup Truck	$ 39,200	$ 5,000	10	10 %	$ 342	$ 2,210
Hay Feeders	$ 3,200	$ 0	10	100 %	$ 320	$ 1,600
Bale Spear	$ 280	$ 0	10	100 %	$ 28	$ 140
Manure Loader	$ 1,000	$ 0	10	100 %	$ 100	$ 500
Manure Spreader	$ 560	$ 0	10	100 %	$ 56	$ 280
Scraper	$ 350	$ 0	10	100 %	$ 35	$ 175
Gooseneck Trailer	$ 8,400	$ 0	10	60 %	$ 504	$ 2520
TOTAL for Cow-Calf Enterprise					$ 1,565	$ 10,725
TOTAL PER COW[3]					$ 31	$ 214

[1] Depreciation = (beginning value − salvage value) / years × % to beef cows

[2] Average Investment = (beginning value + salvage value) / 2 × % to beef cows. Market value may be used to represent the beginning value.

[3] Total per cow = total for cow-calf enterprise (sum of column) / number of cows in herd

Schedule C. Livestock and Feed Storage Buildings and Fence Investment Per Cow

Building	Beginning Value	Salvage Value	Years	% to Beef Cows	Depreciation[1]	Average Investment[2]
Barn	$ 20,000	$ 0	20	100 %	$ 1,000	$ 10,000
Hay Barn	$ 10,000	$ 0	20	100 %	$ 500	$ 5,000
Corrals	$ 6,175	$ 0	20	100 %	$ 309	$ 3,087
TOTAL for Cow-Calf Enterprise					$ 1,809	$ 18,087
TOTAL PER COW[3]					$ 36	$ 362

[1] Depreciation = (beginning value − salvage value) / years × % to beef cows

[2] Average Investment = (beginning value + salvage value) / 2 × % to beef cows. Market value may be used to represent the beginning value.

[3] Total per cow = total for cow-calf enterprise (sum of column) / number of cows in herd

Schedule D. Pasture Acres and Feed Amounts Per Cow Unit

☒ **Replacements Purchased or Raised Outside of Lease** ☐ **Replacements Raised within Lease**

Pasture

Acres/cow and calf 10.0 × 1 unit = 10.0

Acres/replacement heifer _____ × _____ % replacement =

Acres/bull 10.0 ÷ 25 number of cows/bull = .40

Total Pasture Acres Per Cow Unit 10.4

Hay

Pounds/day/cow and calf 12 × 120 number of days ÷ 2,000 = 0.720

Pounds/day/replacement heifer _____ × _____ number of days ÷ 2,000 × _____ % replacement =

Pounds/day/bull 18 × 120 number of days ÷ 2,000 ÷ _____ number cows/bull = 0.043

Total Tons of Hay Per Cow Unit 0.763

Silage

Pounds/day/cow and calf _____ × _____ number of days ÷ 2,000 =

Pounds/day/replacement heifer _____ × _____ number of days ÷ 2,000 × _____ % replacement =

Pounds/day/bull _____ × _____ number of days ÷ 2,000 ÷ _____ number cows/bull =

Total Tons of Silage Per Cow Unit

Crop residue

Pounds/day/cow and calf _____ × _____ number of days ÷ 2,000 =

Pounds/day/replacement heifer _____ × _____ number of days ÷ 2,000 × _____ % replacement =

Pounds/day/bull _____ × _____ number of days ÷ 2,000 ÷ _____ number cows/bull =

Total Tons of Residue Per Cow Unit

Grain

Pounds/day/cow and calf _____ × _____ number of days =

Pounds/day/replacement heifer _____ × _____ number of days × _____ % replacement =

Pounds/day/bull _____ × _____ number of days ÷ _____ number cows/bull =

Total Pounds of Grain Per Cow Unit

Protein

Pounds/day/cow and calf 3 × 120 number of days = 360

Pounds/day/replacement heifer _____ × _____ number of days × _____ % replacement =

Pounds/day/bull 4 × 90 number of days ÷ 25 number cows/bull = 14

Total Pounds of Protein Per Cow Unit 374

Schedule E. Estimated Management Charge

Method 1. Capital Managed

Breeding Herd Investment Per Cow, Schedule A	
Market Value: Cow $ 1,400 + (Bull $ 2,500 ÷ 25 number of cows/bull)	$ 1,112
Machinery and Equipment Investment Per Cow, Schedule B	$ 214
Building and Fence Investment Per Cow, Schedule C	$ 362
Land Investment Per Cow = 10.4 acres/cow (Schedule D) × land value $ 1,600/acre	$ 16,640
Total Capital Managed Per Cow	$ 18,328
Management Charge (typically 0.5 to 1.5%)	0.75
Management Charge Per Cow = Total Capital Managed per Cow × Management Charge	$ 137.46

Method 2. Value of Production

Steers 550 lbs/head × 50% × 87 % calf crop[1] @ sale price $ 1.65 =	$ 394.76
Heifers 525 lbs/head × 50% × 87 % calf crop[1] @ sale price $ 1.45 =	$ 331.14
Cull Cows[2] _____ lbs/head × _____ % replacement rate @ sale price $ _____ =	$
Value of Production Per Cow	$ 725.90
Management Charge (typically 5 to 10%)	7.5%
Management Charge Per Cow = Value of Production per Cow × Management Charge =	$ 54.44

Method 3. Average of Capital Managed and Value of Production Methods

Management Charge Per Cow: Capital Managed	$ 137.46			
Management Charge Per Cow: Value of Production	+ $ 54.44			
Average Value	= $ 184.82	÷ 2	=	$ 92.41

[1] Percent calf crop raised in a typical year

[2] Include cull cows only if cull income is shared and reduce heifer percentage by percent replacement. Example: (50% − 15% replacement = 35% heifers)

6 Business Organization and Tax Considerations

J C. Hobbs

Objectives

- **Present types of businesses producers may choose to own.**
- **Discuss tax and non-tax aspects of each business type.**
- **Provide information on fringe benefits for each type of entity.**
- **Direct owners to pertinent IRS publications.**
- **Present tax tips for producers.**

Choice of Business Entity

The choice of entity decision is one of the most important decisions facing individuals who own and operate businesses. There are several forms to choose from, each of which generates different legal and tax consequences. Further, there is no single form that is appropriate for every type of business owner or entity.

Choosing the appropriate form of entity to operate a business is a complex decision. It depends upon many factors, including the owners' needs and desires and the particular characteristics and needs of the businesses. The federal tax consequences of each type of entity also play an important role, especially in closely held entities where the owner's combined tax liabilities should be analyzed as part of the decision-making process.

In the typical scenario, the choice of entity decision requires a comparative assessment of these forms of business entities:

- Regular or C corporation.
- S corporation.
- Limited liability company.
- General or limited partnership.
- Sole proprietorship.

Performing this assessment requires an understanding not only of the major tax and nontax aspects of each form of business, but also how the comparative advantages and disadvantages of each relate to the needs of the individual. Generally, the decision revolves around two questions:

1. To what extent do the owners want to limit their personal liability for the debts and liabilities of the business?
2. Do the owners want the business to be taxed as a separate legal entity, or do they want the items of income, deduction, loss and credit to flow through to them?

Financial conditions or constraints may require use of one form rather than another to provide some investors with limited liability (limited partners) or vest managerial authority in others (general partners). Similarly, if the entity is expected to generate losses, a pass-through entity such as an S corporation, partnership or limited liability company might be the best vehicle to enable the owners to deduct their shares of the entity's losses on their individual tax returns. Finally, if most of the entity's earnings will be due to the efforts of owner-employees who also want to maximize the purchase of fringe benefits with pretax dollars, then use of a C corporation might be prudent because the potential for double taxation of earnings (once at the entity level and again upon distribution to shareholders) can be offset by corporate deductions for reasonable salaries.

In analyzing the choice of entity decision, it is necessary to understand the relative pros and cons of each major form of business as they might apply in the context of a specific individual. This chapter presents an entity-by-entity assessment of the following major forms of business: Regular or C corporation, S corporation, general partnership, limited partnership, limited liability company and sole proprietorship. To facilitate comparisons, the chapter's approach to each entity focuses on these issues: pros and cons as a form of business, formation and operation, transfer of interest and termination. The end of the chapter discusses tax details specific to cow-calf producers.

Regular or C Corporation

Pros and Cons as a Form of Business

The use of a C corporation as a vehicle for a business enterprise affords both the shareholder and the entity a number of benefits. Perhaps the most significant nontax advantage of a C corporation is its limited liability protection for shareholders. Absent an agreement to the contrary, such as a loan guarantee, C corporation shareholders generally are not personally liable for the corporation's obligations.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

In addition to the limited liability afforded shareholders, another benefit of C corporations is that they do not have restrictions on the types of shareholders they may have. Unlike other entities, a C corporation's shareholders may include individuals, corporations, trusts and partnerships. This ability to attract a variety of investors gives taxpayers a great deal of flexibility in forming a C corporation. This flexibility is enhanced by the fact that there are generally no limits on the number of shareholders a C corporation may have or on the type of business it may conduct.

Of all the forms of business organization, a C corporation gives taxpayers the greatest freedom with regard to the transfer of equity interests. Absent contractual restrictions on share transfers, a C corporation shareholder can transfer their interest by merely selling or transferring the stock. This transaction generally has no effect on the corporate entity or other shareholders. Further, because the transfer does not directly involve the corporation, it is not a taxable event with regard to the corporation.

Although a C corporation provides protection and flexibility, its tax consequences are not entirely favorable. Because a C corporation is a separate entity for tax purposes, items of income, loss, deduction and credit are accounted for at the corporate level. For profitable corporations, this means earnings can be taxed twice: once at the corporate level when earned and again at the shareholder level when distributed. Double taxation also can result upon liquidation of the corporation because the corporation is taxed on any gain on the distribution or sale of corporate assets and shareholders are taxed on the receipt of money or other property in exchange for their stock. For an unprofitable corporation, the C corporation is a separate taxable entity, which means that ongoing operating losses are trapped at the corporate level and do not flow through to shareholders.

Another disadvantage of C (and S) corporations as compared to partnerships and limited liability companies is that such corporations do not permit special allocations of tax benefits to owners. In the partnership setting, such allocations often are incentives for individuals to inject additional capital into an ongoing enterprise. A final potential disadvantage of C corporations is that, unlike less formal forms of business, the C corporation is subject to a number of rules and restrictions with regard to its operation. It is also subject to closer supervision by regulatory bodies than other entity forms, thus its operation may result in greater administrative and compliance expenses than other forms of business.

Formation and Operation

A C corporation is a creature of state statute and, as such, is subject to a number of formal requirements. To form a C corporation, the shareholders generally must file a written corporate charter or articles of incorporation with the state in which it is incorporated, adopt written bylaws, elect a board of directors and hold an organizational as well annual business meetings.

Ownership of a C corporation is through the issuance of shares of stock. C corporations generally are not restricted with regard to the type or amount of stock they may issue. The most common types of stock issued by a C corporation are common and preferred. Common stock normally carries with it voting rights and the greatest potential for appreciation or depreciation in value. In contrast, preferred stock generally has limited or no voting rights but has preferences over common stock regarding payment of dividends and/or liquidating distributions. Because a C corporation may issue different types of stock with different rights associated with each, a C corporation affords taxpayers a great deal of flexibility in its structure and in raising capital.

In general, the act of incorporating is not a taxable event to either the corporation or the shareholders as long as these conditions are met: the shareholders transfer property to the corporation; the transfer is solely in exchange for the stock of the corporation, other than nonqualified preferred stock (see below); and immediately after the transfer, the transferors are in control of the corporation. Thus, it is possible for a taxpayer to transfer appreciated property to the corporation and, provided the above requirements are met, put the asset to use in the corporation yet defer recognition of gain. Conversely, however, since the nonrecognition treatment applies to losses as well as gains, and its application is mandatory, taxpayers ordinarily should not transfer depreciated assets to the corporation because they would be prevented from recognizing a loss on the transfer.

There are three important exceptions to non-recognition treatment:

1. A transferor who receives boot, anything other than stock in the corporation, or nonqualified preferred stock that does not count as stock for purposes of nonrecognition of gain in the exchange must recognize gain equal to the sum of the amount of money received and the fair market value of other property received.
2. A transferor who receives stock in exchange for services must recognize gain because services are not considered property for this purpose.
3. A transferor must recognize gain to the extent that aggregate liabilities of the transferor assumed by the corporation exceed the aggregate basis of assets the transferor transfers to the corporation.

A recourse liability of the transferor has been assumed by the corporation if the corporation agrees and is expected to pay it. The corporation is treated as having assumed a nonrecourse liability if property subject to such a liability is transferred to the corporation.

Note: In general, nonqualified preferred stock is preferred stock that resembles debt, because of a right to purchase it or have it purchased within 20 years, or because of a dividend that tracks interest rates or another index which is likely to have a fixed maturity or reduced risk.

If nonrecognition applies, a shareholder takes a basis in the stock received equal to the basis in the property transferred. If, however, boot is received in the transfer, the shareholder's tax in their stock is reduced by the amount of boot received and increased by the amount of gain recognized on the transfer. The purpose of the latter adjustment is to

prevent double taxation later, such as when the taxpayer sells the stock. The shareholder's basis also is reduced by the amount of liability the corporation is subject to or assumes.

The corporation's basis is computed in a similar fashion. Specifically, the corporation takes a carryover basis in the property received increased by any gain recognized.

Corporations are managed by a board of directors and officers. The president normally controls day-to-day operations, leaving major nonoperating decisions to the board. As a rule, shareholders (in their capacity as such) are not involved in the management of the corporation although certain actions such as mergers require shareholder approval. Often, in closely held corporations, the shareholders also serve as corporate officers and/or board members.

Transfer of Interest

Of all the forms of business, a C corporation offers its shareholders the most flexibility with regard to the transfer of interests. A shareholder's interest in the corporation is manifested by ownership of shares. Thus, a shareholder can transfer this interest simply by selling or otherwise transferring the shares. There is no need for the shareholder or the corporation to worry about the logistics of transferring title to the corporation's underlying assets. Further, the sale of a shareholder's shares has no tax consequences to the corporation. Any and all tax consequences of the transaction are borne by the shareholder; the latter must recognize gain equal to the excess of the amount received over the basis in the stock.

Generally, the transferability of a shareholder's interest is not restricted by the corporation. However, in the case of a closely held corporation, transferability often is restricted through the use of an option, right of first refusal or a shareholder agreement.

Termination

Termination of a C corporation refers to the liquidation and dissolution of the entity. Because this is an organic act, the corporation's decision to terminate requires shareholder approval, and in most cases, requires the filing of articles of dissolution or other documentation, depending upon the state statutory requirements.

A strict hierarchy usually governs distribution of the assets of a corporation in liquidation. Generally, the distribution order is: secured creditors, unsecured creditors, preferred shareholders and finally, common shareholders.

Liquidation is generally a taxable event for both the corporation and the shareholders. The corporation recognizes gain or loss on the liquidating distribution as if the distributed property was sold to the shareholders at fair market value. Thus, the corporation recognizes gain or loss in the amount equal to the difference between its basis in the distributed property and the amount realized on the distribution. Similarly, a shareholder recognizes gain or loss equal to the difference between the value of received property and their basis in the corporation's stock.

S Corporation

Pros and Cons as a Form of Business

An S corporation is essentially identical to a C corporation in the way it functions and with regard to the nontax consequences of doing business in corporate form. For example, it offers investors limited liability and its operation and structure employ a board of directors with officers and shareholders in a manner similar to a C corporation.

S corporations differ dramatically from C corporations with regard to tax matters. Unlike a C corporation, an S corporation is a flow-through entity. As such, the corporation essentially acts as a conduit through which items of tax attributes flow pro rata to shareholders. Double taxation of corporate earnings is avoided because there generally is no corporate-level income tax. Instead, earnings are taxed once at the shareholder level when earned, regardless of when they are distributed.

Example: A C corporation and an S corporation both have $100,000 of taxable income in year one (2020). C's $100,000 is reduced $22,250 by the corporate-level income tax, leaving $77,750 to distribute to shareholders. If C distributes the $77,250 as a dividend to shareholders in the 22% bracket, the latter pays $11,587.50 (qualified dividends taxed at a maximum of 15%) in income tax. As a result of this double tax, C's owners take home $66,162.50 ($100,000 minus $33,837.50). In contrast, S's taxable income flows through to its shareholders and there is no entity-level tax. Thus, if the shareholders are in the 22% bracket, they take home $86,420, which is $20,257.50 more than C's owners.

Thus, an S corporation often is a preferred choice of entity because of the single level of tax and the ability to limit personal liability of shareholders. Furthermore, for startup corporations expected to generate losses in the early years, use of the S corporation often is preferable to a C corporation because losses from an S corporation flow through to shareholders and can be used to offset other income of the shareholders or their spouses.

Despite its advantages, the S corporation is limited in use because of the restrictions imposed on such entities by the Internal Revenue Code. Unlike a C corporation, an S corporation has limits on the number and types of permissible shareholders. For example, it cannot have more than 100 shareholders; issue more than one class of stock; or have corporations, partnerships, nonresident aliens and most types of trusts as shareholders. These restrictions, in turn, limit the transferability of shareholder interests in the corporation since a transfer to an ineligible shareholder would cause the S corporation to lose its S status. Thus, while an S corporation has distinct tax advantages over a C corporation, many enterprises may not be able to qualify for its use.

Formation and Operation

Like a C corporation, the formation of an S corporation generally requires the filing of a written corporate charter or articles of incorporation, adoption of written bylaws,

election of a board of directors and the holding of an organizational meeting. The contents and requirements regarding these items are dictated by state statute.

Unlike a C corporation, an S corporation faces significant restrictions regarding the number and type of shareholders it can have. To qualify as an S corporation, the enterprise must meet the following tests:

1. It can have only one class of stock (the stock may, however, carry different voting rights).
2. The shareholders may only be individuals, estates and certain trusts (corporations, partnerships, many trusts and nonresident aliens may not be shareholders).
3. It must have no more than 100 shareholders.
4. It must not be an ineligible corporation (defined as certain financial institutions, insurance companies and Domestic International Sales Corporations).

Note: Qualified retirement plan trusts and certain charitable organizations may be shareholders in S corporations.

In addition to these restrictions, if a C corporation seeks S status, the shareholders must consent to the S corporation election. This election must be filed with the IRS by day 15 of the third month of the taxable year in which the election is to take effect. If the election is filed after such date, S corporation status takes effect at the beginning of the following taxable year.

The formation of an S corporation, or the conversion of a C corporation to S corporation status, is generally a nontaxable event. However, the conversion of a C corporation with appreciated assets to an S corporation may result in taxation on the built-in gain relating to the assets, measured on the conversion date, if the assets are disposed of within 10 years from the first day the entity is an S corporation.

The operation of an S corporation is similar to that of a C corporation. An elected board of directors and officers manage and control the corporation. Day-to-day decisions are made by the president, and organic decisions, such as the termination of the S corporation, are subject to shareholder approval. Although these entities are similar in management, the results of their activities are taxed very differently from each other.

The taxation of an S corporation is similar to that of a partnership in that both entities pass through their tax attributes, items of income, loss, deduction and credit to their owners. Consistent with this principle, items retain the same character at the shareholder level as at the entity level. Thus, for example, if the corporation's sale of an asset generates capital gain, the character of that gain is capital when it flows through to the shareholders.

Generally, an S corporation that has always been an S corporation pays no entity-level tax. The same treatment applies to C corporations that convert to S status with two exceptions. First, if a former C corporation had appreciated assets when it converted to S status and disposes of those assets within 10 years after its first day as an S corporation, the corporation pays a tax (using the highest corporate rate) on the built-in gains. Second, an S corporation with accumulated earnings and profits from C corporation years may be liable for a corporate-level tax if it has excessive passive investment income.

The tax treatment of nonliquidating S corporation distributions to shareholders differs markedly from, and is more favorable than, the treatment of similar C corporation distributions. A C corporation distribution, if made with respect to the corporation's stock, is ordinarily a dividend to the extent of corporate earnings and profits. Thus, individual shareholders must report it as ordinary income and the corporate distributee cannot deduct the payment. Conversely, such distributions from S corporations get favorable treatment. There is no corporate-level tax, and the distribution is nontaxable to the shareholder to the extent of the recipient's basis in their stock. The amount of the distribution reduces the shareholder's stock basis dollar for dollar until the latter reaches zero. To the extent a distribution exceeds a shareholder's stock basis, it is generally treated as capital gain. Further, when an S corporation shareholder receives proceeds in a redemption that is characterized as a distribution, the entire redemption is treated as a distribution that reduces the corporation's accumulated adjustments account (AAA).

In the case of pass-through items that are not distributions, the shareholder's basis is increased for income items and decreased for loss and deduction items. Losses are deductible by shareholders only to the extent of their basis in the stock and debt owed the shareholder by the corporation. However, the disallowance of a loss deduction in one year may be carried over into subsequent years and later deducted if the shareholder's basis in the stock or debt increases.

Transfer of Interest

Absent restrictions on share transfers, an S corporation shareholder, like a C corporation shareholder, is free to transfer their stock interest to anyone. However, the S corporation shareholder can inadvertently cause the entity to lose its S status by transferring stock to an ineligible shareholder such as another corporation, a partnership or a nonresident alien.

Planning Pointer: Due to the pass-through nature of an S corporation, a shareholder who wishes to sell or otherwise transfer their stock should give careful consideration to the timing of the transfer. As a general rule, a shareholder must report their share of corporation income, losses, deductions and credits for a given year based on the number of days the shareholder owned stock during the year. Thus, without careful planning, it is possible for a shareholder to recognize income under flow-through principles even though the corporation distributes the cash relating to the income after the date the shareholder sells the shares. However, a shareholder's basis in the stock is increased by their share of income, thus reducing gain or increasing loss on a sale of the stock.

Termination

In the context of S corporations, the word termination usually refers to loss of an entity's S status, not to a liquidation of the corporation. An S corporation will lose its

S status, and thus be taxed as a C corporation, if any one of these events occur:

- The shareholders affirmatively revoke the S election.
- The entity fails to meet eligibility requirements, for example, by transferring stock to an ineligible shareholder.
- The entity has passive investment income in excess of the permissible amount for three years and has Subchapter C earnings and profits.

When an S corporation liquidates, in contrast to when a C corporation liquidates, there is only one level of tax. The shareholders recognize gain to the extent their share of the liquidating distribution(s) exceeds their stock basis. However, if the S corporation has appreciated property, the gain becomes taxable to the shareholders but increases their stock basis. This results in the liquidating distribution producing far less taxable gain to the shareholders than a comparable liquidation of a C corporation.

General Partnership

Pros and Cons as a Form of Business

A general partnership provides taxpayers seeking a vehicle for their enterprise with the least costly and simplest choice. A partnership is a noncorporate entity comprised of two or more owners. Unlike a corporation, it requires no formalities to exist. Further, there is generally no limit on the type or number of owners in a partnership. However, unlike a C or S corporation, partners in a general partnership are personally liable for the partnership's obligations. This is the primary nontax disadvantage to general partnerships.

General partnerships are pass-through entities, and while the partnership must file an information return and characterize certain tax items at the partnership level, the partners, not the entity, deduct partnership losses on their income tax returns. Further, the use of a partnership avoids the earnings double taxation problem found in C corporations.

A general partnership also is preferable over other business forms because of the flexibility in the composition of the partnership and the fact that tax benefits can be specially allocated to specific partners.

However, unlike C and S corporations, the transferability of a partner's interest in a partnership is greatly restricted. For example, a partnership terminates for federal tax purposes if, within a 12-month period, there is a sale or exchange of at least 50% of the total interest in partnership capital and profits.

Formation and Operation

A partnership generally is formed by at least two people owning equity interests in an enterprise to be conducted with the intent of making a profit. Unlike an S or C corporation, the formation of a general partnership does not necessarily require the filing of formal documents. A partnership generally is deemed to exist when the parties' conduct evidences intent to engage in business as a partnership. Although not required, written documentation is a good idea. Like the formation of a C or S corporation, the formation of a partnership is usually a tax-free event to the entity and its owners. No gain or loss is recognized upon the contribution of property to a partnership in exchange for a partnership interest. However, if a party transfers services to the partnership in exchange for a partnership interest, the partner must recognize income to the extent of the value of the partnership interest received.

An individual receiving an interest in the partnership takes a basis in the interest equal to the basis of the asset contributed to the partnership. Similarly, the partnership takes a basis in the property received equal to the contributing partner's basis in the asset.

If the contributed asset is subject to a liability at the time of contribution, the liability allocated to other partners is treated as a cash distribution to the contributing partner. This distribution reduces the contributing partner's basis in the partnership interest dollar for dollar, but the other partners' bases are increased by the amount of the liability allocated to them. Although the contribution of an asset does not, by itself, cause gain to be recognized, if the amount of the liability allocated to the noncontributing partners exceeds the contributing partner's basis in the partnership, the excess is taxable as capital gain to the contributing partner.

A partnership is governed by a written or oral partnership agreement. Unlike a C or S corporation, this agreement can contain whatever terms the partners agree upon, providing they fall within any restrictions imposed by state law. Many partnership agreements, however, do not cover all of the issues regarding operation of a partnership. In such cases, the provisions of the state's version of the Uniform Partnership Act (UPA) will govern with respect to these issues.

Generally, a partner in a general partnership may participate in the management of the partnership to whatever extent allowed by the partnership agreement. Day-to-day management often is vested in either the managing partner or a committee. Many decisions, however, require a majority vote by partners, and in the case of organic acts, such as the admission of new partners or liquidation, unanimous consent may be necessary.

Because the partnership is a pass-through entity, all items of income, deduction, loss and credit pass through the entity to the partners and are allocated in accordance with the partnership agreement. Any item that passes through the entity retains its tax character in the hands of the partner. A partner's share of these items is called the partner's distributive share, even though these items are not actually distributed.

As a general rule, a partnership recognizes no entity-level gain or loss on a nonliquidating distribution of property or money to a partner. The distributee partner recognizes no gain as well, except to the extent that the amount of money distributed exceeds the partner's basis in their partnership interest immediately before the distribution, in which case, the excess is treated as capital gain. A distributee partner who receives property other than money in a nonliquidating distribution recognizes no gain. Instead, the distribution

reduces the partner's basis in their partnership interest by the partnership's basis in the asset immediately before the distribution.

Example: Marc, a 25% partner, has a basis in his partnership interest of $60,000. The partnership distributes to Marc $25,000 in cash plus a vacant lot of real estate worth $30,000 (in which the partnership's adjusted basis is $20,000). Marc recognizes no gain; instead, he takes a carryover basis in the lot of $20,000 but must reduce the basis in his partnership interest by $45,000 ($25,000 + $20,000).

To prevent double recognition of gain or loss, a partner's basis in their partnership interest is increased or decreased, as the case may be, to account for items that flow through the partnership and for distributions made by the partnership. For example, a partner's basis is decreased by the amount of losses or deductions passed through and increased by income items.

Transfer of Interest

One of the biggest drawbacks to using the general partnership as a choice of entity is the limitations on the transferability of a partnership interest. A partner may transfer their economic interest in the partnership without restriction. However, a transfer of this nature only entitles the recipient to the economic rights of the assigning partner. If, however, a partner wishes to transfer their entire interest to a third party, the transfer will be subject to substantial restrictions.

Generally, a transfer of a partnership interest as a whole requires the unanimous consent of the partners unless the partnership agreement provides otherwise. If a partner gains permission to sell their interest, the sale generally produces a capital gain or loss measured by the difference between the amount realized and the selling partner's basis in the partnership. However, the amount of gain, if any, attributable to unrealized receivables or inventory is ordinary income.

A partner acquiring a transferred interest will generally pay a price that is roughly equal to a proportionate share of the value of partnership assets. This value may be higher than the transferring partner's actual basis in the assets. Thus, if the partnership later sells an appreciated asset for its fair market value (FMV), part of the gain is taxable to the incoming partner. This can be a somewhat harsh result because the incoming partner paid full FMV for the partnership interest, thus did not reap any real economic gain with respect to the asset. To minimize this problem, the partnership can elect to step up the basis of partnership assets with respect to the incoming partner.

If the new partner is admitted to a partnership with outstanding liabilities, the existing partners may recognize income. Specifically, the admission of a new partner may result in a constructive distribution of cash. In addition, the admission may result in the constructive sale of the existing partners' interests in the partnership's unrealized receivables and substantially appreciated assets.

Termination

Technically, a general partnership has no continuity of life. It dissolves for nontax purposes when a partner ceases to be associated with the partnership. This can occur, for example, when the partner withdraws, dies, becomes bankrupt or gets expelled. Generally, a practical solution to this problem is to put a provision in the partnership agreement providing that, upon the happening of certain events of dissolution, the remaining partners may continue the business and succeed to its assets and liabilities.

For tax purposes, a partnership terminates only when at least one of the following occurs:

- No part of the business is carried on by any of the partners in a partnership (in other words, a total cessation of business).
- Within a 12-month period, there are sales or exchanges totaling 50% or more of the total interest in the partnership capital or profits.

When a partnership is liquidated, distributions to a partner usually consist of interests in partnership assets. As with nonliquidating distributions, the tax consequences depend on the type of assets distributed and the partner's basis in their partnership interest before the distributions. Cash distributed reduces the partner's basis in their partnership interest dollar for dollar. Any basis remaining is allocated first to the partner's share of unrealized receivables and inventory based on the partnership's basis in each and then to any other assets distributed based on the partnership's basis in each. If the partnership continues business after a termination resulting from sales aggregating 50% or more of the partnership interest in capital and profits within one year, the partnership is treated as a new partnership for tax purposes. The old partnership's taxable year, accounting method, depreciation allowance and other elections do not carry over to the new partnership.

Limited Partnership

Pros and Cons as a Form of Business

A limited partnership offers the benefit of a partnership with the liability protection of a corporation. Like a corporate shareholder, limited partners in a limited partnership are not personally liable for the obligations of the partnership; instead, their liability is limited to their financial investment in the enterprise. The only members of a limited partnership who remain personally liable are the general partners and possibly limited partners who participate in management. In addition, limited partnerships are pass-through entities with no restrictions on the number or types of partners who may participate.

In some cases, use of a limited partnership might be preferable to a C corporation because the former has no entity-level tax. Thus, in contrast to a C corporation, its earnings are only taxed once—in the partners' hands based on their respective distributive shares.

A major drawback to limited partnerships is the inability of the limited partners to participate in the management of

the partnership in any significant manner. A limited partner who participates can lose the benefit of limited liability. Because of this prohibition, a limited partner ordinarily may not vote on issues affecting the partnership's ordinary course of business.

Another drawback is that the limited partners are subject to the passive loss rules. This severely restricts their ability to benefit from the tax credits and losses the entity may generate. For this reason, from an investor's perspective, the limited partnership may be a poor choice if the goal is to use the entity's losses to shelter other income.

Formation and Operation

Unlike a general partnership, which does not require formal documentation to exist, a limited partnership is a creature of state statute. The formation of a limited partnership generally requires the filing of a certificate of limited partnership and a partnership agreement. These must comply with the relevant state statutes and be filed pursuant to the state's version of the Uniform Limited Partnership Act (ULPA).

A limited partnership is formed by one or more parties with at least one designated as the general partner. The general partners remain personally liable for the obligations of the partnership and generally manage partnership operations. A corporation, as well as an individual, may be a general partner. The remaining participants are those who wish to participate in the partnership as inactive investors. These are the limited partners.

A limited partnership operates in a manner similar to that of a general partnership except that the general partner makes all the decisions regarding management of the partnership. Limited partners may not participate in the management of the partnership without losing their limited liability. With regard to federal taxation, limited partnerships afford its general partners the same tax treatment as general partnerships discussed above. However, limited partners are subject to special rules.

Transfer of Interests

Like a general partnership, a limited partner has an unrestricted right to transfer their economic interest in the partnership. The substituted partner acquires the right to receive the assigning limited partner's share of the profits and assets upon dissolution. A limited partner cannot assign their interest in the partnership as a whole without unanimous consent of the partners or a provision allowing assignment of all of a partner's rights in the limited partnership agreement.

Termination

Generally, the death, withdrawal or assignment of a limited partner's interest will not cause dissolution of the partnership. However, the death, withdrawal or incapacity of the general partner will dissolve the limited partnership for nontax purposes, unless a provision is included in the partnership agreement or unanimous consent is given for the business to continue.

As discussed above, the rules for terminating a limited partnership for tax purposes are the same as those for terminating a general partnership.

Limited Liability Company

Pros and Cons as a Form of Business

A limited liability company (LLC) is a hybrid entity: it is treated like a corporation for limited liability purposes, but for tax purposes it may be treated like a partnership. Like C corporations and limited partnerships, LLCs afford members limited liability. However, unlike a limited partnership, a member of an LLC can participate in day-to-day management without losing limited liability. Equally important, an LLC, like an S corporation and a partnership, is subject to only one level of taxation if properly structured. However, unlike an S corporation, there are no restrictions on the type or number of members and the tax rules are arguably less burdensome.

Despite all of the positive tax and nontax aspects of LLCs, there are some drawbacks. Because LLCs are creatures of state statute, the legislation establishing and regulating these entities varies from state to state. This lack of uniformity results in some unresolved tax and nontax issues. In addition, an LLC, like a partnership, must meet certain characteristic requirements to receive pass through tax treatment. Some LLCs may be deemed to possess a sufficient number of corporate characteristics to be taxed as a corporation. However, others will be considered to possess less than the requisite amount of characteristics necessary to be taxed as a corporation, thus will be taxed as a partnership.

With regard to nontax issues, the lack of uniformity presents some questions as to the treatment of LLCs in states whose provisions differ. Specifically, the uncertainty centers on whether there is a risk of personal liability in states that impose limits that are not imposed by the entity's state of incorporation.

Formation and Operation

The state statute in the jurisdiction of organization dictates the requirements regarding the formation of an LLC. However, as a general rule, members or their representative must file Articles of Organization with the state. These documents usually include the name of the company, a provision addressing the duration of the enterprise, a provision addressing the membership and new members, a statement of business purpose, management provisions and a provision with regard to the regulation of internal affairs.

Because an LLC is usually taxed as a partnership, a contribution of property to the LLC in exchange for a membership interest ordinarily will not result in the recognition of gain or loss. However, like partnerships, if the member contributes services, nonrecognition does not apply and the member will recognize income equal to the value of the interest received. The member's basis in their interest in LLC is equal to the basis of the asset contributed, increased by any gain recognized on the transfer.

Most state LLC statutes require distributions by the company be made in accordance with the Operating Agreement or, if there is no provision provided, on the basis of the value of the member contributions. Because members are taxed as partners, they generally do not recognize gain or loss on distributions, but reduce their basis accordingly. Further, like a partnership, items of the company's profit and loss may be specially allocated among members. These allocations should also be set forth in the Operating Agreement.

Transfer of Interest

Like a partnership, the transfer of a member's interest in an LLC is usually subject to substantial restrictions. Specifically, a member who wants to transfer their interest as a whole, which includes economic, management participation rights and voting rights, may have to receive unanimous consent from the other members. The only interest a member may transfer without their fellow members' consent is their economic interest in the company.

Like a partner in a partnership, if a member is successful in transferring their interest, the sale generally produces a capital gain or loss, except to the extent the interest represented unrealized receivables or substantially appreciated inventory measured by the difference between the amount realized and the member's basis in the company.

Termination

Like all other aspects of LLCs, state statutes dictate the situations in which a company is considered terminated. However, as a general rule, an LLC will automatically dissolve upon the death, retirement, resignation, expulsion, bankruptcy, dissolution of a member or upon the occurrence of any other event terminating the membership of a member in the company. Further, some states limit an LLCs duration to a specified number of years. An involuntary dissolution may occur upon the application of one member to do so. Despite these methods of termination, in some states, the members of the company may elect to continue the business upon a terminating event if the Articles of Organization provide for such a right.

If an LLC is treated as a partnership for tax purposes, then the tax consequences stemming from its termination are identical to those associated with the termination of a partnership.

Sole Proprietorships

Use of this business form is the simplest noncorporate method. It requires no documentation with regard to its formation. To be considered a sole proprietor, a party must merely commence business. The simplicity involved in forming this type of business is its primary advantage over other business forms.

Unlike other entities, the operation of a sole proprietorship is vested solely in the business operator. However, because the business and its owner are a single legal entity, the owner is personally liable for the debts and other liabilities of the business. Thus, as a practical matter, practitioners representing sole proprietors should work with the owner to attempt to procure enough liability insurance to minimize the prospect that personal assets could be forfeited to satisfy business liabilities.

Formation of a sole proprietorship is not a taxable event. Thereafter, all tax attributes of the business are reported on the owner's individual return.

The transfer of a sole proprietorship is accomplished by simply selling the assets used in the business. Thus, while termination of the business is not, by itself a taxable event, the owner must recognize gain on each asset sale to the extent the amount realized exceeds the owner's basis in the asset. Characterization of gain or loss is determined separately for each asset.

Fringe Benefits

C Corporation

When a corporation provides a fringe benefit, such as medical insurance to an employee, the best result occurs when the corporation can deduct its cost and the employee does not have to include the value of the item in income. In this situation, the employer realizes a tax benefit and there is no offsetting tax cost to the employee.

Tax codes provide for a significant number of benefits not taxable to the employee, but deductible by the corporation if the compensation can be characterized as an ordinary and necessary expense. The most significant of these is the payment of premiums for health insurance. Others include the cost of providing up to $50,000 of group term life insurance, payments for injuries or sickness directly paid by the employer and meals or lodging furnished for the convenience of the employer. In addition, the employer may set up a cafeteria plan under which the employee can choose from among a variety of taxable and nontaxable benefits and cash. In each case, the fringe benefit qualifies for favorable tax treatment only if various statutory requirements are satisfied.

Contributions to a qualified pension plan also receive favorable tax treatment. The employer generally is entitled to an immediate deduction, but the employee does not have to include the item in income until received in a subsequent year. Qualification of a plan is complicated, but provides substantial tax benefits.

Planning Pointer: Individuals should be aware that the tax treatment of fringe benefits such as medical insurance is not as favorable if a partnership, LLC that is taxed as a partnership, or S corporation, rather than a C corporation, is carrying on the business. The favorable treatment of fringe benefits can be an important reason for using a C corporation. On the other hand, the rules for a qualified pension plan are substantially the same for all the entities.

Partnership and S Corporation

As discussed, C corporations can deduct the cost of various employee benefits and the employees do not have to include the value of these benefits in income.

This favorable tax treatment generally does not apply to partnerships. Furthermore, for purposes of determining the tax consequences with regard to employee fringe benefits, a 2% shareholder of an S corporation is treated as a partner of a partnership. A 2% shareholder is defined as any person who owns (directly or by attribution) more than 2% of the corporation's outstanding stock or more than 2% of the voting power on any day during the year. Consequently, a partnership or S corporation can deduct the cost of the benefit, but the partner or employee-shareholder must include the value of the benefit in income.

Note: Partners of more than 2% shareholders of S corporations, and sole proprietors are allowed to deduct up to 100% of the cost of medical insurance to the extent of any income from the business that maintains the plan providing the insurance.

In the case of qualified pension plans, an entity can deduct amounts contributed to the plan on behalf of employees. Further, the employee recognizes income only upon its actual receipt. The rules for a plan established by an S corporation, partnership or sole proprietorship are generally the same as those for plans established by C corporations. Thus, a deduction is allowed for a contribution to a qualified plan, and the beneficiary, which may include the S corporation shareholder, partner or sole proprietor, recognizes income only upon receipt of the benefit. Because the rules with regard to these plans are so similar, pension plans seldom affect the choice of entity decision.

Limited Liability Company

An LLC may be classified for tax purposes as either a partnership or as an association taxable as a corporation. Tax treatment of fringe benefits are furnished by an LLC, therefore, should depend on proper classification of the LLC.

Oklahoma Law

Oklahoma law and federal tax elections yield essentially a choice between two entities: sole proprietorships and limited liability companies. Unlike a C or S corporation, a limited liability company is not subject to franchise tax. After a limited liability company is established in Oklahoma, the Internal Revenue Code allows that limited liability company to elect to be taxed as a C corporation and then, if desired, it can change the election to be taxed as an S corporation.

Tax Issues and Tips

Not carefully deciding what type of business entity to create and not taking care of business has doomed more cattle ranches than drought or cattle prices. If labor is hired, ranchers must comply with Internal Revenue Service, Social Security Administration, Department of Immigration and Labor as well as state and local taxing authorities. Payroll taxes, self-employment tax and the possibility of having a ranch declared a hobby are the most likely problems for new and existing ranchers, especially if they have formed a sole proprietorship or a partnership. IRS Publication 225, Farmer's Tax Guide, is an excellent reference, which explains many of the income tax rules that apply to farmers and ranchers.

Payroll Taxes

If an employee is paid more than $150 per year or total payments to all employees exceed $2,500 per year, the ranch business must get a federal ID number and report payroll taxes. A Taxpayer Identification Number (TIN) can be obtained by filing form SS-4 with the district Internal Revenue Service center. Federal and State income tax and Social Security and Medicare taxes must be withheld and deposited. Forms W-2, W-3 and 943 must be filed by Jan. 31 for the previous calendar year. See IRS Publication 51, Circular A, Agricultural Employer's Guide for complete details.

Self-Employment Tax

Individuals who are employed by a company should receive a W-2 Form stating their wages and withholdings. Based on a W-4 withholding form, employers withhold income tax for each employee and pay the withholding to state and federal tax authorities. Individuals who are in business for themselves must report income and expenses from that business on IRS Schedule C or Schedule F if the net income is at least $433.13. This net income is subject to 15.3% self-employment tax up to the maximum for 2020 of $137,700. Net income above that level is subject to only Medicare taxes of 2.9% without limit. These self-employment taxes are in addition to income tax due when net income from self-employment is combined with the individual's income from other sources on Form 1040. Self-employed individuals also must make quarterly deposits of estimated income tax to avoid tax penalties. If more than 2/3 of total gross income from all sources is from farming or ranching, quarterly estimated tax payments are not required if the individual's tax return is filed by March 1. Please refer to IRS Publication 533, Self-Employment Tax for complete details.

Hobby Loss

An often misunderstood area of taxation causing worry to the taxpayer involved in a business is the hobby loss, which is to deduct expenses in excess of income for a given venture, one must be engaged in that venture for a profit. These rules were originally developed by Congress to set up an objective standard to determine whether a taxpayer has a legitimate business operation or is merely attempting to generate tax losses to offset other income. If there is no intent to make a profit, IRS assumes that the activity is a hobby and will disallow the deductions in excess of income. The general test to measure the profit motive is whether the activity has generated a profit in any three out of five consecutive tax years. If the activity deals with breeding, training, showing or racing horses, the test is any two out of seven years. For the struggling rancher whose business venture is not showing a profit, the worry that the IRS will disallow all deductions can be stressful. More information is available to help the taxpayer in this situation. Once the business has failed to show a profit in three out of five (or two

out of seven) years, the IRS may look at the business. This does not automatically mean that the IRS will, only that they might. In addition, the test does not automatically determine whether a business should be considered a hobby, only that the IRS can look at it. The actual decision of whether a business has been operated with a profit motive is based on all facts and circumstances. Nine factors are set forth in IRS regulations to be used as a guideline. These relevant factors are used only as a guideline – no one factor or group of factors determines the outcome. It is a subjective judgment call where all facts are taken into account. However, taxpayers can protect themselves by being aware of these nine factors and using them as a guideline. Most importantly, taxpayers can further protect themselves by keeping good records to document actions that indicate a profit motive based on the following nine factors:

1. **Is the activity carried on in a businesslike manner?** If the taxpayer keeps businesslike books and records, changes methods of operation that are not working, tries to use techniques of profit-making ventures to increase efficiency and profitability or even abandons a business venture that is going nowhere, the profit motive may be indicated.
2. **Can the producer take advice? What is the expertise of the taxpayer or their advisers?** The taxpayer should be able to show that they have studied the accepted practices of the venture—in this case, ranching—and/or has sought advice from experts in the field. This may include reading books, taking classes, paying advisers and taking their advice. If the producer has gotten advice and information and has operated in a completely different manner, they should be prepared to explain attempts to develop new practices, which could result in profit.
3. **Is the taxpayer spending any time here? How much time and effort is expended by the taxpayer?** If the producer is spending significant personal time and effort on the activity, it can indicate a profit motive. Employing competent persons to run the activity for the taxpayer also may indicate profit motive.
4. **Does anything have value? Are the assets expected to appreciate in value?** Overall profit could be reasonably expected from increase in value of land, cattle or other assets even if operations of the business are not showing a current profit.
5. **Has the taxpayer been profitable in carrying on this or similar activities in the past?** If the taxpayer has carried on similar activities in the past and turned them from unprofitable to profitable, a profit motive could be assumed.
6. **What is the history of income or loss?** Are losses mainly a start-up situation or have they been sustained beyond a reasonable length of time? If there have been unforeseen circumstances beyond the taxpayer's control such as drought, fire, theft, war, depressed market conditions, etc., the reasonable length of time for loss could be extended. Again, very good records would help back up this type of claim.
7. **Has the operation made any money?** What is the amount of profit, if any, that has been earned? The occasional small profit from a venture offset by persistent high losses would probably indicate that there is no profit motive. A solid profit, though infrequent, or a reasonable opportunity to achieve an eventual profit, might back up the taxpayer's profit motive.
8. **Is the taxpayer making any money doing anything else? What is the financial status of the taxpayer?** If there is no substantial income from other sources, it is a good bet that the activity is meant to generate a profit. However, the presence of other income, especially during the startup period of a venture, only shows good planning and would not necessarily negate the profit motive.
9. **The presence of personal pleasure or recreation in an activity has often been used by the IRS to claim that an activity is a hobby.** However, the other factors mentioned in this list also are taken into consideration by the courts. The fact that a person enjoys a business is not sufficient cause to disallow the profit-making motive.

If taxpayers choose to engage in beef production for a profit, they must keep good records. If producers take a class related to the business, consult with an accountant or business expert or buy a book, they must keep the receipts. If producers have taken advice and changed a method of operation to improve efficiency, they must write it down. If there has been flood, drought, disease or other natural disasters in the area affecting business profits, write it down, cut out any news articles, keep records, count hours, record mileage and keep receipts.

Conclusion

Producers must consider carefully what type of business entity to form for the operation. Each type has both pros and cons associated with it. Producers should consult with the area OSU Extension economist, state OSU Extension tax specialist or an income tax preparer to make wise decisions regarding the formation or changing of a business entity.

The above general tax information is provided to educate taxpayers about the income tax consequences of hobby losses. If specific detailed information is needed, or if a farm or business operation is in danger of being declared a hobby by the IRS, please contact the area OSU Extension economist, state OSU Extension tax specialist or an income tax preparer.

References

To access the most current versions of the following referenced publications, go to irs.gov. In the search box, type in Publication followed by the publication's number to download it. For example, type in Publication 225 to get to the current version of the Farmer's Tax Guide.

Circular A, Agricultural Employer's Guide. IRS Publication 51
Farmer's Tax Guide. IRS Publication 225
Self-Employment Tax. IRS Publication 533

7 Economic Considerations in Disaster Management

Derrell Peel and J C. Hobbs

Objective

- **Review strategies for weathering disasters and understand potential financial repercussions expected.**

Oklahoma's weather contributes significantly to agricultural production risk. Most Oklahoma beef producers are impacted by drought one or more times in a 10-year period. Typically, the lack of forage (scarcity coupled with the high price of hay in some years) forces producers to rethink production, marketing and management plans. The financial repercussions of one or more years of drought on an individual farm operation depend on its initial financial position, its historical performance and its stage in the business life cycle (start-up, growing or mature) as well as the financial demands placed on the farm by the family.

Farms with no debt are best positioned to weather financial adversity, as they can draw on savings or unused credit to pay for unexpected expenses and support the family through low-income years. The risk of continued operation during poor income years is that owner equity may be eroded unless the investment horizon is sufficiently long to recoup losses. Prolonged periods of low prices, high costs and/or low yields might be expected to prompt some older producers with no debt to choose retirement, perhaps liquidating some assets to generate retirement income.

Farms that have been profitable may be able to continue operations through several low return years. Lenders may be willing to provide credit to help with cash flow problems or the producers may have sufficient savings or off-farm income to survive. Debt levels may rise and loan repayment will place greater demands on future income; or savings will fall, consequently generating less investment income in the future. Until the operation returns to a profitable status, owner equity will decline.

The operations most vulnerable to high costs or low prices and low yields are the most highly leveraged farms, often with younger operators. For these producers, one or more years of low returns can jeopardize the operation as the need to generate cash for loan repayment and family living expenses is greater than for comparably sized operations with less debt. These producers may contemplate partial or complete liquidation of the cow herd and, sometimes, the farm or ranch.

Financial stress dictates a reassessment of farm goals and priorities. Goals might include protecting owner equity, minimizing losses, staying in production agriculture regardless of the cost to owner equity or orderly liquidation of assets. With changing economic circumstances, the risk environment changes, as does the operator's ability to tolerate risk, both personally and financially. New constraints—for instance, limits on borrowing imposed by a lender—must be recognized. Goals that earlier seemed reasonable may no longer be feasible or may conflict with each other. Once goals and priorities have been reassessed, the operator is prepared to develop a plan for dealing with financial stress.

Prolonged drought leads to serious financial and production consequences.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 7.1. Repercussions of management strategies.

Options for change	*Cash flow*	*Profitability*	*Solvency*	*Tax*
Buy feed or hay.	Increases outflows.	Decreases profitability.	If result is negative net farm income, owner equity will decrease.	More deductible expenses, less income, less income tax.[a]
Rent additional pasture.	Increases outflows.	Decreases profitability.	If result is negative net farm income, owner equity will decrease.	More deductible expenses, less income, less income tax.[a]
Extra culling, partial cow herd liquidation.	Increases inflows.	Minimizes loss if reduced feed and interest expenses offset any loss on cull cows sold.	Minimize loss if reduced feed and interest expenses offset any loss on cull cows sold.	More taxable income. Some gains can be postponed using one of two elections.
Adjust family withdrawals.	Decreases outflows.	No impact on farm profitability.	Retain more farm earnings, increase owner equity. May be temporary effect if only postponing the withdrawals.	No impact on farm income tax. Could reduce itemized deductions.
Adjust farm withdrawals (e.g. postpone capital purchases).	Decreases outflows.	May increase profitability in short run, decrease in long run.	Retain more farm earnings, increase owner equity. May be temporary effect if only postponing the withdrawals.	Fewer deductible expenses, more income tax, but more after-tax profit.
Control costs.	Decreases outflows.	Increase profitability if no loss in production.	If profitable, increase owner equity.	Fewer deductible expenses, more income tax, but more after-tax profit.
Increase returns.	Increases inflows.	Increase profitability.	Increase owner equity.	More income, more income tax, more after-tax profit.
Change enterprise mix.	Depends on enterprise selected. Cash flow plan for alternative enterprise should be evaluated.	Depends on enterprise selected. Increase if enterprise is profitable and complementary.	Increase if enterprise is profitable and complementary.	More net income, more income tax, more after-tax profit.
Change asset ownership: Renting. Leasing. Sale/leaseback.	Increases inflow in short run if assets are sold. In long run, decreases outflows if cost of custom hire, renting or leasing is less than fixed ownership costs, including loan payments.	Increases profitability if cost of custom hire, renting or leasing is less than ownership and operating costs.	Retains earnings, owner equity increases if cost of custom hire, renting or leasing is less than ownership and operating costs.	Recapture of depreciation taxed at ordinary income tax rates. Capital gain is taxed at current capital gain tax rates. (Refer to IRS publication 225 for the current tax rate).
Supplemental income.	Increases inflows.	Possible decline in farm productivity leading to decreased profitability.	If off-farm income offsets farm losses and is invested in farm, increased solvency.	More taxable income, more tax, but greater after-tax cash flow.
Debt rescheduling.	Decreases outflows.	Less interest expense in short run will increase profit in short run, decrease profits in years to which repayment is shifted.	Likely to increase solvency in short run, may decrease it in future years if business does not increase profitability.	Less deductible interest expense, more income, more tax (if not operating at a loss). More after-tax profit in early years, less in later years.
Debt restructuring.	Decreases outflows, but tarnished reputation regarding repayment.	Increases profitability.	Improves potential to remain solvent.	More taxable income unless insolvent or bankrupt.
Investment by outsiders.	Increases inflows.	Increases profitability if invested wisely.	May increase solvency.	More recordkeeping. Repayment of principal not deductible. More tax when investors repaid.
Complete liquidation.	Increases inflows.	N/A	N/A	Recapture of depreciation taxed at ordinary income tax rates. Capital gain is taxed at current capital gain tax rates. (Refer to IRS publication 225 for the current tax rate).

a Net operating loss = no tax paid. Farming net operating losses can be carried back two years or five years, as well as forward to 20 years.

Discussion of a variety of strategies to cope with disaster, using drought as an example, follows. The repercussions — cash flow, profitability, solvency and tax (applying the tax rules applicable for 2020) — of strategies are summarized in Table 7.1.

Early Drought Planning is Important

Producers have the most ability to minimize the adverse impacts of drought by making plans early when drought conditions begin to develop. Every drought is different in terms of timing, severity and specific conditions that affect how the drought will impact a cattle operation. Long before the drought reaches a point where drastic measures must be taken, a producer should develop contingency plans to guide decisions if the drought persists and worsens. This plan should include early evaluation of available pasture, hay and other feed resources; types of production adjustments that may be possible and, finally, a priority list of cattle classes that would guide the order in which cattle would be liquidated if necessary. Consideration of production and marketing alternatives that may be part of drought response become part of the broader financial evaluation of the short- and long-term impacts of drought on the operation.

Buying Feed or Hay

Producers' immediate reaction to a lack of pasture for cows is to begin buying feed or hay. Whether this decision makes sense economically depends on whether the expected forage shortage is predicted to be short in duration, as well as the financial position of the operator and the profitability of the enterprise. For the historically profitable producer, buying feed or hay for more days than usual will reduce the income earned per cow. These producers may be able to afford to feed the cow for several months before incurring a loss. Producers earning low returns in normal years will have a shorter time frame in which they can afford to buy additional feed or forage for the cow before eliminating potential profit. A producer who has not been profitable historically must decide how much equity they are willing to lose to feed the cows. If other enterprises are sufficiently profitable or enough off-farm income is earned, purchasing feed for cows may be feasible, though not necessarily profitable. However, buying feed or hay for more months than usual will mean that equity will build up less quickly or, in the case of a loss, equity will erode more quickly. Whether it is feed or hay purchased, clearly the incentive is to minimize waste, for example by feeding hay in rings with solid sides at the bottom.

Controlling hay costs is the key to controlling cow-calf production costs.

Rarely is drought accompanied by low nonforage feed prices, allowing producers to evaluate the possibility of using concentrates to feed cows. It is possible to reduce forage use by 70% to 80% by limit-feeding some grain to cows. Given the cost of purchasing and hauling hay, limit-feeding grain may reduce the cost of winter-feeding by 25% to 40%. In most cases, a limit-feeding program for cows will require some changes in cow management, may increase labor for feeding and may require additional feedbunks. These considerations will temper the feasibility of this alternative in some operations.

If the quantities of hay or feed purchased are such that losses are generated, owner equity is decreased. Still, this may be a reasonable strategy if the cows are highly valued seedstock that cannot easily be replaced when circumstances change or if the investment horizon is sufficiently long so losses can be recouped. Buying feed or hay is a flexible strategy because it may be bought on an as-needed basis and excess purchases can be stored for future use.

More feed and hay purchases mean more deductible expenses, hence less income tax to be paid at the end of the year. Of course, if a loss is expected, no income tax will be owed anyway. However, if a net operating loss is incurred, it may be carried back to generate a refund of taxes paid or carried forward to reduce future taxable income. Refer to the "Tax Considerations" section later in this chapter for more detailed information about net operating losses.

Renting Additional Pasture

For the profitable producer, renting additional pasture (if it is available) will reduce the income earned per cow and could result in losses to the enterprise. Again, it may be a reasonable strategy if the cows are highly valued seedstock that cannot easily be replaced when circumstances change or if the investment horizon is sufficiently long that the losses can be recouped. Renting additional pasture is a longer term, fixed commitment compared to buying feed or hay. Whether it is cost efficient depends on the lease price and the quantity and quality of forage relative to grain and hay. If several additional acres must be rented per cow, potential profits can quickly disappear. (See: OSU Extension fact sheets AGEC-208, *Evaluating Options for Change*; AGEC-237, *Farm and Ranch Stress Test*; AGEC-239, *IFMAPS: A Partner in Farm Financial Planning*; AGEC-788, *Tax Consequences of Weather Related Sale of Livestock*; and OSU Extension current report CR-216, *Oklahoma Pasture Rental Rates*.)

A producer who has not been profitable historically must decide how much equity they are willing to lose to pasture the cows if this is the strategy chosen. If other enterprises are sufficiently profitable or enough off-farm income is earned, losses may be feasible. However, with the additional pasture costs, as with additional hay or feed costs, equity will be eroded more quickly than in the past.

The tax repercussions of renting additional pasture are the same as those with purchasing hay or grain. Additional expenses reduce current taxable income and after-tax income (or increase the net operating loss).

Calf or Cow Sales

Producers may consider any one of the following or a combination of several alternatives for selling calves or cows to reduce forage use and stretch limited forage supplies. Producers facing the most severe forage shortages may consider weaning calves early to reduce the nutritional needs. Selling lighter-than-usual calves in a down market can result in catastrophic reductions in revenue unless calf-retained ownership is possible. The viability of this strategy depends on available calf management and marketing alternatives.

Normal but earlier rates of culling or additional culling, either early or at the normal time, will further reduce forage demands on the ranch and reduce the need for purchased grain or hay. Cows should be evaluated first for physical and reproductive soundness and productivity. Beyond that, producers may consider additional culling of some older cows. When the cattle industry is in liquidation mode, extra culling is consistent with market signals. Strategically, by culling older cows during a drought when the industry is liquidating cows and replacing them with young cows in the coming months (depending on how fast forages recover), producers will be well positioned to maximize calf production and sales when prices are at cyclical peaks. A producer must not keep more cows than can be maintained in good body condition. Otherwise, poor calf crops and poor herd reproductive performance may later compound the cost of a drought.

While not an ideal solution, selling cows during a drought may prevent losses.

The key to deciding how much to cull should be driven by an evaluation of remaining forage resources and the ability to purchase additional feed. Producers are averse to selling cows at very low prices or perhaps even high prices, if market signals suggest the need for herd growth. However, selling more cows than usual generates cash that can be used to feed the remainder, and if enough are sold, proceeds can be applied to operating debt, which will lower interest expenses. Partial herd liquidations provide time flexibility in rebuilding the forage base. For both the historically profitable producer and the cash-strapped one, culling extra cows will minimize the losses to equity incurred by operating at a loss.

If partial or complete liquidation of the cow herd is being considered, a question that arises is with respect to timing: When should the cows be sold? Table 7.2 summarizes the increase in cow value needed to justify postponing cow sales. The analysis is based on a 100-cow herd, net sales value of $1,500 per cow. Additional net earnings from renting out land or not leasing land of $15,000 per year are included for later sale dates. In this scenario, if a $90 financial loss per cow is anticipated because of drought ($1.00 per cow per day), the cow's value would have to increase $167 or more to justify waiting three months to sell the cow with a 4% opportunity cost on sales proceeds. Potential tax repercussions are not included. It is important to remember that as long as the decision makes economic sense, the tax issues can be managed. A spreadsheet to evaluate whether to sell cows now or later is at beefextension.com.

Adjust Family or Farm Withdrawals

Producers should be sure that their expectations with respect to the farm's ability to generate income are realistic. Curbing family living expenses frees up cash to be used for cow maintenance. Developing a budget, living within it and minimizing nonessential spending may allow producers to pay down high interest loans and credit card debts, reducing

Table 7.2. Cow-calf analysis: sell cows now or later.[a]

Increase in cow value needed to justify waiting to sell	*Sale date*		
	Three months	*One year*	*One year with land rented out*
***4% opportunity* cost on funds**			
No losses			
Losses = $1/cow/day	107	426	576
Losses = $2/cow/day	199	792	942
6% opportunity cost on funds			
No losses			
Losses = $1/cow/day	115	456	606
Losses = $2/cow/day	207	822	927

a Assumes 100-cow herd and current net sales value of $1,500 per cow on average.

future cash obligations for loan repayment. Keeping good records is the first step in understanding family living expenses and identifying ways to control them. Inexpensive software can be a valuable tool in this process (see agecon.okstate.edu/quicken for an example).

Postponing major expenditures or purchases, such as a new vehicle or other similar items, may increase future demands on farm income. Reduction of family withdrawals could reduce itemized deductions if the reduction comes in items such as charitable contributions or medical expenses. However, most farmers' standard deduction is higher than their itemized deductions.

Likewise, delaying farm capital purchases, for example, new machinery, equipment or vehicles and postponing improvements are obvious strategies to preserve cash for cow maintenance. As with postponing family living expenses, the repercussion may be a greater demand on farm income in future years. Even though producers may be able to write off part of the costs of asset purchases, purchases should not be motivated by potential tax benefits. The cash required to make new vehicle payments will pay for substantial repairs on an owned vehicle. Costs of ownership for some items on a per acre or per head basis also may exceed the cost of renting or leasing it.

Control Costs

Periods of financial stress are a good time to do an internal audit of the operation. Are inputs being purchased as cheaply as possible, for instance, is feed bought in bulk rather than in sacks? Producers should look most closely at high cost items—often interest, machinery, rent, feed, fertilizer and labor. Some costs may be relatively fixed; others may be negotiable. Some costs may be reduced by substituting comparable but less expensive inputs, for instance, adjusting feed rations to utilize low-priced grains. Others might be reduced by using inputs more efficiently, such as feeding hay in rings to minimize waste. Controlling costs will reduce deductible expenses, but increase after-tax profits. Again, knowing your costs and having the ability to summarize them early is very helpful in assessing alternative strategies.

Increase Returns

Improving marketing and production practices can increase farm returns. Having a deliberate marketing plan, lowering costs while holding production level (or lowering costs more than any decrease in income) and utilizing all assets that have income potential are keys to maximizing profits. Perhaps range or timberland could be leased for hunting. Underutilized machinery and equipment could be leased out or used for custom farming.

If grain is relatively inexpensive, it may be beneficial to consider confined feeding of cull cows for 30 days to 60 days before marketing. Although this requires additional feed, the payoff may be quite high. With cheap grain, feeding some concentrate feed (with minimal hay) to cull cows may significantly enhance the value of those cull cows, especially if they are thin because of drought-related pasture conditions. In addition to having more pounds to sell, feeding cull cows may increase their price because of increased dressing percentage or an increase in quality grade.

The feasibility of retained stocker programs is driven largely by the relationship between calf and feeder cattle prices. It is a characteristic of the cattle industry that when prices are high in absolute terms, calf prices tend to be relatively higher than feeder prices. Similarly, when prices decrease, calf prices tend to fall relatively more than feeder prices. Thus, at low prices, the value of stocker gain is higher than at high prices.

In the absence of forages typically used for grazing stocker cattle, producers can consider limit-feeding calves using concentrate diets in confinement or semi-confinement. Calves can be program fed to gain a target rate, probably about 2 pounds per day, depending on calf size and marketing intentions. This type of backgrounding program requires some changes in management. Producers should evaluate implications for production and health management of the cattle, additional labor requirements and the possible need for additional facilities and equipment for the confinement-feeding program. Moreover, retained ownership exposes the producer to additional market risk so price risk management should be an integral part of the retained ownership program.

Learning new marketing or management skills may require an investment in time and money. Again, more income may increase the amount of tax paid but also will increase after-tax cash and profits.

Change Enterprise Mix

A whole farm financial plan, complete with enterprise budgets, is a useful means of identifying farm profit centers. Knowing the relative contributions of different crops and livestock allows producers to redirect resources, for instance, labor or land, to profitable enterprises and away from less profitable enterprises. Producers may want to consider a new, promising enterprise if it fits with the rest of the farming operation and farm and family goals.

Reallocating resources can improve farm profitability, resulting in more taxable income. The impact on cash flow depends on changes in the levels of production of existing enterprises, whether capital assets are sold or purchased, and the added cash flow demands of the new enterprises.

Individual assistance in farm financial planning is available through the IFMAPS program (agecon.okstate.edu/ifmaps or 1-800-522-3755).

Change Asset Ownership

If loan payments are crippling cash flow, producers should evaluate the cost of leasing rather than owning assets, including land. While producers often feel they must own land to be farmers or ranchers, some enterprises will not generate the cash necessary to make principal and interest payments. Producers also should evaluate whether machinery and equipment is earning its keep, particularly on small operations. Older equipment that

is fully paid for and depreciated will not contribute to cash flow or profitability problems (unless repair costs and associated down time are very large). However, new machinery and equipment purchases can contribute to cash flow and profitability problems if the assets are held for a relatively short period of time and used on a small acreage. A financial lease is another alternative to owning machinery and equipment. Custom hiring also can be a reasonable alternative when equipment is expensive and used infrequently.

Selling underutilized assets generates cash, which may be needed to maintain cows in the short run. Remember, taxes must be paid on gains as they were with cull cows. Liquidation of capital assets and recapture of depreciation may increase income tax. This additional tax must be weighed against potential cost savings. In planning for the future, annual operating costs will be higher as cash will be needed to make lease payments or hire custom operators. New risks are introduced if assets are sold that make the producer dependent on the custom operator to complete tasks in a timely fashion.

Supplemental Income

Farm income can be supplemented through income from an off-farm job, such as custom work done for other farmers or a home-based business. Extra cash will help alleviate cash flow problems. Additional time away from the farm business could lead to a decline in productivity. Thus, the potential benefits of another job or business must be weighed against the costs.

Debt Rescheduling

Large interest and principal payments in a drought year can be devastating. If the farm has been historically profitable, lenders may be willing to reschedule the loan payments by changing the length of the loan. Rescheduling spreads the principal payments for a longer period of time, thus reducing the principal payments in the short term, but obligating the producer to repayment for more years. If financial conditions improve, the operator may be able to repay during the original time frame if no prepayment penalty is included in the renegotiated loan contract. If the inability to fully make principal and interest payments is caused by lack of profitability in addition to drought stress, then shortfalls will likely recur despite rescheduling.

Reducing interest expenses reduces deductible expenses, increases taxable income and increases after-tax profit in the short term. However, lengthening the repayment period means more total interest expenses during the long term and a reduction in profit in later years.

Debt Restructuring

A lender may be willing to write down either principal or interest if the repayment ability of the borrower is less than the scheduled payments or if the value of the loan collateral has declined to a level below the debt commitment. The lender's willingness and ability to negotiate will depend on both the borrower and lender's financial condition as well as the regulations governing the lending institution. A permanent lowering of principal and interest obligations helps both cash flow and producer profitability (it does the opposite for the lending institution), but tarnishes the future business relationship. Forgiven debt is taxable income, unless the farmer is insolvent or in bankruptcy.

Investment from Outsiders

If the producer is willing to give up some share of ownership in the operation, an infusion of cash from outside can alleviate financial problems. An off-farm heir or another producer may be willing to provide cash to reduce indebtedness or pay bills in return for a share of the business; a lender might be willing to trade a debt obligation for an equity position in the operation. An equity infusion increases cash available and reduces financial risk by increasing the equity capital base. However, taking on additional partners means sharing future business returns or repaying in some other fashion, for instance, transferring ownership of specific assets. Repayment of principal to investors is not a deductible expense.

Complete Liquidation

If the financial situation of the farm or ranch is beyond repair, the best choice may be to end the business, salvaging any remaining equity. Recapture of depreciation is taxed at ordinary income tax rates. Capital gain (sale price greater than purchase price) is taxed at the current capital gain tax rates (refer to IRS Publication 225 for the current rates).

Tax Considerations

It is important to review current tax laws that might come into play as producers make operating changes to minimize the negative impacts following drought. Current tax law provides several benefits to agricultural producers. Consult a tax professional to determine which provisions apply to you. For 2020, the maximum capital gains rate for sales of capital assets is 20% for married filing joint taxpayers with more than $248,300 of taxable income; 15% for married filing joint taxpayers with more than $40,000 and not more than $248,300 of taxable income; and zero for married filing joint taxpayers with not more than $40,000 of taxable income. The Section 179 Expense election amount that can be expensed in the 2020 tax year is $1,040,000. In addition, the threshold for phasing out the Section 179 expense election is $2,590,000. Therefore, if a farmer placed in service more than $2,590,000 of qualified property in 2020, the amount allowed under Section 179 is reduced dollar for dollar. For tax years 2020 through 2022, 100%. Bonus depreciation is allowed for property placed in service during the tax year. The allowed percentage declines to 80% for 2023, 60% for 2024, 40% for 2025, 20% for 2026 and sunset beginning January 1, 2027.

Farmers can use either of two provisions to defer gain recognized on the sale of livestock sold on account of drought, flood or other weather-related conditions. Both apply only to weather-related sales of livestock in excess of normal business practice. The first allows farmers to defer

reporting the gain from the sale of any livestock for one year. The other provision allows farmers to postpone recognizing gain from dairy, draft or breeding livestock if like animals are purchased, to replace those sold, within two years of the end of the tax year of the drought sale. Poultry and livestock for sport purposes are not eligible for postponement of gain. Gain is postponed only for sales in excess of normal sales and is subject to other requirements (see IRS Publication 225). The new replacement livestock must be used for the same purpose as the livestock sold. Therefore, dairy cows must be replaced with dairy cows and beef cows replaced with beef cows. If the farmer normally culls or sells one-fifth of the herd each year, only the sales in excess of one-fifth qualify for postponement of gain. The farmer's tax basis in the replacement livestock equals the basis in the livestock sold, plus any amount invested in the replacement livestock that exceeds the proceeds from the sale. To qualify for the income deferral, there must be a Federal Disaster Declaration that caused the animals to be sold early. To postpone recognition of gain and allow the purchase of replacement animals, a producer must prove the weather-related condition that caused the sale of the excess animals.

Income averaging for farmers continues to be allowed. Farmers can elect to remove all or part of current farm income from total taxable income and spread it over the three preceding years. Tax would be based on the marginal rate effective in the last three years. The potential reduction in tax applies only to income tax and would not reduce self-employment tax in the current or prior years. Attempting to keep taxable income level through the years can maximize long-term after-tax profit. Because of the progressive nature of tax rates (higher taxable income is taxed at higher marginal tax rates), level taxable income reduces taxes paid.

The Net Operating Loss (NOL) carry-back period for farmers is maintained at two years and the NOL carry-forward rules allow the loss to be carried forward until it is reduced to zero subject to an annual limit of 80% of taxable incomoe in a carryforward year. Farmers can waive the carryback of a farm loss and carry the loss forward to future years if the tax benefit is greater.

A larger-than-normal liquidation of capital assets may cause taxable income to increase if depreciation is recaptured. Decisions to liquidate or sell major assets may hinge on determination of the after-tax proceeds of such sales. Taxable proceeds equal the asset's sale price less its adjusted tax basis. Tax basis depends on how the asset was acquired: purchase, gift or inheritance. The donor's tax basis transfers to the donee for gifts, and the tax basis of inherited assets is generally the fair market value of the assets at the decedent's time of death. The tax basis of purchased capital assets is the purchase price (even if the money is borrowed). The adjusted basis is the purchase price less depreciation taken. Depreciation is a method of allocating the fixed cost of the purchase of a capital asset through its useful life. Depreciation for tax purposes is limited by the IRS specification of an asset's fixed useful life and fixed depreciation methods. One-half year of depreciation is allowed both in the year of purchase and the year of sale. While most farm assets are assigned a fixed life of five years seven years, 10 years or 15 years, a special election (Section 179 Expense election) allows a current expense deduction of up to $1.04 million of the cost of a purchased capital asset. In addition. Bonus depreciation allows for the write off of 100% of the purchase price as well. If assets, such as purchased breeding livestock, are sold for more than the adjusted basis, the gain due to depreciation recapture is taxed at ordinary income tax rates. Proceeds from sales of depreciable assets or land are eligible for capital gain tax rates only to the extent these assets are sold for more than the original purchase price. Thus, the net proceeds are a function of an asset's purchase and sale price, adjusted tax basis and depreciation taken, length of time the asset was owned,and the producer's (or business') tax bracket.

For example, a breeding beef cow is purchased in 2020 for $2,500, the IRS fixed life is five years and the method for calculation purposes is straight line. Depreciation for 2020 is $250 as only one-half year of depreciation is allowed in the year of purchase. Depreciation for 2021 is $500. If the cow is sold in 2022, her adjusted tax basis is $1,750 ($2,500 cost less $750 of depreciation taken in 2020 and 2021). If the cow is sold for $1,750, there is no gain or loss and no tax is owed, since the sale price equals the adjusted basis. If the cow is sold for $2,000, a gain of $250 ($2,000 minus $1,750) is recognized due to recapture of depreciation taken, and this gain is taxed at the farmer's ordinary income tax rate. If the cow is sold for $3,000, the gain due to the $750 of depreciation taken is taxed at ordinary income tax rates and the $500 gain in excess of original purchase price ($2,500 minus $2,000) is treated as capital gain and is taxed at the appropriate capital gain tax rate.

When farmers turn over assets to creditors in lieu of repaying debt, voluntarily or not, a tax liability can result. To continue the above example, assume the original loan to purchase the $2,500 cow has been refinanced and a total of $1,900 is owed. The cow is turned over to the lender and sold for $1,800, and the remainder of the debt is forgiven. The farmer is treated as if they sold the cow for $1,800 and owes tax on $50 of depreciation recapture which is taxed at ordinary income rates. In the view of the IRS, an $1,800 cow has been traded for a $100 reduction in debt, which is treated as taxable income to the farmer. Thus, $150 of taxable income ($50 of recaptured depreciation plus $100 debt forgiveness) is generated though not a penny is received. In special cases, where the farmer is not solvent or is in bankruptcy, the debt forgiveness may not be taxable; however, there is no provision to escape the tax owed on the $50 of depreciation recapture.

Conclusion

Almost annually, some Oklahoma producers experience financial stress due to drought. Adjustments may be needed in the farm plan or family spending to deal with this stress. Strategies to compensate for loss of forage may include purchasing feed or hay, renting additional pasture or selling livestock. To alleviate cash flow problems, producers may consider adjusting family or farm withdrawals, postponing

capital purchases, controlling costs, increasing returns, changing asset ownership or control agreements and supplementing income through custom work, an off-farm job or another business enterprise. Debt rescheduling, debt restructuring and investment by outsiders also are possibilities but require willing partners. If profitability has been an ongoing problem, changes in enterprise mix as well as production and financial management may be needed. The appropriate strategy or combination of strategies for farms with financial stress depends on both family and business factors. While the business financial position and historical performance are very important, the willingness and ability to change, the tolerance for risk both personally and financially, market conditions, potential tax liabilities and farm and family goals must also be considered.

References

Doye, D. (2013) Evaluating Options for Change. Extension Fact Sheet AGEC-208, Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Doye, D. (2013) Farm and Ranch Stress Test. Extension Fact Sheet AGEC-237, Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Doye, D., (2015) IFMAPS, A Partner in Financial Planning. Extension Fact Sheet AGEC-239, Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Doye, D. and R. Sahs (2015) Extension Current Report CR-216 Oklahoma Pasture Rental Rates. extension.okstate.edu

Hobbs, J C., Tax Consequences of Weather Related Sale of Livestock. Extension Fact Sheet AGEC-788, Cooperative Extension Service, Oklahoma State University: extension.okstate.edu

IRS Publication 225, Farmer's Tax Guide irs.gov/publications/p225/index.html

8 Livestock and Forage Insurance Options

JJ Jones and Amy Hagerman

This information is intended only to provide educational material to farmers to increase their understanding of livestock and forage insurance and disaster assistance programs available through the USDA-Risk Management Agency (RMA) and the Farm Service Agency (FSA). Nothing in this chapter should be construed as changing any term or provision of any livestock or forage insurance plan reinsured through RMA or FSA. Insurance programs available from RMA (and sold by approved insurance agents) include Livestock Risk Protection (LRP); Livestock Gross Margin (LGM); Pasture, Rangeland and Forage (PRF) and Annual Forage (AF). Disaster assistance programs available from FSA include Noninsured Disaster Assistance Program (NAP); Livestock Forage Program (LFP); Livestock Indemnity Program (LIP) and Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program (ELAP). For more information go to rma.usda.gov or fsa.usda.gov.

RMA Insurance Programs

Livestock Risk Protection (LRP) – Feeder Cattle

LRP-Feeder Cattle Overview

LRP is an insurance policy offering protection against a decline in feeder cattle prices during the insurance period. LRP coverage is based on a regional average of cash prices. Unlike traditional crop insurance policies that have a single sales closing date each year, LRP is priced and available for sale continuously throughout the year. Coverage is offered through endorsements, which offer producers coverage prices and premium rates that are fixed for each business day. Endorsements are available for a variety of time to correspond with the production period of the covered livestock, generally from 13 weeks to 52 weeks. An indemnity is paid if the price index specified in the policy drops below the producer's selected coverage price.

LRP coverage is available on livestock in certain states, depending on the type of livestock. To obtain LRP coverage, an application must be completed and submitted to the RMA through an insurance agent. There is no cost to enroll in the program through the application. Coverage is obtained only with a Specific Coverage Endorsement (SCE), a form that details the coverage price, cost of coverage number of head covered, the length of coverage and endorsement end date among other information.

As a product offered by the RMA, LRP has a premium subsidy. It is available to producers through crop insurance agents affiliated with insurance companies authorized to market RMA livestock insurance products.

LRP Application Process

Producers submit a one-time application through an FCIC-approved insurance provider. A Substantial Beneficial Interest reporting form identifying all persons with a substantial beneficial interest also must accompany the application. Any person with more than 10% interest in the insured livestock is considered to have a substantial beneficial interest.

Once accepted, the producer then has the right, but not the obligation, to purchase Specific Commodity Endorsements (SCE) throughout the year. A producer may purchase multiple endorsements. However, no more than 3,000 head of feeder cattle or fed cattle can be insured under any one endorsement. Annual limits may not exceed 6,000 head of feeder cattle or fed cattle.

LRP Policy Terms

Actual Ending Value – The value at the end of the insurance period as defined in the SCE for the particular class of insured livestock. For example, the LRP-Feeder Cattle actual ending value is established from the Feeder Cattle Reported Index as calculated by the Chicago Mercantile Exchange (CME) multiplied by the Price Adjustment Factor (PAF). Actual ending values are posted on the RMA public website at the end of the insurance period.

Coverage Price – The level of protection provided by the policy is on a dollar per cwt. basis. It is published each day on the RMA website and is selected by the producer when the SCE is purchased.

Expected Ending Value – The market price expected at the end of the insurance period and found in the actuarial documents. The expected ending value is used in calculations on a dollar per cwt. basis to determine the coverage prices.

End Date – The date stated on the specific coverage endorsement on which coverage on that specific coverage endorsement ends.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Specific Coverage Endorsement (SCE) – An endorsement to the policy necessary to provide coverage that includes information about the livestock or livestock product to be insured.

Target Weight – The anticipated weight of the insured livestock at the ending period as estimated by the producer at the time the specific coverage endorsement is purchased.

Coverage Levels - Calculated based on the chosen coverage price. Coverage levels will range from 70% to 100%.

LRP Cash Indices Used for Feeder Cattle and Fed Cattle

The cash price index for feeder cattle refers to a price series compiled and reported by the CME titled *CME Feeder Cattle Index.* The cash price index for fed cattle refers to a price series published by the AMS of the USDA titled *Five Area Weekly Weighted Average Direct Slaughter Cattle.*

LRP Coverage Offered

LRP provides coverage only against price decreases during the insurance period. The policy does not cover any other peril including mortality, condemnation, physical damage, disease, individual marketing decisions, local price aberrations or any other cause of loss as stated.

LRP Insurable Cattle

Feeder cattle eligible for insurance consist of calves, steers and heifers, including animals identified as predominantly dairy and Brahman cattle. Also, feeder cattle producers choose from two weight ranges:

- Less than 600 pounds (steers, heifers and bulls - all categories).
- 600 pounds to 900 pounds (steers and heifers only - all categories).

Insurable fed cattle include heifers and steers expected to weigh between 1,000 pounds and 1,400 pounds at marketing for slaughter at or near the end of the insurance period, grade select or higher and have a yield grade of one to three.

LRP Insurance Periods

Cattle producers select from the endorsement periods offered for sale each day from those listed on the Daily LRP Coverage Prices, Rates and Actual Ending Values website. The endorsement length ending most closely to the time the insured cattle would be marketed should be chosen. Not all available endorsement lengths may be offered for sale each day. Available endorsement lengths range from 13 weeks to 52 weeks for both feeder cattle and fed cattle.

LRP Expiration of Coverage Period

Coverage expires on the end date specified on the SCE:

1. If any part of the insured share is disposed of in the last 30 days of coverage.
2. If at any time during the coverage period, insured livestock are:
   a. Seized, quarantined or destroyed by order of any governmental authority.
   b. Not deliverable due to death or disease.
   c. Notice to company given within 72 hours of such event.

Coverage terminates if any portion of the share in the insured livestock is disposed of prior to the last 30 days of coverage. No indemnity will be paid on that portion and no premium will be refunded on the disposed portion unless properly transferred to an eligible transferee.

LRP Benefits for Producers

- Prices/premiums are set for the day with no bid/ask spread.
- No commission costs.
- Any number of head can be covered, from one head up to program limits.
- LRP is an insurance policy, not a derivative.
- Built in program flexibility because producers may choose the length of the policy period, coverage price, the number of head insured and the timing of the purchase.

Livestock Gross Margin (LGM)

LGM Overview

The Livestock Gross Margin for Cattle (LGM for Cattle) Insurance Policy provides protection against the loss of gross margin (market value of livestock minus feeder cattle and feed costs) on cattle. The indemnity at the end of the 11-month insurance period is the difference, if positive, between the gross margin guarantee and the actual gross margin. The LGM for Cattle Insurance Policy uses adjusted futures prices to determine the expected gross margin and the actual gross margin. Adjustments to futures prices are state- and month-specific basis levels. The price the producer receives at the local market is not used in these calculations.

LGM Eligibility

1. Only agricultural producers of cattle fed in the states of Colorado, Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Montana, Nebraska, Nevada, North Dakota, Ohio, Oklahoma, South Dakota, Texas, Utah, West Virginia, Wisconsin and Wyoming are eligible for the LGM for Cattle Insurance Policy.
2. Eligibility for the LGM for Cattle Insurance Policy is determined exclusively by federal law and regulations promulgated and as interpreted, by the FCIC and its Administrator, the USDA–RMA.
3. The producer's Target Marketings may not be more than the producer's Approved Target Marketings. Approved Target Marketings will be the lesser of the capacity of the producer's cattle operation for the 11-month insurance period as determined by the insurance provider and the underwriting capacity limit as stated in the special provisions.

Coverage

1. The Livestock Gross Margin for Cattle Policy provides insurance only for the difference between the Gross

Margin Guarantee and the Actual Total Gross Margin based on a Producer's Target Marketings and futures prices prior to and during the insurance period. This Policy does not insure against death or other loss or destruction of cattle.

2. There are 12 insurance periods in each calendar year. Each insurance period runs 11 months and no cattle can be insured during the first month of any insurance period. Coverage begins on cattle one full calendar month following the sales closing date, unless otherwise specified in the Special Provisions, provided the premium for the coverage has been paid in full. For example, for the contract with a sales closing date of January 31, coverage will begin on March 1.
3. This is a continuous policy. It will remain in effect following the acceptance of the original application unless cancelled by the insured or the company in accordance with the terms of the policy. After the initial insurance period, the producer must complete a Target Marketings Report by the Sales Closing Date of the next insurance period to be eligible for coverage in that insurance period.
4. The producer must elect the number of cattle to be insured during the insurance period (with the exception of the first month of any insurance period). This will be the producer's Target Marketings. Round Target Marketings to the nearest whole number.
5. All cattle will be insured at 100% share.
6. The Date of End of Insurance is 11 months after sales closing.
7. The producer may choose deductible amounts from $0 per head to $150 per head in $10 increments to apply to all Target Marketings.
8. The producer's premium is due with the signed application for coverage in the initial insurance period and with the completed Target Marketings Report in any subsequent insurance period.
9. Coverage may not be available in instances of a news report, announcement or other event that occurs during or after trading hours that is believed by the Secretary of Agriculture, Manager of the RMA or other designated staff of the RMA to result in market conditions significantly different than those used to rate the LGM for Cattle program. In these cases, coverage will no longer be offered for sale on the RMA website. LGM for Cattle policy sales will resume, after a halting or suspension in sales, at the discretion of the Manager of RMA.
10. Cattle insured in a yearling finishing operation are assumed to weigh 750 pounds (7.5 cwt) when they enter the feedlot, to weigh 1,250 pounds at slaughter (12.5 cwt) and to consume 57.5 bushels of corn. Cattle insured in a calf-finishing operation are assumed to weigh 550 pounds (5.5 cwt) when they enter the feedlot, to weigh 1,150 pounds at slaughter (11.5 cwt) and to consume 54.5 bushels of corn.

Pasture, Rangeland and Forage (PRF) Program

PRF Overview

The Pasture, Rangeland, Forage Insurance Program (PRF) is a pilot federal crop insurance program providing insurance protection for perennial forage produced for grazing or harvested for hay. The program is administered by the USDA RMA and sold through private crop insurance companies. Federal crop insurance is available only through private companies, known as approved insurance providers (AIP). Private crop insurance companies directly insure producers and their crops and then RMA re-insures the companies against a portion of the losses they may suffer. Due to difficulties quantifying price and yield for forage crops, particularly for grazing, standard crop insurance products generally are not an option for insuring forage production. The PRF program is similar to group risk insurance and provides area-wide coverage. For Oklahoma and the majority of the U.S., the program is based on a rainfall index. PRF insures producers based on the average rainfall in their geographic area instead of the producers' individual farm. Producers receive an indemnity payment when rainfall in their area falls below the normal historical level.

PRF Rainfall Index

The Rainfall Index uses National Oceanic and Atmospheric Administration, Climate Prediction Center (NOAA, CPC) data. The areas where the Rainfall Index is available have been divided into 12- by 12-mile grids. These grids do not follow county lines or township boundaries. This data does not directly reflect the rainfall amounts measured at a specific weather station within a particular grid. Instead, it reflects a smoothed result of nearby weather station data in obtaining an estimate. Most group risk insurance provides coverage at the county level, but this product provides coverage at the grid level, which likely is to provide a more accurate estimate of rainfall for a particular acreage than a county level measure. Grid locations can be found by using the Grid ID Locator feature on RMA's website at: prodwebnlb.rma.usda.gov/apps/prf.

PRF Coverage Offered

These products are designed to allow maximum flexibility for the producer. Producers are not required to insure all acres, but cannot exceed the total number of grazing or haying acres they operate. This allows producers to insure only those acres that are important to their grazing program or hay operation. By selecting a productivity factor, producers can establish a value between 60% and 150% of the county base value and match the amount of protection to the value of forage that best represents their specific grazing or hay operation, as well as the productive capacity of the land.

PRF - Insuring Forage

To obtain coverage, producers will be asked to make several choices regarding the intended use, productivity

factor, coverage level, insurable interest, insured acres and index intervals. Producers will work with their crop insurance agents to view the map and index grids for their area and assign acreage to one or more grids based on the location and use of the acreage to be insured. Forage producers can select from several coverage levels: 70%, 75%, 80%, 85% and 90%. Producers may choose the coverage level that fits their needs. Higher coverage levels reduce basic risk.

Intended Use – Producers must choose between insuring their acreage for either grazing or hay. The insurable value for grazing acreage is considerably lower than the value for hay; therefore, the insurance premiums also are lower. To be insured as hay acreage, said acreage must be able to be harvested for hay.

Coverage Level – RMA has established a county base value per acre. These values are different for grazing and hay acreages. Producers must choose a level of 70%, 75%, 80%, 85% or 90% of the baseline county value. The premium cost will increase with higher coverage levels.

Productivity Factor – RMA has established a per acre productivity value for each county, based on income received for haying and grazing operations under normal rainfall conditions. Producers can choose a protection factor between 60% and 150% of the county value. Producers select the amount of protection based on the forage value best representing their specific grazing or hay operation, as well as the productivity of their land. The premium cost will increase or decrease depending on the protection factor selected. Producers only can select one productivity factor for each crop type and county.

Insurable Interest – Producers must choose the appropriate insurable interest for the acreage. Producers can insure both owned and leased acres. Insurable interest is the insured's (person purchasing the insurance policy) percentage of the insured crop at financial risk. Insurable interest in grazing or haying acreage owned by the insured will typically be 100%.

When the insured crop is leased pasture, rangeland or forage acres with an intended use of grazing, the insured's percentage of the insured crop at financial risk will be based on the insured's percentage of one of the following:

1. Interest in the livestock to be grazed on the insured acres, if the acres are cash leased.
2. The value gained of the livestock being grazed on the insured acres if the acres are share leased.

Lessors under a cash lease are not considered to have a share in the insured crop.

Index Intervals – Index intervals act as mini-insurance periods spanning two-month intervals for the Rainfall index. Producers must select at least two, 2-month time periods, called index intervals, when rain is important to the operation. Insurance payments are calculated using NOAA, CPC data for the grid(s) and the chosen index interval(s). If the final grid index is less than the trigger grid index, which is the coverage level times the expected grid index, a loss payment may be issued. This insurance product only provides coverage for a lack of rainfall and is based on rainfall for the entire grid, not individual farms or ranches or specific weather stations. It is possible producers may have low rainfall on their own farm and not receive a payment.

Insured Acres – The same acreage cannot be insured for both haying and grazing in the same crop year. No more than 60% of the insured acreage can be put into one index interval (this applies separately to acres insured for haying or grazing). In addition, the same acres cannot be insured in more than one grid ID or county. If acreage is located in more than one grid, producers can choose to put all acreage in one grid or divide the acreage into separate grids.

PRF Decision Tool

A decision tool is available allowing producers to estimate premiums and indemnities from 1948 to the current year to see how the program would have performed if they were enrolled in previous years. PRF insurance is best suited for producers whose production tends to follow and correlate to the historical average rainfall patterns for the grid so it is important for producers to look at the historical indices. The decision tool can be accessed at: prodwebnlb.rma.usda.gov/apps/prf.

PRF Benefits for Producers

- Timely indemnities.
- Index intervals are mutually exclusive.
- Individual loss adjustment not needed.
- Easily understood index.
- Production records not required.
- Not required to insure 100% of acreage.
- Program supported via the Internet.
- Built-in program flexibility. Producer may choose the length of the policy period, coverage price and the number of acres insured.
- Forage may be harvested directly by grazing animals, harvested for hay or a combination of both.

Annual Forage (AF) Pilot Program

AF Overview

The Rainfall Index – Annual Forage (AF) Insurance Plan is a pilot program providing coverage for annual forage crops in Texas, Oklahoma, Kansas, Nebraska, Colorado, New Mexico, South Dakota and North Dakota. The program covers crops annually planted for forage or fodder intended for, but not limited to, grazing, haying, grazing/haying, grain/grazing, green chop, grazing/green chop or silage. The plan offers Catastrophic Risk Protection (CAT) and buy-up coverage. The pilot program is very similar to the PRF program, which covers perennial forage produced for grazing or harvested for hay. AF coverage includes, but is not limited to, small grains (wheat, oats, barley, rye, triticale) intended for grazing or forage, corn for silage, sorghum forage for grazing or forage, annually planted grasses (sudan, ryegrass, etc.) for grazing or forage and annually planted mixed forages for grazing or forage. The program is based on a rainfall index and insures producers based on the deviation from normal precipitation interpolated to their geographic area instead of the producers' individual farm. The program

does not use actual crop production on the individual farm or in the geographic area. Producers receive an indemnity payment when interpolated precipitation in their area falls below the normal historical level. Details of the rainfall index program are discussed below.

AF Rainfall Index

The rainfall index uses NOAA, CPC data. The areas where the rainfall index is available have been divided into grids and identified by a specific number code, referred to as a grid ID. Each grid is 0.25 degrees in latitude by 0.25 degrees in longitude. The grids are created by NOAA CPC and do not follow county lines or township boundaries. Data used for the rainfall index calculation do not directly reflect the precipitation amounts measured at a specific weather station within a particular grid. This measure reflects a smoothed result of nearby weather station estimates to obtain an estimate for the grid. NOAA uses the closest four reporting weather stations to the grid for any given day to interpolate precipitation to the grid. Grid locations can be found by using the grid locator feature at: maps.agforceusa.com/af/ri/.

AF – Insuring Forage

To obtain coverage, producers will be asked to make several choices regarding the growing season, coverage level, productivity factor, insurable interest, insured acres and index intervals. There are four growing seasons from which to choose: growing season 1 is for crops planted from July 15 to October 15. Growing season 2 for crops planted from October 16 to January 15. Growing season 3 is for crops planted from January 16 to April 15 and growing season 4 is for crops planted April 16 to July 15. Annual forage can be planted in two growing seasons on the same acreage in the same crop year, but the same acres cannot be insured in more than one grid ID or county during a single growing season. Producers will work with their crop insurance agents to view the map and index grids for their area and assign acreage to one or more grids based on the location and use of the acreage to be insured.

CAT Coverage

Producers can choose CAT coverage or buy-up coverage. CAT coverage insures the interpolated precipitation at the 65% coverage level and 45% of the county base value. Producers must choose the appropriate insurable interest for the acreage. Insurable interest is the insured's percentage of the insured crop that is at financial risk. Input the number of acres to insure.

Buy-Up Coverage

Producers can purchase 70% to 90% coverage in 5% increments. The premium cost will increase with higher coverage levels.

Coverage Level

Producers must choose a coverage level of 70%, 75%, 80%, 85% or 90%. Only one coverage level can be selected for each county and must be the same for each growing season.

Productivity Factor

The AF Insurance Plan allows the producer to individualize their coverage based on the productivity of the acreage of the insured crop. Producers can choose a protection factor between 60% and 150% of the county base value. Only one productivity factor can be selected for the county by growing season. Producers will want to select the amount of protection based on the value best representing theirs specific operation as well as the productivity of the land and crop planted. The premium cost will increase or decrease depending on the protection factor selected.

Insurable Interest

Producers must choose the appropriate insurable interest for the acreage. Insurable interest is the insured's percentage of the insured crop that is at financial risk.

Insured Acres

Producers use the number of acres to enroll in AF. The same acres cannot be insured in more than one grid ID or county. If acreage is located in more than one grid, producers can choose to put all acreage in one grid or divide the acreage into separate grids.

Index Intervals: Percent of Value

In each growing season, there are six two-month intervals to insure. Producers must select three intervals when precipitation is important to their operation and crop planted. Producers must choose the percent of value for each interval (that is, the percent of the guarantee to insure in each interval). Producers cannot choose two overlapping intervals (for example, producers cannot choose both the September-October and October-November intervals). The total percentage of value insured in the three intervals must equal 100%. The percentages will be applied to all insured acres and grid ids in the county for each growing season. Insurance payments are calculated using NOAA, CPC data for the grid(s) and the chosen index interval(s). If the final grid index is less than the trigger grid index, which is the coverage level times the expected grid index, a loss payment may be issued. This insurance product only provides coverage for a lack of precipitation and is based on the interpolated precipitation for the entire grid, not individual farms or ranches or specific weather stations. A producer may have low rainfall on their own farm and not receive a payment under the AF policy. The rainfall indices do not measure direct production or loss. A loss payment will only be issued if the final grid index is less than the trigger grid index.

AF Decision Tool

A decision support tool is available allowing producers to estimate premiums and indemnities from 1949 to the current year to see how the program would have performed if they were enrolled in previous years. Producers also can view the historical rainfall indices for an area using the tool.

AF insurance is best suited for producers whose production tends to follow and correlate to the historical average rainfall patterns for their grid, so it is important for

producers to look at the historical indices. Producers should review their past production records against the historical information to assess whether the product correlates to their production. Utilization of production records and the historical indices tools will assist producers in selecting the optimal Index Intervals, Percent of Value assigned to each index interval, productivity factor and the coverage level that best mirrors their past production. The decision support tool can be found on the RMA website: af.agforceusa.com/ri.

Producers must visit their local crop insurance agent to obtain current rates and coverage for the crop year in which they are enrolling. However, the decision tool is extremely useful to understand how the program works, estimate premiums and indemnities for prior years and view historical rainfall indices.

AF Sign-Up Deadline

To participate in AF, producers must submit an application to a crop insurance agent by July 15 for all growing seasons. Producers should visit a crop insurance agent to enroll in AF or to obtain more information.

AF Eligibility & Additional Rules

Producers must insure all insurable acreage under AF. Producers can be ineligible to participate in AF if they have enrolled the particular acreage in other government programs, especially conservation programs that prohibit them from grazing the land. For example, producers who enroll land in the Farm Service Agency's (FSA) Conservation Reserve Program agree to plant resource-conserving vegetative covers that would generally preclude grazing. Producers may select only one coverage level and dollar amount of protection per acre for each of the insured crop types in the county. The dollar amount of protection per acre selected will be applied to each Grid ID and crop type. Producers are not required to report yield history or maintain production records for the AF policy. However, producers should continue to maintain production records in case an Actual Production History (APH) plan of multiple peril crop insurance becomes available in future years.

AF Acreage Reporting

An acreage report must be submitted for each growing season and should include share, intended use, annual forage commodity, planting date, grid ID, FSA farm number, FSA tract number and FSA field number. If an acreage report is not filed by the acreage reporting date, no coverage would be available for any index interval for the applicable growing season. The acreage reporting deadlines are:

- Season 1 - October 15.
- Season 2 - January 15.
- Season 3 - April 15.
- Season 4 - July 15.

AF Indemnities

Producers do not need to file a claim or submit any documentation for a loss under the AF policy. Payments will be made after precipitation data is collected for each interval and provided to RMA and crop insurance companies, which means payments may be issued multiple times in a year. However, an indemnity will not be issued prior to the acreage reporting date.

Other Insurance Coverage

Producers are not allowed to obtain any other crop insurance policy authorized under the Federal Crop Insurance Act on their share of the insured crop for the same commodity (for example, producers cannot insure wheat under both a yield protection policy and an AF policy in the same crop year).

FSA Disaster Assistance Programs

Noninsured Crop Disaster Assistance Program (NAP)

Noninsured Crop Disaster Assistance Program (NAP) provides financial assistance to producers of noninsurable crops when a loss has occurred due to a natural disaster. NAP insurance is only available through the Farm Service Agency (FSA). Eligible producers are landowners, tenants or sharecroppers who share in the risk of producing an eligible crop. The types of crops covered are:

- Crops grown for food.
- Crops grown for livestock production, including but not limited, to grain and forage crops including native forage.
- Crops grown for fiber (except trees).
- Crops grown in a controlled environment (floriculture).
- Specialty crops such as honey and maple sap.
- Value loss crops such as aquaculture, Christmas trees, ornamental nursery and turfgrass sod.

Eligible natural disasters include any of the following:

- Damaging weather such as drought, freeze or hail, excessive moisture, excessive wind or hurricanes.
- An adverse natural occurrence, such as earthquake or flood.
- A condition related to damaging weather or an adverse natural occurrence, such as excessive heat, plant disease, volcanic smog and/or insect infestation.
- Any combination of the above.

To apply for NAP coverage, an eligible producer must sign up by the intended crops deadline and pay the applicable service fee. The deadline is different depending on their crop. Producers should check with their local FSA office to determine the correct sign up date. The service fee is $250 per crop with a maximum of $750 per producer per county. A producer must sign up for NAP with the county's FSA office where their farm is registered. The maximum for producers with farming interests in multiple counties is $1,875. Limited resource farmers can request to have the service fee waived if they fit the criteria.

NAP Service Fee Example

Consider this scenario: Producer A has 300 acres of warm-season pasture and 5 acres of pecan trees in County X and 50 acres of warm-season hay and 5 acres of pecan trees in County Y. Producer A wants to sign up for NAP for all of

their crops in both counties. The service fee for Producer A is the following:

$250 for the warm-season pasture in County X
$250 for the pecan trees in County X
$250 for the warm-season hay in County Y
$250 for the pecan trees in County Y
$1,000 Total

Producer B has 500 acres of warm-season pasture, 500 acres of cool-season pasture, 10 acres of pecan trees and 200 acres of warm-season hay in county X. He has 200 acres of warm-season hay, 400 acres of cool-season hay and 5 acres of pecan trees in County Y. He also has 10 acres of pecan trees and 50 acres of warm-season hay in County Z. Producer B wants to sign up for NAP for all of their crops in all counties. The service fee for Producer B is the following:

$250 for the warm-season pasture in County X
$250 for the cool-season pasture in County X
$250 for the warm-season hay in County X
$0 for the pecan trees in County X - Producer B has met the $750 per county maximum
$250 for the warm-season hay in County Y
$250 for the cool-season hay in County Y
$250 for the pecan trees in County Y
$250 for the pecan trees in County Z
$125 for the warm-season hay in County Z - Producer B has met the $1,875 maximum.
$1,875 Total

To receive a payment under NAP, a producer must have a yield loss of greater than 50% of the expected production. Expected production is based on FSA approved yields and reported acreages. Producer losses also are determined by FSA. NAP payments are calculated using the following factors:

- crop acreage
- approved yield
- net production
- 55% of an average market price for the commodity
- a payment factor reflecting decreasing costs incurred in the production cycle

Producers interested in the NAP program should visit the county FSA office for full details.

Livestock Forage Program (LFP)

The Agricultural Act of 2014 (2014 Farm Bill) made the Livestock Forage Disaster Program (LFP) a permanent program. LFP provides compensation to eligible livestock producers who have suffered grazing losses due to drought or fire. LFP payments for drought are equal to 60% of the monthly feed cost for up to five months. LFP payments for fire on federally managed rangeland are equal to 50% of the monthly feed cost for the number of days the producer is prohibited from grazing the managed rangeland, not to exceed 180 calendar days. Please consult your local FSA office for details.

An eligible livestock producer who owns or leases grazing land or pastureland physically located in a county rated by the U.S. Drought Monitor (droughtmonitor.unl.edu/) as having a:

- D2 (severe drought) in a county for eight consecutive weeks or more during the normal grazing period. Assistance equals one monthly payment.
- D3 (extreme drought) in a county anytime during the normal grazing period: assistance equals three monthly payments.
- D3 (extreme drought) in a county for four weeks or more during the normal grazing period or D4 (exceptional drought) anytime during the normal grazing period. Assistance equals four monthly payments.
- D4 (exceptional drought) in a county for four weeks (consecutive weeks unnecessary) during the normal grazing period. Assistance equals five monthly payments.

The Drought Mitigation Center has developed a tool to assist producers in determining potential LFP eligibility that may be found at: droughtmonitor.unl.edu/fsa/Home.aspx. Producers interested in the LIP program should visit their county FSA office for full details.

Livestock Indemnity Program (LIP)

The 2014 Farm Bill authorized the Livestock Indemnity Program (LIP) to provide benefits to livestock producers for livestock deaths in excess of normal mortality caused by adverse weather. In addition, LIP covers attacks by animals reintroduced into the wild by the federal government or protected by federal law, including wolves and avian predators. LIP payments are equal to 75% of the market value of the applicable livestock on the day before the date of death of the livestock as determined by the Secretary. The 2014 Farm Bill makes LIP a permanent program LIP is administered by the FSA.

LIP Eligible Livestock Owners

To be eligible for LIP, a livestock producer must have legally owned the eligible livestock on the day the livestock died. To be eligible for LIP, an owner's livestock must:

- Have died as a direct result of an eligible adverse weather event occurring:
  - On or after Oct. 1, 2011.
  - No later than 60 calendar days from the ending date of the applicable adverse weather event.
  - In the calendar year for which benefits are requested have been maintained for commercial use as part of a farming operation on the day they died.
  - Not have been produced for reasons other than commercial use as part of a farming operation. Excluded livestock includes wild free-roaming animals, pets or animals used for recreational purposes, such as hunting, roping or for show.

LIP Eligible Livestock Contract Growers

To be eligible for LIP, a contract grower must have had

the following on the day the livestock died:

- Possession and control of the eligible livestock.
- A written agreement with the eligible livestock owner setting the specific terms, conditions and obligations of the parties involved regarding the production of livestock.

In addition to the requirements previously listed for livestock owners, the only eligible livestock of contract growers under LIP are poultry and swine.

LIP Payments

LIP payments are calculated by multiplying the national payment rate for each livestock category by the number of eligible livestock in each category. LIP national payment rate for eligible livestock owners are based on 75% of the average fair market value of the livestock. The LIP national payment rate for eligible livestock contract growers are based on 75% of the average income loss sustained by the contract grower with respect to the dead livestock. A contract grower's LIP payment will be reduced by the amount of monetary compensation received from their contractor for the loss of income suffered from the death of livestock under contract.

Applying for LIP

Producers may apply to receive LIP benefits at local FSA offices. Producers who suffer livestock death losses should submit a notice of loss and an application for payment to the local FSA office maintains their farm records. To be eligible, the notice of loss must be submitted the earlier of:

- Thirty calendar days of when the loss of livestock is apparent to the producer.
- Thirty calendar days after the end of the calendar year in which the loss of livestock occurred.

LIP Livestock Death Loss Documentation

Livestock owners should record all pertinent information of livestock death losses due to adverse weather and attacks by animals reintroduced into the wild by the federal government or protected by federal law. Applicants must provide adequate proof that the eligible livestock deaths occurred as a direct result of an eligible adverse weather event or eligible attack by an eligible animal or avian predator in the calendar year for which benefits are being requested. The quantity and kind of livestock that died as a direct result of the eligible event may be documented by:

- Purchase records.
- Veterinarian records.
- Bank or other loan documents.
- Rendering truck receipts or certificates.
- Federal Emergency Management Agency records.
- National Guard records.
- Written contracts.
- Production records.
- Records assembled for tax purposes.
- Property tax records.
- Private insurance documents.
- Other similar documents.

If adequate verifiable proof of death records documentation is not available, FSA will accept reliable records in conjunction with verifiable beginning and ending inventory records as proof of death. Reliable records may include, but are not limited to:

- Contemporaneous producer records existing at the time of the adverse weather event.
- Pictures(s) with a date.
- Brand inspection records.
- Dairy herd improvement records.
- Other similar reliable documents.

FSA will accept certifications of livestock deaths by third parties on form CCC-854 along with verifiable beginning and ending inventory documentation if the following conditions are met:

- The livestock owner or livestock contract grower, as applicable, certifies in writing:
  - There is no other documentation of death available.
  - The number of livestock in inventory at the time of the adverse weather event.
- The third party provides their telephone number, address and a written statement containing:
  - Specific details about their knowledge of the livestock deaths.
  - Their affiliation with the livestock owner.
  - The accuracy of the deaths claimed by the livestock owner

FSA will use data furnished by the applicant to determine eligibility for program benefits. Furnishing the data is voluntary; however, without all required data, program benefits will not be approved or provided. Producers interested in the LIP program should visit their county FSA office for full details.

Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program (ELAP)

The Emergency Assistance for Livestock, Honeybees and Farm-Raised Fish Program (ELAP) to provide emergency assistance to eligible producers of livestock, honeybees and farm-raised fish. ELAP covers losses due to an eligible adverse weather or eligible loss condition, including blizzards, disease (including cattle tick fever), water shortages and wildfires, as determined by the Secretary of Agriculture, that occur on or after Oct. 1, 2011. ELAP covers losses not covered under other Supplemental Agricultural Disaster Assistance Payment programs established by the 2014 Farm Bill, specifically the Livestock Forage Disaster Program (LFP) and the Livestock Indemnity Program (LIP).

9 Beef Cow-Calf Marketing

Derrell Peel

Objectives

- **Discuss the many facets of cow-calf marketing.**
- **Recommend strategic management practices.**
- **Present enterprise alternatives.**

Cow-Calf Marketing Philosophy

Cow-calf production represents a long-term investment in land and cattle. Moreover, cow-calf production is tied more closely to the physical environment and location in which it takes place than perhaps any other sector of the cattle industry. In most instances, the ranch production systems, location and environment play a large role in determining the type of cattle, cow size and genetic type that are feasible. Seasonal climate and forage production patterns usually add strong economic incentives to manage cow-calf production with high levels of uniformity and consistency. This means there is considerable economic value in managing genetics, breeding and calving seasons and weaning programs to produce the most homogenous set of calves possible. The effect is that good production management will result in a uniform set of calves available to be marketed on no more than one or two occasions per year. Thus, it is often the view of cow-calf producers that, having made the decision to be in the cow-calf business, there is relatively little marketing flexibility in a cow-calf operation. While there is some truth to this view, relatively speaking, it is also true there are a number of ways cow-calf producers can and should respond to short-term and long-term market influences.

Many times, producers have the view that cow-calf production means calves are the only product being marketed. In fact, a more accurate view of cow-calf production is that of an industry whose job it is to market forage to its best use and value. Viewed this way, the cow-calf operation will be seen to consist of many production activities that offer substantial flexibility in marketing. This view particularly is important given that many producers have a more or less fixed land base and, therefore, forage base with which they are operating. Instead of asking what marketing opportunities there are for calves, whose timing and availability are almost totally determined by production schedules, producers may ask what activities will allow them to market their forage production for greater value. This broadens the view of the ranch from selling a single set of calves annually to a more conscious consideration of strategic and tactical production and marketing possibilities such as the role of retained ownership of calves or subsets of calves, calf production alternatives, complementary stocker production, cull cow marketing and replacement heifer development and marketing.

Influence of Price Cycles and Seasonality

Cattle markets are characterized by regular patterns of prices each year and cycles of prices and production over a period of years. These seasonal and cyclical patterns originate in a complex set of supply and demand influences, many of which are based on the strong production influences at the cow-calf level. Unique and distinct seasonal price patterns are typical for all classes of cattle. The most pronounced of these are those directly applicable to the cow-calf sector, namely seasonal price patterns for calves and for cull cows (Figure 9.1).

Both calves and cull cows have the largest degree of variation in prices across the year compared to other classes of feeder and fed cattle. The general tendency for calf prices to be the lowest in the fall and highest in the spring reflects the fact many producers have relatively little production and marketing

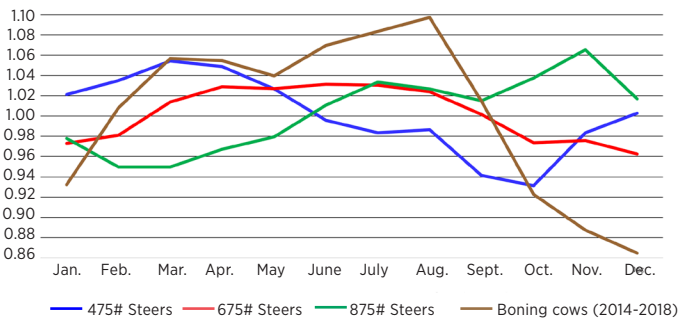


Figure 9.1. Cattle price seasonality, Oklahoma, 2015-2019

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

flexibility for calves, but this may provide opportunities for some producers. Likewise, the seasonal low prices for cull cows reflects typical patterns of culling and cull cow marketing but may offer some attractive opportunities to market underutilized forage.

The U.S. cattle industry has for many years been subject to pronounced cycles of production (Figure 9.2) and prices (Figure 9.3). Although the cycles are not precisely predictable, they are quite regular and inevitable. These cycles occur for a complex set of reasons that relate to the rather extreme price signals needed to induce the cow-calf sector to respond to needed changes in beef production. In the absence of external shocks, cattle cycles are self-correcting changes in production internal to the beef industry. Sometimes external shocks will impact cattle cycles by either offsetting or exaggerating cyclical adjustments in the beef industry or shortening or extending the time of cyclical adjustments. Although there may be a reason to think that cattle cycles are evolving through time, there is little reason to believe they will not continue to occur in some fashion. While there is little a cow-calf producer can do to avoid these price cycles, recognizing them and responding to them can minimize the adverse effects on the financial health of the operation.

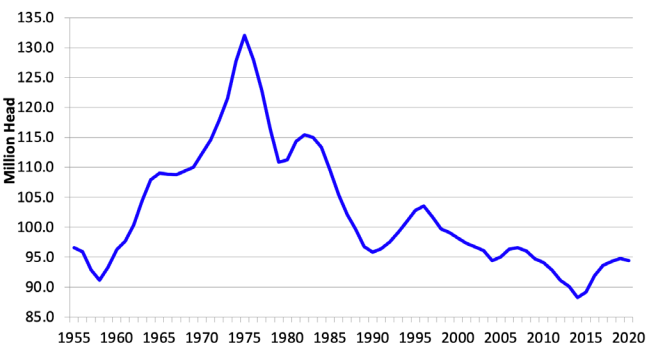


Figure 9.2. U.S. Cattle inventory, 1955-2020.

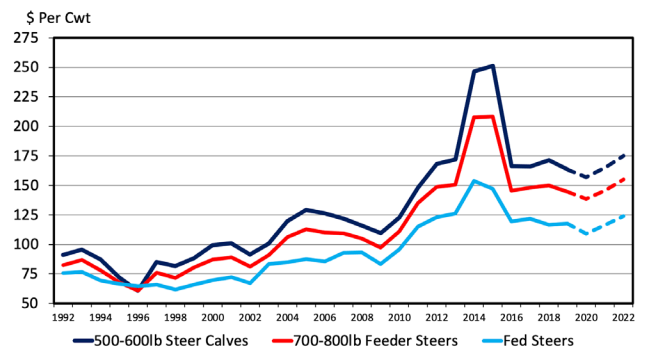


Figure 9.3 Average annual cattle prices, Southern Plains. Data Source: USDA-AMS, Compiled and Forecasts by Livestock Marketing Information Center.

Strategic Cow-calf Management

Cow-calf production always represents a long-term commitment to a particular production system and genetics program. Historically, calf production has been viewed largely as commodity production with producer choices of genetics and cattle types almost entirely determined by personal preference and individual production needs. However, as the needs of the market have become more specific and exacting, the growth in alliances and other coordinating programs has greatly increased the opportunities for cow-calf producers to participate in value-added systems. In many cases, these require producers to have a specific production focus and management commitment. Increasingly, these long-term strategic production choices represent the most important marketing decisions of producers. It is not enough to be in the cow-calf business in the sense of simply selling commodity calves, but rather producers must identify a specific market focus and target the entire production process to a specific market segment, concentrating on the final consumer's requirement and expectation for beef products.

Production values in the cattle industry have always represented a balance of production traits and consumer traits. In many cases, there is a negative relationship between these two sources of value. In other words, some of the traits that increase production value, such as hardiness and adaptability to adverse climates, are often at odds with carcass traits that produce the highest meat value. Historically, production traits have been somewhat overvalued in most live animal markets. The growth of more highly coordinated production and marketing systems implies more value placed on consumer traits all the way to the initial production levels. The implications of these programs will be considered in more detail in chapter 10.

All cow-calf producers, including those who have a well-developed strategic focus, will be subject to the cycles of prices and production that characterize the beef industry. Thus, a cow-calf producer can inevitably expect to experience considerable variability in revenues and, consequently, in profits throughout the course of a cattle cycle. This suggests a producer who desires to minimize the impacts of cyclically low prices will consider cost management as well as decisions about what to produce and market. Although this chapter focuses on marketing, the integrated nature of cow-calf production and marketing means that cost as well as revenue will be impacted by a producer's response to cattle cycles. When the goal is profit maximization, it is imperative to consider both revenue and cost management.

It is not uncommon for calf prices to decrease by 50% from the cyclical peak to the low. This means there are times when the market values calves only half as much as other times, meaning the market wants fewer calves. For the industry as a whole, cyclically low prices result in a reduction of cow-calf production and cow herd liquidation. For the individual producer, the value of forage marketed as calves is reduced and the important question is whether the producer can make production and marketing adjustments

to increase forage value during these periods. By the same token, when prices are cyclically high, the market encourages more calf production and more use of forage resources for calf production. These market signals imply an incentive for producers to adjust cow herd size in response to price cycles. The herd size adjustments discussed here are in addition to normal culling activities, so strategic culling may go beyond culling based only on productivity considerations. A producer who has a normal culling rate of 12% might find it advantageous to push that number to 15% or 20%in some years and occasionally reduce that number to 9% or 10% in other years.

The general cyclical strategy identified above suggests that a producer who is anticipating cyclical higher calf prices will want to expand the cow herd to maximum productive potential to be able to sell the maximum number of calves at the higher prices. Maximum herd size must be determined relative to the productivity and carrying capacity of forage resources and must be determined relative to the production risk associated with maintaining adequate forage reserves to respond to climatic impacts.

Likewise, a producer who anticipates cyclically low prices has an incentive to reduce calf production and try to find other enterprises to increase returns to forage. Since annual maintenance costs of cows are one of the highest components of cow-calf costs, this strategic response has the added benefit of reducing costs during a time when revenues from calf sales are falling. These reductions in the cow herd beg the question of what the producer will do with the excess forage. These alternatives will be discussed below. The degree to which different producers can feasibly adjust the size of the cow herd will vary considerably depending on individual circumstances.

Even producers who do not dramatically adjust herd size may find strategic advantage in adjusting the age composition of the cow herd during the course of a cattle cycle. A producer will reduce the average age of the cow herd during the phase when prices are rising as an attempt to have the highest levels of productivity (both reproductive productivity and average weaning weights) during the highest prices. Moreover, with younger cows, a producer can afford to reduce replacements for a year or two during the highest prices in order to sell the maximum number of calves. To do this, producers should let the average herd age increase through the declining price phase and begin aggressively retaining heifers when prices are perceived to be near the cyclical low. Another advantage of this is reducing average cow cost during the entire cycle compared to using a constant replacement rate.

The strategy of adjusting cow herd age during the cattle cycle also has been stated in terms of a constant value of replacements (Lawrence). If the value of replacement heifers varies over the course of a cattle cycle, a strategy of spending a constant number of dollars for replacements each year will vary the rate of replacements and cause exactly the variation in herd age suggested above. For example, suppose a producer estimates that the long-term cost of a replacement heifer is $1,200 per head and the producer wishes to have an average replacement (culling) rate of 12% per year, which leads to an average productive life for cows of 8.3 years. Suppose the value of replacement heifers will vary from a low of $900 per head to a high of $1,500 per head during the course of a cattle cycle. Using the constant value of replacements would mean that a producer would be varying the actual culling rate from more than 16% at low prices to less than 10% at high prices. This strategy would allow the average age of the cow herd to vary by perhaps 1 $^{1}/_{2}$ years to two years and would have lower rates of culling during high prices, which would allow for more calf sales.

Additionally, controlling the timing of other periodic production expenses may have strategic benefits during the course of a cattle cycle. The idea is to schedule various expenses where some discretion in timing is allowed so that they do not coincide with those years of lowest prices. This can help reduce the equity drain during low prices and reduce dependence on borrowed capital. Examples of this could include:

- Bull replacements.
- Periodic pasture revitalization or brush/weed control.
- Modified pasture fertilization schedules.
- Delaying capital investments or equipment replacement.
- Other items.

The feasibility and degree of adjustment will depend on the circumstances of the individual producer. It should be noted however, that it is unlikely to be advantageous to make changes that will negatively affect herd nutrition or herd health programs. The comments above assume there are no obvious ways to change the nutrition program to save money. Otherwise, producers should do that regardless of the current phase of the cattle cycle. The items mentioned need to be done periodically but not necessarily in any certain year. Planning ahead is the key to timing such activities to the greatest advantage.

Strategic adjustments in herd size and/or age combined with strategic cost management can significantly reduce the variations in profits through the cattle cycle. However, it may not be possible to entirely mitigate the negative effects of cyclically low prices.

Enterprise Alternatives

The strategic considerations described above suggest that cyclical market conditions may at times favor more than simply selling weaned calves. In fact, strategic reductions in the cow herd will free up forage and other production resources for other activities. Other production enterprises may be attractive at times.

Retained Ownership of Feeder Cattle

Retained ownership may occur for a number of reasons and may occur on ranch or off ranch as retained stocker or feedlot production. Off-ranch retained ownership may be motivated by alliance participation, marketing objectives, such as changing the timing of animal sales, or interest in investment alternative. The focus of this section is efficient

utilization of ranch resources and therefore, the following discussion is directed only to ranch-based retained ownership alternatives. Off-ranch retained ownership is considered in chapter 10.

Generally, when cattle prices decrease cyclically, calf prices tend to fall proportionally more than feeder cattle prices, meaning the value of stocker gain increases relative to the value of cow-calf production. The broad implication of this is a general incentive to reduce calf production and use some forage for stocker-based gains. Clearly, the feasibility of this depends on a number of individual factors including the quality of forage available and its suitability for stocker-based production. With an excess of good-quality harvested forage, programmed feeding in confinement may be another feasible alternative.

It is particularly important in considering retained ownership to not think of marketing the calf crop as an all-or-nothing proposition. There are a number of ways to divide the calf crop into marketing groups based on weight and sex. Even in the best managed herds, there often is at least a 100-pound range from the biggest to the smallest calves. Possible calf marketing groups include:

- Sell everything at weaning.
- Sell the big steers and heifers and retain the little ones.
- Sell the steers and retain the heifers.
- Sell the heifers and retain the steers.
- Retain the little steers.
- Retain the little heifers.
- Retain the big heifers as possible replacements.

It is possible a producer might recognize the incentive to retain stockers, but also recognize their own calves are not the best ones to retain. This might be the case when a producer has calves big enough and fleshy enough to be very attractive for feedlot placement but not ideally suited for a stocker program. It is within the spirit of this alternative to consider selling all of the calves produced and buying stockers as a separate but complementary enterprise. It should be noted, however, that purchased stockers represent a new enterprise and carry a host of different production, financial and management challenges. Producers who might have little problem retaining owned calves may experience many production headaches with purchased calves. OSU enterprise budget software is available at agecon.okstate.edu/budgets to assist producers in evaluating stocker alternatives.

Replacement Heifers

In most instances, it is assumed the producer is selling weaned calves or retained stockers as commercial feeder cattle. However, the last option in the list of calf marketing groups includes possibly retaining heifers as replacements. At certain times, the market for replacement females may be strong enough to consider devoting some effort toward marketing heifers to the breeding market rather than as feeder animals. This may be particularly attractive when the right genetics and management are in place to somewhat specialize in breeding female development. This can occur on a variety of levels including:

- Merchandising weaned heifers specifically as potential replacements.
- Retaining some heifers to grow to breeding age/weight and merchandising as potential replacements.
- Retaining some heifers, breeding them and merchandising as bred heifers.
- Retaining some heifers, breeding, calving and merchandising as pairs.

Each of the alternatives above may provide a high-value mechanism for marketing forage and other ranch resources including producer labor and management skills in developing heifers.

Preconditioning

Preconditioning calves prior to sale may provide a means to add value to calves before marketing. Preconditioning may be done formally, as part of a recognized or certified preconditioning program, or informally as an individual. The difficulty, especially for individual preconditioning programs, is to successfully market calves for sufficient additional value relative to the cost of preconditioning. Nevertheless, preconditioning may open the door to marketing opportunities not otherwise available. One such program in Oklahoma is the Oklahoma Quality Beef Network (OQBN), which provides producers the opportunity to certify calves and participate in special sales. It should also be noted that the retained ownership programs described above imply preconditioning and, in fact, retained ownership may be the best means to capture the benefits of preconditioning in some cases. Chapter 10 has more information on the value of preconditioning programs and additional information on the OQBN program is available at oqbn.okstate.edu.

Creep Feeding

Creep feeding calves is a way to increase calf weights and may increase returns to the cow-calf enterprise. The economic feasibility of creep feeding depends on several factors. First, it is essential to understand the relationship between animal weight and price per pound to understand the marginal value of increasing calf sale weight. The value of gain will vary considerably through time, as relative prices for calves and feeder animals change. Secondly, the value of gain must be balanced against the cost per pound of gain for creep feed needed to increase animal weight. Finally, creep feeding may change the marketing target for calves. Creep feeding may increase weight and finish of calves such that they are no longer best suited to selling into stocker markets but rather, they may need to be merchandised as feeder animals ready for feedlot placement.

Early Weaning

Early weaning is most often viewed as a contingency for drought management or other emergencies. Certainly early weaning should be considered promptly when drought-forced decisions are looming. Since early weaning reduces forage requirements of cows, an early weaning program may be considered as a means to increase carrying capacity of the ranch. This may have strategic value at some points of the cattle cycle. Careful analysis of the tradeoffs of marketing

light early-weaned calves and regular-weaned calves is necessary to evaluate early weaning programs.

Spring versus Fall Calving

Like so many decisions that affect cow-calf marketing, the choice of calving season is heavily influenced by production considerations. The optimal calving season is likely to be more of a cost of production consideration than purely a marketing decision, but it is clearly one that influences marketing alternatives. In some cases, it is feasible and desirable to simultaneously manage two calving seasons, which has the obvious advantage of providing more marketing opportunities and flexibility for the operation but does increase the management challenges.

Commercial Stockers

Commercial stockers represent a separate and distinct business from cow-calf production. The term commercial stocker is used here to refer to programs using purchased lightweight calves for a variety of post-weaning growing programs (Peel). These may appear very similar to retained ownership programs, but purchased cattle represent a very different set of nutritional and health management skills. Nevertheless, although stocker programs are separate from cow-calf production, such programs may be very complementary to cow-calf operations in a variety of ways.

First, as noted above, purchased stockers may be more appropriate than ranch-raised calves to utilize forage resources when market conditions favor stocker-based gains. Stocker programs typically favor use of relatively thin lightweight calves with good growth potential in forage based production systems. A well-managed cow-calf operation may be producing calves that are too heavy or too fleshy for stocker programs and are better marketed for feedlot placement. Secondly, a stocker enterprise may play an important role in managing forage and production risk. In situations where forage production is highly variable from year to year, it may be less financially disruptive to use a stocker enterprise to utilize excess forage in good years and reduce or eliminate the stocker enterprise in times of low forage production. The combination of stocker and cow-calf enterprises increases the flexibility to implement the strategic cyclical adjustments described previously. The cyclical motivations for adjusting herd size and/or age in response to the cattle cycle is even easier when there is a stocker enterprise that can be expanded or contracted simultaneously.

Adding Value to Calves

A number of well-recognized management practices significantly influence the value of calves. Many of these practices are routinely managed by some producers, but are opportunities overlooked by others. The value of these practices has been well documented (Mintert et al.; Sartwelle et al.; Smith et al. and Williams, et. al.) and often represents $50 per head to more than $100 per head in value of weaned calves at the time of sale. These management practices for individual animals include castration of bulls, vaccinations and dehorning as well as marketing practices for groups of animals including sorting and selling larger lots of uniform animals. Additionally, marketing practices such as the level of fleshiness and fill of animals at the time of marketing can affect animal value. These are all things that can be done to add value to existing animals. Changing genetics also may offer opportunities to increase weaning weight, as well as frame and muscle score, or match marketplace preferences, which will improve the value per pound of animals.

Price Risk Management for Cow-calf Producers

Many factors cause cattle prices to fluctuate and producers often have little means to even anticipate, let alone control, these fluctuations. Nevertheless, there are risk management alternatives that may be considered, depending on the risk management needs of the producer and the type and source of risk under consideration.

Price variation in the cattle industry can be broadly thought of as originating either internal to the industry or from external sources. Internal price risk is risk associated with normal or typical supply and demand forces in the industry. These include seasonal price changes and cycles of prices through a period of years. These internal forces change the level of prices as well as the relationship among prices for various classes of cattle. External price risk is risk that originates in the broader economy or outside of normal industry supply and demand forces. Examples of external risk include the impact of the macroeconomy on overall economic performance in the U.S. or international trade issues, especially things such as exchange rate impacts or geopolitical events. Also included in this category are shocks, such as an animal or human health outbreak, that severely disrupt markets. Although an animal health event, such as Bovine Spongiform Encephalopathy or Foot and Mouth Disease, is specific to the animal industry, it is an unforeseeable and unpredictable event based on normal industry activities and is treated as an external risk.

The process of marketing cattle consists of three distinct activities: 1) determining price, 2) determining the buyer and 3) physical transfer of the cattle. Price risk management involves separating these activities with the use of marketing alternatives. In the simplest case, all three functions occur at the same time. For example, selling cattle at a cash auction establishes a price, determines a new owner and transfers possession all the same time. In order to reduce price risk, it is necessary to establish price prior to the time when possession is transferred. As discussed below, using futures or options is a way to establish an expected fixed or minimum price well before the new owner is identified and possession is transferred. With a forward cash contract, the ownership and price are established well before possession is transferred.

Futures/Options for Cow-calf Risk Management

In principle, a producer can use futures or options to establish an expected fixed or minimum price for future cattle marketings. For weaned calves, the closest type of contract is the feeder cattle futures, which means a producer is cross-hedging calves with this contract. This highlights the fact that, since the contract is not an exact fit, the basis risk can be considerable and, in some cases, is as large as the market risk, which means hedging is not very effective at reducing the price risk for weaned calves. For example, in the declining price element of the cattle cycle, calf prices typically fall further and faster than feeder cattle prices. This means much of the adverse price risk is captured as changes in the basis and not by the hedge. One of the advantages of retained ownership, which often is more attractive as calf prices fall, is the ability to manage price risk with futures and options is enhanced when the producer is selling retained feeders rather than weaned calves. More information and tutorials on hedging with futures and options can be found in the Education section of the Chicago Mercantile Exchange website at cmegroup.com.

Retained Ownership

As noted previously, retained ownership is mostly a production alternative and is usually motivated more by production considerations, in conjunction with marketing, rather than a marketing alternative. However, retained ownership provides means to change marketing timing. This flexibility may be particularly useful to avoid short-term shocks that reduce market values but are expected to be short lived. However, retaining ownership to avoid a loss now may not be beneficial if the production and marketing decisions of the retained ownership program are not carefully considered.

Forward Cash Contracting

A producer may establish a forward price for cattle by forward contracting the cattle prior to weaning or delivery. This may be done as a direct sale at the ranch or through a video or Internet sale. Forward cash contracting is a straightforward means to reduce the risk of market price changes. There are some risks and considerations associated with this alternative. There may be some production risk about exactly how many calves will be available to sell or, more typically, some uncertainty about how much the calves will weigh at delivery. Details associated with how shrink, weighing conditions and price slides will be handled may impact the worth of a forward cash price. Moreover, cash contracts often are informal, which increases the seller's risk of buyer nonperformance if market conditions change dramatically. Without a written contract and a down payment, the risk of the buyer defaulting on the contract increases directly as the conditions under which the contract has the most value to the seller increases or when prices fall significantly.

Using Options as Disaster Insurance

The cattle industry faces arguably greater external risks now than previously. Increased market globalization increases the exposure of the markets to economic shocks, along with increasing the risks of animal and human health impacts from increased international trade of meat and cattle. General macroeconomic weaknesses coupled with heightened geopolitical tensions since Sept. 11, 2001, imply all markets are more vulnerable to shocks than before. Some of this vulnerability may diminish with time, or it may simply be a sign of operating conditions of the future.

The limitation of futures and options in pricing cattle for ongoing business transactions was noted above. However, options on futures contracts provide a way for all cattle producers to have some disaster level of price protection. While it may not work well to use options to hedge cattle profits at current market levels (protect against normal price risk), it certainly is true that an option would capture at least a portion of a devastating market decline in the wake of a major shock. Cow-calf producers may want to consider the use of options purely to provide some coverage against massive price declines. Thus, in the event of a Bovine Spongiform Encephalopathy case or a Foot and Mouth Disease outbreak, a futures option that does not become effective until the market drops by $15 per cwt. will look good if the market actually drops by $40 per cwt. or $50 per cwt. Such an option might not keep a producer from losing money on the current set of cattle, but it might prevent an irreparable financial impact that puts the producer out of business.

Livestock Risk Protection (LRP) Program

Beginning in June 2003, the USDA's Risk Management Agency began offering price insurance for livestock producers. The pilot program, available in selected states including Oklahoma, allows feeder cattle producers to purchase revenue insurance. The program functions much like futures options and serves much the same purpose. However, the LRP may provide advantages for some producers including:

- Variable quantity of coverage, which may help small producers to match their actual production level.
- Variable lengths of time provide more flexibility to match production programs.

LRP contracts are purchased through authorized crop insurance dealers and do not require an account with a commodity broker. However, the contracts are related to feeder cattle futures contracts and indemnity calculations are based on the cash settlement price index calculated by the Chicago Mercantile Exchange (CME). This means producers using the LRP need to understand the basis relationships between their local cash price and the CME feeder cattle futures price. More details are provided in chapter 8.

Marketing Tactics

Marketing cattle generally involves two levels of decision-making. First are those strategic production and

marketing decisions that relate to what products will be marketed and how to establish a value in the market. These decisions are made before, during and sometimes after production and relate to all the things previously discussed in this chapter. Second, tactical decisions involve actually choosing a particular marketing channel and physically moving the animals into the marketplace. Sometimes these tactical decisions are highly related to the strategic decisions. For example, the use of futures to manage price risk has relatively little impact on whether the producers ultimately market the animals through an auction or by private treaty or whether they retain ownership. However, the choice of forward cash contracting simultaneously determines the price and the ultimate destination of the animals.

The choice of marketing channels also may affect a producer's approach to the marketing challenge. One of the primary considerations of marketing animals is to ensure the producer receives a fair market value for the animals. There is considerable variability in the informational burden on the producer, depending on the marketing method employed. For example, an auction generally has the benefit of providing multiple buyers to compete and establish a value for the animals. On the other hand, a direct ranch sale implies the producer is accepting all of the responsibility of knowing the value of the animals and negotiating a fair value. In some cases, the tactical details of transferring ownership can significantly affect the outcome of a sale. These details include items such as shrink, weighing conditions and price slides.

Shrink and Weighing Conditions

Shrink and weighing conditions both are related to the process by which a pay weight will be established for animals (Barnes et al.). In the best of circumstances, shrink and weighing conditions should not be biased in favor of either the buyer or the seller. The buyer clearly should not be expected to pay for excessive gut fill nor should the seller be penalized for excessive loss of gut fill or, in extreme cases, actual tissue loss.

Shrink, although a physical process, is usually taken as one of the terms of trade to mean an adjustment to the actual recorded weight of animals. Referred to as pencil shrink, the amount of adjustment logically should be closely related to the agreed-upon weighing conditions, which will clearly affect the actual amount of shrink in the animals. As a general rule, when weighing will occur at the place and time of loading or very soon after, a higher rate of pencil shrink is used to account for extra gut fill in the animals. On the other hand, fill shrink occurs very rapidly and animals trucked even relatively short distances to scales should require less pencil shrink for a fair deal. Shrink also will be greatly influenced by the amount of time animals spend standing in corrals or on trucks and by the amount of handling and sorting to which they are subjected. Unfortunately, both buyers and sellers can engage in a variety of games to try to manipulate shrink into an unfair advantage. A classic example is the buyer making sure that the trucks arrive three or four hours later than the agreed loading time to increase shrink in penned animals. Also, a seller may have animals eating a very salty feed in the corral, causing animals to drink extra water.

Weighing conditions relate specifically to when, where and how the animals will be weighed thereby establishing the base to determine the pay weight. These can be extremely important relative to the appropriate level of pencil shrink. For example, if animals are to be weighed on the truck (or trailer) rather than in pen scales, the fill loss before weighing may still be in the truck if not in the animals. It is important that producers clearly understand the weighing conditions and shrink allowances in order to avoid disputes.

Price Slides

When animals are sold prior to actual delivery, there usually is some uncertainty over what the animals will weigh at delivery. Buyers and sellers often negotiate a price slide that reflects, in varying degrees, the relationship between animal price and weight that usually exists in the cattle industry. Price changes by animal weight are usually higher for lightweight animals compared to heavier feeder cattle and vary according to price level or cyclical conditions. Much of the cyclical impact is eliminated if the price adjustment by weight is expressed as a percent of the animal price (Peel and Riley). In Oklahoma, the average price adjustment for animals less than 500 pounds is about 9% of the price. For example, for a 425-pound animal, priced at $100 per cwt., the decrease in price per cwt. for increasing the weight to 450 pounds would be about $0.09 for each pound, or $2.25 per cwt., resulting in a price of $97.75 for the 450-pound animal. Expressing the rollback as a percent of price means that variation in cattle prices due to the cattle cycle or other factors should result in adjustments in price slides according to price level. For example, this means when the 425-pound animal is priced at $2.50 per cwt., the price slide, at a percent of price, would be $0.225 per pound. Animals between 500 pounds and 650 pounds have an average price adjustment of 6.5% of the price and animals more than 650 pounds have an average adjustment of 5% of price.

As with shrink and weighing conditions, a fair price slide should not create bias for either the buyer or the seller. However, price slides tend to be negotiated or subject to customary practices in various regions and may or may not accurately reflect changing market conditions. Price slides are usually specified in terms of the amount of price adjustment per pound that animals will be subject to and often a weight window around the target weight (Bailey and Holmgren). Both the size of the slide and the size of the window are negotiable and sellers often will use these terms to indicate their confidence in meeting the target weight. A producer quite confident of the target weight may agree to a relatively large price adjustment for heavier weights and a small weight window before the slide takes effect. Although price slides should logically apply to weights both lighter and heavier-than-target weight, there is a tendency, especially in some regions, to only slide the price down, lower for heavier-than-expected animals, with little or no adjustment for lighter-than-expected weights. This clearly favors the buyers and puts more risk on the sellers. Sometimes this tendency is more negotiable in times of limited cattle supplies. Most important is that terms of trade, such as details of how a

price slide is to be applied, should be clearly understood by both buyers and sellers.

Marketing Channels

Producers have a variety of marketing channels to choose from, each of which offers advantages and disadvantages in various circumstances. Principal alternatives include auctions, direct sales, video/Internet sales and special sales. These are briefly discussed in Table 9.1.

Marketing Cull Cows

Cow-calf producers often give relatively little consideration to marketing cull cows to a higher value. Consequently, the pronounced seasonality of fall culling decisions results in a low price for cull cows in the fall and a tendency for a strong price recovery in the first quarter of the year (Figure 9.4). Cull cows, especially cows that are thin but sound in the fall, represent one of the few opportunities in the cattle business to increase both weight and price per pound between November and the January to March period. Cull cows also represent an opportunity to utilize lower quality forages or pasture that may not be well suited for younger animals. Thus, like other enterprise considerations discussed previously, cull cow marketing depends on the availability and quality of feed resources and what other opportunities exist for use of those resources. In some cases, retaining cull cows for 60 days to 100 days may provide a nice return for surplus feed resources.

Further Reading

This subject is addressed in more detail in chapter 10. AGEC-613 *Cull Cow Grazing and Marketing Opportunities* at extension.okstate.edu

References

Amadou, Z., K.C. Raper, J. Biermacher, B. Cook and C. Ward. Extension Fact Sheet AGEC-619 Adding Value to Cull Cows. Oklahoma Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Bailey, D. and L. Holmgren. Price Slides for Feeder Cattle. BCH-8470, Beef Cattle Handbook. Distributed by MidWest Plan Service, Iowa State University.

Barnes, K., S. Smith and D. Lalman (1999) Managing Shrink and Weighing Conditions. OSU Extension Fact Sheet ANSI-3257, Managing Shrink and Weighing Conditions in Beef Cattle. Oklahoma Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Feuz, D.M. Marketing Cull Cows. BCH-8120, Beef Cattle Handbook. Distributed by MidWest Plan Service, Iowa State University.

Lawrence, J.D. Profiting from the Cattle Cycle: Alternative Cow Herd Investment Strategies. Retrieved from econ.iastate.edu/FACULTY/LAWRENCE/Acrobat/AlternativeCowHerdInvestStratBRR.pdf#search='Profiting%20from%20the%20Cattle%20Cycle:%20Alternative%20Cow%20Herd%20Investment%20Strategies'.

Livestock Marketing Information Center. Denver, CO. Retrieved from www.Lmic.info.

Mintert, J.R. et al. (1988) Factors Affecting Auction Prices of Feeder Cattle. Bulletin C-697. Cooperative Extension Service, Kansas State University.

Peel, D.S. (2003) Beef Cattle Growing and Backgrounding Programs. Veterinary Clinics of North America, Food Animal Practice: Economics of the Red Meat and Dairy Industries 19:365-385.

Peel, D.S. and D. Doye. Extension Fact Sheet AGEC-613,Cull Cow Grazing and Marketing Opportunities. Oklahoma Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Peel, D.S. and J.M. Riley. "Feeder Cattle Price Fundamentals." Western Economic Forum, December 2018, Volume 16, Issue 2:6-19.

Raper, K.C., J.T. Brermacher and Zakou Amadou, Extension Fact Sheet AGEC-627, Marketing Cull Beef Cows: Does Body Condition Score Matter? Oklahoma Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Sartwelle, J.D. III et al. (1996) Improving the Value of Your Calf Crop: The

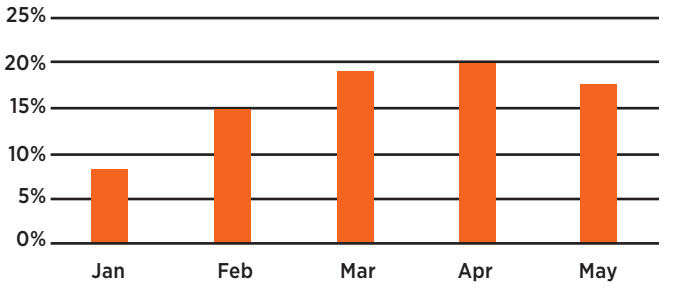


Figure 9.4. Percent change in breaking cow price from previous November, Oklahoma, 2010-2019.

Table 9.1. Beef cattle marketing channels.

Market type	*Advantages*	*Disadvantages*
Local/regional auction	Easy to use; requires little advance planning; numerous buyers; distance is limitation; works well for small lots or diverse sets of animals.	Cost; seller is subject to commission, shrink and hauling.
Direct (or ranch) sale	No commission with minimal hauling and shrink; may facilitate reputation sales and long-term relationship with buyer; facilitates forward pricing.	Requires seller knowledge of value and ability to negotiate; less feasible for small producers; requires buyer contacts.
Video/nternet sales	Larger buyer base; reduced shrink/hauling.	Subject to commissions; requires planning; usually means forward sales; less feasible for small producers; works best for large lots of uniform animals.
Special sales	May attract a better and bigger buyer base; may facilitate reputation sales.	Same as for auctions.

Impact of Selected Characteristics on Calf Prices. MF 2142 (revised). Cooperative Extension Service, Kansas State University.

Smith, S.C., D.R. Gill, and C. Bess III. (1998) Circular E-955, Effect of Selected Characteristics on the Sale Price of Feeder Cattle in Eastern Oklahoma. Oklahoma Cooperative Extension Service, Oklahoma State University.

Williams, G.S., K.C. Raper, E.A. DeVuyst, D. Peel and D. McKinney. "Determinants of Price Differentials in Oklahoma Value-Added Feeder Cattle Auctions." JARE 37(1):115-128, 2012.

10 Value-Added Marketing Opportunities

Kellie Curry Raper and Paul Beck

Objectives

- **Discuss two opportunities to add value to cow herd enterprises:**
  1. **Preconditioning and health management practices for calves.**
  2. **Retention and feeding strategies for cull cows for delayed marketing.**
- **Discuss other value-enhancing alternatives that may interest some producers:**
  1. **Cooperative marketing/purchasing.**
  2. **Strategic alliances and USDA-Verified programs.**
  3. **Custom cattle feeding.**

Many Oklahoma cattle producers do not take advantage of potentially value-adding management practices and marketing strategies, even with evidence that they add value to their cattle and profitability to their operation. Additionally, producers sometimes implement these recommended management practices, then fail to adequately market the practices when selling cattle. The first step in marketing cattle more effectively is to better understand marketing alternatives, evaluate the costs and returns for each alternative and assess which option has the most profit potential for their individual operation, given the operation's resources and constraints. A producer's final decision regarding practice adoption and marketing strategy is based on many things, including time, tradition, upfront costs, facilities, labor availability, perceived premiums, accessibility to marketing options and many others. As a cow-calf operator, there are two primary sources of revenue from cattle, including the sale of calves and the sale of breeding animals that reach the end of their useful life for the operation. This chapter discusses two means of adding value: (1) how calves are managed and marketed and (2) how cull cows are managed and marketed. Those alternatives apply to virtually every cow-calf producer. Some producers also may have an interest in other marketing alternatives. Additional information is presented in this chapter about other opportunities such as cooperative marketing programs, strategic alliances, custom feeding and direct marketing to consumers, i.e. freezer beef.

Each value-added alternative has pros and cons for an individual cattle producer—based on individual resources and constraints. The overriding economic criterion for evaluating each alternative is relatively simple in concept but not as simple in reality. Does an alternative opportunity add more value than cost to producer's cattle? How much risk and uncertainty is associated with adding value while incurring those additional costs?

Industry Trends Underlying Marketing Alternatives

The cattle industry, like most of production agriculture, faces ever-changing market conditions. Catalysts for change range from weather to changing consumer preferences. On the production side, for example, a long-term drought from 2011 to 2015 in the Southern Plains forced early calf marketing and herd reduction decisions through higher cow culling rate and even whole herd liquidation in some cases. On the demand side, consumers continue to voice greater interest in animal welfare, the environmental impact of production and healthfulness of meat choices. Amidst constant change, questions abound about how to add value to cattle and move beef from a commodity sector to a value-added product sector. In processing and retailing, the extra value typically occurs by developing processed, branded products. However, opportunities to develop branded products in the beef production sector of agriculture do not exist on a widespread scale for an average-sized production. However, there are opportunities to establish a positive reputation with cattle buyers. The emphasis for producers should be on identifying what can be done to individually or collectively add value for the buyer at the next production or processing stage.

For stocker operators, one of the most important factors affecting profits is calf health. Cattle feeders also recognize the value of cattle health on feeding performance and carcass characteristics. This has increased the focus on preconditioning calves at the cow-calf level to improve animal health by strengthening the immune system. Superior Livestock Auction is an electronic livestock auction with more than 8,000 active buyers and generally represents cow-calf operations with herds of 300 cows or larger

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 10.1. Basic Description of Superior Livestock Auction Value-added Health Protocols*

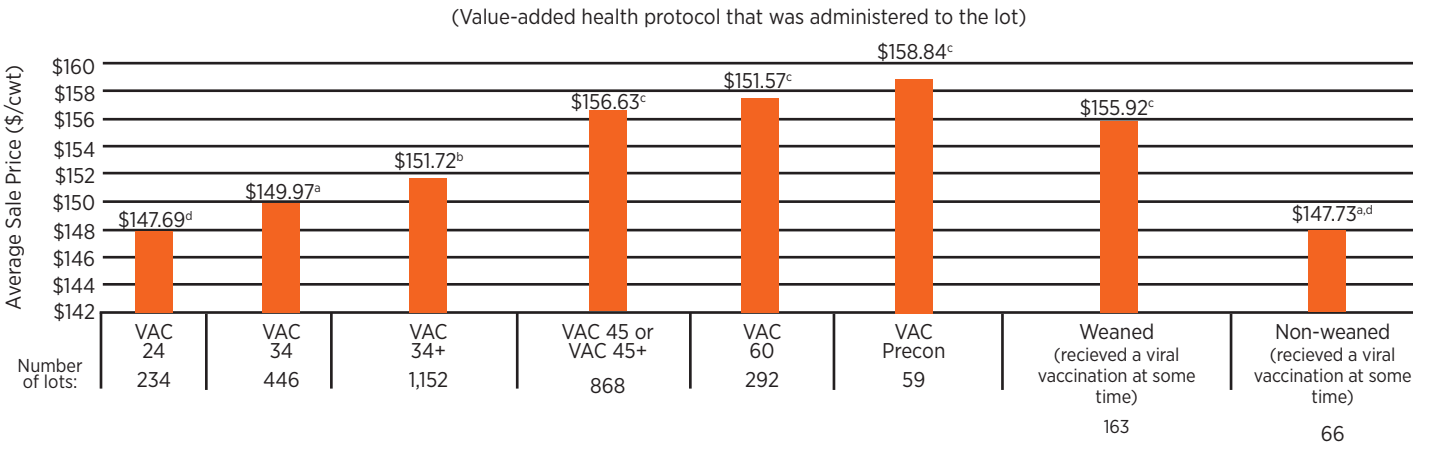
Health Protocol	*Protocol Basic Description*
VAC 24	Sold off the cow Vaccinations • 1 round (Clostridial, viral, Pasteurella) at 2 months to 4 months of age
VAC 34	Sold off the cow Vaccinations • 1 dose Clostridial at branding • 1 dose Clostridial, viral and Pasteurella two weeks to four weeks pre-shipping
VAC 34+	Sold off the cow Vaccinations • two doses Clostridial and viral at branding and two weeks to four weeks pre-shipping; one dose Pasturella two weeks to four weeks weeks pre-shipping
VAC 45/VAC 45+	Minimum 45 days weaned Vaccinations • (45) two doses Clostridial and viral; one dose Pasteurella; · (45+) two doses blackleg, three doses viral, two doses Pasteurella
VAC 60	Minimum 60 days weaned Vaccinations • two doses Clostridial and viral, one dose Pasteurella
VAC PreCon	Purchased cattle Weaned 60 days prior to delivery Vaccinations • two doses Clostridial • two doses Viral • one dose Pasteurella

Source: Superiorlivestock.com, *Detailed information available on website

(Odde, November 2019), In 1995, 40% of lots sold through Superior were unweaned calves with no vaccinations. By 2013, that percentage was 0%, and from that time forward, even unweaned calves marketed through Superior have at least some level of vaccinations prior to marketing. Table 10.1 gives a brief overview of Superior Livestock Auction's value-added health protocols. Figure 10.1 reports average prices across those health protocols for Superior's summer auctions for Summer 2020. The auction results indicate the benefits of preconditioning are recognized by buyers via market premiums for extended weaning periods and expanded vaccination protocols. A portion of this chapter will discuss implementation of calf health management practices and preconditioning calves as a means of adding value to the cow-calf enterprise.

Cow herd owners may not realize that 10% to 20% of their total revenue from the cow herd comes from selling cull cows. Indeed, many times the annual profit is from the sales of cull livestock. Cow herd owners often simply remove cows from the herd as quickly as possible when they are found to be open or their health warrants culling. However, research suggests that a planned management and marketing program for cull cows may add value to the cow-calf enterprise. For these reasons, discuss marketing strategies for cull cows as a means of adding value to the cow-calf enterprise is discussed.

The average size cow herd in Oklahoma is about 40 head. Many smaller cow-calf producers are at a comparative disadvantage in one or more ways. Research at OSU (Figure 10.2) indicates higher prices were paid for larger sale lots at various livestock markets across Oklahoma from 2010 to 2013 (Mallory, et al 2016), confirming the results of many similar studies. Most cow herd owners in Oklahoma cannot market large sale lots of uniform calves, but the data shows



a, b, c, d Means without a common superscript differ (P<.05)

Figure 10.1. Factors affecting the sale price of beef calves sold through Superior Livestock Auction video sales, Summer 2020. Source: Drovers.com

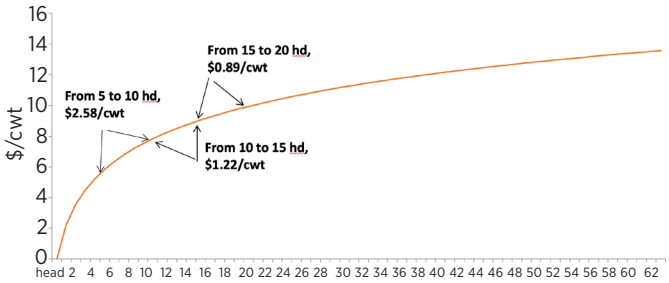


Figure 10.2. Lot Size Premiums ($/cwt) for 2010-2013 Oklahoma Quality Beef Network Sale Site Data, OQBN and non-OQBN sale dates. Source: Mallory, et al 2016.

that even moving from selling in single head lots to selling in five-head lots can make a significant difference in sale price. Also, many producers in Oklahoma are interested in upgrading their cow herd genetics and making management changes to increase uniformity of their calves in terms of weight and frame size. An alternative adopted by small groups of producers in some states is to form a cooperative marketing organization. These have varying objectives. Some are designed to upgrade cow herd genetics, some to pool calves into larger, more uniform lots for marketing and some to purchase inputs collectively.

Beginning in the 1990s, the concept of value-based marketing in the beef industry led to the development of strategic alliances. Such alliances typically fall into one of two categories: consumer-based programs and calf-based programs. These programs often attempt to better understand buyers' needs and determine what can be done to improve coordination and meet those demands. One of the key reasons cattle feeders state for joining alliances is to access carcass data (Schroeder et al. 2002). The interest in having carcass data comes from cow herd owners wanting to improve their cow herds and produce calves that have a better chance of meeting consumers' demands.

This chapter will discuss some dimensions of custom feeding producers should consider. With grid pricing, custom feeding is one means of getting feedlot performance and carcass data on calves produced. This information can assist cow herd owners in making improvements in genetics and management of the calves raised. However, feeding cattle extends the ownership period for the producer. One implication is that custom feeding adds significant risks for the producer even though for some, it also may increase the possibility of being paid for assuming the added risk. Finally, this chapter will offer some resources for consideration of direct-to-consumer marketing of beef.

Preconditioning Calves

Many cow herd owners in Oklahoma manage the cows to calve in the spring, then sell calves around October at weaning. Unfortunately, because so many producers sell calves at about the same time, calf prices are typically at their seasonal low during this time. Calves are stressed from being separated from their mothers, transported to unfamiliar surroundings, commingled with other calves and put on an unfamiliar diet. Those factors frequently combine to cause sickness and sometimes death.

An alternative is to keep calves on the ranch after weaning for a preconditioning program (Lalman and Mourer 2017). Preconditioning typically bundles the management practices of castration, dehorning, deworming, feed bunk training with a supplemental nutrition program, a 45-day, on-ranch weaning period and two rounds of respiratory vaccinations into a marketing package. After preconditioning, calves are marketed with a stronger immune system, which enables them to cope with the stress from transportation, handling, unfamiliar surroundings, commingling and a new diet. Research shows preconditioned calves perform better in a stocker or feedlot setting and in carcass quality. Through preconditioning, cow-calf operators can influence the market value of their calves by following industry-accepted management practices.

Preconditioning programs with varying names and management requirements are sponsored by cattle organizations, livestock markets and pharmaceutical companies. The Oklahoma Quality Beef Network (OQBN) program is sponsored by the Oklahoma Cattlemen's Association and Oklahoma Cooperative Extension Service (oqbn.okstate.edu). These types of programs require a minimum 45-day post-weaning phase, a specified animal health program, dehorning horned calves, castration of bull calves and bunk feeding.

Preconditioning involves added management time and cost on the ranch before marketing. These added costs must be weighed against the potential added benefits from marketing preconditioned calves. Table 10.2 is a partial budget to aid in evaluating the added costs and revenue factors. Preconditioning budget tools are available at beef.okstate.edu in a Microsoft® Excel spreadsheet. Producers can substitute their actual or anticipated values for highlighted cells and see the effects on net benefits. The top section of the budget (Table 10.2), traditional management, shows estimated revenue from selling calves at weaning. The next two sections, preconditioning management revenue and preconditioning management costs, show the revenue and costs, respectively from preconditioning calves. The last section (traditional versus preconditioning summary) compares the two marketing alternatives to arrive at net benefits.

Preconditioning Benefits

Benefits from preconditioning stem from a combination of three factors. First, additional weight gain during the preconditioning phase enables producers to sell more pounds (heavier calves) relative to selling calves at weaning. Second, seasonal prices typically increase from when calves are frequently weaned and sold in mid-October to marketing preconditioned calves in early December. Third, a potential price premium is associated with preconditioning management practices implemented at the ranch.

Additional Weight Gain

One benefit from preconditioning is selling additional

Table 10.2. Preconditioning Partial Budget Calculator.

Traditional Management Revenue	*Base*	*Alternate*
Ranch (marketing) weight (lbs.)	575	575
Shrink (%)	3.0	3.0
Sale weight (lbs.)	558	558
Price ($/cwt.)	155.00	155.00
Gross revenue ($/head)	864.51	864.51

Preconditioning Management Revenue	*Base*	*Alternate*
Days from weaning to marketing	55	55
ADG (lbs./day)	2.00	1.60
Ranch (marketing) weight (lbs.)	685	663
Shrink (%)	1.0	1.0
Sale weight (lbs.)	678	656
Price change from weaning to marketing ($/cwt.)	0.00	0.00
Estimated price slide ($/cwt)	-10.00	-10.00
Calculated price change due to heavier weight ($/cwt)	-12.04	-9.86
Price discount for increased flesh ($/cwt.)		
Management premium ($/cwt.)	10.00	10.00
Final price ($/cwt.)	**152.96**	**155.14**
Gross revenue ($/head)	1,037.30	1,018.28

Traditional vs Preconditioning Summary ($/head)	*Base*	*Alternate*
Traditional gross revenue	$864.51	$864.51
Preconditioning gross revenue	$1,037.30	$1,018.28
Increased revenue	$172.79	$153.77
Less preconditioning costs	$114.95	$90.29
Net return from preconditioning management	**$57.83**	**$63.47**
Weight gain (lbs.)	**120**	**99**
Total cost of gain ($/cwt)	$95.48	$91.56
Feed cost of gain ($/cwt)	$60.62	$49.01
Value of gain ($/cwt)	$143.51	$155.92

Preconditioning Management Costs	*Base*	*Alternate*	*Base*	*Alternate*
			Percent of Total	
Interest rate (%)	5.0	5.0		
Cattle interest ($/head)	6.51	6.51	6	7
Vaccine, health supplies and medicine ($/head)	10.75	10.75	9	12
Death loss (%)				
Death loss ($/head)	0.00	0.00	0	0
Labor ($/head)	13.20	13.20	11	15
Equipment ($/head)	7.50	7.50	7	8
Pasture ($/head)		5.00	0	6
Fertilizer ($/head)		23.19	0	26
Hay ($/head)	32.17		28	0
Feed/supplement ($/head)	40.07	19.39	35	21
Mineral ($/head)	0.75	0.75	1	1
Added marketing costs (tags, commission) ($/head)	4.00	4.00	3	4
Total cost ($/head)	**114.95**	**90.29**	**100**	**100**

pounds after the preconditioning phase. The example in Table 10.2 compares 1.6 and 2.0 pounds per day gains that translate into marketing an additional 98-120 pounds per calf after preconditioning, compared with the same calf at weaning. Heavier calves usually bring a lower price per pound than lighter calves. To account for that decrease in sales price per pound, a 10% slide is assumed. The Budget tool gives producers the option to insert the expected sale price for preconditioned calves instead of calculating the slide. BeefBasis.com is an online tool that helps producers forecast a price using futures markets and a historical basis from a livestock market located in the state. Even with a lower price, there is a significant benefit from marketing heavier calves after preconditioning.

Seasonal Price Increase

From 10 years of historical market report data (2003-2013) at Oklahoma City, the seasonal price increase for steers weighing 500 pounds to 550 pounds averaged $5.94 per cwt. between mid-October and the first week of December. However, producers should not expect this seasonal price change every year. A seasonal price increase was found in eight years out of 10 years, and the average increase was $2.04 per cwt. when omitting the two largest, atypical seasonal price increases. This more modest price change still translates into more income for producers from marketing preconditioned calves.

Management Premium

OSU and other university research has shown preconditioning is not only beneficial to animal health and performance, but also returns more money when sold at market. The premium for 2020 at the Superior Livestock Auction was approximately $11 per cwt., while OQBN premiums realized by producers in Oklahoma (Figure 10.3) were $10.00 per cwt. or above from 2011 through 2019

(weighted average with no quality adjustments). Without adjusting for other quality factors, OQBN participants received an average price of $11.93 per cwt. in 2019, more than calves of similar weight marketed with no preconditioning. OQBN premiums over non-preconditioned calves differ by gender and weight class, as illustrated in Figure 10.4, again without adjusting for other quality factors. However, this premium is not a guarantee. It depends on the reputation of the rancher, the quality of the calves, the preconditioning program, the number of value-added calves at the sale, the reputation of the livestock market and its manager and how the livestock sale is conducted. For example, selling on a day when fewer lots of value-added calves are at the sale is likely to dampen premiums since the likelihood of a critical mass of value-added calf buyers is probably also low for that sale date.

Other Sources of Added Value

A survey of Oklahoma cow-calf producers indicates 28% of producers do not castrate bull calves before marketing. The number of non-adopters jumps to approximately 50% for both deworming and feed bunk training. Weaning 45 days and two rounds of respiratory vaccinations have higher rates of non-adoption at 59% and 64%, respectively (Williams, et al. 2012). Some management practices, such as castration and dehorning, require labor, but are otherwise relatively low-cost with minimal on-farm holding period for healing prior to marketing. Other practices, such as two rounds of respiratory vaccinations and a 45-day weaning period require some upfront costs in addition to labor, as well as on-farm resources for keeping calves separate from cows during this period.

Even if it is not feasible for a producer to adopt the full bundle of practices required for a preconditioning program, there is still value for producers in adopting individual practices. Research points to premiums for specific practices implemented on Oklahoma ranches for calves sold in Oklahoma livestock markets. Williams et al. (2012) looked at premiums for calves marketed in 2010 across 10 livestock market sites and across 30 sale dates in Oklahoma. Two basic management practices readily verifiable by buyers at livestock markets are castration and dehorning. Steer calves received a $5.77 per cwt. premium over intact bull calves of similar weight, hide color and quality. Other studies have estimated this to be as high as $12 per cwt.. Sale lots with any calves containing horns were discounted approximately $3.00 per cwt. and the discount applied to the entire lot, not just to the calf or calves with horns. Other value-added practices create calf attributes that are not as readily verified. This is particularly true of many practices associated with formal preconditioning programs. Without third party verification, cattle buyers are left with some degree of uncertainty as to whether seller claims of practices such as administered vaccinations and extended weaning periods are true. Still, Williams, et al. (2014) found calves with 45-day weaning garner net returns of $5.13 per cwt. with a 60% probability of positive returns over unweaned calves while calves with respiratory vaccinations completed garnered $6.01 per cwt. in net returns with a 64% probability of positive returns over unvaccinated calves (Table 10.3).

Not all preconditioning programs include sorting as part of their protocol. In those cases where they do, cow-calf producers might receive a price premium for more uniform sale lots of calves. Recent research found a premium associated with uniform sale lots of $6.59 per cwt. (Stutts et al., 2012).

Condition can affect feeder calf prices positively or negatively. Thin calves may be discounted, especially if there is evidence of thinness being related to poor health or muscling, and those discounts can be significant. However, if associated with poor nutrition, thin calves may receive

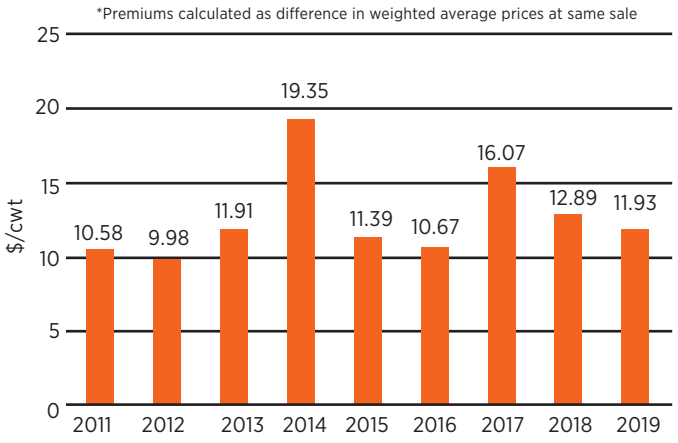


Figure 10.3. OQBN Premium over Calves Marketed with No Preconditioning ($/cwt)*, all calves, 2011-2019.

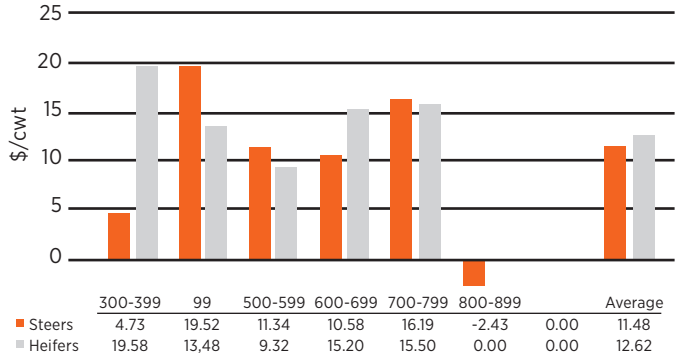


Figure 10.4. 2019 OQBN Premium by Weight Class and Gender over Calves with No Preconditioning ($/cwt).

Table. 10.3. Probability of Positive Returns for Various Management Practices.

Practice Adopted	*Net Returns ($/cwt)*	*Probability of Positive Returns*
Weaned	$5.13	0.59
Vaccinated	$6.01	0.64
Dehorned	$6.31	0.59
Weaned and Vaccinated	$5.36	0.59
Weaned, Vaccinated, and Dehorned	$10.98	0.67
Weaned, Vaccinated, Dehorned and Certified	$12.90	0.79

Source: Williams, et al (2014)
Data Source: Oklahoma Livestock Auctions

a price premium because buyers expect compensatory gains after improving the nutritional level. Fleshy calves are usually discounted, a recognition by buyers that no compensatory gains are likely. In some cases, fleshy calves are preferred as long as the degree of fleshiness is slight or moderate and is associated with health or thriftiness of the animals. Preconditioned calves that receive or are provided a high degree of nutrition may appear fleshy. Thus, in some cases, preconditioned calves may be discounted due to their fleshy condition. Sometimes, however, buyers may associate slight or moderate fleshiness with higher nutrition and health and may pay a price premium for preconditioned calves. Previous research found fleshy calves were discounted from $5.78 per cwt. to $10.35 per cwt. (Gadberry and Troxel, 2013).

In years past, a potential "stand alone" source of added value for cow herd owners was source and age verification on calves marketed. Source and age verification qualified cattle for specific beef export markets that imposed restrictions in the post-BSE era, allowing producers to capture any premiums associated with those export markets. As those restrictions have relaxed, premiums have dwindled for source and age verification as a stand-alone attribute. Superior Livestock Auction results through July 2020 indicate about $2.50/cwt. for source and age verification. Note that this premium is likely dependent on marketing calves where multiple buyers place value on the verification (Speer, 2020). That said, as consumers show more interest in food sources, source and age verification does have value combined with other attributes as part of a consumer-based marketing alliance program for calves. Such programs are discussed later in the chapter.

Summary of Benefits

Readers must be cautioned that the benefit examples given here are neither guaranteed nor additive. Still, preconditioning offers the opportunity to add value from several sources.

Preconditioning Costs

A key question is whether the added value from preconditioning offsets the added costs associated with the program. Preconditioning costs involve the added cost to feed calves for the 45-day preconditioning period, vaccination and deworming, dehorning and castrating and the opportunity costs of owning calves for the preconditioning period. Several Noble Foundation cooperators shared their cost data for 2004 and 2005. This enabled estimated costs to be as representative as possible.

The largest preconditioning cost item was for animal nutrition during the 45-day period. Feed/mineral and hay costs averaged $33 per head. Vaccination cost, a critical component of a preconditioning program, averaged $8.25 per head. Another significant cost is added labor and management time to follow the preconditioning requirements. Time may be more limiting to some producers than out-of-pocket expenses. Without question, preconditioning requires greater management oversight and more labor to implement. Those costs must be considered and weighed against the potential added gains from marketing preconditioned calves.

Producers also must consider opportunity costs. If calves are sold at weaning, the income can be used to pay expenses, reduce debt or potentially invest in some interest-earning account. Keeping calves on the ranch another 45 days means tying up capital or requiring additional borrowed funds and incurring the associated interest costs. Either of these is a cost that producers should consider when thinking about preconditioning.

Summary of Costs

Preconditioning is relatively expensive. Total costs often range from $60 per head to $70 per head or more though some producers report lower costs. Regardless of the exact amount, producers need to recognize the higher cost associated with owning calves through the preconditioning period.

Evaluating Preconditioning

Williams, et al. (2014) estimate that the expected net return from participation in OQBN's Vac-45 program in 2010 was $58 per head with an 80% probability of a positive net return. That number — a conservative one — includes premiums, the value of additional gain and the cost of preconditioning. However, individual producers must assess the added gains against the added costs for their own operation. Table 10.2 is a spreadsheet example of that process. Estimated costs are believed to be applicable to most VAC-45 programs and could be modified for other preconditioning protocols. Revenue from marketing calves at weaning is compared with marketing calves after a 45-day preconditioning program. Shaded cells in the spreadsheet can be changed to fit each producer's situation or to explore the sensitivity of results to changes in selected items. This example was intended to show close to actual costs and returns based on recent research in Oklahoma. As mentioned previously, the OQBN budget tool also could aid producers in deciding if preconditioning will return a profit using producer's individual input cost and marketing values.

The results would be less favorable with many circumstances such as lower average daily gains, lower seasonal price increases, lower premiums for preconditioned calves, higher costs, etc. On the contrary, with these same factors in reverse (higher average daily gains, larger seasonal price increases, higher premium for preconditioning, lower costs, etc.), the results would be more favorable. Producers must be careful to enter realistic values for their specific case.

Table 10.2 can also be used to find how sensitive net returns are to various changes in production, costs or market conditions. Using calculations from Williams et al. (2014) and Oklahoma City prices for 550 pound feeder calves, below are several budget changes and how they affect net returns. Note in each case, only one budget item was changed at a time.

Market Conditions

- A $2 per cwt. increase (decrease) in the seasonal price change from October to December results in an $11.90 per head increase (decrease) in net returns.

- A $2 per cwt. increase (decrease) in the price premium also results in an $11.90 per head increase (decrease) in net returns. Reducing the price premium to zero, which is possible depending on when and where calves are marketed, still results in a net return of $59.17 per head for preconditioned calves under the assumptions in this budget.
- A $2 per cwt. increase (decrease) in the final price results in a $11.90 per head increase (decrease) in net returns.

Production Experience

- A one-day increase (decrease) in the length of the preconditioning program results in a $3.02 per head increase (decrease) in net returns.
- A 0.1 per pound increase (decrease) in average daily gain results in a $9.70 per head increase (decrease) in net returns.
- Increasing death loss to 1.5% results in a $13.28 per head reduction in net returns.

Costs

- Increasing feed/mineral and hay costs $5 per head results in a $5 per head reduction in net returns.
- Increasing vaccination and animal health costs $2 per head results in a $2 per head reduction in net returns.

While actual changes will be dependent on the marketing year, this illustrates how changes in market conditions, production performance and costs can alter the expected returns from preconditioning. These potential changes help assess where the risks are and how these changes in specific areas can affect net returns.

Some resources for those interested in preconditioning can be found at beef.okstate.edu and oqbn.okstate.edu. and at the following sites.

- extension.okstate.edu/fact-sheets/does-preconditioning-pay-a-benefit-cost-decision-tool.html
- OQBN spreadsheet tool: agecon.okstate.edu/faculty/publications/3943.xlsx

USDA Verified Programs

Verifying management practices through a USDA verified program is another possibility for adding value to calves. There is typically a cost associated with qualifying cattle for these type of programs. Source and age verification is a good example of this. Premiums for age and source verification as a stand-alone attribute have decreased since Japan increased the age limit of the cattle they import from 20 months to 30 months of age in February 2013. However, age and source verification remains a strong signal to buyers of quality cattle and is often required by other USDA verified programs such as natural or grass fed, for example. Many of these programs are available and are driven by consumer demand.

USDA verified programs exist to meet any number of verification claims a producer may want to validate for their management practices on their cattle. Typically, the verification claims are easily defined so consumers can make purchasing decisions at the retail level. Source verification is the ability to trace beef back to the farm or ranch that supplied the cattle. Age verification is the ability to document and verify the age of the animal throughout the system, including at slaughter. Natural verification is the ability to document that no antibiotics, implants or other additives have been given to the animal. Producers must have valid calving records and be willing to share those records. But production records alone do not qualify cattle to be sold as verified. Verified claims have to be validated either through a USDA Process Verified Program (PVP) or a USDA Quality System Assessment (QSA) Program, both of which have auditing systems in place. PVP programs generally include age and source verification of cattle, but are also used to verify and market claims about other beef attributes such as preconditioning, all natural, etc. Each program is unique. QSAs were created in 2004 as a simpler version of PVPs primarily to facilitate source, age and non-hormone treated cattle (NHTC) verification for export markets. Most QSAs are only for source and age verification, but some also verify NHTC. For a more detailed discussion of QSA and PVP programs and their associated marketing options, see OSU Fact Sheet AGEC-612, available at extension.okstate.edu/fact-sheets/minding-your-cattle-ps-and-qs-basic-facts-on-source-age-and-other-claim-verification-through-pvp-and-qsa-programs.html.

Producers Access to a PVP or QSA Program

Local access to these programs is likely through an approved feedyard or livestock market under an umbrella program for a QSA or PVP. Interested producers would begin by exploring individual PVPs to determine whether they are already producing cattle with the potential to capture additional value beyond source and age verification. For example, some PVPs and all QSAs verify source and age, but some PVPs verify source and age along with other practices (such as preconditioning, antibiotic free or specific feeding programs). So if a producer's goal is primarily source and age verification, then a PVP offered by a breed association or information management company that entails only source and age verification is likely a good fit. Most USDA-approved QSA programs are administered through breed associations, feedlots or through the cattle feeding arm of a major packer.

The links provided in the next section list current PVP and QSA programs. Most provide information about the program's specific requirements for recordkeeping, as well as approved supplier listings, which may indicate specific local access points. That access point, whether a livestock market or a local feedyard,can provide more information about enrolling calves. To enroll a cow herd as an approved supplier in a PVP or QSA program, a producer completes an initial application that may ask for details about the cattle operation, calving season, production practices, etc. The program will then typically conduct an on-site evaluation at your ranch. At a minimum, PVP and QSA programs with source and age verification will require detailed birth records. Calf birth dates can be documented in one of two ways. The first is to document birthdates of the first and last calves from a herd's calving season. The entire calf crop from a herd for that calving season is then assigned the first calf's

birth date. Alternatively, producers can document individual calf birth dates for the entire calf crop. One implication for cow-calf producers is that if they do not have and/or do not wish to have a defined calving season, they need to keep individual calf birth records to qualify cattle for source and age verification.

Evaluating a PVP or QSA

Marketing cattle through PVP or QSA programs does not guarantee increased profitability, since the cost of qualifying cattle for programs is not free and premium levels are variable across programs and across years. For example, participation in natural verification programs may entail an initial evaluation, a per head verification fee, and occasional ranch audits. The ranch of origin may have to be audited every three years at a cost of $1,000 or more. Premiums can help to offset those fees. Speer (2020) estimated Verified Natural Beef premiums for steers at $17.78/cwt., Non-hormone Treated Cattle premiums at $7.29/cwt., and Where Food Comes From's (WFCF) Beef CARE certified premiums at $15.67/cwt. The loss of production from not using growth technologies and enrollment cost must be evaluated to assess if these programs are profitable for individual producers. Typical costs include fees for tags, audit costs, products required that are specific to the program, and perhaps additional annual fees or per animal fees. Part of a producer's profitability analysis should consider what the break-even number of cattle marketed through the program would be. Generally, participation in a QSA will be less expensive and perhaps less cumbersome than participation in a PVP since many PVPs require documentation and proof of attributes in cattle beyond age and source. Beyond cash outlay for participation, both types of programs require documenting and sharing cattle records with auditors and/or program administrators. Either type of program will also require keeping calving records for three years for auditing purposes.

Additional resources, including lists of USDA-approved PVP and QSA programs, protocols and audit procedures can be found at the following sites.

- http://www.ams.usda.gov/services/auditing/livestock-poultry
- CR-3279, Cow-calf Production Record at extension.okstate.edu/fact-sheets/cow-calf-production-record-software.html.

Marketing Cull Cows

Many producers cull and market spring-calving cows immediately after fall weaning, when cull cow prices are usually lowest, but the consistent seasonality of cull cow prices may provide opportunities to increase cull cow salvage value by retaining them for delayed marketing to capture seasonal price increases (Peel and Doye). Key factors in the profitability of delayed marketing of cull cows are retention cost (feed, labor and other costs), weight gain, cow health and market expectations.

Cows may be culled from the herd in the fall for one or more reasons. Cows are assessed for health and condition at weaning, may be pregnancy checked and found to be open (unbred) and may be culled prior to increased feeding requirements through the winter months. Producers keeping cows that have been pregnancy checked, then rechecked them in 30 days to 60 days may find some cows thought to be open are in fact pregnant. These can be reinserted into the herd and will calve in the spring. Putting bulls with cows thought to be open may result in some percentage of them being rebred. These might be kept until the spring or summer and sold as bred cows for considerably more than they would bring as open slaughter cows. Feeding cows for 30 days to 90 days may add value in several ways. Depending on the feeding system, cows may be heavier when marketed, may be in better body condition, and may reach a higher slaughter cow grade when harvested. In addition, cows will be sold typically in a higher price period than in the lower price months during the fall.

Cull cow marketing requires several considerations. Holding and feeding cows, sorting them into a separate group for rebreeding, pregnancy checking, etc. requires more management time and cost and perhaps more facilities or pastures. Most importantly, producers need to weigh the potential added benefits against the expected added costs of alternative cull cow marketing programs.

The potential added benefits and costs are addressed in Table 10.4, a partial budget, similar in structure to the one discussed earlier for preconditioning calves. It is also available at agecon.okstate.edu/faculty/publications.asp as a Microsoft® Excel spreadsheet. Producers can substitute their actual or anticipated values for the highlighted cells to see the effect on net benefits. The top section of the spreadsheet, traditional management, shows estimated revenue from selling cull cows after weaning, assumed here to be in October. The next two sections (cow feeding revenue and cow feeding costs) show the revenue and costs associated with holding and feeding cows for some period. The last section (traditional versus cow feeding summary) compares the two marketing alternatives to arrive at net benefits.

Cow Feeding Benefits

Benefits from holding and feeding cows for 30 days to 90 days beyond culling come from three primary sources. First is the potential weight gain from feeding cows, which may translate into more pounds of cows sold at harvest. Second is improving the body condition score (BCS) of cows during the feeding phase and potentially improving the slaughter cow grade at harvest, thereby adding value to the cull cow. Third, and perhaps the most influential factor, is marketing cull cows at a higher point in the seasonal price pattern.

Additional Weight Gain

How much weight cows gain in a feeding phase depends on several factors. One is the health and condition of cows when feeding begins. If there are questions about a cow's health, producers should sell her rather than risk having her die in the feeding phase. Cows with low to medium BCSs

Table 10.4. Cull cow retention partial budget.

Cow feeding partial budget	*OSU Budget*	*Your Budget*
Traditional management		
Cull cow (marketing) weight (lbs.)	1,100	0
Shrink (%)	5.0	0.0
Sale weight (lbs.)	1045	0
Price ($/cwt.)	50.00	0.00
Gross revenue ($/head)	522.50	0.00
Cow feeding revenue		
Beginning cull cow weight (lbs.)	1,100	0
Days on feed	90	0
ADG (lbs./day)	1.0	0.0
Fed cow (marketing) weight (lbs.)	1,190	0
Shrink (%)	4.0	0.0
Sale weight (lbs.)	1,142	0
Cull cow price from traditional management ($/cwt.)	50.00	0.00
Price change from cull date to marketing date ($/cwt.)	5.00	0.00
Price slide for heavier weight ($/cwt.)	-2.00	0.00
Price premium for increased BCS/quality grade ($/cwt.)	2.00	0.00
Final price ($/cwt.)	55.00	0.00
Gross revenue ($/head)	628.32	0.00
Cow feeding costs		
Interest rate (%)	5.0	0.0
Cattle interest ($/head)	3.58	0.00
Health supplies and medicine ($/head)	2.00	0.00
Death loss (%)	1.00	0.00
Death loss ($/head)	6.28	0.00
Labor and equipment ($/head)	6.00	0.00
Feed, hay, and pasture ($/head)	60.00	0.00
Additonal marketing costs (tags, commission, etc.) ($/head)	2.00	0.00
Total cost ($/head)	79.86	0.00
Traditional vs Cow feeding Summary ($/head)		
Traditional gross revenue	522.50	0.00
Cow feeding gross revenue	628.32	0.00
Increased revenue	105.82	0.00
Less cow feeding costs	79.86	0.00
Net return from cow feeding	25.96	0.00

(<6) will gain faster and add more total pounds than cows with BCSs in the 7 to 8 range. Producers may keep cows with lower BCSs longer than cows with higher beginning BCSs. Another key variable is the type of feeding program. Cows might be kept and grazed on stockpiled forages, grazed on wheat pasture, fed harvested forages and supplement or placed in a drylot feeding program on a high concentrate ration. The amount of gain and cost of gain will vary widely for these alternative programs. In our example in Table 10.4, we assume producers have stockpiled forages to graze cull cows. We assume cows begin the program relatively lean, with a BCS of 4 to 5, are kept for a 90-day feeding period and gain 1 pound per day.

Improved BCS and Slaughter Grade

AGEC-613, Cull Cow Grazing and Marketing Opportunities discusses the relationship between BCS and USDA slaughter cow grades (Peel and Doye). There is not a one-to-one correlation, but a BCS in the 3 to 5 range is approximately equivalent to a "lean" marketing category and a USDA grade of "cutter." For more information about cattle grades, see chapter 35. Cows in a feeding program that gain about 150 pounds can probably increase their BCS about two steps, say from BCS 4 to 6 or BCS 5 to 7. This also translates into upgrading from a "lean" to a "boner" category and from USDA "cutter" to USDA "utility" grade. Our example in Table 10.4 assumes a two-step increase in BCS and a step increase from "lean" to "boner" and USDA "cutter" to "utility" grade. The expected price increase associated with the grade increase is $1.50 per cwt.

Seasonal Price Increase

Prices typically increase for slaughter cows from the seasonal low in November through the seasonal high in July. However, there is no guarantee prices will increase or by how much. For example, cull cow price levels fell dramatically from 2018 to 2019 as U.S. federally inspected cow slaughter was the highest since 2013 and as cow slaughter capacity saw limits. The budget in Table 10.4 assumes an average slaughter cow price increase of $5 per cwt. from November to February. Note that some years the seasonal price increase is lower and some years higher. Whether market influences drive general price levels higher or lower, the seasonal pattern tends to persist. The $5 seasonal difference can be adjusted in Table 10.4 to reflect price levels more reflective of the producer's current marketing period.

Summary of Benefits

The example in Table 10.4 shows combined added benefits before considering added costs of $105.92. Added revenue comes from marketing more pounds, marketing at a higher seasonal price and marketing cows with improved BCS and USDA slaughter cow grade.

Cow Feeding Costs

The key to determining net benefits is whether or not added benefits discussed in this chapter cover and exceed the added costs for holding and feeding cows. The largest expected cost for feeding cows is for feed. In this case, that means stockpiled forage or pasture cost and the added cost for supplement. Besides being the largest cost item, pasture and feed costs will vary greatly by the condition of the cows, type and quality of forage and type and cost of supplement. Therefore, producers need to carefully consider the feeding program and estimate costs when planning to feed cows. Figure 10.5 illustrates weight gain and feed cost for a relatively low-cost dry-lot system versus a native pasture retention system, taken from a 3-year joint study by OSU and The Samuel Roberts Noble Foundation (Raper, et al., 2017). The differences in cost and gain between systems can be substantial.

While not a large cost item on a dollar per head basis, another key item is labor and management. Not included in the Table 10.4 budget is the cost of facilities. Since cull cows on feed are likely managed as a group separately from the

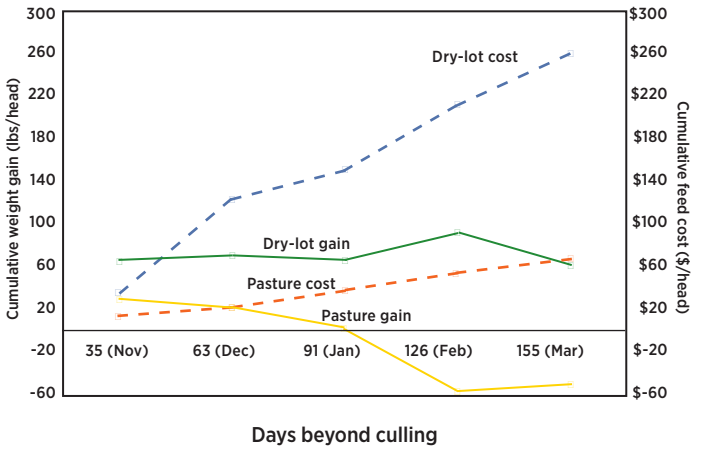


Figure 10.5. Weight Gain and Feed Cost for Cull Cows by Retention Feeding System.

breeding herd, producers need to have additional facilities or pasture for cull cows. Not considered here also is the fact that feeding cows utilizes forage resources that might be used for another cattle enterprise, either more brood cows or stocker cattle.

Summary of Costs

Feeding cows is relatively expensive. Our example shows added costs of $81.29 per head. Longer, more intense feeding programs would increase per head costs. Producers need to be aware of these added costs when considering a feeding program.

Evaluating Cow Feeding

A consideration in feeding cull cows is risk. Cow health is an imperative. Only healthy cows should be considered for feeding. Beginning weight and BCS are important to determine the potential weight gain and increase in BCS and/or slaughter grade. Heavier cows with a BCS 7 or above may not be expected to gain enough weight and change enough in BCS and slaughter grade to be likely candidates for an economical cow feeding program. Raper, et al., 2017 discuss the impact of BCS at culling on net returns from marketing cull cows at fall culling versus retaining cull cows for delayed marketing. Net returns were examined across five marketing periods (at culling and monthly through March) and two retention systems (native pasture and low-input dry lot) relative to BCS at culling as a sorting trigger. Cull cows were classified as thin (initial BCS <5), medium (initial BCS ≤ 6), or heavy (initial BCS > 6) based on research and discussions with ranch managers regarding how they sort cows when addressing nutrition and feeding regimens (Encinias and Lardy, 2000).

Generally, retaining cull cows in the native grass pasture system was more profitable than retaining them in the low-input dry lot system (Amadou et al. 2013). When BCS scores at culling are considered, thin and medium cows were typically more profitable than cows with higher initial BCS, regardless of the feeding system (Figures 10.6 and 10.7). Initial BCS appears to be an important influence on net returns from retaining and feeding cull cows beyond the culling date. As such, initial BCS should play an important role in the decision of whether to sell cull cows at the time of culling or to retain them for sale later when the typical seasonal price upswing occurs. Cows classified as heavy at culling generally yielded net returns that were statistically zero or negative relative to revenue at culling, regardless of retention system or pricing method. Cows with lower initial BCS scores generally yielded positive net returns above revenue at culling in a native grass pasture retention system, though net returns were typically negative in the dry lot system. Average daily gain (ADG) decreased with time for each BCS category in each management system, but thin and medium cows tended to have higher ADGs than heavy cows in each system.

From a practical management perspective, study results suggest heavy cows should be sold immediately after culling, regardless of the feeding system. For those cull cows with lower BCS, the seasonality of cull cow prices provides opportunity for increasing the cow's salvage value. For more information on how to assign body condition scores to beef cows, see chapter 20.

Further, Table 10.4 can be used to determine how sensitive net returns are to changes in certain assumptions. Note in each following example, only one budget item is changed at a time.

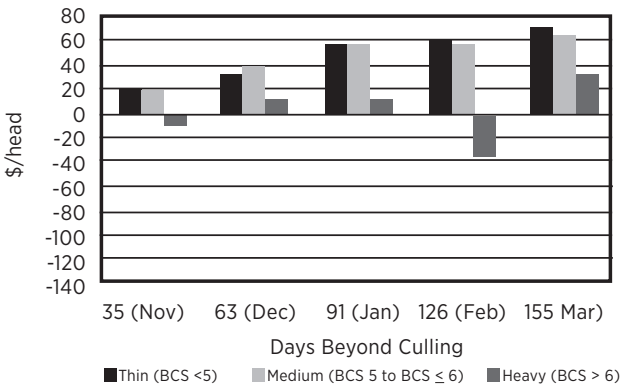


Figure 10.6. Net Returns ($/head) By Body Condition Score Across Marketing Periods for Cull Cows Retained in Pasture System, Estimated Prices (2003-2010).

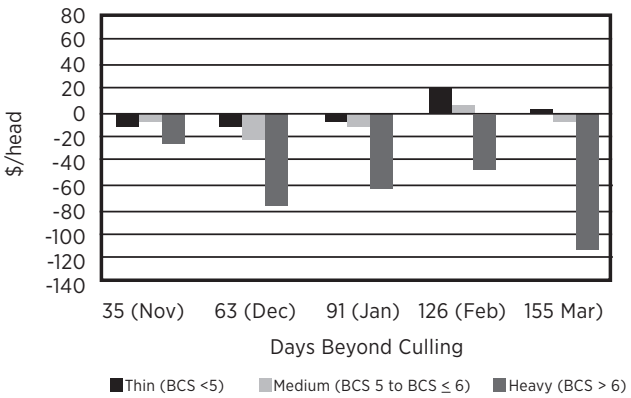


Figure 10.7. Net Returns ($/head) By Body Condition Score Across Marketing Periods for Cull Cows Retained in Dry Lot Pasture System, Estimated Prices (2003-2010).

Market conditions

- A $2 per cwt. increase (decrease) in the seasonal price change from October to January results in a $22.62 per head increase (decrease) in net returns.
- A $2 per cwt. increase (decrease) in the price premium for increased BCS/slaughter cow grade also results in a $22.62 per head increase (decrease) in net returns.
- A $2 per cwt. increase (decrease) in the final price results in a $1.74 per head increase (decrease) in net returns.

Production experience

- A one-week increase (decrease) in the length of the feeding program results in a $3.43 per head increase (decrease) in net returns.
- A 0.25 per pound increase (decrease) in average daily gain results in an $11.01 per head increase (decrease) in net returns.
- Increasing death loss to 2% results in a $5.88 per head reduction in net returns.

Costs

- Increasing feed, hay and pasture costs $10 per head results in a $10 per head reduction in net returns.
- Increasing vaccination and animal health costs $2 per head results in a $2 per head reduction in net returns.

The above confirms the importance of seasonal price changes, change in the premium for increased BCS and slaughter grade, average daily gain and feed costs. These variables help identify the key risk factors in evaluating a cull cow feeding program.

Some resources for those interested in feeding cows can be found at the following sites.

- extension.okstate.edu/fact-sheets/beef-cull-cow-management-and-marketing-alternatives.html#seasonality-and-resources
- extension.okstate.edu/fact-sheets/marketing-cull-beef-cows-does-body-condition-score-matter.html

Cooperative Marketing Programs

Cooperative marketing programs can be very diverse. They are cooperative in the sense of producers working together toward a common goal or mutual objectives. But they need not be organized legally as a cooperative form of business. Three specific objectives of such programs are: (1) add value to calves through improved cow herd genetics, (2) add value to calves by increasing uniformity of calves and marketing in larger sale lots, and (3) lower production costs by cooperatively purchasing inputs.

People Issues

Perhaps nothing is more important in considering a cooperative marketing program than ensuring everyone who agrees to work together understands and agrees to the objectives of the program. Everyone must understand that each person must adhere to the requirements in order to participate. Any cooperative effort can be undermined by one person not doing what is expected of everyone. Commitment to the program is essential.

Another essential ingredient is leadership. One person or a small group must assume the leadership role in organizing potential participants, accumulating information, planning and conducting meetings, etc.

Producers are encouraged to write clearly and specifically the objectives and requirements of each cooperator. Undoubtedly at some future time, there will be a challenge or question raised about someone's involvement. Having everything in writing will help avoid selective listening and miscommunication.

Genetic Improvement

If the goal is to improve the genetics, producers should purchase or lease bulls with similar attributes, or agree to artificially inseminate (AI) cows with semen from bulls with similar attributes. This may involve a common breed or breeds and a set of criteria such as breeding and carcass EPDs (Expected Progeny Differences). Typically, producers determine a set of common management practices, such as beginning and ending breeding dates to shorten and target the calving period, for example, 60 days in length.

Then progeny from the commonly-selected genetic base are typically marketed at the same time. Marketing programs can vary. The program may be designed so producers can retain heifers for their cow herd and only market steer calves. Producers may choose to market calves independently or advertise and market them as a group through a local livestock market or directly to buyers. Most important is the objective of the group. Much also may depend on the number of animals, location of producers or other factors.

Larger, Uniform Sale Lots

A second, common objective of a cooperative marketing program is to market more uniform calves in larger lots. This can be done independently of using common genetics and management but is also a logical extension of the genetic improvement objective. Having similar genetics and cows that calve in a predetermined period (based on the predetermined breeding period) are means of moving toward more uniform sale lots. Producers typically also have a common set of management practices to follow after calving. These often follow a preconditioning protocol. This, too, increases the uniformity of calves marketed in terms of weaning date, nutrition program, vaccination program, castration, dehorning, etc.

Actual marketing of these calves may differ according to the objectives of the cooperative group. Calves may be marketed by each producer independently, marketed at a predetermined livestock market on a set date, marketed in commingled lots at a specified market and on a set date, marketed directly to buyers or retained for a stocker or feeding program.

Cooperative Purchasing of Inputs

While this chapter's focus is on adding value, some

producer cooperatives are formed to purchase production inputs cooperatively. They determine the needs of producers in the group, determine appropriate specifications, solicit bids and purchase from the chosen bidder. The decision may not be based on the low bid, but may consider reliability and reputation of the bidders as well. The group must determine the criteria on which they will base group purchases.

This type of cooperative program may be independent of improving genetics and value-added marketing or may be an additional objective. Groups have found that local suppliers are often unwilling to bid or are unhappy when they are not the chosen bidder. However, they quickly learn that to win the cooperative group's business, they must be competitive both in price and service.

Evaluating a Group Marketing Program

Forming a group of producers with clearly defined, common objectives does not occur overnight or easily. If producers have a starting date in mind, they must start planning several months in advance. Such an effort takes time, numerous planning meetings, some research or use of outside resources and some risk taking. Often, experienced groups are willing to share their experiences. Some have websites and will communicate quickly and efficiently via e-mail. Experienced groups often can be especially helpful in identifying pitfalls an interested group might avoid. However, each group effort is different and each may have its own unique problems and pitfalls.

Participating in a Strategic Alliance

Strategic alliances as used here are broadly defined. Some alliances prefer referring to themselves as a cooperative, partnership, marketing program or some other term. Here, they are all categorized as strategic alliances. Strategic alliances in the beef industry typically enable producer participants to fundamentally maintain their independence for most production decisions. They also share information to more effectively price products and improve coordination among the vertical production-marketing stages.

Participation in an alliance may be done independently of the alternatives discussed thus far. However, each of the above alternatives may also be part of an alliance. Nearly all alliances have a targeted set of carcass characteristics. Increased uniformity may enable producers to more easily meet the target. Stated differently, increased uniformity reduces the number of carcasses that do not meet the criteria and which might be discounted or disallowed from the alliance program. Some require truckload lots of cattle. Thus, a value-added program that enables marketing on larger sale lots may fit one of these types of alliances. Seven alliances have formal ties with one or more feedlots where producers can custom feed cattle. Generally speaking, value-based marketing alliances are categorized as either consumer-based programs or calf-based programs. Consumer-based programs have predefined consumer product specifications and are seeking cattle to feed and market cattle that fit those specifications. Well known examples are Certified Angus Beef® and Creekstone Farms Premium Beef®. Calf-based programs are based on procuring calves that fit specified value requirements. An example is MFA Health Track Beef Alliance. Many are set up as USDA verification programs discussed earlier.

Information Needed

Producers need specific information regarding alliances they are considering joining. First, producers need to have a solid understanding of the quality of their production. Will production be compatible with what the alliance wants or will substantial capital investments and changes be needed to adhere to the requirements? Here are a few questions to ask:

- What are the objectives of the alliance? Does its objectives match yours?
- Is there a required commitment for number of head?
- What is the per head fee and/or capital commitment? What does that allow me to do or receive?
- What are the management requirements? Genetics? Preconditioning? Use of implants?
- Which feeders, packers and retailers are part of the alliance?
- Does the alliance have its own brand? Are cattle in the alliance targeted toward specific retail brands?
- How much have past participants benefited from the alliance?

Retaining Ownership through Custom Feeding

Retained ownership through cattle feeding is indeed risky and not for everyone. That represents one of the major disadvantages. Advantages include knowing how the cattle perform in the feedyard. Marketing fed cattle on a grid also provides information on how your cattle perform in carcass form. One desirable feature of grid pricing is that better carcasses do not subsidize poorer carcasses. Each carcass is essentially priced individually rather than all cattle in the pen receiving the same price. Most commercial feedlots have pens requiring 50 to 200 head to fill, making this only an opportunity for larger cow calf producers. Also, many of the best commercial feedyards maintain full residency of their pens. Contact the feedyard well in advance to ensure they will have pens available when your calves are ready to ship to them.

Questions to Ask

Producers interested in custom feeding are encouraged to ask several questions before determining where to feed or with whom to feed cattle (Gill, Barnes and Lalman). Here are a few:

- Does this feedlot typically handle your kind of calves (weaned, bawling, preconditioned, cattle off wheat or grass, etc.)?
- Will the feedlot manager provide examples of closeout sheets for similar kinds of cattle?
- Will the feedlot manager provide names of other customers as referrals?
- What receiving practices are followed and what rations are fed?
- What are their pen sizes?
- How are feed and services priced? How do these

compare with other lots? How often are cattle owners billed?
- Will feedlots provide financing? Risk management services? Insurance?
- Who determines when fed cattle are marketed? To which packer? By which pricing method?
- Does the feedlot sort fed cattle before marketing them?

Financing and Risk Management Considerations

Producers need to contact their lender before entering into a custom feeding arrangement. Similarly, it is wise to contact a futures market broker and assess risk management alternatives. This might be advisable even if the feedlot provides such services. Three-way agreements have worked well for some producers. These involve communication between the lender, broker and cattle owner. Margin and brokerage fees can be billed directly to the lender and be included in the loan agreement so stress is not caused during the hedging period for the producer (Eilrich, Ward and Peel).

Evaluating a Custom Feeding Opportunity

Producers should do some budgeting and risk assessment before entering into a custom feeding arrangement. The Microsoft® Excel spreadsheet, Oklahoma Beef Calf Retention Decision Aid 2.0, is available at beef.okstate.edu/pages/calculators and has a sample custom feeding budget to compute the fed cattle breakeven price. The tool allows producers to explore various retention scenarios beyond weaning, including custom feeding. The spreadsheet can be changed to fit each producer's situation or to explore the sensitivity of results to changes in selected items. Realistic values need to be used. It is advisable to use less optimistic values for selected variables than what may be experienced to see the sensitivity of the breakeven price to those variables. Some variables to consider changing, perhaps one at a time, include days on feed, fed cattle price, death loss, veterinary costs, conversion and ration cost.

Marketing Beef Directly to Consumers

Cattlemen marketing beef direct to consumers is not new, but COVID-19's disruptions in the meat supply chain certainly enhanced interest in this marketing avenue, both by producers and consumers. If you are interested in exploring this as a marketing avenue, some resources that might be helpful are AFS-3302, An Introduction to Finishing Beef and FAPC-232, Regulatory Landscape for the Direct Marketing of Meat and Poultry in Oklahoma. The Oklahoma Cattleman's Association publishes a list of members who market beef directly to consumers at okcattlemen.org/beef-direct-listing. You must be a member of the Association to appear on that list. Finally, the University of Florida's IFAS Extension offers a 4-part series of recorded webinars covering various issues related to Direct-to-Consumer Beef Marketing available at nwdistrict.ifas.ufl.edu/phag/2020/07/31/4-part-video-series-how-to-start-marketing-freeze-beef-or-beef-products/

Conclusions

Often, cow herd owners feel as though there are no opportunities for them to add value to their cow-calf enterprise. While no costless alternatives are available, alternatives do exist. Premiums (or positive net returns) for specific practices or bundles of practices are not guaranteed. However, research suggests for many practices, market premiums exist along with a high likelihood of positive net returns. Similarly, research suggests retaining cull cows can increase returns with the right conditions. Producers should make a retention decision annually for cull cows in the lower BCS categories considering the operation's available and potentially underutilized forage resources, cash flow needs, input prices and expectations of price movements.

The purpose of this chapter was to discuss a few alternatives. It should be repeated that none of these may appeal to some producers who are satisfied with marketing calves as they have in the past. Others may be looking for alternatives to consider and may or may not find alternatives discussed here attractive. In either case, producers need to recognize both the potential advantages and known risks associated with each alternative. In a cow-calf operation, good management and good marketing should go hand in hand.

References

DeVuyst, E. A., K. C. Raper, D. Doye and D. Lalman. Oklahoma Beef Calf Retention Decision Aid 2.0.. Oklahoma Cooperative Extension Service Agribusiness Management Series, 2010. Available at beef.okstate.edu/pages/calculators

Eilrich, F., C. Ward and D. Peel. Lender Preferences for Price Risk Management Alternatives for Fed Cattle. Current Farm Economics 65(1992):3-12.

Gadberry, M.S. and T.R. Troxel, 2013 Population and price differences for sale barn marketed calves in 2000, 2005 and 2010 due to management influenced phenotype. *Journal of Animal Science* 91 (e-Suppl. 1):24.

Kelley, S., K. Stutts, M. Beverly and B. Freel. 2012. Health characteristics and their Impact on selling price of Texas feeder cattle. *Journal of Animal Science* 90 (e-Suppl. 1):26.

Lalman, D., B. Ladd, and D. Doye. Cow-Calf Production Record Software. Oklahoma Cooperative Extension Service, Current Report CR-3279, March 2012. extension.okstate.edu

Lalman, D. and G. Mourer. "Effects of Preconditioning on Health, Performance and Prices of Weaned Calves." Oklahoma Cooperative Extension Service Fact Sheet AFS-3529. March 2017. Available at extension.okstate.edu/fact-sheets/effects-of-preconditioning-on-health-performance-and-prices-of-weaned-calves.html

Mallory, S., E. A. DeVuyst, K. C. Raper, D. Peel and G. Mourer. "Effect of Location Variables on Feeder Calf Basis at Oklahoma Auctions." *Journal of Agricultural and Resource Economics* 41(3):393-405. 2016.

Nelson, J. and S. Yates. Regulatory Landscape for the Direct Marketing of Meat and Poultry in Oklahoma. Oklahoma Cooperative Extension Fact Sheet FAPC-232, May 2020. Available at extension.okstate.edu/fact-sheets/regulatory-landscape-for-the-direct-marketing-of-meat-and-poultry-in-ok.html

New, M., E. Ward and D. Zook. An Introduction to Finishing Beef. Oklahoma Cooperative Extension Service Fact Sheet AFS-3302. August 2020. extension.okstate.edu/fact-sheets/an-introduction-to-finishing-beef.html

Peel, D. and D. Doye. Cull Cow Grazing and Marketing Opportunities. Oklahoma Cooperative Extension Service, Fact Sheet AGEC-613. extension.okstate.edu

Raper, K. C. and C. Richards. Minding Your Cattle P's and Q's: Basic Facts on Source and Age Verification through PVP and QSA Programs. Oklahoma

Cooperative Extension Service, Fact Sheet AGEC-612, March 2017. extension.okstate.edu/fact-sheets/minding-your-cattle-ps-and-qs-basic-facts-on-source-age-and-other-claim-verification-through-pvp-and-qsa-programs.html

Raper, K. C., J. Biermacher and Z. Amadou. "Marketing Cull Beef Cows: Does Body Condition Score Matter?" AGEC-627, Oklahoma Cooperative Extension Service, Oklahoma State University, Stillwater, Oklahoma. March 2017.

Raper, K. C. and J. T. Biermacher. "Beef Cull Cow Management and Marketing Alternatives." Oklahoma Cooperative Extension Service Fact Sheet 629. March 2017. Available at extension.okstate.edu/fact-sheets/beef-cull-cow-management-and-marketing-alternatives.html#seasonality-and-resources

Schroeder, T. C., C. E. Ward, J. Lawrence and D.M. Feuz. Fed Cattle Marketing Trends and Concerns: Cattle Feeder Survey Results. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, MF-2561, June 2002.

Speer, N. "Feeder Cattle Premiums Remain Stout." Beef Magazine, August 2020. Available atbeefmagazine.com/feedlots/feeder-cattle-premiums-remain-stout.

Stutts, K., M. Beverly, S. Kelley and B. Freel. 2012. Management practices on selling price of Texas feeder cattle. *Journal of Animal Science* 90 (e-Suppl. 1):25-26.

Williams, B. R., E. A. DeVuyst, D. S. Peel and K. C. Raper. "The Likelihood of Positive Returns from Value-Added Calf Management Practices." *Journal of Agricultural and Applied Economics* 46(1):125-138. February 2014

Williams, G. S., K. C. Raper, E. A. DeVuyst, D. Peel, and D. McKinney. "Determinants of Price Differentials in Oklahoma Value-Added Feeder Cattle Auctions." *Journal of Agricultural and Resource Economics*, Volume 37-1(April 2012):115-128.

11 Grazing Management

Ryan Reuter and Laura Goodman

Objectives

- **Understand key concepts that affect the success of grazing management.**
- **Become familiar with adaptation, use and best management practices for forage species commonly grown in Oklahoma.**
- **Describe grazing management systems and their possible effects on livestock, plants and other environmental variables.**

Introduction

Grazing management is critical to the sustainability of livestock enterprises in Oklahoma. The majority of the state's land is managed by ranchers for the primary purpose of providing grazing for beef cattle. These grazinglands are a vital part of the natural and economic resources of the state, and provide many diverse benefits to landowners and society. In a sense, grazing management affects all citizens of Oklahoma.

Grazing management is truly a meld of art and science. The best graziers (grazing managers) combine understanding of the biological and physical processes at work in these systems with economic, logistic and social considerations to achieve sustained success. Sustainability and success can be difficult to define, but achieving a long-term balance among production, profitability, ecosystem health, simplicity and personal satisfaction is the ultimate goal for many.

Key Concepts

Several key concepts are important to inform further discussions of grazing management:

- Grazing enterprises are very complex systems. Considering all the aspects and potential ramifications of decisions is important. Management practices often can have unintended consequences and can cause one kind of result in the short term and the opposite result in the long term.
- Grazinglands have multiple uses and provide a range of benefits to both the owner and the public at large. Grazinglands provide income from livestock, hay and potentially recreational or energy leases. They also play a key role in protecting soil, water and wildlife resources for the public. Mismanagement of grazinglands can be detrimental to all stakeholders.
- In general, maximizing the percentage of the livestock's diet that is grazed is beneficial to profitability, simplicity and sustainability. Grazed forage, assuming it is well managed, generally is cheaper than harvesting and feeding hay or supplemental feed.
- Stocking rate (the number of animals on a land area over time) is the most important variable for a manager to consider.

Forage Types

Two major forage types in Oklahoma have many similarities, but also many important differences.

Rangeland

Rangelands are areas that are uncultivated and typically grow plants native to the region. These areas are not cultivated because they are too dry, have rugged terrain or have soils that are too sandy, rocky or shallow. There are approximately 22 million acres of rangelands in Oklahoma, at least 8.7 million of which are native grasslands. Oklahoma's major native grasslands are tallgrass, mixed grass and short-grass prairies. In addition, the Cross Timbers rangeland cuts a swath across central Oklahoma and is a native tallgrass prairie/oak savanna. These prairies are characterized by predominantly warm-season perennial grasses mixed with other grasses, forbs, shrubs and even trees in some locations. These ecosystems evolved through millions of years with the influence of the long-term climate and soil of Oklahoma, periodic fire and periodic grazing by large ungulates.

Rangelands provide many benefits to grazing managers and society at large. Under the proper stocking rate, rangelands are resilient producers of forage for livestock. They require minimal inputs for successful management. They provide excellent habitat for Oklahoma's wildlife species. Properly managed, rangelands are resistant to wind and water erosion, thereby protecting soil and watersheds.

Rangelands are sensitive to mismanagement. Stocking too heavily for too long, especially during late summer and

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

fall, removes the vegetative cover on the soil, exposing the soil to erosion. Heavy stocking diminishes the ability of the desirable perennial forage plants to regrow quickly and vigorously, allowing less desirable plants to colonize the area. Removing prescribed fire from rangelands allows encroachment of woody species (i.e. eastern redcedar), which decrease forage production, reduce habitat for prairie wildlife species and negatively impact other important ecosystem services.

Rangelands are best managed with an ecological style of management, emphasizing use of conservative stocking rates, periodic rest from grazing and prescribed fire.

Introduced Forages

Introduced forage systems also are very important to Oklahoma's producers. These systems typically involve one species of forage that is planted and managed with agronomic inputs and practices. Examples of non-native introduced forages include Bermudagrass, Old World bluestems, tall fescue, weeping lovegrass, forage sorghum, alfalfa, wheat, rye and ryegrass. Even native grasses, such as switchgrass, might be lumped into this category when managed in monoculture. These plants have been selected and bred to have desirable traits, like grazing tolerance and often are planted/re-planted by ranchers to take advantage of genetic improvements.

Introduced forages can have some very beneficial traits. Yield, persistence, forage nutritive value, timing of forage production, tolerance of heavy grazing, responsiveness to fertilizer, resistance to herbicides and other traits can be found in introduced forages. While any individual species or variety may have some of these traits, no forage possesses all beneficial traits. A key benefit of most introduced forages is the potential to support greater stocking rates and livestock production than rangelands. Properly managed, most introduced forages also protect soil and water resources.

Introduced forages require planting or sprigging, and typically require significant input costs every year to maintain their productivity and advantages. In general, they are not as beneficial to wildlife as rangelands. Introduced forages typically are managed in an agronomic approach, using periodic replanting, commercial fertilizers and herbicides.

Complementary Forage Systems

No single forage produces high-quality, abundant forage year round in Oklahoma. Warm-season perennial grasses typically produce forage in late spring and early summer. Late summer production is dependent upon yearly rainfall variation. Warm-season perennial grasses also can have a second period of production in early fall. Warm-season annual grasses, such as forage sorghum and crabgrass, produce quality forage in summer with adequate rainfall. Cool-season perennial grasses, such as tall fescue, have thus far not been proven to be widely adapted to the western part of the state. In the east, fescue produces good forage during the fall and spring. Cool-season annuals such as wheat, rye and ryegrass produce high-quality forage from late fall to spring. Fall production of these forages can be highly dependent on species and variety, weather and management choices such as planting date. Legumes often are very high-quality forages but can be variable in yield, timing, cost and availability.

A key management strategy is to combine different types of forages to take advantage of the traits of each while minimizing the negative effects. Most operations already involve multiple types of forages. Sometimes, complementary forages can be planted as a mixture, such as Bermudagrass and tall fescue, or rye and ryegrass. In annual cropping systems, complementary forages can be grown on the same land at different times of the year. An example would be wheat in the winter and crabgrass or cowpeas in the summer. However, most complementary forage opportunities arise from having different types of forages growing in separate pastures and rotating animals among them at opportune times. An example of this would be a ranch that included 320 acres of rangeland, 80 acres of Bermudagrass and 40 acres of wheat. Managing each of these areas with its best management practices—and planning for their use as a complementary system—will typically achieve the best outcome.

Grazing Systems

The term "grazing system" typically refers to the way livestock are managed and allowed access to the grazing land. Research indicates that the two basic systems can support approximately the same stocking rates and produce similar net returns. In practice, some graziers dramatically prefer one system over another. Some of the purported benefits of one system vs. another are difficult to reproduce in small-scale experiments.

Continuous Grazing

In continuous grazing, livestock are allowed continuous access to the entire grazing area. Benefits of continuous grazing are simplicity of management and minimal fencing and water development requirements. Minimizing fencing and uneven grazing patterns can be beneficial to wildlife. Timing of grazing and animal distribution across the pasture is not controlled in this system.

Rotational Grazing

Rotational grazing is moving animals from one pasture to another regularly. Typically, the goal of rotational grazing is to force animals to consume forage more uniformly than they would otherwise, then allow that forage a rest period to recover from grazing. Potential benefits of rotational grazing can include more uniform forage use, minimal increased stocking rate, improved long-term yield, improved quality through controlling forage maturity and better animal management. These benefits are more prevalent in introduced pastures. Disadvantages can include decreased animal performance, increased management effort, increased cost for fencing and water development, increased risk of overgrazing a small area, increased consumption of toxic plants and decreased wildlife habitat.

At its simplest, moving livestock back and forth between two pastures would be a form of rotational grazing. Rotations can range in length from an entire growing season to very short durations of a day or less. Many practitioners would tend to think that six pastures to eight pastures are needed to begin to see some of the potential benefits of rotational grazing. If the goal of rotational grazing is to provide rest, then there is a diminishing return to building additional paddocks into a rotational system (Table 11.1). A potential way to start a rotational grazing system would be to build four paddocks to six paddocks and begin at that scale. These paddocks can be divided as the rancher sees the need.

Many variations of rotational grazing have been documented and used, including strip grazing, ultra-high density grazing, mob grazing and multiple herd systems such as the Merrill four-pasture, three-herd system.

Table 11.1. Rest periods with additional paddocks in one, complete 28-day grazing rotation.

No. Paddocks	*Grazing rotation days*	*Rest days*
1	Continuous	0
2	28	14
4	28	21
8	28	24

Fencing Considerations in Rotational Grazing

Typically, rotational grazing requires fencing and water development. Ranch boundary fences should be constructed to contain animals safely inside the ranch perimeter. Interior fences to create paddocks for rotation can be constructed much lighter and less expensive than perimeter fences. Electric fencing has been used successfully for interior fencing. For cows, a single smooth high-tensile electrified wire can separate paddocks. This style of fencing is intended to be permanent, and strong corners and bracing are required. The high-tensile wire should be under substantial tension; this allows for wide line post spacing and resistance of the fence to damage from deer. Temporary fencing can be constructed from "polywire," especially when animals are trained to honor electric fences. (Interior fences for rotational grazing of sheep typically require additional wires; containing goats is yet another level of difficulty.)

Traditional net wire or barbed wire fences are physical barriers, while electric fences are psychological barriers. As such, the key to success is to always maintain an adequate electric charge on the fence. This also is one of the biggest challenges with electric fencing. New technology in fence energizers is helping to alleviate some of the difficulties, but electric fences require frequent attention and maintenance. Some producers grow tired of maintaining electric fence and either replace it with traditional fence or scale back their rotational grazing systems.

Creating new paddocks typically requires developing water sources as well. Cattle drink significant amounts of water; a lactating beef cow can easily consume 25 gallons per day in the summer. Surface water, such as ponds, often provide the lowest maintenance way of providing drinking water. Streams also can provide water, but if unmanaged, cattle can rapidly degrade the riparian area along watercourses. If ponds are used as water sources, producers should consider fencing the pond to provide a riparian buffer and allowing livestock access at one or two reinforced access points. Drought may impact the reliability of ponds and streams.

Ranchers also may consider developing wells with either solar-, electric- or wind-powered pumps to provide drinking water. Oftentimes, water from a well can be piped to several paddocks as needed. Consideration should be given to required water volume and flow rates when specifying pumps, pipe sizes, etc. Some ranchers consider hauling water in bulk tanks to grazing cattle, but in practice, most quickly realize this is a strategy best left to dealing with short-term emergencies.

Redistributing Grazing Without Fencing

Some of the benefits of rotational grazing can be obtained by improving livestock grazing distribution without the need for additional fence construction. Since cattle grazing typically decreases in areas greater than 1 mile from water, developing water sources in areas far from existing water will improve grazing distribution. Offering salt and mineral or supplemental feed in these areas will have a similar effect. In rangelands, a method of implementing prescribed burning called "patch burning" has the effect of redistributing grazing. In this method, different areas or patches of a pasture are burned each year and livestock have access to both burned and unburned patches. In following years, the unburned patches are burned, so the entire pasture would be burned through the years. The burned patch attracts the livestock to the new, fresh forage, which rests the unburned areas of the pasture. The subsequent burn distributes grazing and rest across the pasture. Grazing distribution isn't controlled as well as with fences, but the patch burn system is accomplished without the expense of additional fencing or water sources, and it incorporates the benefits of prescribed burning including woody plant control and increased forage production. This approach decreases livestock use of sensitive riparian areas and increases use of areas far from water, while minimizing the need for winter supplemental protein.

Grazing System Modifications

Many creative grazing management modifications can be applied to the two main grazing systems (continuous and rotational grazing). One example is leader-follower grazing, in which one herd of animals with greater nutrient demands (for example, heifers) is allowed to graze a fresh pasture and consume the best parts of the plants, then they are moved on to another fresh pasture. A herd with lower nutrient demand (for example, mature cows) grazes the pastures as the follower, using the rest of the forage left behind. Another example of grazing system modification is creep grazing, in which cow/calf pairs are grazed on a forage, but calves are allowed access to an adjacent high-quality pasture through a creep gate or creep fence.

Supplementation

Practically all grazing systems require supplementation to meet the requirements of modern livestock. Most forages are deficient in salt and phosphorus. A balanced mineral mix offering free choice typically is the most cost effective mineral supplement. Minerals should contain at least 4% phosphorus and adequate trace minerals. Warm-season perennial grasses require protein supplementation from late summer through winter until green-up in the spring. Without protein supplementation, digestibility and voluntary intake are reduced and livestock are unable to maintain productivity. Livestock grazing other forages during different times of the year may benefit from strategic supplementation.

A common complementary forage strategy is to use a high-quality forage as a supplement to a lower-quality one. A classic example is maintaining cows on dormant native range or Bermudagrass in the winter and "supplementing" them by periodically allowing them to graze an adjacent wheat pasture. These systems require some management but can be very effective at reducing supplementation costs.

Stocking Rate

Stocking rate is the number of animals on a given area over a period of time. It is the key variable in managing grazing. Maintaining the proper stocking rate balances forage supply with demand, and allows for animal production simultaneously with long-term forage productivity and health. Understocking a pasture can allow forage to mature quickly and degrade in nutritive value and can be financially unsustainable. However, overstocking is the bigger concern. Overstocking results in long-term declines in the health and productivity of the forage stand, which translates into less animal production and degradation of the environmental benefits of grazinglands. Overstocking also increases the risk to grazing enterprises during drought. It can take many years of good management to reverse the damage to grazinglands from a year or two of overstocking. Producers can be tempted to overgraze because of the short-term increase in animal production per acre, but experienced graziers manage with long-term economic and environmental sustainability in mind.

Implementing the correct stocking rate is a challenge. Forage supply can be quite variable from year to year due to weather conditions and management factors. Using estimates of expected forage production from the soil survey, tempered with experience and long-term data about your ranch, is typically the best way to set an initial stocking rate. A good strategy is to build a grazing plan so animal demand can be adjusted quickly in response to changing forage conditions without severe financial costs. An example is a plan to stock a ranch at a conservative stocking rate with brood cows that could be maintained even in a mild drought. Calves can be retained as stockers in normal years, and additional stockers could be grazed in good years. In severe droughts, older and less productive cows can be culled to balance forage supply with demand, while maintaining a base of livestock from which to build again. Strategies like this increase the long-term sustainability of a grazing enterprise.

The effective stocking rate is a function of the forage demand of an animal. It is not enough to simply think a ranch can maintain "X" cows. Cattle consume and require forage in relationship to their body size and milk production potential and possibly other factors, such as breed type and genetic propensity, for feed efficiency. Stocking rate estimates must be adjusted to account for the differences in forage demand of the type of cattle under consideration. Conversely, the selection emphasis for breeding stock should consider the impact on stocking rate.

Building a Grazing Management Plan

A grazing management plan begins with a survey of the land resources available. A map delineating property and pasture boundaries is most useful. Such a map can be generated using online tools or with assistance from the local NRCS office or OSU Extension office. Once pasture boundaries are known, the grazeable acreage in each pasture should be determined. This can be done by tracing out the areas in each pasture that do not provide forage for cattle. Such areas are closed canopy forest, ponds, lakes, buildings, roads, etc. Soil type should then be determined in each pasture. This information is available in the soil survey for almost every county in the U.S. Soil characteristics such as texture and depth are major determinants of productivity of different forage species. Finally, the existing forage in each pasture should be inventoried. Some ranchers may benefit from professional help in determining species, condition and vigor of their existing forage base. Yield, quality and timing of production can be estimated from this information. The ultimate usable forage supply might be less than total yield because animals will avoid areas far from water sources, slopes, etc.

Once forage supply is estimated, the forage demand must be estimated. One approach is to determine the demand of the existing livestock herd, or the demand of the desired herd and production system. Another approach is to consider the existing forage yield, quality and seasonal distribution and what type and size of livestock herd is best suited to that forage base. For example, a ranch with mostly native range might be best suited to a cow-calf enterprise at a relatively low stocking rate with calves sold at weaning. Conversely, a ranch with a large proportion of forage from wheat pasture is suited to a stocker enterprise. A ranch with a mix of native range, Bermudagrass, fescue and some wheat might be suited to a more intense cow/calf enterprise with calves retained to graze as yearlings. If some pastures contain significant amounts of browse, adding goats to the grazing plan may be a good option.

A key consideration in a forage management plan is grazing efficiency. This is the percentage of the yield consumed by the animal. A portion of the forage produced

must be left unused to maintain vegetative cover on the soil and provide the plant with the ability to consume nutrients and produce new growth. Removing too much of the forage yield inhibits plant recovery from grazing, ultimately causing a decline in the sustainability of the system. This is the definition of overgrazing. Many introduced forages can tolerate a high grazing efficiency. For example, if Bermudagrass produces 5,000 pounds of dry matter per acre, approximately 65% can be used by livestock. However, rangeland that produces 5,000 pounds of dry matter per acre only can tolerate about 25% grazing efficiency. The "take half, leave half" rule of thumb indicates that half of the forage of native range must be left to maintain condition of the range. However, other forage uses besides just the livestock exist. Forage trampling and decay, insects and wildlife typically consume as much forage at the livestock consume. Accounting for these forage uses results in the recommended 25% grazing efficiency target. The duration of the rest period following grazing has a major impact on the long-term effects of an intense defoliation event.

Finally, other forage demands besides direct livestock use must be considered. Intended hay harvest and forage growth to promote improving range condition, fuel to enable prescribed burning and a forage cushion to deal with drought must all be factored into the grazing plan. When all of these factors are considered, a plan can be developed that guides grazing the right animals on the right forage for the right amount of time. That is the working definition of effective grazing management.

Tools, decision support and further reading

Web Soil Survey
websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Calculating grazeable acres
extension.okstate.edu/fact-sheets/using-google-earthtm-for-mapping-and-assessing-grazeable-land.html

Forage budgets
extension.okstate.edu/fact-sheets/forage-budgeting-guidelines.html

Pasture rental rates
extension.okstate.edu/fact-sheets/oklahoma-pasture-rental-rates-2018-2019.html

Grazing plans
extension.okstate.edu/fact-sheets/plan-grazing-management-using-the-oklahoma-grazing-stick.html

Prescribed fire
extension.okstate.edu/topics/environment-and-natural-resources/rangeland-management/prescribed-fire/

Patch burning
extension.okstate.edu/fact-sheets/patch-burning-integrating-fire-and-grazing-to-promote-heterogeneity.html

Stocking rate
extension.okstate.edu/fact-sheets/stocking-rate-determination-on-native-rangeland.html

Management in rangelands and introduced pastures
extension.okstate.edu/fact-sheets/management-strategies-for-rangeland-and-introduced-pastures.html

Managing bermudagrass to replace hay
extension.okstate.edu/fact-sheets/bermudagrass-pasture-management.html

Supplementation
extension.okstate.edu/fact-sheets/supplementing-beef-cows.html

Conclusion

Grazing enterprises are complex systems. Proper management of them is vital to the livelihood of ranchers, as well as the sustainability of food production and conservation of the natural resources of Oklahoma. Stocking rate is the key variable in grazing management decisions. Introduced forage systems and rangelands both contribute to grazing enterprises, and proper grazing management addresses the differences required to sustain them. Good grazing management balances animal demand with forage supply to promote long-term economic, environmental and biological sustainability of the enterprise.

References

Bidwell, T. G. and D. D. Redfearn (2002) Drought Management Strategies. OSU Extension Fact Sheet NREM-2870, Cooperative Extension Service, Oklahoma State University.

Bidwell, T. G. and B. Woods (2000) Seeding Marginal Cropland to Perennial Grasses. OSU Extension Fac Sheet NREM-2581, Cooperative Extension Service, Oklahoma State University.

Bidwell, T. G. and B. Woods (2002) Management Strategies for Rangeland and Introduced Pastures. OSU Extension Fact Sheet NREM-2869, Cooperative Extension Service, Oklahoma State University.

Bidwell, T. G. et al. (2003) Using Prescribed Fire in Oklahoma. OSU Extension Circular E-927, Cooperative Extension Service, Oklahoma State University.

Bidwell, T. G. et al. (2003) Fire Effects in Oklahoma. OSU Extension Fact Sheet NREM-2877. Cooperative Extension Service, Oklahoma State University.

Bidwell, T. G. et al. (2004) Fire Prescriptions for Maintenance and Restoration of Native Plant Communities. OSU Extension Fact Sheet NREM-2878. Cooperative Extension Service, Oklahoma State University.

Conner, J. B. (1991) Social and Economic Influences on Grazing Management. chapter 9 in Grazing Management: An Ecological Perspective. R. K. Heitshmidt and J. W. Stuth editors. Online at cnrit.tamu.edu/rlem/textbook/textbook-fr.html

Redfearn, D. D. and T. G. Bidwell (2003) Stocking Rate-The Key to Successful Livestock Production. OSU Extension Fact Sheet PSS-2871, Cooperative Extension Service, Oklahoma State University.

Redmon, L., J. Baker and E. Krenzer. Cool Season Annual Forage Grasses. OSU Extension Fact Sheet PSS-2571, Cooperative Extension Service, Oklahoma State University. Redmon, L. A., J. L. Caddel, and J. D. Enis (2003) Forage Legumes for Oklahoma. OSU Extension Fact Sheet PSS-2585, Cooperative Extension Service, Oklahoma State University.

Sahs, R. (2008) Sample Forage Budget generated using OSU Enterprise Budget Software.

Woods, R. and L. Rommann. Forage Budgeting Guidelines. OSU Extension Fact Sheet PSS-2584, Cooperative Extension Service, Oklahoma State University.

Zhang, H. et al. (2002) OSU Soil Test Interpretations. OSU Extension Fact Sheet PSS-2225, Cooperative Extension Service, Oklahoma State University.

Endnotes

1 CR-216 – extension.okstate.edu/fact-sheets/oklahoma-pasture-rental-rates-2018-2019.html

2 PSS-2584 – extension.okstate.edu/fact-sheets/forage-budgeting-guidelines.html

12 Hay Production, Storage and Feeding

Courtney Bir and Paul Beck

Objectives

- **Discuss hay production.**
- **Discuss ways to reduce dry matter losses.**
- **Present an example hay budget.**
- **Discuss stockpiled forages.**

The process of producing, harvesting and storing hay is a common practice in the beef cattle industry for several reasons. One major reason is to provide forage during times of limited forage availability. Many ranching operations grow more forage during the growing season, particularly during spring and early summer than the stock can efficiently utilize during that time period. Logically, the majority of hay is fed during winter when most perennial forage species are dormant and access to standing forage may be limited (Figure 12.1). Harvesting, storing and feeding hay for winter months or times of drought is a way to spread available forage throughout the year.

Another reason hay is produced is to preserve forage quality. Since forage quality declines with advancing maturity and weathering, hay harvested during the growing season usually will have higher protein concentration and higher digestibility compared to standing cured forage.

Hay, whether raised or purchased, also can be used to increase the stocking density of a ranch. Once extensive hay feeding becomes part of the management plan, the average days of hay feeding, pounds of hay fed per animal unit and/or total number of animal units on a given land resource may gradually increase through time, particularly if an investment is made in hay equipment. Accurate hay production, purchase records and feeding records should be maintained and monitored over time to ensure hay production and feeding decisions are cost effective.

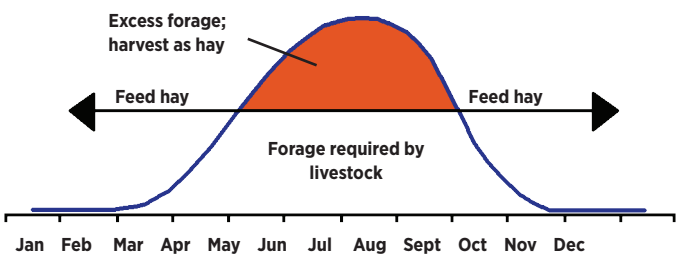


Figure 12.1. Forage production and utilization.

Hay Production Costs

Although producing, storing and feeding hay may be necessary as insurance against extreme weather conditions (drought, severe winters, etc.), it is an expensive source of nutrients for beef cattle compared to grazing standing forage. Software tools to assist producers in evaluating cost of forage production are available at agecon.okstate.edu/budgets.

Forage production costs depend on the cost of establishment, years of stand life and maintenance costs such as fertilizer and pesticide. These costs vary with different types of forage. A hay enterprise budget (Table 12.1) can be used to estimate the costs and returns of hay production. Hay production is valued at the price the hay would bring if sold—or its value in livestock production, which could be the cost of buying equivalent hay—times the quantity produced. Hay production costs include both costs of operating inputs and fixed costs associated with machinery and land ownership.

Operating costs include the costs of inputs used up in the production period. Annual operating costs in hay production include fertilizer, pesticide, interest on operating money, labor, custom hire of machinery and equipment, fuel, lube and repairs. The forage establishment costs are prorated throughout the expected life of the stand.

Fixed costs include a portion of the forage establishment costs plus interest, depreciation, taxes and insurance on machinery and equipment plus interest and taxes on land. If the fixed ownership costs of machinery and equipment are spread over more acres, the fixed cost per ton of hay is reduced. In this example, the fixed costs of machinery are $56 per acre. If the baled acreage is doubled (320 acres), fixed machinery per acre is halved to $28. This reduces the fixed cost for machinery from approximately $21 to $11 per ton.

Machinery costs can account for as much as 50% of the annual total cost of producing a crop (excluding land costs). Choices made concerning machinery matters can have a

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 12.1. Sample Bermudagrass hay budget, 160 acres, owned hay equipment.

	Units	*Price($)*	*Quantity*	*Total $/Acre*
PRODUCTION				
Hay Sales	Tons	100	2.16	216.00
Total receipts				**$216.00**
OPERATING INPUTS				**$/Acre**
Fertilizer	Acre	88.94		88.94
Pesticide	Acre	4.59		4.59
Annual Operating Capital	$	6.50%	42.62	2.77
Machinery Labor	Hour	10.50	2.28	23.99
Equipment Labor	Hour	10.50	0.06	0.63
Custom Hire	Acre	6.10		6.10
Machinery Fuel, Lube, Repairs	Acre	79.74		79.74
Equipment Fuel, Lube, Repairs	Acre	1.21		1.21
Total operating costs				**207.97**
Returns above total operating costs				**$ 8.03**
FIXED COSTS	**Units**	**Rate**		**$/Acre**
Establishment	Acre	264.63		33.99
Machinery/Irrigation				
Interest at	$	6.40%		18.71
Taxes at	$	1.00%		3.15
Insurance	$	0.60%		1.38
Depreciation	$			22.80
Equipment				
Interest at	$	6.40%		1.94
Taxes at	$	1.00%		0.61
Insurance	$	0.60%		0.18
Depreciation	$			2.43
Land	$/Acre	1,750		
Interest at	$	0.00%		
Taxes at	$	0.50%		8.75
Total fixed costs				**$93.94**
Total costs (operating + fixed)				**$301.91**
Returns above all specified costs				**$ (85.91)**

Source: Sahs. agecon.okstate.edu/budgets.

significant impact on farm profitability. Producers are faced with many decisions regarding farming equipment. For example:

1. What is the cost of operating owned machinery?
2. How would the cost of operating new or larger equipment compare to those currently owned?
3. What would be the difference in cost of used machinery versus new machinery?
4. How much investment is needed to add a particular crop to the operation for the first time?
5. Would owning equipment be less expensive than using a custom service?

There are no easy answers to these questions because each answer depends on the particular set of circumstances. Considering the timeliness of operations plus the cost and quality of work, the machinery selection process often is very complex. Two of the most important factors in determining the cost of owning and operating machinery are the total hours of usage per year and length of ownership. If a machine is sold before its useful life is spent, the cost of ownership may be high. As an example, Figure 12.2 shows how swathing costs are affected by the number of acres harvested and total years of ownership. If the swather covers 400 acres per year, its estimated cost is $50 per harvested acre if the swather is owned eight years. Incidentally, only 14% of the swather's life is used after eight years at 400 acres per year. If the same swather is used to harvest 1,600 acres per year, the cost of owning and operating this machine drops to less than $18 per harvested acre. After eight years, this machine has reached 55% of its life.

For small acreages, custom hire of hay raking and baling is typically less expensive than machinery and equipment ownership and maintenance. Of course, the trade-off is forced reliance on someone else to perform operations in a timely manner to the producer's quality standards. Information on the cost of custom work in Oklahoma is in CR-205, *Oklahoma Farm and Ranch Custom Rates* available online at extension.okstate.edu/fact-sheets/oklahoma-farm-and-ranch-custom-rates-2017-2018.html or through local OSU Extension offices.

Hay feeding costs do not end with the cost of production. Since dry matter losses during harvesting, storage and feeding can dramatically increase the cost of producing and feeding hay, producers must take steps to ensure minimum waste in each of these areas.

Reducing Hay Production Losses

There are three stages during the hay harvesting process where field losses are most likely to occur: mowing,

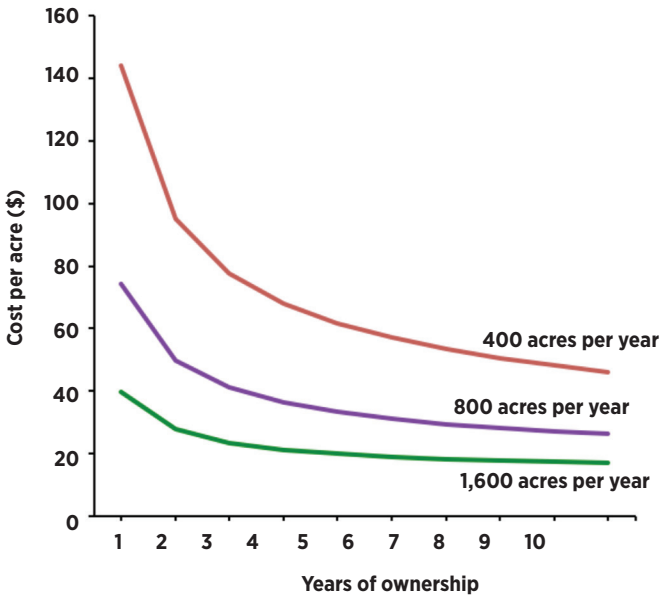


Figure 12.2. Estimated cost of owning and operating a swather based on acres harvested and length of ownership. Source: Huhnke.

raking and baling. Dry matter losses as a result of mowing are minimal. However, dry matter losses do occur with raking and baling. Dry matter losses due to raking can range from 5% to more than 20%. The high dry matter losses generally are those associated with the production of legume hay. These losses are usually due to leaf shattering as a result of raking hay that is too dry. To avoid extreme losses in dry matter in legume hay production, rake when the moisture is 45% to 55%. Anytime hay must be raked or fluffed to aid in drying, losses in dry matter will result from leaves that are separated from the stems. Additional losses from baling operations can range from as low as 1% to more than 15%. Forages that are more dry and brittle during baling generally will have greater dry matter losses.

Two additional situations that can significantly impact dry matter losses during hay production are plant respiration and weather. Dry matter loss that occurs as a result of plant respiration is unavoidable. Respiration is a normal process that occurs in all plants. It is simply the breakdown of food materials used for plant growth. Respiration continues after the plant is cut until the moisture content drops below 40%. Since the plant does not have the capability to grow after it has been cut, respiration results in lost production. Losses due to weather conditions usually are the result of unplanned weather patterns. The losses resulting from adverse weather conditions can be minimal to greater than 35%. These losses have their greatest negative impact between mowing and baling.

Most of the problems encountered during the hay-making process are the result of poor environmental conditions that occur from the time the hay is mowed until it has been baled. Remember that many field losses from hay crop production are avoidable. The most critical factor affecting hay production is moisture content, so there is a lot of truth in the saying, "Make hay while the sun is shining." Although hay is usually considered to be dry, properly cured hay has between 10% and 15% moisture. Hay that is cured and harvested under ideal conditions will still have losses around 10%. However, under less-than-ideal conditions, these losses can be as high as 75%.

Round Bale Hay Storage

Large round bales were introduced in Oklahoma in the early 1970s. One of the reasons for the popularity of this hay package was its low labor demand. Harvesting and storing round bales only requires one to two people, whereas, two to four people often are needed to harvest and store small square bales. Another reason some hay producers have chosen large round bales instead of square is storage requirements. In most cases, square bales must be stored under cover, preferably in an enclosed barn. Round bales, however, often are stored outside and unprotected because their shape enables them to shed precipitation. Still, there is much uncertainty about projected storage losses in exposed large round bales and the economic feasibility of providing some type of protection.

Generally, the value of storage depends on the projected hay loss while in storage and the price of hay when sold or used. Table 12.2 shows the dollar value loss of hay based on a percent storage loss with a range of hay prices. For example, if hay with a market price of $100 per ton has a 20% loss during storage, the value or cost of the hay lost would be $20 per ton. This loss in hay value, added to the cost of the storage system such as an enclosed barn, gives the total storage cost, which can be used to compare various types of storages. One of the biggest problems in determining total storage cost of a system is estimating the loss of hay value during storage.

Table 12.2. Value of hay lost in storage[a].

Storage Loss (%)	Hay price ($ per ton)				
	$40	$60	$80	$100	$120
	$ per ton				
5	2	3	4	5	6
10	4	6	8	10	12
15	6	9	12	15	18
20	8	12	16	20	24
25	10	15	20	25	30
30	12	18	24	30	36
35	14	21	28	35	42
40	16	24	32	40	48

a Does not include losses associated with shrinkage or reduced quality.
Source: Huhnke.

Bales Stored Outside and Unprotected

Research has shown losses in large round bales stored outside and unprotected can be far greater than hay producers realize. Quality indicators such as acid detergent fiber and dry matter disappearance can be adversely affected more than 10%.

Dry matter losses can reach 50%, depending on bale quality, storage conditions and length in storage (Table 12.3). The lower value of each range represents well-formed bales located in areas with low rainfall (less than 25 inches per year) and low relative humidity, such as the conditions in northwestern Oklahoma. The higher values are for areas with high rainfall (greater than 40 inches per year) and high relative humidity such as southeastern Oklahoma.

Table 12.3. Percent dry matter loss of round hay bales.

Storage Method	Storage period	
	Up to 9 months[a]	12 to 18 months
Exposed		
Ground	5 to 20	15 to 50
Elevated	3 to 15	12 to 35
Covered		
Ground	5 to 10	10 to 15
Elevated	2 to 4	5 to 10
Under roof	2 to 5	3 to 10
Enclosed barn	Less than 2	2 to 5

a If used before spring warm-up.
Source: Huhnke.

Table 12.4. Amount of dry matter in outer layers of large round bales.

	Outer layer depth			
Bale diameter (ft)	*2 inches*	*4 inches*	*6 inches*	*8 inches*
	% dry matter loss			
4	16	31	44	56
5	13	25	36	46
6	11	21	31	40
7	9	18	27	34
8	8	16	23	31

Source: Huhnke.

Severe deterioration usually is confined to the outside 2 inches to 8 inches of the bale. Depending on the bale diameter, just two inches can represent more than 10% of the bale's dry matter (Table 12.4). An 8-inch weathered layer represents a significant volume even in the largest round bales. The depth or thickness of weathering depends on many factors, including the amount of rainfall and environmental conditions (temperature and humidity) during the storage period, type and condition of hay when baled, bale shape and density.

Bale Density

Bales should be well-shaped and as dense as possible. Limited research indicates storage losses for variable-chamber bales may be slightly less than fixed-chamber bales. However, do not make the next baler purchase on this inconclusive evidence. One of the important keys to reducing weathering is the tightness of the outer layer of the bale. Moisture penetration and bale deterioration are inversely proportional to the tightness of the outer 2 inches to 6 inches. The tighter the outer layer, the lower the losses regardless of whether the bale was formed using a variable- or fixed-chamber baler.

Outer layer tightness or density is not easy to measure. A rule of thumb is to push on the outer surface of a newly-formed bale with the palm of your hand. If you can depress the surface more than 1/2 inch, the bale could undergo significant storage losses when placed outside and unprotected. If using sisal or plastic twine, wraps should be no greater than 8 inches (preferably 6 inches) apart along the bale's length. This does, however, require additional time and expense during baling. If bales are stored outside, the added time and expense is easily justified. Research shows net-wrapped bales have similar storage losses to the standard plastic or twine wrap when the outer layers are at the same density.

Environmental Conditions

The amount of precipitation that falls on unprotected bales can affect storage losses. However, precipitation alone is not a good predictor of projected losses. In studies at OSU, storage losses were found to be related to precipitation in combination with air temperature and humidity. Much of the dry matter loss associated with outside storage is the result of microbial respiration where carbohydrates in the plant tissue plus oxygen are converted to carbon dioxide, water and heat. Extended periods of warm, humid and cloudy conditions with abundant rainfall are more favorable for microbial activity resulting in greater losses in forage dry matter and quality than periods of cool, dry and sunny conditions. To minimize storage losses, bales stored outside and unprotected should be used by early spring, before the air temperature, humidity and precipitation significantly increase. In Oklahoma, use bales before March 1.

Storage Site

The storage site is another important consideration in reducing bale losses. Select an unshaded site, open to breezes to enhance drying conditions. In addition, the site should be well-drained to minimize moisture absorption into the underside of the bales. As much as 12 inches of the bottom of a bale can be lost through high moisture conditions resulting from the wicking action. Compare estimated losses for ground and elevated storage (Table 12.3). Ground contact can account for more than half of the total dry matter losses. Where practical, keep bales off the ground using low-cost, surplus materials such as discarded pallets, racks, fence posts, railroad ties and used tires.

Orientation

Bales should be stored in rows, butted end-to-end and oriented in a north/south direction. The combination of the north/south orientation and at least 3 feet between rows provides for good sunlight penetration and airflow that will allow the area to dry faster after a rain. Keep vegetation mowed between rows. Research has shown that orientation is a minor consideration if the bales are used before early spring because the losses associated with rows oriented east/west are minor until that time. If stored into the summer, bales oriented in east/west direction can experience severe deterioration on the north-facing surface.

Covers

Large round bales stored outside and covered with plastic or canvas usually sustain much less deterioration compared to unprotected bales (Table 12.4). As shown in Figure 12.3, the amount of covering per bale can vary depending on storage configuration. A single bale can require as much as 63 square feet to cover its top. If 5-foot-diameter by 5-foot-long bales are stacked three high, the size of the covering can be as low as 13 square feet per bale.

Covering materials range in price from about $0.07 per square foot for 6-mil black polyethylene or plastic to more than $0.75 per square foot for a tarp. To determine the cost of a storage cover made with a material such as plastic, multiply the area of coverage from Figure 12.3 by the cost of the covering. Assuming a 6-mil black plastic at $0.07 per square foot is used to cover a stack three high and three wide, the covering cost would be $1.96 per bale (28 times $0.07). Considering interest on the investment for money spent on plastic, the cost would increase to about $2.10 a bale or about $4.20 per ton if bales weigh 1,000 pounds. Because plastic

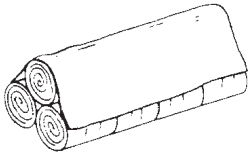
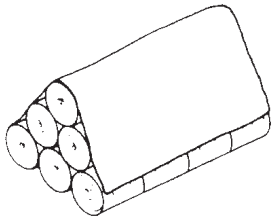
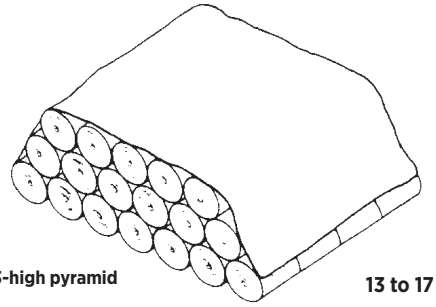
	Bale size	
	5-foot Dia x 5 feet	6-foot Dia x 6 feet
	Square feet per bale	
Single bale	55	63
 2-high, 2-wide pyramid	37	44
 3-high, 3-wide pyramid	28	33
 3-high pyramid	13 to 17	16 to 20

Figure 12.3. Cover requirements for large round bale storages. Source: Huhnke.

generally lasts only one year, the $4.20 per ton would be an annual cost. This cost does not include a charge for labor or for fasteners, tie downs or weighty material to secure the plastic.

Because of its relatively low cost, plastic is a very attractive alternative as a storage covering; however, plastic has several shortcomings. First, it does not breathe. If high moisture hay (more than 20%) is sealed under plastic, heavy losses in dry matter and forage quality can occur due to excessive heating and mold development. Second, nonreinforced plastic requires continual maintenance. High winds can cause large tears that must be repaired as quickly as possible. For this reason, consider using reinforced plastic. It withstands punctures and tears and can last more than three years with proper handling and storage between uses. To help reduce tearing in any type of covering, weigh down the cover along the edges and ends to allow some movement. Do not tie a cover down tight.

Total Storage Cost

As stated earlier, total storage cost is the sum of the storage system and the cost of the projected losses while bales are in storage. If the bales were valued at $160 and stored under a plastic cover, storage cost with an estimated 8% ($12.80 per ton) dry matter loss would be about $17.00 per ton ($4.20 per ton plastic cost plus $12.80 per ton loss in hay value). **Note:** This does not include the costs for labor or materials to secure the cover.

If the same alfalfa hay is stored outside uncovered, loss of hay value could be as much as 10% or $16.00 per ton. This assumes the bales are well shaped with a tight outer layer, but in contact with the ground. If elevated, dry matter loss can be less than 4% or $6.40 per ton.

With estimated storage costs of $17.00 per ton for covers and $6.40 to $12.80 per ton for no protection, it would appear that providing protection is not cost effective. However, these estimates do not include losses in quality or consider the end user. If the hay producer is going to feed this hay to their own beef herd, the losses associated with bales stored outside and unprotected may not be a major concern. Commercial hay producers would have difficulty marketing hay to dairies if bales are stored outside and unprotected, especially during periods of surplus hay supplies.

Reducing Hay Feeding Losses

Proper hay feeding management is critical to minimize waste and reduce hay costs. Large round bales are especially prone to hay losses due to trampling when hay is fed in large quantities without hay rings or racks. Studies have shown that 30% to 50% of hay offered to cattle may be lost when a multiple-day supply of hay is fed without a rack or hay ring. Even a single day's supply of hay fed on the ground is subject to losses of 10% to 15%. By contrast, large round bales will have losses less than 10% when fed in hay rings or racks, even when a multiple-day supply of hay is provided to cattle.

Feeding losses will be reduced if cattle are offered smaller quantities of fresh hay daily on a clean, well-drained site. Large round bales provide considerable flexibility and convenience for producers, but unless carefully managed, large round bales also contribute to increased winter feed costs for producers.

Stockpiled Forages

One option to reduce the amount of hay fed during the winter is growing stockpiled forages. Stockpiled forage is forage that is allowed to accumulate in the pasture for grazing when production is slow during the winter months. The only out-of-pocket cost associated with growing stockpiled forages is the fertilizer cost plus any application cost. However, this has more risk than feeding hay because the success depends almost entirely on rainfall. When successful, the cost of grazing stockpiled forage per animal unit is lower than the cost of feeding hay or the cost of feeding a protein supplement on dry grass.

Grazing stockpiled forages is not a new concept. Livestock producers have grazed dormant native grass pastures for many years. Hay generally is not fed on native

grass pastures during the winter except during periods of heavy snow cover. Stockpiling native grass pastures is different than stockpiling introduced grass pastures, such as Bermudagrass and tall fescue. Stockpiling fall growth of Bermudagrass and tall fescue requires nitrogen fertilization, whereas stockpiling native grass pastures is from nonfertilized summer growth. Even with today's higher nitrogen fertilizer prices, 1 ton of stockpiled Bermudagrass or tall fescue forage would cost one-third the cost of purchased hay.

Bermudagrass

Forage production from stockpiled Bermudagrass can be quite variable depending on the amount of late summer rainfall. A rule of thumb is to expect between 25 pounds to 50 pounds of forage per acre for each pound of applied nitrogen. For example, 50 pounds of actual nitrogen per acre (108 pounds of urea) would produce from 1,250 pounds to 2,500 pounds of forage per acre.

Pasture preparation is a key to producing quality fall grown forages. Summer growth of Bermudagrass should be removed by late August. This can be accomplished through grazing, haying or mowing. To take advantage of late summer rainfall, 50 pounds to 75 pounds of actual nitrogen per acre should be applied by late August. For short Bermudagrass, application of 50 pounds to 75 pounds of actual nitrogen per acre in August can supply one ton of forage per acre. This stockpiled forage can be grazed prior to February to reduce the length of the hay-feeding season. One acre of stockpiled Bermudagrass will provide grazing for one cow for approximately 45 days.

Tall Fescue

Management of stockpiled tall fescue is similar to the management for stockpiling Bermudagrass. The two major differences are the amount of nitrogen fertilizer applied and the grazing period. To take advantage of late summer rainfall, 75 pounds to 100 pounds of actual nitrogen per acre should be applied by early September. Similar to Bermudagrass, fall production is highly dependent on rainfall. Research conducted in the Cherokee Prairie on stockpiling tall fescue concluded that an average of 1 ton of fall growth from fertilizing tall fescue is possible. Stockpiled tall fescue can be grazed from late December through February One acre of fall-fertilized tall fescue will provide grazing for one cow for approximately 45 days.

Beef cow grazing stockpiled Bermudagrass as a means to reduce supplemental winter feeding.

Managing Hay Costs

Winter feeding costs usually are the most expensive part of annual cow costs. Hay use is common and can provide an economical source of nutrients. However, unless hay is carefully managed during production, storage and feeding, it can be more expensive than other feed sources.

Consider the following to reduce winter feeding costs:

- Minimize hay requirements with better pasture and grazing management. The cow is a forage harvesting machine and grazing will always be cheaper than providing harvested forages. Good grazing and pasture management can help significantly reduce the need to feed hay. Stockpiled forages can provide good nutrition and simultaneously extend the grazing season significantly.
- Minimize hay requirements with good hay storage and feeding management. To the extent that hay is needed, proper storage and feeding may reduce hay needs by up to half. Good-quality Bermudagrass hay (10% crude protein) valued at $80 per ton will provide protein at a cost of $0.50 per pound and total digestible nutrients (TDN) at a cost of $0.092 per pound if storage and feeding losses are 20%. However, if losses reach 40%, the cost of protein increases to $0.68 per pound and TDN cost increases to nearly $0.12 per pound. At this level, hay becomes more expensive than other feed sources in many cases.
- Know the quality of hay being used and the relative cost of alternative feed sources. Poor-quality hay is rarely a bargain. It may cost $50 per ton or more to produce hay, even when machinery ownership costs are ignored. In general, the term "low-quality hay" refers to lower concentrations of digestible nutrients and higher concentration of indigestible nutrients. This combination results in lower forage dry matter intake and lower forage digestibility. When these two results are combined, the animal is not physically capable of harvesting enough energy (and possibly other nutrients) to maintain their body weight, growth or milk production. In fact, if there is a significant mismatch between forage quality and the animals' requirements, they can lose weight and body condition. This scenario leads to the need for supplementation to make up for the inadequacy of nutrient supplied by low-quality hay. Generally, the need to feed other sources of nutrients (high quality and more expensive) to eliminate these deficiencies is what makes low-quality hay a more expensive feed source than the price would indicate.
- Consider buying hay or having hay custom harvested. Although the convenience and reduced hassle of owning haying equipment is clear, the cost should be considered carefully. Haying equipment is a large investment and requires many acres of use to lower fixed costs to acceptable levels. However, the answer is not producing

more hay of low quality, replacing grazing or will be wasted with poor storage and feeding management. This may lower hay costs on a per ton basis but still represent higher feed costs for cattle. If hay requirements are reduced with application of items 1 through 3 above, the need for good-quality hay is reduced and purchased hay becomes more attractive. If haying equipment is owned, it may be possible to reduce fixed costs of hay production by doing custom hay harvesting for other producers.

Conclusion

Hay production for livestock feeding is economically important throughout the U.S. and hay production and feeding plays an integral role in many cattle operations. Forages conserved as hay can provide an excellent nutrient source for livestock during periods of slow forage growth.

All forages packaged in large round bales benefit from protection while in storage. However, there are several factors that must be considered in justifying the cost of providing this protection. These factors include hay value, projected in-storage losses, local environmental conditions and location of hay use. If round bales are stored outside and unprotected, losses can be greatly reduced by storing only those bales that are well-shaped with dense outer layers, keep them off the ground to eliminate wicking and use these bales before spring warm-up to avoid excessive weathering.

The highest costs of keeping cattle are generally winter-feeding programs and hay feeding is the most common program. Hay feeding is less risky and requires the least amount of planning, but it also can be the most expensive. Harvested forages represent one of the largest components of annual cow costs. Proper management of hay requirements, production, storage and feeding may reduce annual costs significantly. Estimating a hay budget such as the sample provided in Table 12.5 is useful to producers who are planning a hay feeding program.

The most common forages harvested for hay are the warm-season, perennial grasses, such as Bermudagrass and

Table 12.5 Dryland Bermuda Enterprise Budget - Hay Only.

1,000 acres farmed, 160 acres for this budget

PRODUCTION	***Units***	***Price***	***Quantity***	***Total $/Acre***
Hay Sales	Tons	$ 85.00	2.50	$ 212.50
Other Income	Acre	$ -	0	$ -
Total Receipts				**$ 212.50**
OPERATING INPUTS	***Units***	***Price***	***Quantity***	***$/Acre***
Fertilizer	Acre	$ 54.35	1	$ 54.35
Custom Harvest	Acre	$ -	0	$ -
Pesticide	Acre	$ 3.45	1	$ 3 .45
Annual Operating Capital	Dollars	5.50%	33.42	$ 1 .84
Machinery Labor	Hrs.	$ 15.00	2.22	$ 33.30
Equipment Labor	Hrs.	$ 15.00	0.00	$ -
Custom Hire	Acre	$ 6.58	1	$ 6.58
Machinery Fuel, Lube, Repairs	Acre	$ 66.16	1	$ 66.16
Equipment Fuel, Lube, Repairs	Acre	$ -	0	$ -
Other Expense	Acre	$ 3.00	1	$ 3 .00
Total Operating Costs				**$ 168.68**
Returns Above Total Operating Costs				**$ 43.82**
FIXED COSTS	***Units***	***Rate***		***$/Acre***
Establishment	Acre	$ 276.19		$ 35.47
Machinery/Irrigation				
Interest at	Dollars	5.75%		$ 22.81
Taxes at	Dollars	1.00%		$ 3 .92
Insurance	Dollars	0.85%		$ 1 .69
Depreciation	Dollars			$ 27.86
Equipment				
Interest at	Dollars	5.75%		$ -
Taxes at	Dollars	1.00%		$ -
Insurance	Dollars	0.85%		$ -
Depreciation	Dollars			$ -
Land	$/acre	$ 2,000		
Interest at	Dollars	0.00%		$ -
Taxes at	Dollars	0.43%		$ 8.60
Total Fixed Costs				**$ 100.35**
Total Costs (Operating + Fixed)				**$ 269.03**
Returns Above All Specified Costs				**$ (56.53)**

native grasses. The process for hay production is relatively simple. The forage is cut, dried and baled. However, there are several factors that can result in this process not being so straightforward. Producers need to be aware of the causes of dry matter loss and take precautions to avoid this expense.

Note: Updated from an earlier version authored by Darren Redfearn, Ray Huhnke, Roger Sahs and Damona Doye.

References

Huhnke, R.L. (2002) That new swather – Can I afford it? IN: Proceedings of the Intermountain Forage Symposium. Technical Bulletin LTB 02-1. Colorado State University, Boulder, CO.

Huhnke, R.L. (2017) Round Bale Hay Storage. OSU Extension Facts BAE-1716, OSU Cooperative Extension Service, Oklahoma State University.

Sahs, R. (2019) CR-205, Oklahoma Farm and Ranch Custom Rates. OSU Extension current report. OSU Cooperative Extension Service, Oklahoma State University.

Sahs, R. (2020) Sample Forage Budget generated using OSU Enterprise Budget Software. agecon.okstate.edu/budgets

13 Small Grain Forage Management

Alex Rocateli

Objectives

- **Describe and compare common small grains options for forage production in Oklahoma.**
- **Present relevant small grains traits for appropriate variety selection.**
- **Discuss the best management practices for establishing, fertilizing and grazing small grains.**

Forage Small Grains Options for Oklahoma

The southern Great Plains climate allows cattlemen to utilize small grains as a forage source when warm-season pastures are dormant. Small grains as forage work great in the region because temperatures are frequently favorable for high-quality forage production from late fall to late spring (if grazed out). Also, the fact that there are few snow-covered days allows a great grazing potential, ranging from 120 days to 150 days. While wheat is the most popular small grain in Oklahoma, other small grains such as rye, triticale, barley and spring oats are good forage crop options as well.

Wheat

Wheat is the most adopted small grain in the region because it is a flexible crop. Wheat is primary cultivated for grain production; however, considerable acreage is managed as either dual-purpose (i.e., grazed by cattle in the fall and early spring, then harvested for grain) or grazing out. The OSU Wheat Improvement Team (WIT) (wit.okstate.edu) has been developing varieties adapted to Oklahoma soil and weather conditions and providing detailed best management practices. Every year, the OSU WIT releases a comprehensive small grain variety performance report. Find the best performing varieties to a specific Oklahoma location by accessing the most current report, available at extension.okstate.edu/fact-sheets/

In summary, early September is the optimal planting time for maximizing wheat fall forage yield; however, planting that early results in suboptimal grain production. Thus, plan to seed in early September if only forage production (i.e., a graze-out system) is the goal. Otherwise, delay planting to mid or late September if forage and grain production (i.e., a dual-purpose system) is the goal. Furthermore, for graze-out and dual-purpose systems, increase the seeding rate to 90 pounds and 120 pounds of pure live seed (PLS) per acre in dryland and irrigated fields, respectively. Although variety choice and soil fertility play significant roles in forage production, producers can expect weather-related yields variation of 1,000 pounds to 3,5000 pounds of dry forage production per acre during the fall and, if grazed out, an addition of 2,000 pounds to 4,500 pounds of forage per acre during the spring. Make sure to stop grazing somewhere in February when wheat plants reached the first hollow stem if grain production is expected from a particular field. For specific information on wheat forage production, access the following OSU fact sheets: PSS-2174 *First Hollow Stem: A Critical Wheat Growth Stage for Dual-Purpose* and PSS-2178 *Dual-purpose Wheat - Management for Forage and Grain Production* available at extension.okstate.edu/fact-sheets.

Rye

Rye is the small grain that can provide the most consistent and uniform forage production throughout the season. Rye can be planted from late August and rapidly grow during fall. It is the most winter hardy small grain, extending its forage production through the winter while wheat declines in growth. Although rye provides higher forage production than wheat during fall, winter and early spring, it matures and loses its forage quality fast in mid-spring. Therefore, rye is not the right choice for hay production during spring. At first glance, rye may appear the most attractive small grain option for grazing because it can deliver a great amount of fair-quality forage during the most critical time of the year—winter and early spring. However, its adoption is minimal because wheat fields following rye might be infested by volunteer rye (feral rye). Feral rye is a concerning weed in wheat fields for grain production, which causes wheat grain dockage, grade, quality reduction and, consequently, less profit. Thus, do not plant rye in a field that wheat grain production is expected in the next years.

Triticale

Triticale is a hybrid of wheat and rye, gaining popularity in New Mexico and western Texas. Its popularity is due

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

to its high forage yields, winter growth, nitrogen uptake and resistance to pests and diseases. According to variety performance trials conducted in eastern New Mexico and western Texas, irrigated triticale yields on average 9,000 pounds of dry matter per acre (clovissc.nmsu.edu/variety-trials.html). Perhaps triticale might be a good option for western Oklahoma because weather conditions in that area are very similar to these other regions' conditions.

Triticale follows a growth pattern similar to wheat throughout fall and early spring. However, it matures later than wheat, allowing more grazing days during late spring. Triticale has a higher forage production potential than wheat. Nevertheless, its feeding value is lower and the hay drying process is challenging due to its thick stems.

Barley

Barley is the small grain that produces the least amount of forage; however, it contains the greatest forage quality. It contains high levels of crude protein and digestible nutrients (TDN); consequently, its relative forage quality exceeds 200 units when harvested at the boot stage. Although barley produces high-quality forage, it does not compensate for its lower yields. Furthermore, barley provides more forage production earlier in the fall than the other small grains; consequently, it can be grazed sooner. It matures earlier than wheat and triticale and later than rye.

Barley is very tolerant of high-salinity soils; therefore, it becomes the only option on marginal soils (i.e., soils with electrical conductivity (ECe) values greater than 4 dS/m). The spring barley types are not winter hardy; therefore, it is not recommended to plant them during the fall. Very few varieties were tested in Oklahoma, and more testing is needed for accurate recommendations in the state.

Spring Oats

Oats do not survive the Oklahoma winter in most years. Some producers reported some oats resuming spring growth after mild winters in southern Oklahoma, which may occur in one out of four winters. Furthermore, new oat varieties show improved winter hardness in Oklahoma; these new options are expensive and more testing is needed for conclusions. Consequently, oats are mostly used as a "plan B," i.e., planted in February if the previously planted winter wheat has a thin stand or failed. For specific information in establishing and managing spring oats, access the fact sheet PSS-2160 *Spring-Planted Oat for Grazing or Hay Production* available at extension.okstate.edu/fact-sheets.

Oats have forage quality greater than wheat when they are compared at the same growth stages. However, oats yields are lower (approximately 25% less) than well-established winter wheat.

Variety Selection

The trait producers pay attention to when selecting a small grain variety for forage is its yield potential. However, it is essential to consider all relevant traits to guarantee a successful system. The producers' field soil fertility, weed and pest pressure and the next year's weather conditions differ from the conditions found in variety performance trials fields. Keep in mind that researchers and Extension educators manage the trials fields with high fertilizer, herbicide and pesticide inputs. In many cases, producers are not committed to this high-input management, drastically affecting the performance of the selected variety. Here are the relevant traits to select an appropriate small grain variety:

- **Tolerance to low soil pH.** Low soil pH is a common problem in Oklahoma. For most small grains, forage production decreases if soil pH is lower than 6.0. Therefore, consider a pH tolerant variety if soil analysis indicated that soil pH is lower than 6.0. The pH tolerant variety can maintain greater forage yields than the others if the soil has a pH within 5.5 to 5.9.
- **Germination sensitivity to high temperature.** Planting small grains for forage production, such as wheat, is recommended much earlier than grain production. Consequently, soil temperatures are relatively high. In these conditions, some varieties that have high-temperature germination sensitivity do not germinate until temperatures decrease, resulting in less plant emergence and poor establishment. Avoid varieties with high-temperature germination sensitivity when planting early for maximum forage production.
- **Coleoptile length.** Planting at high soil temperatures also decreases the coleoptile length. A short coleoptile might reduce seedling emergence, resulting in a sparse low forage yielding field. Therefore, consider a variety with a long coleoptile.
- **Resistance to pests and diseases.** The best disease and pest management strategies are to select varieties resistant to the most recurring pests and diseases to a specific location. Resistant varieties will save money and time by eliminating or drastically reducing the need for chemical control. To select the most appropriate variety, assess the most common small grain pests and diseases that occur at your location in past years. In Oklahoma, the OSU Pest e-Alerts (entoplp.okstate.edu/pddl/advisory.htm/) is a reliable source containing

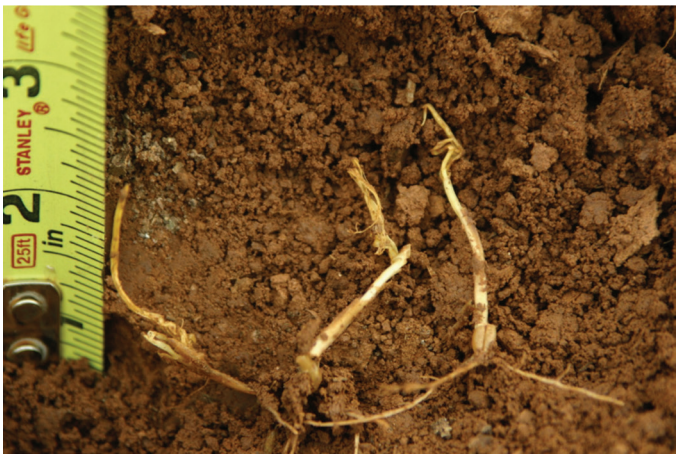


Figure 13.1. Hot soil temperatures reduce wheat coleoptile length. Wheat sown deeper than the coleoptile will not emerge.

reports of the occurring small grains pests and diseases through Oklahoma. The archived reports can be used to assess the most recurring pests and diseases through Oklahoma.

- **Forage yield potential.** Public trials are managed by state universities, which is an unbiased source of information to the public. Furthermore, public variety trials use proper scientific methodology to compare different varieties and disclose all pasture management to the public, allowing the most objective and accurate evaluation. In Oklahoma, the OSU WIT releases a comprehensive small grain variety performance report. Find the best performing varieties to a specific Oklahoma location by accessing the most recent current report at extension.okstate.edu/fact-sheets/.
- **Specific traits for dual-purpose winter wheat.**
  - ***Grain yield potential after grazing.*** Some wheat varieties grain potential heavily relies on fall tillering; consequently, fall grazing significantly reduces grain yields. Select a variety that grain production is the least dependent on fall tillering.
  - ***First hollow stem date.*** First hollow stem is the critical period to stop grazing the wheat to warranty grain production. It occurs after the wheat breaks dormancy in the spring, and there is about 5/8 inch of hollow stem (the diameter of a dime) below the developing head. Varieties differ in first hollow stem date. Choosing a variety with a late first hollow stem date can increase the grazing window during the spring. For more information on measuring first hollow stem, access PSS-2147, *First Hollow Stem: A Critical Wheat Growth Stage for Dual-Purpose Producers* available at extension.okstate.edu/fact-sheets.

Establishment

Seedbed Preparation

All small grains should be planted in a firm seedbed to promote good soil-seed contact. Loose seedbeds may result in a poor seedling emergency. The optimal seeding depth is within 1 inch to 1.5 inches for most small grains. Shallow planting leads to uneven germination and potential seed dissection.

Small grains forage can successfully be established using conventional or no-till planting methods. Early-season moisture availability is frequently the dominant factor governing small grains establishment in Oklahoma, so care should be taken to preserve soil moisture during seedbed preparation. This is especially true in conventional tillage systems because tillage operations generally occur during late summer when soil water evaporation is high. Shallow tillage operations reduce soil moisture losses. Finally, a no-till management system is the best approach to preserve soil moisture for seed germination.

Producers often are faced with a dilemma when planting into dry soil conditions: is it better to plant to moisture or "dust in" and hope for rain? Every situation is different, but if the seeding depth exceeds 1.5 inches to reach moisture, the better choice is to dust in. The coleoptile is the first structure protruding from a germinating seed. The coleoptile's purpose is to break the soil surface, so the first true leaf emerges above ground. If this does not happen, the seedlings' first true leaf emerges below the soil surface, folds like an accordion, then perishes (Figure 13.1). There are some forage-type varieties available with longer coleoptiles that allow for deeper sowing.

Several methods can be used to obtain a stand of small grains for grazing or hay production. However, if grain production is the end goal, a more uniform, consistent stand is required, so a grain drill is advised. Ideally, a drill used for sowing small grains should 1) have a row spacing of 7.5 inches or narrower, 2) provide enough downforce to ensure accurate seed placement in hard soils and 3) have closing wheels linked to the disk openers. Acceptable plant stands also can be obtained by disking, then broadcast seeding. It is important to note this method results in inconsistent plant stands and forage production.

Planting Date and Seeding Rate

Few things impact fall forage production by small grains as much as planting date and seeding rate. Late August or early September planting produces the greatest forage amounts, and late September planting produces the least forage amounts (Figure 13.2). Small grains planted for forages must have a seeding rate of 25% to 30% higher than if plating for grain production. At higher seeding rates, forage yield cumulates faster, stem size is reduced, nutritive value is improved and plants dry faster for baling. For instance, increasing wheat seeding rate to 90 pounds to 120 pounds of pure live seed (PLS) per acre will increase forage yield and quality enough to justify the seed's additional cost (Figure 13.2). Producers intending to manage wheat for grazing plus grain (dual purpose) production need to plant in mid-September to balance increased forage production with reduced grain yield associated with early planting. For more information on the effects of grazing on wheat grain yield, access the fact sheet PSS-2157 *Impact of Grazing on Wheat Grain Yield* available at extension.okstate.edu/fact-sheets.

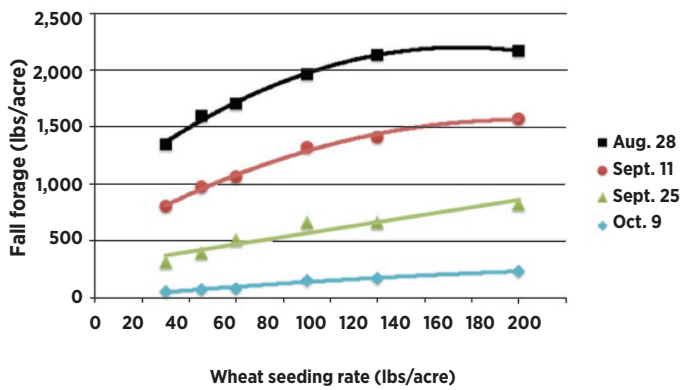


Figure 13.2. Wheat fall forage yield as affected by seeding rate and planting date at Lahoma from 1991 to 1994.

Fertility

Managed forage systems require adequate nitrogen, phosphorus and potassium to maintain acceptable production levels. Also, soil pH must be monitored and managed to remain within acceptable ranges. The first tool for managing soil fertility is a recent soil test. Pulling a soil sample takes a few minutes, and analysis is inexpensive; however, the information garnered from a soil test can save the producer thousands in fertilizer costs and/or result in thousands of dollars in increased production. For more information on how to take a soil sample and submit for testing, access the fact sheet PSS-2207, *How to Get a Good Soil Sample* available at extension.okstate.edu/fact-sheets.

In Oklahoma, many of our soils have adequate potassium levels for small grains forage production. Thus, potassium fertilizer generally is not required. However, most Oklahoma soils are deficient in phosphorus and require fertilizer. Broadcast applications of phosphorus according to soil test recommendations can supply plant needs. However, the most efficient and economical way to deliver phosphorus to wheat sown for forage is in-furrow banding. In-furrow banding is more efficient than broadcast because the phosphorus is readily available to young wheat plants with limited root systems. The concentrated bands reduce the amount of phosphorus bound by aluminum at low soil pH (Figure 13.4). However, do not exceed 20 pounds of actual nitrogen plus potassium when in-furrow banding fertilizer; otherwise, high salinity may reduce or inhibit seedling growth. Both dry and liquid starter fertilizers can meet plant needs and the decision between the two comes down to cost, equipment and personal preference.

Nitrogen is essential for plant growth and has a large impact on small grains forage production. It takes about

Figure 13.3. In-furrow phosphorus application is critical to ensure adequate fall forage production by wheat sown into soils with a pH less than 5.5. As demonstrated by the plant on the left, in-furrow application of phosphorus hastens emergence, increases early-season root growth and results in increased tillering and forage growth, compared to plants not receiving in-furrow phosphorus shown on the right.

Figure 13.4. Wheat variety, lime application and in-furrow banding of phosphorus can have a huge impact on early season wheat growth and forage production.

30 pounds of actual nitrogen to produce 1,000 pounds of dry forage or 100 pounds of beef per acre. Another way to estimate nitrogen needs is to assume 15 pounds of actual nitrogen per animal per month on the pasture. Soil tests based on surface and subsoil samples indicate how much nitrogen is readily available in the soil. By subtracting the soil test value from the requirement, producers can estimate how much nitrogen fertilizer should be applied to meet plant needs. A good rule of thumb is that at least 60 pounds of actual nitrogen should be available for fall forage production. Additional fertilizer also needs to be provided before the first hollow stem in late winter to fuel spring growth.

For small grains, soil pH is more critical for forage than grain production. When soil pH drops below 6.0, aluminum is released into the soil solution, causing plant toxicity and limiting phosphorus availability. When a seedling root emerges into the soil with toxic aluminum levels, root growth is hindered, resulting in less water and nutrients absorption by the plant. Also, aluminum binds with phosphorus to form insoluble compounds that are no longer plant available. The combination of suppressed root growth and lower phosphorus availability can significantly impact fall forage production of small grains. As plants grow in the spring, root mass increases and their ability to extract soil water and nutrients increases accordingly. As a result, aluminum toxicity symptoms might decrease as the growing season progresses, but the damage to fall forage production has already occurred.

Growers should use multiple strategies to combat low soil pH. First and foremost, fields should be sampled at least every two years to assess current soil pH. Second, producers with low soil pH should consult the fact sheet PSS-2142 *Wheat Variety Comparison Chart* (extension.okstate.edu/fact-sheets) and plant a variety known to be tolerant of low soil pH (Figure 13.4). Finally, producers with long-term leases, lease agreements that provide partial compensation for lime or those farming owned ground should consider the application of agricultural lime to increase soil pH. Lime quality is determined by fineness and purity and lime recommendations are based on 100% ECCE

(effective calcium carbonate equivalent) lime sources. If the purchased lime is 50% ECCE, apply 2 tons per acre of product to satisfy a 1-ton-per-acre recommendation from a soil test. It is important to stress that there are no shortcuts when it comes to lime. There are no alternative products that will substitute agricultural lime. Products such as pelletized lime are convenient and easy to handle, but the same amount of ECCE is required to neutralize soil pH with these products as with regular agricultural lime.

Grazing Management

Grazing by cattle should not be initiated until wheat plants have developed a secondary root system. The secondary root system provides adequate anchoring for the wheat plants and prevents the plants from being pulled out of the ground during the grazing process. Start digging and sampling whole plants to assess root development when they achieved at least 6 inches of growth. Another technique is mimicking grazing by holding and pulling the wheat crop canopy firmly. Start to introduce cattle when the roots are not coming out anymore.

Furthermore, grazing should be avoided if wet or waterlogged soil conditions persist during the fall grazing window. Damage and soil compaction from hoof traffic reduces small grain forage regrowth. Overgrazing small grains can result in winter kill. Stop grazing at 3 inches canopy stubble height or 50% green canopy cover to allow fast small grain forage regrowth. The Canopeo app, available to iOS and Android smartphone systems, is a reliable tool to estimate small grains canopy cover (research.okstate.edu/appcenter/app-canopeo.html).

Small grain pastures effectively provide quality forage for both growing calves and mature animals. However, stockers and fall-calving cows can use the forage more profitably because they can take advantage of wheat forage's high nutritional value. Both continuous and rotational grazing systems are appropriate for stocker cattle. Rotational grazing increases stocking rates, reduces spot grazing, and extends the grazing season; however, it comes at a price. Rotational grazing is more labor intense, demands more fencing, water and supplemental structures. Make sure to select the grazing systems that maximize profits.

Stocking rates vary considerably from year to year, depending on weather and management that influence small grain forage yield. Therefore, producers need to assess forage production and make stocking rate decisions based on annual forage production. There are 200 pounds of dry forage per acre for every inch of small grain canopy height as a rule of thumb. To correctly calculate stocking rates, download the GrazeOK app available to iOS and Android smartphones (youtube.com/watch?v=-uYNVwx9Rb4&t=6s) and consult OSU Extension fact sheet PSS-2871 *Stocking rate: The Key to Successful Livestock Production* and PSS-2594 *Plan Grazing Management Using the Oklahoma Grazing Stick* available at extension.okstate.edu/fact-sheets.

In most years, recommended fall and winter stocking rates range from 250 pounds to 600 pounds of animal per acre (1 to 2 acres per stocker, depending on weight). Spring stocking rates are usually 1.5 times to 2 times greater than for fall (0.75 acres to 1.3 acres per stocker, depending on weight). Providing stockers with dry feed in addition to the small grain pasture allows increased stocking rates, better use of the small grains' nutritional value and may improve animal health.

If dual-purpose wheat production is the goal, cattle should be removed from the wheat pasture at the first hollow stem stage of growth. Cattle weight gains associated with grazing past the first hollow stem are insufficient to offset decreases in wheat yield associated with grazing past this growth stage. Wheat is at the first hollow stem stage of growth when 1/2 inch (about the diameter of a dime) of the hollow stem is present below the developing grain head (Figure 13.5). More information on dual-purpose wheat can be found in the fact sheets AGEC-265, *Effect of Grazing Past First Hollow Stem on Wheat and Stocker Profits;* PSS-2147, *First Hollow Stem: a Critical Wheat Growth Stage for Dual-purpose Producers*; PSS-2170, *Dual Purpose Wheat: Improving Grazing Management Using a Smartphone App*; and PSS-2178 *Dual-Purpose Wheat: Management for Forage and Grain Production*. All listed fact sheets are available at extension.okstate.edu/fact-sheets/.

Relevant online multimedia materials:

1. Managing Wheat and Small Grains for Grazing (youtube.com/watch?v=RdkV_mHG-TE&feature=youtu.be)
2. Setting Stocking rates and Supplementing Calves on Wheat (youtube.com/watch?v=RVZ6W1i73CE&feature=youtu.be)
3. Mineral Supplementation on Wheat Pasture (youtube.com/watch?v=NjWmUIu1kp8&feature=youtu.be)

Figure 13.5. The first hollow stem stage of wheat is characterized by 0.5 inch or about the diameter of a dime of hollow stem present below the developing grain head.

4. Using Wheat Pastureto Supplement Cows (youtube.com/watch?v=MsizvAVhmHg&feature=youtu.be)
5. Winter Wheat Management for Fall & Winter Pests (youtube.com/watch?v=PbmiTsGSdh0&feature=youtu.be)
6. Managing small grains cover crops for livestock (youtube.com/watch?v=WES9gD3eDbQ&feature=youtu.be)
7. Managing Market Expectations and Risk of the Stocker Cattle Enterprise (youtube.com/watch?v=co4AVdD4pS8&feature=youtu.be)

References

Ditsch, D.C. and M.J. Bitzer. AGR-160. Managing small grains for livestock Forage. Cooperaative Extension Service, University of Kentucky. Available at: www2.ca.uky.edu/agcomm/pubs/agr/agr160/agr160.pdf (accessed on Dec. 13, 2020)

Marsalis, A. Circular 630. Small Grains Forages for New Mexico. Cooperative Extension Service, New Mexico State University. Available at: aces.nmsu.edu/pubs/_circulars/CR630/welcome.html (accessed on Dec. 13, 2020)

14 Fire and Livestock Production

John R. Weir

Objectives

- **Discuss the importance of fire on the land.**
- **Explain why fire frequency or repeated fires are needed.**
- **Discuss specific benefits of fire to livestock.**

Fire was a major landscape disturbance that Native Americans used to shape the grazing lands of our continent. Only one other ecological process impacts the land greater than fire — rainfall. Without fire, the land essentially can be in a fire drought, from which most of our lands are suffering, as seen by the major encroachment of woody plants. No other land management practice impacts the land greater than prescribed fire. Fire has positive impacts on soil microorganisms to plant roots underground, plus plant and animal diversity aboveground.

Prescribed fire also has a lower application cost compared to other land management options. In comparison with mechanical or chemical treatments, prescribed burning is usually the most economical way to manage native landscapes. Mechanical and chemical treatments do not mimic what fire does for the land. When lands have undergone years of mismanagement, prescribed fire alone may not be the most effective management method. If this is the case, incorporation of mechanical or chemical treatments along with prescribed fire may be needed to reclaim certain areas. Combining treatment options allows prescribed fires to be more effective. Ultimately, it is up to the land manager to choose which treatment is best suited to their goals and objectives on a particular parcel of land. Throughout the U.S., numerous studies have been completed comparing different land management techniques and the ecological impacts of those techniques. To find out which treatments would be the most effective and economical in your area, consult the local OSU Extension, USDA-NRCS or land management consultant for specific information.

One of the main reasons many people use prescribed fire is for the enhancement of livestock grazing. When properly managing grazing lands with fire, individual animal performance usually increases and possibly carrying capacity. One of the main ways this is accomplished is through the control of woody plant species that are invading rangelands throughout the country.

A significant woody plant problem that occurs throughout much of the Great Plains is the invasion of eastern redcedar (*Juniperus virginiana*). This juniper species causes many problems in the areas where it grows, with the primary problem being a drastic decline in forage production. This reduction in available forage, in turn, affects carrying capacity, stocking rate and livestock performance. In fact, a range site with a potential to produce 4,000 pounds per acre of forage, with a population of 200 eastern redcedar trees per acre would produce only 3,700 pounds of forage per acre. If that site is left unmanaged, in 10 years the site could increase to 470 eastern redcedar trees per acre and would produce less than 2,000 pounds per acre of forage. With the reintroduction of prescribed fire at two- to five-year intervals, the land could return to its production potential once again.

Prescribed burning has limitations for woody plant control, especially if the wait is too long before fire is reintroduced. Many plant species will gradually grow too

Figure 14.1. Fire frequency, or how often a place is burned, is the most important aspect of fire for the control of shrubs and trees. The pictures on the left are from southeastern Oklahoma in oak-pine forest (photos courtesy of Ron Masters) and pictures on the right are from sand shinnery oak-grassland in western Oklahoma. Both sets of pictures depict the same areas with no fire (top) and a two-year fire frequency (bottom).

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

large to be impacted by typical prescribed burns. Eastern redcedar is a prime example of this. Prescribed fire has been shown to be the most efficient and economical method for controlling this invasive non-sprouting native juniper and nearly any type of fire will kill trees less than 1 foot tall. Fire fuel loading is one of the most important considerations of any burn when the objective is to control woody vegetation. Greater fuel loads will allow the burn to be conducted with safer conditions (lower temperature and higher relative humidity) and still achieve goals. While eastern redcedar trees from 1 foot to 5 feet tall can be controlled very well when herbaceous or fire fuel loads are more than 4,000 pounds per acre, if the fuel load is reduced by half, only 60% of the trees less than 5 feet tall are killed. As the eastern redcedar trees grow beyond 5 feet in height, they are even harder to control, requiring a greater fire fuel load or a more extreme burn prescription. Using an extreme prescription would mean burning with higher temperatures and lower relative humidity, which means a greater risk for an escaped fire. Therefore, maintaining adequate fuel loads through proper stocking rates is the most important part of any prescribed fire and grazing program.

Other brush species also are overtaking or invading the grasslands, shrublands and forestlands of the U.S. Most of these species resprout after a fire. Some of these include oaks (*Quercus spp.*), sumac (*Rhus spp.*), plum (*Prunus spp.*), dogwood (*Cornus spp.*) and other junipers (*Juniperus spp.*). Although these species are native, they are increasing in height, density and coverage area. Fire typically reduces the height of these plants, but increases the number of stems due to their propensity to resprout. Repeated fires will keep most of these plants suppressed or even totally remove certain species from the system.

A commonality in fire frequency has been found when comparing sand shinnery oak (*Quercus havardii*) in western Oklahoma grasslands to oak-shortleaf pine (*Pinus echinata*) forests in southeastern Oklahoma and pine forests of northern Florida. Even though these sites are hundreds of miles apart and precipitation ranges from 20 inches in western Oklahoma to more than 50 inches at the southeastern site in Oklahoma, these studies concluded that to manage woody plants and keep them suppressed, a fire return interval of three years or less should be used.

An important point to remember is that prescribed fire will not solve all land management problems, but can solve some of them. Also keep in mind that prescribed fire is not a one-time treatment. It is a program that must be continued and fire frequency is the key to success. For more information about fire effects, see OSU Extension fact sheet NREM-2877, *Fire Effects in Native Plant Communities.*

Another major benefit of using prescribed burning to increase livestock production is the increase in weight gains of stocker cattle. Studies have shown that prescribed burning increases summer stocker cattle gains by 10% to 20% in the summer following the burn. There has been little work published on the effects of prescribed fire on cow/calf operations. People who conduct research on cow/calf operations and use fire to manage their land have noted that cows can usually increase their body condition score by a factor of one over cows on unburned range and researchers have noticed a possible side benefit to calves with increased weaning weights.

Figure 14.2. Burning will cause an earlier green-up of plants following a dormant season burn, due to the blackened soil surface causing soil temperatures to warm earlier. Fire also removes the old forage growth, allowing the new growth to be utilized earlier. Fire can be used to remove old forage growth to improve the palatability and increase the nutrient content of new growth.

Burning will cause an earlier green-up of plants following a dormant season burn because the fire removes the old forage growth, allowing the new growth to be utilized earlier (Figure 14.2). Blackened soil surface causes soil temperatures to warm up earlier. Fire also can be used to remove old forage growth to improve the palatability and increase the nutrient content of new growth. An overall increase in the diversity of the plant community also is important. Fire changes the structure of many plants, which in turn increases palatability. Many times, cattle will not eat certain plants, but following a fire, the regrowth becomes highly preferred.

If certain areas within a pasture are not frequented by fire, livestock aversion to those areas may be due to old growth of grass, previous grazing patterns, topography, distance from salt or water, or type and age of livestock traditionally used. If fire is used to improve the quality and availability of the forage, then livestock should begin to use these areas again. This can improve animal performance and possibly increase carrying capacity, as well as improve forage quality and quantity of the area (Figure 14.3).

Prescribed burning generally will assist with overall land management and facilitate the best use of the land by livestock. In areas without fire, it can be difficult to observe and oversee the health of livestock because of shrub or tree cover. Some ranchers using prescribed fire noted it is worth the cost of burning just to be able to drive into a pasture and see all of their cattle. These fire effects also can be very helpful when it comes to gathering livestock. Livestock living in brushy areas often will use the dense cover to evade and escape capture. As fire opens up a pasture, livestock will have fewer places to hide.

Prescribed fire also can be used to control external parasites on cattle, such as horn flies, face flies and ticks, which have a negative impact on production. Most of the

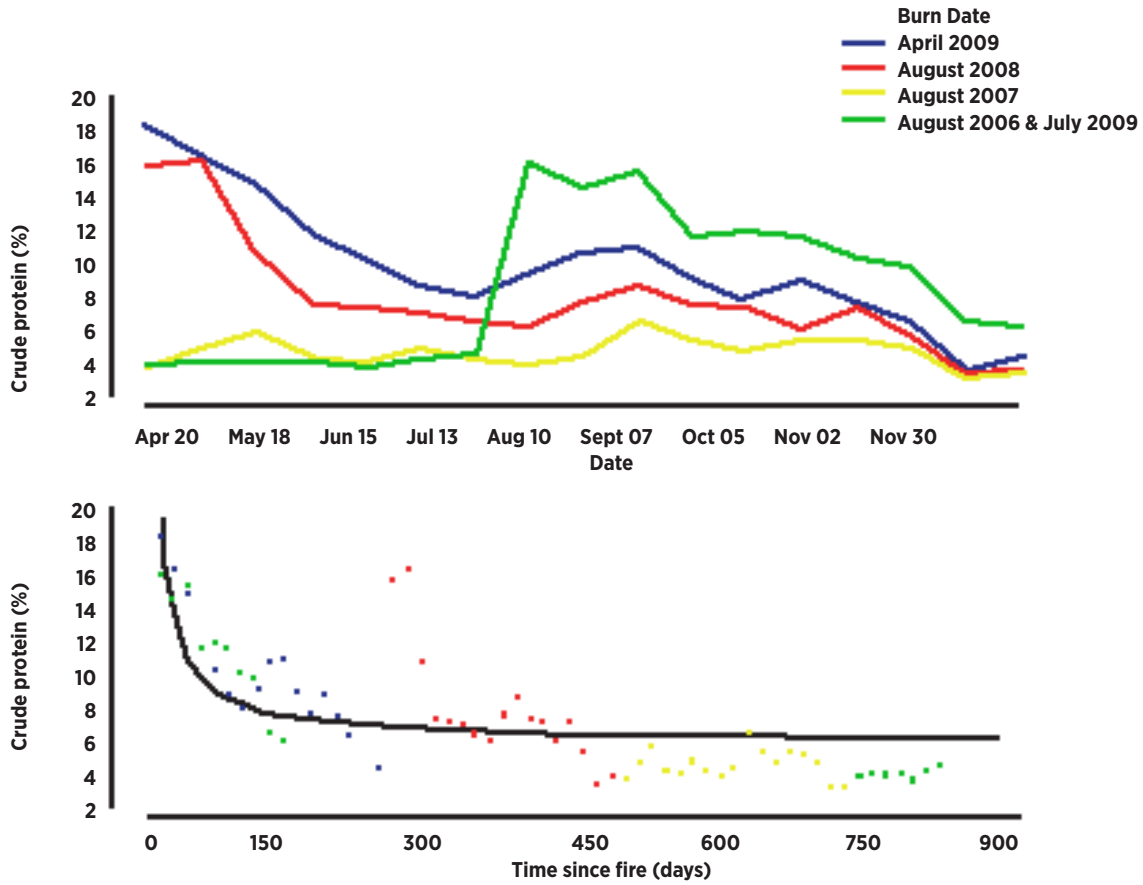


Figure 14.3. The effects of fire on forage quality (% crude protein) throughout the growing season. Recently burned areas (less than one year) contain higher forage quality. A prescribed fire in mid-July increases quality of forage, making it significantly better than other areas. This increase remains through the end of the growing season. The amount of time since a particular area has been burned determines the forage quality available to livestock.

time, the fire does not impact or kill the parasite directly, but fire reduces or destroys the habitat those parasites need for a specific phase in their life cycle. Fire also has been shown to reduce certain species of internal parasites that affect wildlife and livestock by interrupting their life cycle outside of the host. The use of fire can lower overall insecticide applications, input costs and associated losses in production in livestock due to parasites.

Finally, patch-burning and cattle production has been researched extensively. Patch-burning is the prescribed burning of an area or patch within a fenced pasture and giving grazing livestock free access to choose burned or unburned areas. Patch-burning moves fire and grazing disturbances around the landscape and causes vegetation patterns to shift through space and time. Depending on the time since a given patch has burned, the probability of grazing or burning of that patch varies due to the resulting vegetative structure. Moreover, patch-burning is different from conventional approaches to grazing management because it integrates conservation and production, which is becoming increasingly important in many rangeland landscapes. Patch-burning is a bottom-up, low-input approach totally opposite to many of the intensive grazing systems that use large infusions of fencing, labor and other inputs. For more information on patch-burning, see Extension circular E-998, Patch Burning: *Integrating Fire and Grazing to Promote Heterogeneity.*

Several important steps to be considered when conducting prescribed burns are fire plans, firebreaks, weather conditions, smoke management and the actual

Figure 14.4. There are several important steps to be considered when conducting prescribed burns. Fire plans, firebreaks, weather conditions, smoke management and the actual conducting of the burn.

conducting of the burn (Figure 14.4). Several OSU Extension fact sheets are available for more information on how to conduct prescribed burns at extension.okstate.edu. Videos are available at local Extension offices. Contact the local Extension office or Natural Resource Conservation Service (NRCS) center for more information. Additionally, many counties in Oklahoma have local prescribed burn associations. These associations help local landowners assist each other with conducting prescribed burns. To find out more or about burn associations, or to see if one is available in your area, visit the Oklahoma Prescribed Burn Association website at OK-PBA.org.

(Adapted from J.R. Weir, 2009. Conducting Prescribed Fires a Comprehensive Manual. Texas A&M University Press)

15 The Ruminant Animal

Greg Highfill and David Lalman

Objectives

- **Explain and display rumen anatomy.**
- **Demonstrate the stratification of ruminal contents.**
- **Discuss the relationships between microorganisms, the rumen and the animal (or the animal's nutrient supply).**

Ruminants serve an important role in the food production chain. They consume forages and feed byproducts not suitable for human consumption and convert them into nutritious products such as meat and milk (Figure 15.1). Land not suitable for growing food crops can be utilized to grow forage for ruminants.

A marvelous symbiotic relationship exists between rumen bacteria and the cow, allowing consumption and utilization of dietary material that are indigestible to simple-stomached animals and humans. Forages provide energy for ruminants through the fermentation of plant carbohydrates. Immature, high-quality forages are rapidly and thoroughly digested, resulting in high levels of forage and total energy intake. As forages mature, the indigestible fiber (lignin) content increases, making the remaining plant carbohydrates less available and slower to digest by the bacteria.

Ingesting forage triggers rumination, the process of ingesting feed rapidly and chewing it at a later time. The regurgitated material is called a bolus or cud and consists primarily of chewed material coated with saliva. The rumination process results in the secretion of saliva, up to 45 gallons per day. Saliva neutralizes the acids produced during fermentation and helps to maintain an ideal environment for microbial growth. The process of rumination reduces the particle size of feeds, which enhances microbial function and feed passage. One research trial shows the time cattle spend ruminating and grazing throughout a day (Figure 15.2).

Figure 15.1. Forages and feed byproducts are used by ruminants to produce products for human consumption.

Stomach Compartments

A ruminant animal has four stomach compartments:

- the reticulum
- the rumen
- the omasum
- the abomasum (Figure 15.3).

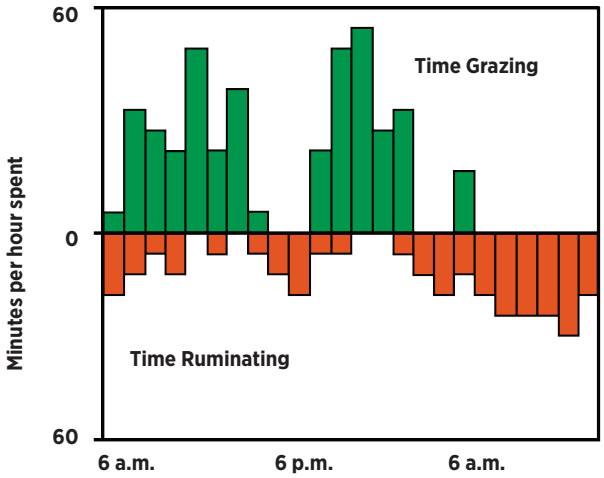


Figure 15.2. Time spent ruminating and grazing throughout a day. Source: Bowen.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

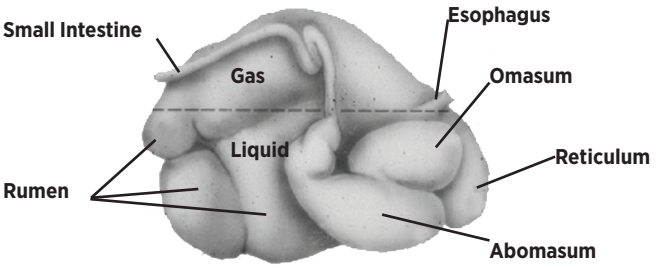


Figure 15.3. Stomach compartments. Source: Bowen.

Figure 15.4. The lining of the reticulum has a honeycomblike structure.

The reticulum is a smaller fermentation compartment in front of the rumen. The reticulum is distinguished by its honeycomb epitheleal (lining) structure (Figure 15.4) and primarily is responsible for assisting in rumination contractions and distributing feed within the rumen system. The reticulum can contain up to 2 1/2 gallons of feed being digested.

The rumen is a large, hollow, muscular organ. It is the primary fermentation vat that holds about 50 gallons in mature cattle and nearly fills the entire left side of the abdominal cavity. Microorganisms or microbes living in the rumen consist primarily of small bacteria and large protozoa. Small bacteria make up about half of the total mass of microbes, although they represent more than 99% of the population in terms of numbers per unit of volume. Microbial fermentation is a process through which rumen microbes break down complex dietary ingredients to produce end products that can be used by the host animal. Fermentation of carbohydrates produces volatile fatty acids that provide up to 80% of a beef cows energy needs. Sixty percent of the protein needs are supplied by digestion of rumen microbes with the remainder supplied by dietary feed proteins.

The wall of the rumen is lined with small finger-like structures called papillae (Figure 15.5). These papillae serve to dramatically increase the surface area of the rumen epithelia, thus enhancing absorption and stimulating rumination. Strong rumen contractions result in maximum exposure of microbes to ingested feeds. The rumen contents are generally stratified in three layers: a small gas cap, a middle fibrous mat layer and a lower liquid layer. The gas cap consists of 60% to 70% carbon dioxide and 20% to 30% methane, along with a few other products of fermentation. The fibrous mat layer is composed of long dietary fiber materials.

The bacteria found in the rumen—more than 150 billion per teaspoon—are distributed within the fibrous mat and liquid layers (Figure 15.6). Type of feed material and bacterial reproductive rate determine which organisms are present at any given time. Bacteria and protozoa that do not reproduce quickly must attach to fibrous material that is digested slowly. This allows long enough rumen retention

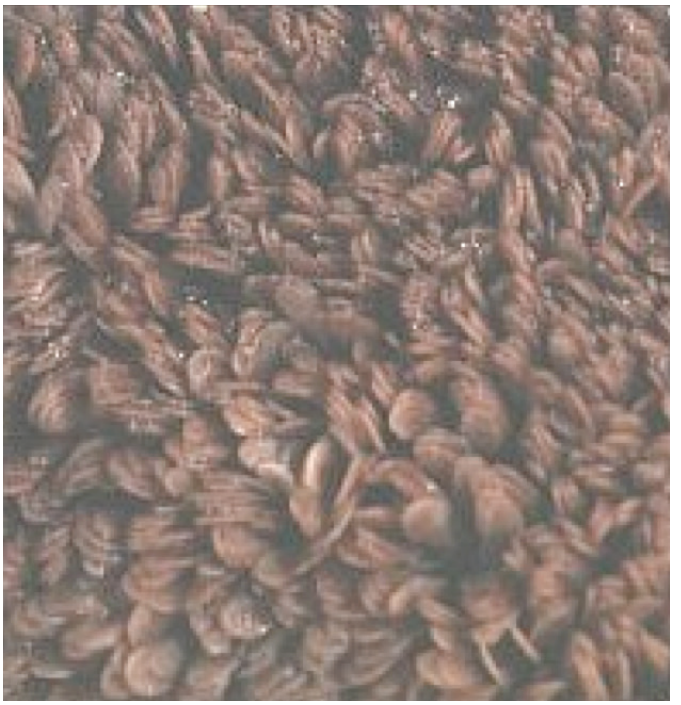


Figure 15.5. Papillae line the rumen wall and increase absorptive capacity.

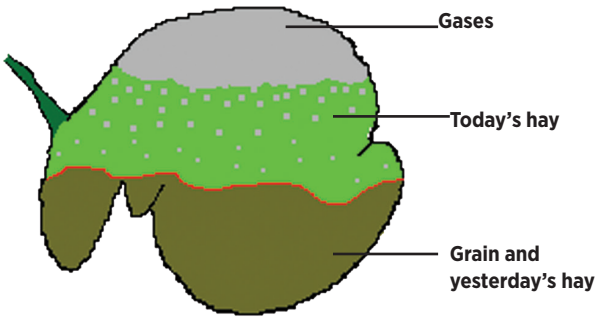


Figure 15.6. Layers of rumen contents. Source: Bowen.

time for reproduction, while continuing the fermentation process in feeds that are slowly digested.

Following microbial fermentation in the rumen undigested feed components and liquids are passed into the third chamber; the omasum. This is a basketball-sized stomach on the right side of the cow and the location where a great deal of water absorption occurs. The omasum contains up to 4 gallons of digesta and plays a major role in controlling particle passage rate as it flows out of the rumen and into the abomasum. The omasum is frequently referred to as the manyplies because it contains numerous large parallel epithelial folds or leaves (Figures 15.7 and 15.8).

Figure 15.7. The large folds or leaves of the omasum.

Figure 15.8. The epitheleal tissue of the abomasum or true stomach.

Figure 15.9. Rumen microorganism. Source: Bowen.

The abomasum frequently is referred to as the true stomach because it is similar to a human's stomach in structure and function. The epithelial tissue in the abomasum contains secretory cells responsible for producing mucous, pepsinogen and hydrochloric acid (Figure 15.9). Consequently, the environment within the abomasum is very acidic with a pH of between 2 and 4. Here, digestive enzymes and the strong acids initiate the breakdown of rumen bacteria, complex proteins and starches for digestion in the small intestine. The abomasum holds about 5 gallons, and the digesta moves through it quickly.

Conclusion

Beef cattle can efficiently utilize a wide range in dietary ingredients to meet their nutrient requirements when microbial fermentation and microbial reproduction are optimized. Knowledge of base-diet nutritive value and the animal's nutrient requirements provide the foundation for ensuring microbial fermentation is optimized. The following chapters provide basic guidelines to assist beef cattle managers in monitoring and adjusting dietary and grazing management to accomplish optimal rumen fermentation and efficiency of feed utilization.

References

Bowen, R.A., L. Austgen and M. Rouge (2000) *Pathophysiology of the Digestive system.*

NASEM (2016) *Nutrient Requirements of Beef Cattle* (8th Edition). National Academy Press, Washington D.C.

Van Soest, P.J. (1982) *Nutritional Ecology of the Ruminant.* Comstock Publishing Associates.

16 Nutrient Requirements of Beef Cattle

David Lalman and Amanda Holder

Objectives

- **Discuss the nutrient requirements of beef cattle.**
- **Provide tables that list the nutrient requirements of beef cattle at different stages of life.**
- **Explain how a balanced and cost-effective nutrition program is essential to the success of any beef cattle operation.**

Grazing and feed expenses make up about 42% to 52% of cow/calf enterprise expenses and about 60% to 70% of stocker and backgrounding operation expenses. For this reason, grazing systems, supplementation programs and complete feeding programs must be designed to meet the nutrient needs of beef cattle, and at the same time, make the most of the available feed resources. Nutrient requirements of cattle change with age, stage of production, sex, breed, environmental conditions and basal diet quality and amount. Therefore, gaining knowledge of nutrient requirements and the factors influencing these requirements is a necessary first step to designing a nutrition program that is both efficient and cost effective. This section will discuss the protein, energy, mineral and vitamin requirements of beef cattle. In addition, tables of nutrient requirements are provided.

Dry Matter Intake

There really is no requirement for feed intake, although an estimate of how much forage and feed an animal will consume is essential when evaluating rations, supplements or predicting animal performance. Voluntary feed dry matter (DM) intake is influenced by a number of different factors. A few of the more important variables include animal weight, body condition, stage of production, level of milk production, forage quality, amount and type of supplement or feed provided, as well as environmental conditions.

Cattle have a daily requirement for a certain quantity of specific nutrients such as protein, calcium and vitamin A. The necessary concentration of these nutrients in the diet (to meet the animal's requirement) is then determined by the amount of feed the animal is expected to consume given free-choice access to feed or forage. For example, steer calves gaining 2 pounds per day may require 1.6 pounds of protein per day. If they consume 15 pounds of DM daily, the protein requirement could be expressed as 10.7% of DM intake. On the other hand, if they are limit fed to consume only 10 pounds of DM daily, the protein requirement for 2 pounds of gain could be expressed as 16% of DM intake.

Intake in forage-fed cattle is generally limited by the forage capacity of the digestive tract. Values presented in Table 16.1 provide rule-of-thumb guidelines for variation in

Table 16.1. Forage capacity of beef cows[a].

Forage type and maturity	*Stage of production*	*Forage dry matter intake capacity, % of body weight*
Low quality forage (< 52% total digestible nutrients)	Dry	1.8
Dry winter forage, mature legume and grass hay, straw	Lactating	2.2
Average quality forage (52% to 59% total digestible nutrients)		
Dry summer pasture, dry pasture during fall, late-bloom	Dry	2.2
legume hay, boot stage and early-bloom grass hay	Lactating	2.5
High quality forage (> 59% total digestible nutrients)		
Mid-bloom, early-bloom and prebloom legume hay,	Dry	2.5
preboot stage grass hay	Lactating	2.7
Lush, growing pasture	Dry	2.5
	Lactating	2.7
Silages	Dry	2.5
	Lactating	2.7

a Intake estimates assume protein requirements are met by the forage or through supplementation when forage protein is not adequate. When protein requirements are not met, forage intake will be lower than the values shown in the table.
Source: Hibbard and Thrift.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

DM intake based on differences in forage quality and stage of production for beef cows. Forage digestibility values rarely exceed 70% of DM. Calves and yearlings frequently are fed higher quantities of concentrate feeds to improve weight gain and feed conversion above what can be achieved with forage alone. When diet digestibility approaches 70%, feed intake is no longer regulated or limited by the capacity of the digestive tract. Rather, with diets high in digestible energy, physiological mechanisms are turned on to limit intake (Figure 16.1). This response can be thought of as a built-in safety mechanism so cattle are less likely to consume too much of a highly digestible diet, causing digestive upset, bloat and founder.

Forage intake is highly correlated with forage quality as shown in Figure 16.2 and Table 16.1. The more rapid rate of digestion and passage of higher-quality forage results in considerably higher dry matter intake compared to forage lower in digestibility.

Cattle with greater mature body weight and frame size consume more forage compared to smaller-framed cattle. Lactating cows consume considerably more of the same quality forage compared to gestating cows (Figure 16.3). Additionally, fleshy cattle consume 2.5% to 5% less feed or forage compared to cattle in average to thin condition. Cold stress increases dry matter intake, while heat stress reduces dry matter intake. Growth-promoting implants decrease feed intake by an average of about 6%, whereas the feed additive Rumensin® decreases feed intake by about 3%. With this many factors influencing voluntary feed intake, accurately predicting daily feed intake can be difficult.

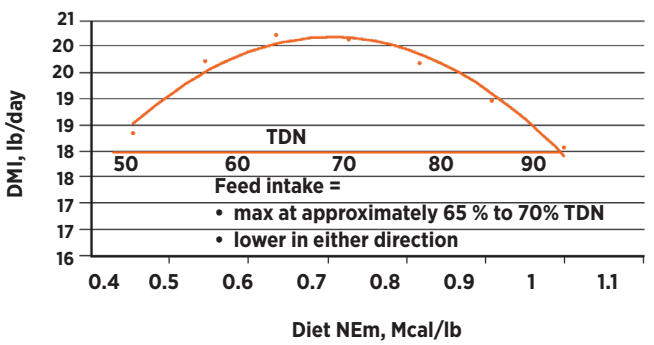


Figure 16.1 Influence of diet digestibility or energy concentration on voluntary feed intake of growing cattle. Source: NASEM, 2016

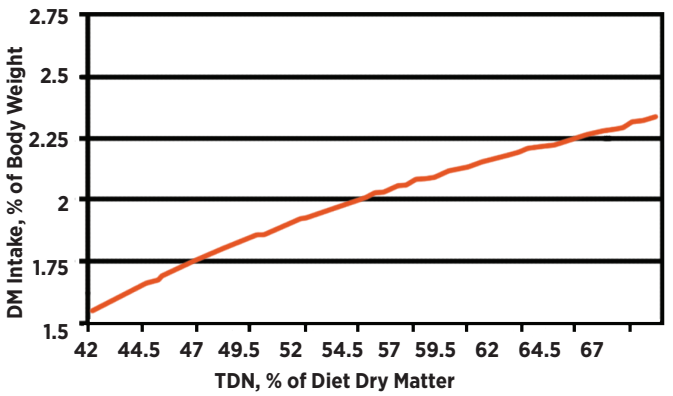


Figure 16.2. The relationship of forage digestibility to dry matter intake in beef cows. Source: NRC.

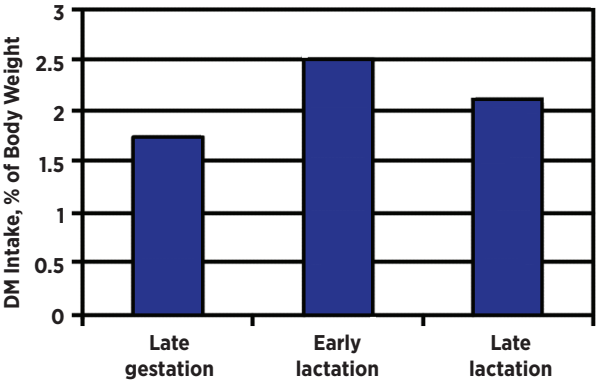


Figure 16.3. Dry matter intake, expressed as percent of body weight, of beef cows consuming low quality forage during three different stages of production. Source: Johnson et al.

Estimates of dry matter intake presented in the nutrient requirement tables are determined using published prediction equations. These equations take into account the effects of the animal's weight, level of milk production for lactating cows, energy content of the diet, stage of production and body condition in the case of the pregnant replacement heifers. It is important to note all of these equations assume adequate protein is supplied in the diet to maximize ruminal fermentation. In other words, if the diet is deficient in protein, these dry matter intake values will overestimate the amount the cattle will actually consume.

Protein

Proteins are large chemical units made up of hundreds of amino acids. Amino acids, in turn, are organic or carbon-containing compounds that also contain nitrogen, oxygen and sometimes sulfur. Animals consume proteins in their diets, then utilize the amino acids for synthesis of muscles, blood proteins and other body components. In swine, poultry and other nonruminants, the amino acids must be supplied in definite proportions in the diet. However, in ruminants, microorganisms (bacteria and protozoa) break down most dietary proteins and incorporate the nitrogen and amino acids into their own body tissue. The microorganisms are digested in the small intestine of the ruminant animal. The bacteria themselves have a protein requirement and must have adequate protein to do their job of digesting roughages into end products that can be utilized by the cow.

Because of the ruminal breakdown of dietary proteins and because the amino acid makeup of microorganisms is adequate to meet amino acid requirements for most classes of beef cattle, feed and forage amino acid composition is generally not critical compared to nonruminant diets. On the other hand, a high priority should be placed on providing adequate ruminally available protein to allow the bacteria to grow, reproduce and digest roughages. Chemical crude protein concentration is determined by multiplying the feed nitrogen concentration by 6.25 because protein

molecules contain an average of 16% nitrogen (1/16 = 6.25).

The crude protein system has been the standard for evaluating beef cattle protein requirements and dietary supply for many years.

More recently, the metabolizable protein (MP) system has been used to better characterize protein degradability as well as site and extent of digestion. To effectively use the MP system, the user must become familiar with several terms. These include rumen degradable intake protein (RDIP), rumen degradable protein (RDP), rumen undegradable protein (RUP) and metabolizable protein (MP). Rumen degradable protein is the feed protein fraction degraded in the rumen. Nitrogen from RDP is used either for microorganism protein synthesis or passes through the rumen wall into the blood stream and is carried to the liver as ammonia. In the liver, this nitrogen can be converted to urea, after which it is recycled to the rumen through saliva or filtered out of the blood stream in the kidney, to be excreted in the urine. Rumen undegradable protein is the feed protein fraction that bypasses fermentation in the rumen to be degraded and absorbed in the small intestine. The RUP value of a feed also can be calculated by subtracting the RDP value from one. Metabolizable protein is the sum of protein derived from microorganism origin plus UIP (Figure 16.4).

Perhaps one of the most practical applications of the MP system is the calculation of the animal's RDP requirement to ensure optimal rumen function. For this reason, feed RDP values are included in Table 16.1. The requirement for RDP is thought to be closely associated with the amount of fermentable energy in the diet. Specifically, the RDP requirement can be calculated as 10% to 13% of daily total digestible nutrients (TDN) intake. Lower values in this range are used when the cattle are receiving a low-quality diet, such as dry winter range forage or low-quality hay, whereas higher values in the range are used when the cattle are receiving high-quality forage or a ration including at least 50% concentrate.

An example of RDP requirement follows. Assume a cow is consuming 25 pounds of hay dry matter that contains 50% TDN. The cow therefore consumes a total of 12.5 pounds of TDN per day. Therefore, the RDP requirement is 12.5 pounds x 10%, or 1.25 pounds of RDP per day. If the hay contains 6% crude protein (DM basis), of which 65% is RDP, the forage would supply 0.98 pound of RDP each day (6% x 65% x 25 pounds). The requirement for supplemental RDP would be 0.27 pound (1.25 pounds – 0.98 pound).

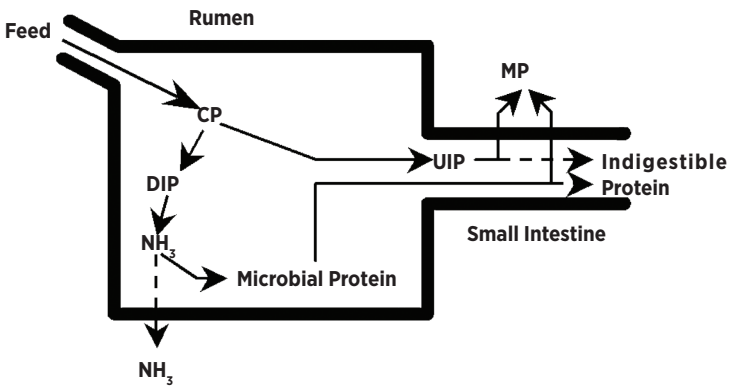


Figure 16.4. Illustration of protein digestion and absorption in the ruminant. Source: Lalman.

Nutrient requirements for beef cows and replacement heifers are shown in Tables 16.2 and 16.3. Requirements for growing calves and yearlings are shown in Tables 16.4 and 16.5. Requirements for growing and mature bulls are shown in Table 16.6. These values were adapted from the National Research Council's (NRC) Nutrient Requirements of Beef Cattle publication. One exception is that the NRC calculates the crude protein requirement for some classes of cattle to be less than 7%. Research demonstrates ruminal fermentation may be compromised with low protein diets. Therefore, 7.5% dietary crude protein was the minimum value used in the nutrient requirements in Table 16.1.

The requirements are expressed in both pounds per day of crude protein and in terms of the percentage of dry matter required in the diet. These tables illustrate the influence of age, weight, desired rate of weight gain, stage of production and genetic milking ability on nutrient requirements.

Replacement heifers need to gain about 1 pound to 1.5 pounds per day to reach 55% to 65% of their expected mature weight and puberty by 15 months of age. They also need to gain around 1 pound per day from the time they are bred until they calve to reach approximately 80% of their mature weight when they calve for the first time. The requirement of protein for muscle and organ growth is reflected in the large daily requirement for protein. Growing heifers require a high concentration of protein in the diet because of their low dry matter intake. They must have access to good-quality forage or be fed supplemental protein to achieve adequate growth prior to their first breeding season.

Gestation has little effect on the cow's protein requirement until about the seventh month of pregnancy. About two-thirds of the fetal growth occurs during the last one-third of pregnancy and the protein intake of the cow should be increased during the last one-third of pregnancy to ensure the cow will be in good condition at the time of calving. The cow is programmed to take care of the fetus at the expense of her own body and losses of body condition frequently occur in late pregnancy, when daily protein or energy are not increased to match the needs of the pregnant cow. Adequate dietary protein during this period also is essential for the cow to produce abundant, high-quality colostrum or first milk, which will influence the newborn's immune system for the remainder of its life.

Lactation is the most nutritionally stressful activity for the cow. The modern commercial beef cow produces around 25 pounds of milk each day during peak lactation. Milk contains a high concentration of protein. Therefore, lactating cows, particularly during early lactation, require nearly twice the daily protein of dry cows. Research shows cows in moderate condition at calving should at least maintain body weight from calving to rebreeding for good conception rates. Failure to take into account the increased protein demand brought on by lactation may result in long intervals before rebreeding. Beef breeds with superior milking ability (30 pounds or more per day) and selection for high milk production within a breed have an even higher protein requirement.

Increasing cow size adds to the daily protein requirement but not nearly to the extent that lactation does. As mature size increases, more protein is required to maintain the heavier muscle mass and to permit faster gains that must be made by young females of larger breeds.

Energy

The cow requires energy for grazing, traveling, fetal development, milk production, temperature maintenance, reproduction, digestion and voiding of body wastes. In addition, first- and second-calf heifers require additional energy for growth until they mature at about 4 years of age. If cows are thin, additional energy will be required to restore their body condition to a moderate level. The bulk of energy for grazing cattle comes from rumen digestion of forages and roughage products. With proper amounts of protein and minerals, the rumen is capable of getting energy from a wide range of feeds that are useless to nonruminants.

Because the rumen bacteria requires protein, just as the animal's body does, it is impossible to discuss ruminant energy requirements separately from ruminant protein requirements. With too little protein in the diet, the bacteria will not efficiently digest roughages; with too much protein in the diet, the protein will be deaminated. Deamination is the process of removing nitrogen from the protein molecule. When this occurs, the nitrogen is excreted in the urine and the excess winds up serving as an expensive energy source.

Energy requirements expressed in Table 16.1 are in terms of TDN and net energy for maintenance (NEm) and/or net energy for gain (NEg). TDN is the sum of the digestible starch, fiber, protein and fat in a feed with a correction factor for the high energy content of fat and the amount of ash or mineral content. TDN requirements are expressed as a percent of the diet dry matter as well as in pounds per day required. Net energy requirements are expressed in terms of mega calories per pound of feed and mega calories required per day.

A close look at the nutrient requirement Table 16.2 shows the same factors that influence protein requirements also influence energy requirements: animal weight, rate of gain, lactation and fetal development. Lactation represents the greatest need for additional energy beyond what is for maintenance. An average milking beef cow requires nearly 50% more TDN or net energy than when dry. It should be noted that lactating cows consume more forage compared to gestating cows due to the increased energy demand.

Energy requirements for first-calf heifers are higher than for mature cows because energy is needed for growth in addition to body maintenance and lactation. Inadequate energy during the last third of gestation and during the critical time from calving to rebreeding can lead to poor rebreeding.

Large cows will require more energy than small cows. For example, a 1,300-pound dry pregnant cow in the middle third of pregnancy requires 32% more TDN per day than a 900-pound cow at the same stage of production. As a result, mature cow size should be considered when determining appropriate stocking rates and estimated daily hay needs.

Vitamins and Minerals

The National Research Council publishes equations to determine calcium and phosphorus requirements and these estimated requirements are shown in Tables 16.2 through 16.6. Less is known about specific dietary requirements for the other important macro and micro minerals. Therefore, the National Research Council provides general dietary guidelines and maximum tolerable levels for each of these minerals (Table 16.7). Specific functions and sources of vitamins and minerals are discussed in greater detail in chapter 19.

Water

Remember—water is a common, but an entirely essential nutrient. Water intake increases dramatically with increased age, weight and temperature (Table 16.8). Clean water is most important for young, growing calves. Dirty water can retard performance and be a breeding ground for disease in cattle of all ages.

Other Considerations

The requirements shown in the tables are designed for healthy unstressed cattle in good condition. Thin heifers or cows should be fed additional energy and protein to achieve good body condition. Some additional energy should be allowed for cows having to travel over large areas for feed or water. Cows subjected to extremely cold temperatures, especially if combined with rain or snow, need extra energy for maintenance. The protein requirement is not increased during cold stress, however. Kansas State University research shows a 1,200-pound cow subjected to 20 F in a 14 mph wind requires about 28% more energy than at 32 F with no wind.

Conclusion

Nutrient requirements include those for protein, energy, vitamins, minerals and water. Nutrient requirements vary dramatically among animals and are influenced by age, weight, stage of production, rate of growth, environmental conditions, breed, gender and other factors. Tabular data provided in this chapter should assist beef producers in determining specific nutrient requirements for their cattle.

References

Gadberry, S. (2002) Extension bulletin MP 391, University of Arkansas. uaex.edu/Other_Areas/publications/.

Hibbard, C.A. and T.A. Thrift (1992) Supplementation of Forage-Based Diets: Are Results Predictable? *Journal of Animal Science* 70 (Suppl. 1):181. (Abstr.)

Johnson, C.R. et al. (2003) Influence of milk production potential on forage dry matter intake of Multiparous and primiparous Brangus females. *Journal of Animal Science* 81:1837-1846.

NRC. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, D.C.

Table 16.2. Nutrient requirements of beef cows.

Gestating cow, middle 1/3 of pregnancy

				Diet nutrient density					Daily nutrients per animal				
Weight (lbs)	*Expected calf birth weight (lbs)*	*DM intake (lbs/day)*	*DM intake % of BW*	*TDN (% DM)*	*NEm (Mcal/lb)*	*CP (% DM)*	*Ca (%DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*CP (lbs)*	*Ca (g)*	*P (g)*
900	64	16.6	1.8	50	0.44	7.5	0.28	0.17	8.3	7.1	1.35	21	13
1,000	70	18.0	1.8	50	0.44	7.5	0.28	0.17	9.0	7.7	1.35	23	14
1,100	75	19.3	1.8	50	0.44	7.5	0.29	0.18	9.7	8.2	1.45	25	16
1,200	83	21.4	1.7	50	0.44	7.5	0.29	0.18	10.7	9.1	1.6	28	18
1,300	85	21.9	1.7	50	0.44	7.5	0.29	0.18	11.0	9.3	1.64	29	18
1,400	90	23.1	1.7	50	0.44	7.5	0.30	0.18	11.6	9.9	1.73	31	19
1,500	95	24.4	1.6	50	0.44	7.5	0.30	0.19	12.2	10.4	1.83	33	21

Gestating cow, last 1/3 of pregnancy

900	64	18.6	2.1	54	0.51	7.5	0.25	0.16	10.1	9.4	1.4	21	14
1,000	70	20.1	2.0	54	0.51	7.5	0.25	0.17	10.9	10.2	1.51	23	15
1,100	75	21.6	2.0	54	0.51	7.5	0.26	0.17	11.7	10.9	1.62	25	17
1,200	83	23.9	1.9	54	0.51	7.5	0.26	0.17	13.0	12.1	1.8	28	19
1,300	85	24.5	1.9	54	0.51	7.5	0.26	0.18	13.3	12.4	1.84	29	20
1,400	90	25.9	1.8	54	0.51	7.5	0.27	0.18	14.1	13.1	1.94	31	21
1,500	95	27.3	1.8	54	0.51	7.5	0.27	0.18	14.8	13.8	2.20	33	22

Lactating cow, first 90 days after calving

Weight (lbs)	*Peak milk lb/day*	*DM intake lb/day*	*DM Int % of BW*	*TDN % DM*	*NEm Mcal/lb*	*CP % of DM*	*Ca Req % of DM*	*Phos Req % of DM*	*TDN lb/day*	*NEm Mcal/day*	*CP lb/day*	*Ca g/day*	*Phos g/day*
	10	21.3	2.4	56	0.53	8.8	0.24	0.16	12.0	11.4	1.9	23	16
900	15	23.3	2.6	58	0.56	9.8	0.27	0.18	13.4	13.0	2.3	29	19
	20	25.1	2.8	59	0.58	10.6	0.30	0.19	14.9	14.7	2.7	34	22
	15	24.7	2.5	58	0.55	9.6	0.27	0.18	14.2	13.7	2.4	30	20
1,000	20	26.6	2.7	59	0.58	10.4	0.30	0.19	15.7	15.3	2.8	36	23
	25	28.4	2.8	60	0.60	11.1	0.32	0.20	17.1	17.0	3.1	41	26
	20	28.0	2.5	59	0.57	10.1	0.29	0.19	16.4	16.0	2.8	37	24
1,100	25	29.9	2.7	60	0.59	10.8	0.31	0.20	17.9	17.6	3.2	43	27
	30	31.7	2.9	61	0.61	11.4	0.34	0.21	19.3	19.2	3.6	48	30
	17.7	29.6	2.3	57	0.55	9.5	0.27	0.18	16.9	16.3	2.8	37	24
1,200	25	31.3	2.6	59	0.58	10.6	0.31	0.20	18.5	18.3	3.3	44	28
	30	33.1	2.8	61	0.60	11.2	0.33	0.21	20.0	19.9	3.7	50	31
	25	32.6	2.5	59	0.58	10.4	0.31	0.20	19.3	18.9	3.4	45	29
1,300	30	34.4	2.6	60	0.60	11.0	0.33	0.21	20.7	20.5	3.8	51	32
	35	36.3	2.8	61	0.61	11.5	0.34	0.22	22.2	22.1	4.2	57	36
	25	33.9	2.4	59	0.57	10.3	0.30	0.20	20.0	19.5	3.5	47	30
1,400	30	35.8	2.6	60	0.59	10.8	0.32	0.21	21.4	21.1	3.9	52	33
	35	37.6	2.7	61	0.60	11.3	0.34	0.21	22.9	22.7	4.3	58	37
	25	35.2	2.3	59	0.57	10.1	0.30	0.20	20.6	20.1	3.6	48	31
1,500	30	37.1	2.5	60	0.59	10.7	0.32	0.20	22.1	21.7	4.0	54	34
	35	38.9	2.6	61	0.60	11.2	0.34	0.21	23.5	23.4	4.3	59	38

Table 16.3. Pregnant yearling replacement heifer, middle 1/3 of pregnancy.

Pregnant yearling replacement heifer, middle 1/3 of pregnancy

Current weight (lbs)	*Current BCS (1-9)*	*Mature Wt @ BCS=5*	*Calf birth weight*	*Maternal tissue ADG, lb*	*Gravid uterus ADG, lb*	*Diet nutrient density*											
						DM intake		*TDN*		*Nem, Mcal*		*Crude Protein*		*Calcium*		*Phosphorous*	
						lb/day	*% of BW*	*lb/day*	*% DM*	*per day*	*per lb*	*lb/day*	*% of DM*	*g/day*	*% of DM*	*g/day*	*% of DM*
600	5	1000	75	1.0	0.29	16.4	2.7	9.1	55.5	8.6	0.52	1.4	8.3	29	0.39	12	0.16
600	5	1000	75	1.5	0.29	16.6	2.8	10.0	60.0	9.9	0.59	1.6	9.5	34	0.45	14	0.19
600	5	1000	75	2.0	0.29	16.6	2.8	10.9	66.0	11.3	0.68	1.8	11.0	39	0.52	17	0.22
700	6	1000	75	1.0	0.29	18.4	2.6	10.3	56.0	9.9	0.53	1.4	7.7	30	0.36	13	0.15
700	6	1000	75	1.5	0.29	18.7	2.7	11.4	61.0	11.4	0.61	1.6	8.7	34	0.40	15	0.18
700	6	1000	75	2.0	0.29	18.6	2.7	12.3	66.0	12.7	0.68	1.8	9.7	38	0.45	17	0.20
800	7	1000	75	1.0	0.29	20.5	2.6	11.7	57.0	11.2	0.55	1.5	7.5	31	0.33	14	0.15
800	7	1000	75	1.5	0.29	20.7	2.6	12.8	62.0	12.9	0.62	1.7	8.1	35	0.37	16	0.17
800	7	1000	75	2.0	0.29	20.5	2.6	13.7	67.0	14.3	0.70	1.8	8.9	38	0.41	17	0.18
750	5	1200	80	1.0	0.31	19.2	2.6	10.4	54.0	9.6	0.50	1.5	7.8	31	0.36	14	0.16
750	5	1200	80	1.5	0.31	19.6	2.6	11.5	58.5	11.2	0.57	1.7	8.8	37	0.41	16	0.18
750	5	1200	80	2.0	0.31	19.7	2.6	12.4	63.0	12.5	0.64	1.9	9.9	41	0.46	18	0.20
850	6	1200	80	1.0	0.31	21.2	2.5	11.7	55.0	11.0	0.52	1.6	7.5	33	0.34	15	0.15
850	6	1200	80	1.5	0.31	21.6	2.5	12.7	59.0	12.5	0.58	1.8	8.2	37	0.38	17	0.17
850	6	1200	80	2.0	0.31	21.6	2.5	13.8	64.0	14.1	0.65	2.0	9.2	41	0.42	19	0.19
950	7	1200	80	1.0	0.31	22.0	2.5	12.2	55.5	11.5	0.52	1.6	7.5	33	0.33	15	0.15
950	7	1200	80	1.5	0.31	23.5	2.5	14.1	60.0	13.9	0.59	1.8	7.8	37	0.35	17	0.16
950	7	1200	80	2.0	0.31	23.5	2.5	15.0	64.0	15.3	0.65	2.0	8.4	41	0.38	19	0.18
900	5	1400	85	1.0	0.33	21.9	2.4	11.7	53.5	10.8	0.49	1.6	7.5	35	0.35	15	0.15
900	5	1400	85	1.5	0.33	22.4	2.5	12.8	57.0	12.2	0.55	1.9	8.3	39	0.38	18	0.17
900	5	1400	85	2.0	0.33	22.6	2.5	13.8	61.0	13.7	0.61	2.1	9.2	43	0.42	20	0.19
1,000	6	1400	85	1.0	0.33	23.8	2.4	12.9	54.0	11.9	0.50	1.8	7.5	35	0.33	16	0.15
1,000	6	1400	85	1.5	0.33	24.3	2.4	14.1	58.0	13.7	0.56	1.9	7.9	40	0.36	18	0.17
1,000	6	1400	85	2.0	0.33	24.4	2.4	15.1	62.0	15.2	0.62	2.1	8.7	44	0.40	20	0.18
1,100	7	1400	85	1.0	0.33	25.7	2.3	14.0	54.5	13.1	0.51	1.9	7.5	36	0.31	17	0.15
1,100	7	1400	85	1.5	0.33	26.1	2.4	15.3	58.5	14.9	0.57	2.0	7.5	40	0.34	19	0.16
1,100	7	1400	85	2.0	0.33	26.2	2.4	16.4	62.5	16.5	0.63	2.1	8.1	44	0.37	21	0.17

Table 16.3. Nutrient requirements of pregnant replacement heifers (continued).

Pregnant yearling replacement heifer, last 1/3 of pregnancy

Current weight (lbs)	*Current BCS (1-9)*	*Mature Wt @ BCS=5*	*Calf birth weight*	*Maternal tissue ADG, lb*	*Gravid uterus ADG, lb*	*Diet nutrient density*											
						DM intake		*TDN*		*Nem, Mcal*		*Crude Protein*		*Calcium*		*Phosphorous*	
						lb/day	*% of BW*	*lb/day*	*% DM*	*per day*	*per lb*	*lb/day*	*% of DM*	*g/day*	*% of DM*	*g/day*	*% of DM*
700	5	1000	75	0.5	0.96	18.4	2.6	10.3	56.0	9.8	0.53	1.5	8.2	25	0.30	15	0.18
700	5	1000	75	1.0	0.96	18.7	2.7	11.4	61.0	11.4	0.61	1.7	9.2	29	0.35	17	0.20
700	5	1000	75	1.5	0.96	18.6	2.7	12.4	67.0	12.9	0.70	1.9	10.3	34	0.40	19	0.22
800	6	1000	75	0.5	0.96	20.4	2.5	11.4	56.0	10.8	0.53	1.6	7.8	26	0.28	16	0.17
800	6	1000	75	1.0	0.96	20.7	2.6	12.6	61.0	12.6	0.61	1.8	8.6	30	0.32	18	0.19
800	6	1000	75	1.5	0.96	20.5	2.6	13.7	67.0	14.3	0.70	2.0	9.5	34	0.36	19	0.21
900	7	1000	75	0.5	0.96	22.3	2.5	12.5	56.0	11.8	0.53	1.7	7.5	27	0.27	16	0.16
900	7	1000	75	1.0	0.96	22.6	2.5	14.0	62.0	14.1	0.62	1.8	8.2	31	0.30	18	0.18
900	7	1000	75	1.5	0.96	22.3	2.5	15.2	68.0	15.9	0.71	2.0	9.0	35	0.34	20	0.20
850	5	1200	80	0.5	1.02	21.2	2.5	11.7	55.0	11.0	0.52	1.7	7.9	28	0.29	17	0.17
850	5	1200	80	1.0	1.02	21.6	2.5	12.7	59.0	12.5	0.58	1.9	8.7	32	0.33	19	0.19
850	5	1200	80	1.5	1.02	21.6	2.5	13.8	64.0	14.1	0.65	2.1	9.6	36	0.37	21	0.21
950	6	1200	80	0.5	1.02	23.1	2.4	12.7	55.0	11.9	0.52	1.8	7.6	29	0.28	18	0.17
950	6	1200	80	1.0	1.02	23.5	2.5	14.1	60.0	13.9	0.59	2.0	8.3	33	0.31	20	0.19
950	6	1200	80	1.5	1.02	23.4	2.5	15.2	65.0	15.6	0.67	2.1	9.1	37	0.35	22	0.20
1,050	7	1200	80	0.5	1.02	24.9	2.4	13.7	55.0	12.8	0.52	1.9	7.5	30	0.26	18	0.16
1,050	7	1200	80	1.0	1.02	25.3	2.4	15.2	60.0	15.0	0.59	2.0	7.9	34	0.30	20	0.18
1,050	7	1200	80	1.5	1.02	25.3	2.4	16.4	65.0	16.9	0.67	2.2	8.6	37	0.33	22	0.19
1,020	5	1400	85	0.5	1.09	24.2	2.4	13.0	54.0	12.1	0.50	1.9	7.7	31	0.28	19	0.17
1,020	5	1400	85	1.0	1.09	24.7	2.4	14.3	58.0	13.9	0.56	2.1	8.4	35	0.32	21	0.19
1,020	5	1400	85	1.5	1.09	24.8	2.4	15.4	62.0	15.4	0.62	2.2	9.1	39	0.35	23	0.20
1,120	6	1400	85	0.5	1.09	25.9	2.3	14.0	54.0	13.0	0.50	1.9	7.5	32	0.27	20	0.17
1,120	6	1400	85	1.0	1.09	26.4	2.4	15.3	58.0	14.9	0.56	2.1	8.0	36	0.30	22	0.18
1,120	6	1400	85	1.5	1.09	26.6	2.4	16.7	63.0	16.9	0.64	2.3	8.7	40	0.33	24	0.20
1,220	7	1400	85	0.5	1.09	27.8	2.3	15.3	55.0	14.4	0.52	2.1	7.5	34	0.27	21	0.17
1,220	7	1400	85	1.0	1.09	28.3	2.3	16.7	59.0	16.3	0.58	2.2	7.7	37	0.29	23	0.18
1,220	7	1400	85	1.5	1.09	28.3	2.3	18.0	63.5	18.3	0.64	2.4	8.3	41	0.32	25	0.19

Table 16.3. Nutrient requirements of pregnant replacement heifers (continued).

Lactating first-calf heifer, first 90 days after calving

Current weight (lbs)	*Current BCS (1-9)*	*Mature Wt @ BCS=5*	*Peak milk lbs/day*	*Maternal tissue ADG, lb*	*Gravid uterus ADG, lb*	*Diet nutrient density*											
						DM intake		*TDN*		*Nem, Mcal*		*Crude Protein*		*Calcium*		*Phosphorous*	
						lb/day	*% of BW*	*lb/day*	*% DM*	*per day*	*per lb*	*lb/day*	*% of DM*	*g/day*	*% of DM*	*g/day*	*% of DM*
700	5	1000	8	0.5		18.4	2.6	11.0	60.0	8.3	0.45	1.8	9.7	24	0.29	16	0.19
700	5	1000	12	0.5		19.8	2.8	12.0	61.0	8.1	0.41	2.1	10.5	28	0.31	18	0.20
700	5	1000	16	0.5		21.2	3.0	13.3	62.5	8.2	0.38	2.4	11.3	33	0.34	21	0.22
800	6	1000	10	0.5		20.9	2.6	12.7	61.0	9.4	0.45	2.0	9.6	27	0.28	18	0.19
800	6	1000	15	0.5		22.7	2.8	14.2	62.5	9.4	0.41	2.4	10.6	32	0.32	21	0.21
800	6	1000	20	0.5		24.5	3.1	15.7	64.0	9.4	0.39	2.8	11.4	38	0.34	25	0.22
900	7	1000	10	0.0		20.9	2.3	12.4	59.0	8.8	0.42	1.9	9.0	24	0.25	17	0.18
900	7	1000	15	0.0		22.8	2.5	13.9	61.0	9.0	0.39	2.3	10.0	29	0.28	20	0.19
900	7	1000	20	0.0		24.4	2.7	15.2	62.0	8.7	0.36	2.7	10.9	35	0.31	23	0.21
850	5	1200	10	0.5		21.5	2.5	12.9	60.0	9.5	0.44	2.1	9.7	28	0.29	19	0.19
850	5	1200	15	0.5		23.2	2.7	14.1	61.0	9.2	0.40	2.4	10.6	33	0.32	22	0.21
850	5	1200	20	0.5		25.0	2.9	15.6	62.5	9.2	0.37	2.8	11.4	39	0.34	25	0.22
950	6	1200	12	0.5		23.9	2.5	14.6	61.0	10.6	0.44	2.3	9.7	32	0.29	21	0.19
950	6	1200	17	0.5		25.8	2.7	16.1	62.5	10.7	0.42	2.7	10.5	37	0.32	24	0.21
950	6	1200	22	0.5		27.5	2.9	17.5	63.5	10.6	0.38	3.1	11.3	43	0.34	28	0.22
1,050	7	1200	12	0.0		23.7	2.3	14.0	59.0	9.8	0.41	2.2	9.2	28	0.26	20	0.18
1,050	7	1200	17	0.0		25.4	2.4	15.2	60.0	9.5	0.37	2.6	10.1	34	0.29	23	0.20
1,050	7	1200	22	0.0		27.1	2.6	16.5	61.0	9.3	0.34	3.0	10.9	39	0.32	26	0.21
1,020	5	1400	12	0.5		24.6	2.4	14.7	59.5	10.5	0.43	2.4	9.6	33	0.29	22	0.19
1,020	5	1400	17	0.5		26.5	2.6	16.2	61.0	10.6	0.40	2.8	10.5	38	0.32	25	0.21
1,020	5	1400	22	0.5		28.3	2.8	17.5	62.0	10.4	0.37	3.2	11.2	44	0.34	28	0.22
1,120	6	1400	15	0.5		27.5	2.5	16.8	61.0	11.8	0.43	2.7	9.8	37	0.30	25	0.20
1,120	6	1400	20	0.5		29.2	2.6	18.1	62.0	11.7	0.40	3.1	10.5	43	0.32	28	0.21
1,120	6	1400	25	0.5		31.0	2.8	19.5	63.0	11.6	0.37	3.5	11.2	48	0.34	31	0.22
1,220	7	1400	15	0.0		27.0	2.2	15.9	59.0	10.7	0.40	2.6	9.5	34	0.28	24	0.19
1,220	7	1400	20	0.0		28.7	2.4	17.2	60.0	10.5	0.37	2.9	10.3	39	0.30	27	0.21
1,220	7	1400	25	0.0		30.4	2.5	18.5	61.0	10.3	0.34	3.3	11.0	45	0.33	30	0.22

Table 16.4. Nutrient requirements of growing steer and heifer calves.

			Diet nutrient density						*Daily nutrients per animal*					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (%DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,200 pounds at finishing														
300	0.5	7.9	54	0.50	0.24	9.2	0.30	0.16	4.3	3.1	0.42	0.73	9	5
	1.0	8.4	59	0.57	0.31	11.4	0.46	0.23	5.0	3.1	0.90	0.95	18	9
	1.5	8.6	64	0.64	0.37	13.6	0.62	0.29	5.5	3.1	1.40	1.17	22	14
	2.0	8.6	69	0.72	0.44	16.2	0.79	0.36	5.9	3.1	1.92	1.39	32	14
	2.5	8.5	75	0.81	0.52	18.9	0.96	0.40	6.4	3.1	2.46	1.61	36	18
	3.0	8.2	83	0.92	0.62	22.2	1.17	0.51	6.8	3.1	3.00	1.83	45	18
400	0.5	9.8	54	0.50	0.24	8.7	0.27	0.15	5.3	3.8	0.52	0.85	14	9
	1.0	10.4	59	0.57	0.31	10.4	0.39	0.20	6.1	3.8	1.12	1.08	18	9
	1.5	10.7	64	0.64	0.37	12.1	0.50	0.24	6.8	3.8	1.74	1.30	23	14
	2.0	10.7	69	0.72	0.44	14.1	0.62	0.29	7.4	3.8	2.39	1.51	32	14
	2.5	10.6	75	0.81	0.52	16.3	0.75	0.34	8.0	3.8	3.50	1.72	36	18
	3.0	10.2	83	0.92	0.62	19.0	0.90	0.41	8.5	3.8	3.72	1.94	41	18
500	0.5	11.6	54	0.50	0.24	8.4	0.25	0.15	6.3	4.5	0.62	0.97	14	9
	1.0	12.2	59	0.57	0.31	9.8	0.34	0.18	7.2	4.5	1.32	1.19	18	9
	1.5	12.6	64	0.64	0.37	11.2	0.42	0.22	8.1	4.5	2.06	1.41	23	14
	2.0	12.7	69	0.72	0.44	12.8	0.52	0.25	8.8	4.5	2.82	1.63	32	14
	2.5	12.5	75	0.81	0.52	14.7	0.62	0.30	9.4	4.5	3.60	1.84	36	18
	3.0	12.1	83	0.92	0.62	16.9	0.74	0.35	10.0	4.5	4.40	2.05	41	18
600	0.5	13.2	54	0.50	0.24	8.2	0.23	0.14	7.1	5.2	0.71	1.08	14	9
	1.0	14.0	59	0.57	0.31	9.4	0.30	0.17	8.3	5.2	1.51	1.31	18	9
	1.5	14.4	64	0.64	0.37	10.6	0.38	0.20	9.2	5.2	2.36	1.53	23	14
	2.0	14.6	69	0.72	0.44	11.9	0.44	0.22	10.1	5.2	3.23	1.74	32	14
	2.5	14.4	75	0.81	0.52	13.6	0.52	0.26	10.8	5.2	4.13	1.95	36	18
	3.0	13.8	83	0.92	0.62	15.7	0.62	0.30	11.5	5.2	5.04	2.17	41	18
700	0.5	14.9	54	0.50	0.24	8.0	0.22	0.14	8.0	5.8	0.79	1.19	14	9
	1.0	15.8	59	0.57	0.31	9.0	0.28	0.16	9.3	5.8	1.70	1.42	18	14
	1.5	16.2	64	0.64	0.37	10.1	0.33	0.19	10.4	5.8	2.65	1.64	23	14
	2.0	16.3	69	0.72	0.44	11.4	0.39	0.21	11.2	5.8	3.63	1.85	27	14
	2.5	16.1	75	0.81	0.52	12.8	0.46	0.24	12.1	5.8	4.64	2.06	32	18
	3.0	15.5	83	0.92	0.62	14.6	0.54	0.27	12.9	5.8	5.66	2.27	36	18

Table 16.4. Nutrient requirements of growing steer and heifer calves (continued).

			Diet nutrient density						*Daily nutrients per animal*					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (%DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,400 pounds at finishing														
300	0.5	7.8	54	0.49	0.24	9.4	0.31	0.17	4.2	3.1	0.39	0.73	14	5
	1.0	8.3	58	0.56	0.30	11.5	0.48	0.23	4.8	3.1	0.84	0.95	18	9
	1.5	8.6	63	0.63	0.36	13.7	0.63	0.29	5.4	3.1	1.31	1.17	23	14
	2.0	8.6	68	0.70	0.42	16.2	0.80	0.36	5.8	3.1	1.80	1.40	32	14
	2.5	8.6	73	0.78	0.50	18.7	0.96	0.43	6.3	3.1	2.30	1.61	36	18
	3.0	8.3	80	0.88	0.58	22.0	1.18	0.52	6.6	3.1	2.81	1.83	45	18
400	0.5	9.7	54	0.49	0.24	8.8	0.28	0.16	5.2	3.8	0.49	0.85	14	9
	1.0	10.3	58	0.56	0.30	10.4	0.39	0.20	6.0	3.8	1.04	1.07	18	9
	1.5	10.6	63	0.63	0.36	12.2	0.51	0.25	6.7	3.8	1.63	1.30	23	14
	2.0	10.7	68	0.70	0.42	14.1	0.63	0.30	7.3	3.8	2.23	1.51	32	14
	2.5	10.7	73	0.78	0.50	16.1	0.76	0.35	7.8	3.8	2.85	1.72	36	18
	3.0	10.4	80	0.88	0.58	18.7	0.90	0.41	8.3	3.8	3.49	1.94	41	18
500	0.5	11.5	54	0.49	0.24	8.4	0.25	0.15	6.2	4.5	0.58	0.97	14	9
	1.0	12.2	58	0.56	0.30	9.8	0.34	0.18	7.1	4.5	1.23	1.19	18	9
	1.5	12.6	63	0.63	0.36	11.2	0.43	0.22	7.9	4.5	1.93	1.41	27	14
	2.0	12.6	68	0.70	0.42	12.9	0.53	0.26	8.6	4.5	2.64	1.63	32	14
	2.5	12.6	73	0.78	0.50	14.6	0.63	0.30	9.2	4.5	3.37	1.84	36	18
	3.0	12.2	80	0.88	0.58	16.8	0.75	0.35	9.8	4.5	4.12	2.05	41	18
600	0.5	13.2	54	0.49	0.24	8.2	0.24	0.15	7.1	5.2	0.66	1.08	14	9
	1.0	14.0	58	0.56	0.30	9.3	0.31	0.17	8.1	5.2	1.42	1.31	18	9
	1.5	14.4	63	0.63	0.36	10.6	0.38	0.20	9.1	5.2	2.21	1.52	27	14
	2.0	14.4	68	0.70	0.42	12.1	0.46	0.23	9.8	5.2	3.03	1.74	32	14
	2.5	14.4	73	0.78	0.50	13.5	0.54	0.26	10.5	5.2	3.87	1.95	36	18
	3.0	14.0	80	0.88	0.58	15.4	0.64	0.31	11.2	5.2	4.73	2.16	41	18
700	0.5	14.8	54	0.49	0.24	8.0	0.23	0.14	8.0	5.8	0.74	1.18	14	9
	1.0	15.7	58	0.56	0.30	9.0	0.29	0.17	9.1	5.8	1.59	1.42	23	14
	1.5	16.2	63	0.63	0.36	10.1	0.34	0.19	10.2	5.8	2.48	1.64	27	14
	2.0	16.3	68	0.70	0.42	11.3	0.41	0.21	11.1	5.8	3.40	1.85	32	18
	2.5	16.2	73	0.78	0.50	12.7	0.47	0.24	11.8	5.8	4.34	2.05	36	18
	3.0	15.8	80	0.88	0.58	14.4	0.55	0.27	12.6	5.8	5.30	2.27	41	18

Table 16.5. Nutrient requirements of growing yearlings.

			Diet nutrient density						Daily nutrients per animal					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,100 pounds at finishing														
605	0.7	16.3	50	0.45	0.20	7.5	0.22	0.13	8.2	5.2	1.0	1.2	18	9
	1.9	17.3	60	0.61	0.35	10.0	0.36	0.19	10.4	5.2	3.0	1.7	27	14
	2.9	16.9	70	0.76	0.48	12.7	0.49	0.24	11.8	5.2	4.8	2.2	36	18
	3.6	15.9	80	0.90	0.61	15.3	0.61	0.29	12.7	5.2	6.1	2.4	45	23
	4.0	14.7	90	1.04	0.72	17.8	0.72	0.34	13.2	5.2	7.0	2.6	50	23
660	0.7	17.5	50	0.45	0.20	7.5	0.21	0.13	8.8	5.5	1.1	1.3	18	9
	1.9	18.4	60	0.61	0.35	9.7	0.34	0.18	11.0	5.5	3.2	1.8	27	14
	2.9	18.0	70	0.76	0.48	12.3	0.45	0.23	12.6	5.5	5.1	2.2	36	18
	3.6	17.0	80	0.90	0.61	14.7	0.56	0.27	13.6	5.5	6.5	2.5	45	23
	4.0	15.7	90	1.04	0.72	17.1	0.66	0.32	14.1	5.5	7.4	2.7	45	23
715	0.7	18.5	50	0.45	0.20	7.5	0.20	0.13	9.3	5.9	1.1	1.4	18	9
	1.9	19.6	60	0.61	0.35	9.2	0.32	0.17	11.8	5.9	3.5	1.8	27	14
	2.9	19.1	70	0.76	0.48	11.5	0.42	0.21	13.4	5.9	5.5	2.2	36	18
	3.6	18.1	80	0.90	0.61	13.7	0.52	0.26	14.5	5.9	6.9	2.5	41	23
	4.0	16.7	90	1.04	0.72	15.9	0.61	0.30	15.0	5.9	7.9	2.7	45	23
770	0.7	19.6	50	0.45	0.20	7.5	0.20	0.12	9.8	6.2	1.2	1.5	18	9
	1.9	20.7	60	0.61	0.35	8.8	0.30	0.16	12.4	6.2	3.6	1.8	27	14
	2.9	20.2	70	0.76	0.48	10.9	0.39	0.20	14.1	6.2	5.8	2.2	36	18
	3.6	19.1	80	0.90	0.61	12.9	0.48	0.24	15.3	6.2	7.3	2.5	41	23
	4.0	17.6	90	1.04	0.72	14.8	0.56	0.28	15.8	6.2	8.3	2.6	45	23
825	0.7	20.6	50	0.45	0.20	7.5	0.19	0.12	0.3	6.6	1.3	1.6	18	14
	1.9	21.8	60	0.61	0.35	8.4	0.28	0.16	13.1	6.6	3.8	1.8	27	18
	2.9	21.3	70	0.76	0.48	10.3	0.37	0.19	14.9	6.6	6.1	2.2	36	18
	3.6	20.1	80	0.90	0.61	12.1	0.44	0.23	16.1	6.6	7.7	2.4	41	23
	4.0	18.6	90	1.04	0.72	13.9	0.52	0.26	16.7	6.6	8.8	2.6	45	23
880	0.7	21.7	50	0.45	0.20	7.5	0.19	0.12	10.9	6.9	1.3	1.6	18	14
	1.9	22.9	60	0.61	0.35	8.1	0.27	0.15	13.7	6.9	4.0	1.9	27	14
	2.9	22.4	70	0.76	0.48	9.8	0.34	0.18	15.7	6.9	6.4	2.2	36	18
	3.6	21.1	80	0.90	0.61	11.4	0.42	0.22	16.9	6.9	8.1	2.4	41	23
	4.0	19.5	90	1.04	0.72	13.1	0.48	0.25	17.6	6.9	9.2	2.6	41	23

Table 16.5. Nutrient requirements of growing yearlings (continued).

			Diet nutrient density						*Daily nutrients per animal*					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,200 pounds at finishing														
660	0.7	17.5	50	0.45	0.20	7.5	0.22	0.13	8.8	5.5	1.1	1.3	18	9
	2.0	18.4	60	0.61	0.35	10.2	0.36	0.19	11.0	5.5	3.3	1.9	32	18
	3.0	18.0	70	0.76	0.48	13.0	0.49	0.24	12.6	5.5	5.2	2.3	41	18
	3.8	17.0	80	0.90	0.61	15.8	0.61	0.29	13.6	5.5	6.5	2.7	45	23
	4.2	15.7	90	1.04	0.72	18.4	0.72	0.34	14.1	5.5	7.4	2.9	50	23
720	0.7	18.6	50	0.45	0.20	7.5	0.21	0.13	9.3	5.9	1.1	1.4	18	9
	2.0	19.7	60	0.61	0.35	9.7	0.34	0.18	11.8	5.9	3.5	1.9	32	18
	3.0	19.2	70	0.76	0.48	12.2	0.45	0.23	13.4	5.9	5.5	2.3	41	18
	3.8	18.2	80	0.90	0.61	14.6	0.56	0.27	14.6	5.9	7.0	2.7	45	23
	4.2	16.8	90	1.04	0.72	17.0	0.66	0.32	15.1	5.9	7.9	2.9	50	23
780	0.7	19.8	50	0.45	0.20	7.5	0.20	0.13	9.9	6.3	1.2	1.5	18	14
	2.0	20.9	60	0.61	0.35	9.2	0.32	0.17	12.5	6.3	3.7	1.9	32	18
	3.0	20.4	70	0.76	0.48	11.4	0.42	0.21	14.3	6.3	5.8	2.3	41	18
	3.8	19.3	80	0.90	0.61	13.6	0.52	0.26	15.4	6.3	7.4	2.6	45	23
	4.2	17.8	90	1.04	0.72	15.8	0.61	0.30	16.0	6.3	8.4	2.8	50	23
840	0.7	20.9	50	0.45	0.20	7.5	0.20	0.13	10.5	6.6	1.3	1.6	18	14
	2.0	22.1	60	0.61	0.35	8.8	0.30	0.16	13.3	6.6	3.9	1.9	32	18
	3.0	21.6	70	0.76	0.48	10.8	0.39	0.20	15.1	6.6	6.2	2.3	41	18
	3.8	20.4	80	0.90	0.61	12.8	0.48	0.24	16.3	6.6	7.8	2.6	45	23
	4.2	18.8	90	1.04	0.72	14.7	0.56	0.28	16.9	6.6	8.9	2.8	54	23
900	0.7	22.0	50	0.45	0.20	7.5	0.19	0.12	11.0	7.0	1.3	1.7	18	14
	2.0	23.3	60	0.61	0.35	8.4	0.28	0.16	14.0	7.0	4.1	2.0	27	18
	3.0	22.7	70	0.76	0.48	10.2	0.37	0.19	15.9	7.0	6.5	2.3	36	18
	3.8	21.5	80	0.90	0.61	12.0	0.44	0.23	17.2	7.0	8.3	2.6	45	23
	4.2	19.8	90	1.04	0.72	13.8	0.52	0.26	17.8	7.0	9.4	2.7	45	23
960	0.7	23.1	50	0.45	0.20	7.5	0.19	0.12	11.6	7.3	1.4	1.7	18	14
	2.0	24.4	60	0.61	0.35	8.1	0.27	0.15	14.6	7.3	4.3	2.0	32	18
	3.0	23.9	70	0.76	0.48	9.7	0.34	0.19	16.7	7.3	6.8	2.3	36	23
	3.8	22.5	80	0.90	0.61	11.3	0.41	0.22	18.0	7.3	8.7	2.5	41	23
	4.2	20.8	90	1.04	0.72	13.0	0.48	0.25	18.7	7.3	9.9	2.7	45	23

Table 16.5.Nutrient requirements of growing yearlings (continued).

			Diet nutrient density						Daily nutrients per animal					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,300 pounds at finishing														
715	0.8	18.5	50	0.45	0.20	7.5	0.22	0.13	9.3	5.9	1.1	1.4	18	9
	2.1	19.6	60	0.61	0.35	10.2	0.36	0.19	11.8	5.9	3.5	2.0	33	18
	3.2	19.1	70	0.76	0.48	13.0	0.49	0.24	13.4	5.9	5.5	2.5	42	23
	4.0	18.1	80	0.90	0.61	15.7	0.61	0.29	14.5	5.9	6.9	2.8	50	23
	4.5	16.7	90	1.04	0.72	18.3	0.72	0.34	15.0	5.9	7.9	3.1	54	27
780	0.8	19.8	50	0.45	0.20	7.5	0.21	0.13	9.9	6.3	1.2	1.5	18	14
	2.1	20.9	60	0.61	0.35	9.6	0.34	0.18	12.5	6.3	3.7	2.0	32	18
	3.2	20.4	70	0.76	0.48	12.1	0.45	0.23	14.3	6.3	5.8	2.5	41	23
	4.0	19.3	80	0.90	0.61	14.5	0.56	0.27	15.4	6.3	7.4	2.8	50	23
	4.5	17.8	90	1.04	0.72	16.9	0.66	0.32	16.0	6.3	8.4	3.0	54	27
845	0.8	21.0	50	0.45	0.20	7.5	0.21	0.13	10.5	6.7	1.3	1.6	18	14
	2.1	22.2	60	0.61	0.35	9.1	0.32	0.17	13.3	6.7	3.9	2.0	32	18
	3.2	21.7	70	0.76	0.48	11.4	0.42	0.22	15.2	6.7	6.2	2.5	41	23
	4.0	20.5	80	0.90	0.61	13.6	0.51	0.26	16.4	6.7	7.9	2.8	50	23
	4.5	18.9	90	1.04	0.72	15.7	0.60	0.30	17.0	6.7	8.9	3.0	50	27
910	0.8	22.2	50	0.45	0.20	7.5	0.20	0.13	11.1	7.1	1.4	1.7	18	14
	2.1	23.5	60	0.61	0.35	8.7	0.30	0.17	14.1	7.1	4.1	2.0	32	18
	3.2	22.9	70	0.76	0.48	10.7	0.39	0.20	16.0	7.1	6.6	2.5	41	23
	4.0	21.6	80	0.90	0.61	12.7	0.48	0.24	17.3	7.1	8.3	2.7	45	23
	4.5	20.0	90	1.04	0.72	14.6	0.56	0.28	18.0	7.1	9.4	3.0	50	27
975	0.8	23.4	50	0.45	0.20	7.5	0.20	0.13	11.7	7.4	1.4	1.7	23	14
	2.1	24.7	60	0.61	0.35	8.3	0.28	0.16	14.8	7.4	4.4	2.1	32	18
	3.2	24.1	70	0.76	0.48	10.2	0.37	0.19	16.9	7.4	6.9	2.5	50	23
	4.0	22.8	80	0.90	0.61	11.9	0.44	0.23	18.2	7.4	8.8	2.7	45	23
	4.5	21.0	90	1.04	0.72	13.7	0.52	0.26	18.9	7.4	9.9	2.9	50	27
1,040	0.8	24.5	50	0.45	0.20	7.5	0.19	0.13	12.3	7.8	1.5	1.8	23	14
	2.1	25.9	60	0.61	0.35	8.0	0.27	0.15	15.5	7.8	4.6	2.1	32	18
	3.2	25.3	70	0.76	0.48	9.6	0.34	0.19	17.7	7.8	7.2	2.4	41	23
	4.0	23.9	80	0.90	0.61	11.3	0.41	0.22	19.1	7.8	9.2	2.7	45	23
	4.5	22.1	90	1.04	0.72	12.9	0.48	0.25	19.9	7.8	10.4	2.9	50	27

Table 16.5. Nutrient requirements of growing yearlings (continued).

			Diet nutrient density						*Daily nutrients per animal*					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,400 pounds at finishing														
770	0.8	19.6	50	0.45	0.20	7.5	0.22	0.13	9.8	6.2	1.2	1.5	18.	14
	2.2	20.7	60	0.61	0.35	10.1	0.36	0.19	12.4	6.2	3.7	2.1	36	18
	3.4	20.2	70	0.76	0.48	12.9	0.49	0.24	14.1	6.2	5.8	2.6	41	23
	4.2	19.1	80	0.90	0.61	15.6	0.61	0.29	15.3	6.2	7.3	3.0	54	27
	4.7	17.6	90	1.04	0.72	18.1	0.72	0.34	15.8	6.2	8.3	3.2	59	27
840	0.8	20.9	50	0.45	0.20	7.5	0.21	0.13	10.5	6.6	1.3	1.6	18	14
	2.2	22.1	60	0.61	0.35	9.6	0.34	0.18	13.3	6.6	3.9	2.1	36	18
	3.4	21.6	70	0.76	0.48	12.1	0.45	0.23	15.1	6.6	6.2	2.6	41	23
	4.2	20.4	80	0.90	0.61	14.5	0.56	0.27	16.3	6.6	7.8	3.0	50	27
	4.7	18.8	90	1.04	0.72	16.8	0.65	0.32	16.9	6.6	8.9	3.2	54	27
910	0.8	22.2	50	0.45	0.20	7.5	0.21	0.13	11.1	7.1	1.4	1.7	23	14
	2.2	23.5	60	0.61	0.35	9.1	0.32	0.17	14.1	7.1	4.1	2.1	36	18
	3.4	22.9	70	0.76	0.48	11.3	0.42	0.22	16.0	7.1	6.6	2.6	41	23
	4.2	21.6	80	0.90	0.61	13.5	0.51	0.26	17.3	7.1	8.3	2.9	50	27
	4.7	20.0	90	1.04	0.72	15.6	0.60	0.3	18.0	7.1	9.5	3.1	54	27
980	0.8	23.5	50	0.45	0.20	7.5	0.20	0.13	11.8	7.5	1.4	1.8	23	14
	2.2	24.8	60	0.61	0.35	8.7	0.30	0.17	14.9	7.5	4.4	2.2	32	18
	3.4	24.2	70	0.76	0.48	10.7	0.39	0.20	16.9	7.5	6.9	2.6	41	23
	4.2	22.9	80	0.90	0.61	12.6	0.47	0.24	18.3	7.5	8.8	2.9	50	27
	4.7	21.1	90	1.04	0.72	14.5	0.56	0.28	19.0	7.5	10.0	3.1	54	27
1,050	0.8	24.7	50	0.45	0.20	7.5	0.20	0.13	12.4	7.9	1.5	1.9	23	14
	2.2	26.1	60	0.61	0.35	8.3	0.28	0.16	5.7	7.9	4.6	2.2	32	18
	3.4	25.5	70	0.76	0.48	10.1	0.37	0.20	17.9	7.9	7.3	2.6	41	23
	4.2	24.1	80	0.90	0.61	11.9	0.44	0.23	19.3	7.9	9.3	2.9	50	27
	4.7	22.2	90	1.04	0.72	13.6	0.51	0.26	20.0	7.9	10.5	3.0	50	27
1,120	0.8	25.9	50	0.45	0.20	7.5	0.19	0.13	13.0	8.2	1.6	1.9	23	14
	2.2	27.4	60	0.61	0.35	8.0	0.27	0.16	16.4	8.2	4.8	2.2	32	18
	3.4	26.8	70	0.76	0.48	9.6	0.34	0.19	18.8	8.2	7.7	2.6	41	23
	4.2	25.3	80	0.90	0.61	11.2	0.41	0.22	20.2	8.2	9.7	2.8	45	27
	4.7	23.3	90	1.04	0.72	12.8	0.48	0.25	21.0	8.2	11.1	3.0	50	27

Table 16.6. Nutrient requirements of growing and mature bulls.

			Diet nutrient density						Daily nutrients per animal					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
1,700-pound mature weight														
900	0.4	22	50	0.45	0.20	7.5	0.16	0.11	11.0	8.0	0.9	1.7	18	14
	1.6	23	60	0.61	0.35	7.5	0.23	0.14	14.0	8.0	3.5	1.7	23	14
	2.5	23	70	0.76	0.48	8.8	0.30	0.16	15.9	8.0	5.8	2.0	32	18
	3.1	22	80	0.90	0.61	10.2	0.36	0.19	17.2	8.0	7.6	2.2	36	18
1,000	0.4	24	50	0.45	0.20	7.5	0.16	0.11	11.9	8.7	1.0	1.8	18	14
	1.6	25	60	0.61	0.35	7.5	0.22	0.13	15.1	8.7	3.8	1.9	27	14
	2.5	25	70	0.76	0.48	8.1	0.27	0.15	17.2	8.7	6.3	2.0	32	18
	3.1	23	80	0.90	0.61	9.3	0.32	0.18	18.6	8.7	8.2	2.2	32	18
1,100	0.4	26	50	0.45	0.20	7.5	0.16	0.11	12.8	9.4	1.0	1.9	18	14
	1.6	27	60	0.61	0.35	7.5	0.20	0.13	16.2	9.4	4.1	2.0	27	14
	2.5	26	70	0.76	0.48	7.5	0.25	0.14	18.5	9.4	6.8	2.0	32	18
	3.1	25	80	0.90	0.61	8.6	0.29	0.16	19.9	9.4	8.8	2.1	32	18
1,200	0.4	27	50	0.45	0.20	7.5	0.16	0.11	13.7	10.0	1.1	2.0	18	14
	1.6	29	60	0.61	0.35	7.5	0.19	0.12	17.3	10.0	4.4	2.2	27	18
	2.5	28	70	0.76	0.48	7.5	0.23	0.14	19.7	10.0	7.2	2.1	27	18
	3.1	27	80	0.90	0.61	7.9	0.26	0.15	21.3	10.0	9.4	2.1	32	18
1,300	0.4	29	50	0.45	0.20	7.5	0.16	0.11	14.5	10.6	1.2	2.2	23	14
	1.6	31	60	0.61	0.35	7.5	0.19	0.12	18.4	10.6	4.6	2.3	27	18
1,400	0.4	31	50	0.45	0.20	7.5	0.16	0.11	15.4	11.2	1.2	2.3	23	18
	1.6	32	60	0.61	0.35	7.5	0.18	0.12	19.4	11.2	4.9	2.4	27	18
1,500	0.4	32	50	0.45	0.20	7.5	0.16	0.11	16.2	11.8	1.3	2.4	23	18
	1.6	34	60	0.61	0.35	7.5	0.17	0.12	20.5	11.8	5.1	2.6	27	18
1,600	0.4	34	50	0.45	0.20	7.5	0.16	0.12	17.0	12.4	1.4	2.6	23	18
	1.6	36	60	0.61	0.35	7.5	0.16	0.11	21.5	12.4	5.4	2.7	27	18
1,700	0.0	33	46	0.39	0.00	7.5	0.16	0.12	15.1	13.0	0.0	2.5	23	18
	0.4	36	50	0.45	0.20	7.5	0.16	0.12	17.8	13.0	1.4	2.7	27	18

Table 16.6. Nutrient requirements of growing and mature bulls (continued).

			Diet nutrient density						*Daily nutrients per animal*					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
2,000-pound mature weight														
1,000	0.5	24	50	0.45	0.20	7.5	0.17	0.12	11.9	8.7	1.0	1.8	18	14
	1.7	25	60	0.61	0.35	7.5	0.25	0.14	15.1	8.7	3.8	1.9	27	18
	2.8	25	70	0.76	0.48	9.1	0.32	0.17	17.2	8.7	6.3	2.2	36	18
	3.5	23	80	0.90	0.61	10.5	0.38	0.20	18.6	8.7	8.2	2.4	41	22.7
1,100	0.5	26	50	0.45	0.20	7.5	0.17	0.12	12.8	9.4	1.0	1.9	18	14
	1.7	27	60	0.61	0.35	7.5	0.23	0.14	16.2	9.4	4.1	2.0	27	18
	2.8	26	70	0.76	0.48	8.4	0.29	0.16	18.5	9.4	6.8	2.2	36	18
	3.5	25	80	0.90	0.61	9.8	0.35	0.19	19.9	9.4	8.8	2.4	41	23
1,200	0.5	27	50	0.45	0.20	7.5	0.17	0.12	13.7	10.0	1.1	2.0	23	14
	1.7	29	60	0.61	0.35	7.5	0.22	0.13	17.3	10.0	4.3	2.2	27	18
	2.8	28	70	0.76	0.48	7.9	0.27	0.16	19.7	10.0	7.2	2.2	36	18
	3.5	27	80	0.90	0.61	9.0	0.32	0.18	21.3	10.0	9.4	2.4	36	23
1,300	0.5	29	50	0.45	0.20	7.5	0.17	0.12	14.5	10.6	1.2	2.2	23	14
	1.7	31	60	0.61	0.35	7.5	0.21	0.13	18.4	10.6	4.6	2.3	27	18
	2.8	30	70	0.76	0.48	7.5	0.25	0.15	21.0	10.6	7.7	2.3	32	18
	3.5	28	80	0.90	0.61	8.4	0.29	0.17	22.6	10.6	10.0	2.4	36	23
1,400	0.5	31	50	0.45	0.20	7.5	0.16	0.12	15.4	11.2	1.2	2.3	23	18
	1.7	32	60	0.61	0.35	7.5	0.20	0.13	19.4	11.2	4.9	2.4	27	18
1,500	0.5	32	50	0.45	0.20	7.5	0.16	0.12	16.2	11.8	1.3	2.4	23	18
	1.7	34	60	0.61	0.35	7.5	0.19	0.13	20.5	11.8	5.1	2.6	32	18
1,600	0.5	34	50	0.45	0.20	7.5	0.17	0.12	17.0	12.4	1.4	2.6	27	18
	1.7	36	60	0.61	0.35	7.5	0.18	0.12	21.5	12.4	5.4	2.7	32	18
1,700	0.5	36	50	0.45	0.20	7.5	0.16	0.12	17.8	13.0	1.4	2.7	27	18
	1.7	38	60	0.61	0.35	7.5	0.18	0.12	22.5	13.0	5.6	2.9	32	23
1,800	0.5	37	50	0.45	0.20	7.5	0.16	0.12	18.5	13.5	1.5	2.9	27	18
	1.7	39	60	0.61	0.35	7.5	0.17	0.12	23.5	13.5	5.9	2.8	32	23
1,900	0.5	39	50	0.45	0.20	7.5	0.16	0.12	19.3	14.1	1.5	2.9	27	23
	1.7	41	60	0.61	0.35	7.5	0.17	0.12	24.5	14.1	6.1	3.1	32	23
2,000	0.0	37	46	0.39	0.00	7.5	0.17	0.13	17.1	14.6	0.0	2.8	27	23
	0.5	40	50	0.45	0.20	7.5	0.16	0.12	20.1	14.6	1.6	3.0	32	23

Table 16.6. Nutrient requirements of growing and mature bulls (continued).

			Diet nutrient density						Daily nutrients per animal					
Body weight (lbs)	*ADG (lbs)*	*DM intake (lbs/day)*	*TDN (% DM)*	*NEm (Mcal/lb)*	*NEg (Mcal/lb)*	*CP (% DM)*	*Ca (% DM)*	*P (% DM)*	*TDN (lbs)*	*NEm (Mcal)*	*NEg (Mcal)*	*CP (lbs)*	*Ca (grams)*	*P (grams)*
2,300-pound mature weight														
1,200	0.5	27	50	0.45	0.20	7.5	0.18	0.12	13.7	10.0	1.1	2.0	23	14
	1.9	29	60	0.61	0.35	7.5	0.24	0.14	17.3	10.0	4.4	2.2	32	18
	3.0	28	70	0.76	0.48	8.7	0.30	0.17	19.7	10.0	7.2	2.5	41	23
	3.8	27	80	0.90	0.61	10.1	0.36	0.20	21.3	10.0	9.4	2.7	45	23
1,300	0.5	29	50	0.45	0.20	7.5	0.17	0.12	14.5	10.6	1.2	2.2	23	18
	1.9	31	60	0.61	0.35	7.5	0.23	0.14	18.4	10.6	4.6	2.3	32	18
	3.0	30	70	0.76	0.48	8.2	0.28	0.16	21.0	10.6	7.7	2.5	41	23
	3.8	28	80	0.90	0.61	9.4	0.34	0.19	22.6	10.6	10.0	2.7	45	23
1,400	0.5	31	50	0.45	0.20	7.5	0.17	0.12	15.4	11.2	1.2	2.3	23	18
	1.9	32	60	0.61	0.35	7.5	0.22	0.14	19.4	11.2	4.9	2.4	32	18
	3.0	32	70	0.76	0.48	7.7	0.26	0.15	22.2	11.2	8.1	2.4	36	23
	3.8	30	80	0.90	0.61	8.8	0.31	0.18	23.9	11.2	12.5	2.6	41	23
1,500	0.5	32	50	0.45	0.20	7.5	0.17	0.12	16.2	11.8	1.3	2.4	27	18
	1.9	34	60	0.61	0.35	7.5	0.21	0.13	20.5	11.8	5.2	2.6	32	23
1,600	0.5	34	50	0.45	0.20	7.5	0.17	0.12	17.0	12.4	1.4	2.6	27	18
	1.9	36	60	0.61	0.35	7.5	0.20	0.13	21.5	12.4	5.4	2.7	32	23
1,700	0.5	36	50	0.45	0.20	7.5	0.17	0.12	17.8	13.0	1.4	2.7	27	18
	1.9	38	60	0.61	0.35	7.5	0.19	0.13	22.5	13.0	5.7	2.9	32	23
1,800	0.5	37	50	0.45	0.20	7.5	0.17	0.12	18.5	13.5	1.5	2.8	27	23
	1.9	39	60	0.61	0.35	7.5	0.19	0.13	23.5	13.5	5.9	2.9	32	23
1,900	0.5	39	50	0.45	0.20	7.5	0.17	0.12	19.3	14.1	1.5	2.9	32	23
	1.9	41	60	0.61	0.35	7.5	0.18	0.13	24.5	14.1	6.2	3.1	36	23
2,000	0.5	40	50	0.45	0.20	7.5	0.17	0.12	20.1	14.6	1.6	3.0	32	23
	1.9	42	60	0.61	0.35	7.5	0.18	0.13	25.4	14.6	6.4	3.2	36	23
2,100	0.5	42	50	0.45	0.20	7.5	0.17	0.13	20.8	15.2	1.7	3.3	32	23
	1.9	44	60	0.61	0.35	7.5	0.17	0.12	26.3	15.2	6.6	3.3	36	23
2,200	0.5	43	50	0.45	0.20	7.5	0.17	0.13	21.6	15.7	1.7	3.2	32	23
	1.9	46	60	0.61	0.35	7.5	0.17	0.12	27.3	15.7	6.9	3.5	36	27
2,300	0.0	45	46	0.39	0.00	7.5	0.16	0.12	20.5	16.3	0.0	3.4	32	23
	0.5	47	50	0.45	0.20	7.5	0.16	0.12	23.5	16.3	1.8	3.5	36	27

Table 16.7. Mineral requirements and maximum tolerable concentration and vitamin requirements, dry matter basis.

			Cows		
Mineral/vitamin	*Unit*	*Growing and finishing*[a]	*Gestation*	*Early lactation*	*Maximum tolerable level*
Magnesium	%	0.10	0.12	0.20	0.40
Potassium	%	0.60	0.60	0.70	3.00
Sodium	%	0.06-0.08	0.06-0.08	0.10	--
Sulfur	%	0.15	0.15	0.15	0.35 or 0.5[b]
Cobalt	ppm	0.15	0.15	0.15	25.00
Copper	ppm	10.00	10.00	10.00	40.00
Iodine	ppm	0.50	0.50	0.50	50.00
Iron	ppm	50.00	50.00	50.00	500.00
Manganese	ppm	20.00	40.00	40.00	1,000.00
Selenium	ppm	0.10	0.10	0.10	5.00
Zinc	ppm	30.00	30.00	30.00	500.00
Vitamin A	IU/lb	1,000.00	1,270.00	1,770.00	--
Vitamin D	IU/lb	125.00	125.00	125.00	--
Vitamin E[c]	IU/lb	16.00	16.00	16.00	--

a Also for breeding bulls.
b Maximum tolerable level recommended by NRC (205) = 0.5% of diet dry matter for cattle consuming diets with >40% forage and 0.35% of diet dry matter for cattle conuming diets with <1% forage.
c 108 to 225 for high-stress receiving cattle.
Source: NASEM, 2016.

Table 16.8. Approximate total daily water intake of beef cattle (gallons)[a].

	Temperature (F)[b]					
Weight (lbs)	*40*	*50*	*60*	*70*	*80*	*90*
Water intake (gallons/day)						
Growing heifers, steers and bulls						
400	4.0	4.3	5.0	5.8	6.7	9.5
600	5.3	5.8	6.6	7.8	8.9	12.7
800	6.1	6.8	7.9	9.2	10.6	15.0
Finishing cattle						
600	6.0	6.5	7.4	8.7	10.0	14.3
800	7.3	7.9	9.1	10.7	12.3	17.4
1,000	8.7	9.4	10.8	12.6	14.5	20.6

Wintering pregnant and lactating cows

Cow Body Weight (lb)	Milk Production (lb/day)	*Gallons of Water/ Day 40	65	90
1,100	0	8.2	10.8	13.4
1,100	10	10.5	13.1	15.7
1,100	25	12.8	15.4	17.9
1,300	0	9.2	11.8	14.3
1,300	15	12.2	14.8	17.4
1,300	30	14.5	17.1	19.7
1,500	0	10.2	12.7	15.3
1,500	20	14.0	16.5	19.1
1,500	35	16.3	18.8	21.4

*1 gallon is equivalent to 8.35 pounds.

a Adapted from NASEM, 2000.
b Water intake of a given class of cattle in a specific management regime is a function of dry matter intake and ambient temperature. Water intake is quite constant up to 40 F.
c Dry matter intake has a major influence on water intake. Heavier cows are assumed to be higher in body condition and to require less dry matter and thus, less water intake.
d Cows larger than 900 pounds are included in this recommendation.

17 Nutritive Values of Feeds

Paul Beck, David Lalman and Alexi Moehlenpah

Objectives

- **Discuss chemical composition and nutrient content of feeds.**
- **Present average nutrient values for common Oklahoma feeds.**

Animals require consumption of chemical elements and compounds to sustain bodily functions to support the reproductive process and for skeletal and tissue growth. The necessary chemical elements and compounds are referred to as nutrients and can be classified into six categories: water, carbohydrates, lipids or fats, proteins, minerals and vitamins. Requirements for these nutrients were discussed in chapter 16. The objective of feed evaluation is to provide a rapid and economical method to determine the nutrients available (nutritional value) of a feed. For more than 100 years, the proximate analysis system has been used to describe the chemical composition of feeds. Components of proximate analysis are shown in Figure 17.1.

Nutritional value is determined by nutrient concentration and nutrient digestibility. Proximate analysis is one method used to determine nutrient concentration, although very little information about nutrient digestibility is gained. True nutrient digestibility information is determined using digestion trials, but it is not practical to test digestibility on all feeds. Therefore, previous digestibility information from similar feeds and previous relationships between digestibility and some nutrient concentration measures is commonly used to estimate digestibility. Table 16.1 contains average nutrient concentration values for numerous feeds that can be used in cattle diets. Values in the table represent averages from numerous different sources, such as the National Academy of Sciences, Engineering and Medicine's, Nutrient Requirements of Beef and Dairy Cattle publications, commercial laboratories, research trials and other publications.

Producers must recognize values published in any table are merely averages. Variation among grains, oilseeds, byproducts and, in particular, forages and roughages, can be extreme. Furthermore, various processing methods also may alter digestibility. For this reason, producers are advised to have their feeds and forages tested for nutrient composition by a feed testing laboratory. To improve quality control and standardization among commercial laboratories, the National Forage Testing Association (NFTA), found at foragetesting.org, provides a unique certification service. At this website, one also can view the NFTA's recommendations for laboratory procedures and equations for use in predicting energy availability for different forage types.

Wet chemistry procedures are more expensive, although they represent the standard for nutritive values. Many laboratories will offer both. One of the primary decisions to make is whether to use wet chemistry procedures and

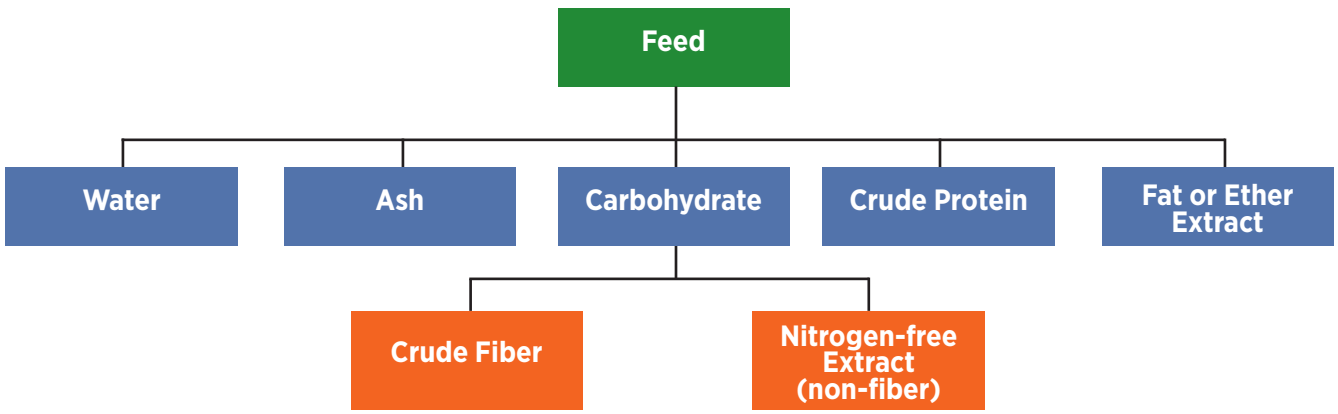


Figure 17.1. Nutrient components of feed determined from proximate analysis.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Near Infrared Reflectance Spectrophotometer (NIRS) procedures to determine protein and energy values.

NIRS analyses are less expensive. Basically, random portions of a sample are loaded into an NIR sample holder and reflected light from the ground sample is measured in the infrared region (generally 1,100 nm to 2,500 nm). The NIRS instrument is part of a system calibrated by using representative samples from the population (forage type) to be tested. Prediction equations are selected based on calibration statistics. Consequently, it is important to know whether the laboratory is using equations developed with forage similar to that which you intend to have tested. For example, since alfalfa hay is common across the country, most laboratories use equations specifically designed to determine protein and energy content of alfalfa hay. However, grass and other legume species can vary widely in cell structure and chemical composition. Generally, NIRS is less costly because it predicts wet chemistry values by bouncing light through samples. With this type of analysis, the lab should have a list of types of feed samples they can analyze by this method. For instance, most labs can perform quality NIRS analysis on alfalfa samples. Consider having wet chemistry analysis completed on feeds that the laboratory has not calibrated for NIRS.

Dry Matter

Dry matter (DM) expresses the proportion of the feed that is not water. The moisture concentration is determined by weighing the feed sample soon after it has been collected. Next, the sample is placed in a drying oven until all of the water has evaporated. Finally, the dried sample is weighed again and the DM content is calculated by the difference. Other than physical characteristics of the feed, moisture content has little to no bearing on the availability of nutrients within that feed.

Dry matter is an extremely variable component among and within types of feeds. Fresh forages, silages and wet byproduct feeds are likely to vary the most in DM content. Some silages and byproduct feeds contain as little as 25% DM (75% moisture). A good rule of thumb is that dry feeds should contain no more than 12% moisture for safe storage in overhead bins.

Fiber

The original proximate analysis system separated carbohydrates into crude fiber and nitrogen-free extract (NFE) fractions. The crude fiber portion of the feedstuff was intended to represent the indigestible fiber fraction, while NFE was supposed to represent the more readily digestible carbohydrates, such as sugars and starches. However, it was soon discovered this system had serious limitations, particularly for fibrous feeds like forages.

Because of the wide variation in chemical analyses for crude fiber and NFE, a new system called the detergent fiber system was developed, which better reflects true carbohydrate digestibility in ruminants (Figure 17.2). The neutral detergent solubles (NDS) fraction is comprised of cell contents that are nearly 100% digestible. The neutral detergent insoluble fiber (NDF) fraction is primarily cell wall tissue, which consists of hemicellulose, cellulose and lignin. The NDF fraction also contains small amounts of silica and fiber-bound or heat-damaged protein. The NDF fraction of feeds and forages is quite variable in digestibility. Using an acid solution, the NDF residue can be further separated into acid detergent solubles (ADS; primarily hemicellulose) and acid detergent insoluble fiber (Figure 17.3). The acid detergent insoluble fiber fraction contains cellulose and lignin. The lignin portion is nearly indigestible, whereas the cellulose portion is variable in digestibility.

With purchased feeds that come with a feed tag, crude fiber is the only fiber analysis required. Unfortunately, this provides little assistance in determining the nutrient value or digestibility of the feed. However, it may be possible for a feed representative to provide NDF and ADF values.

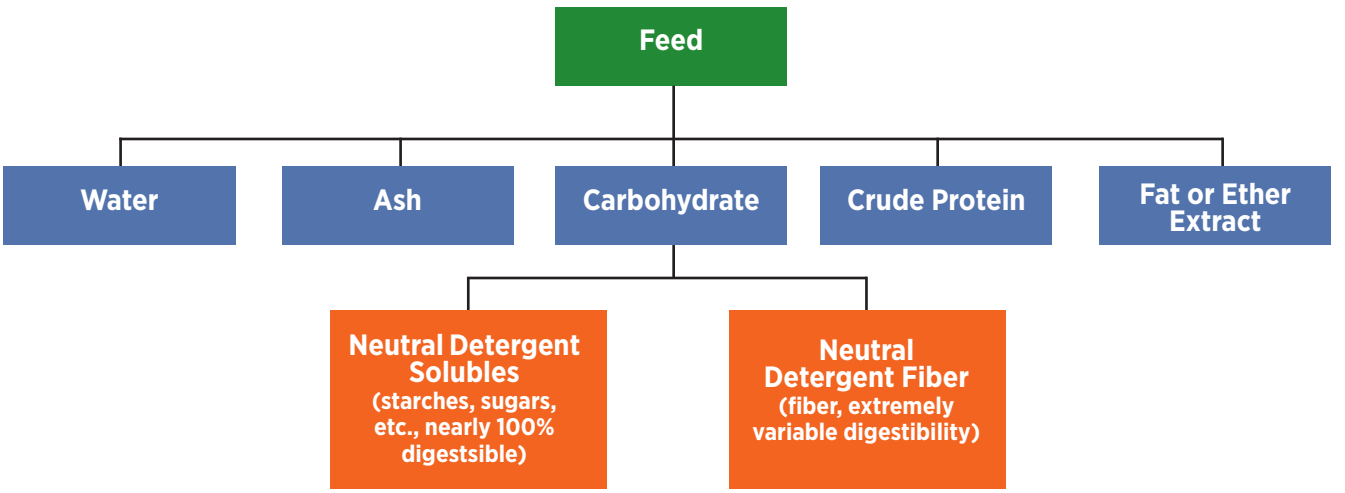


Figure 17.2. The detergent fiber system.

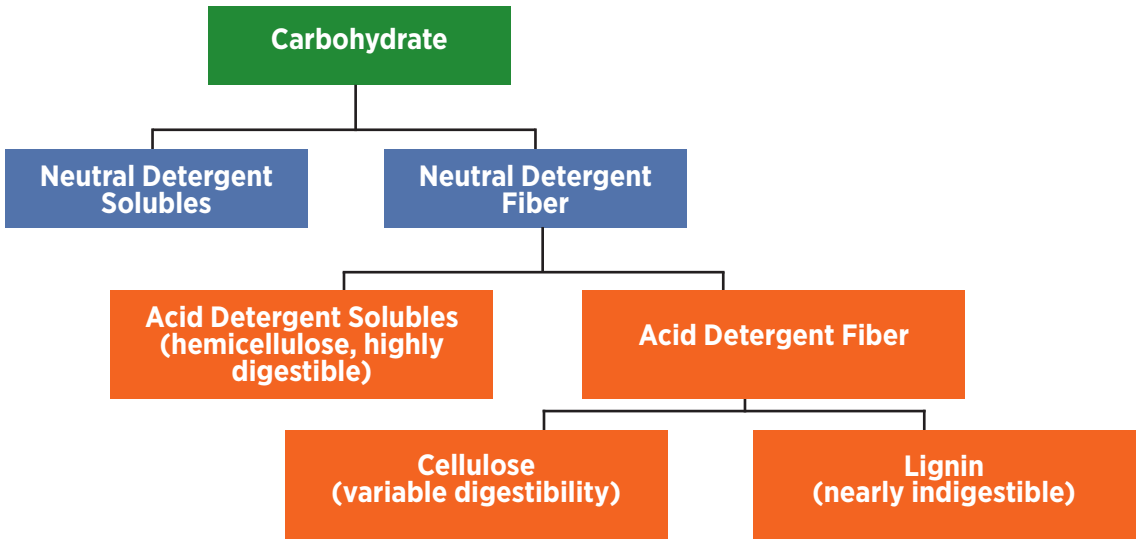


Figure 17.3. Fiber fractions in the detergent fiber system.

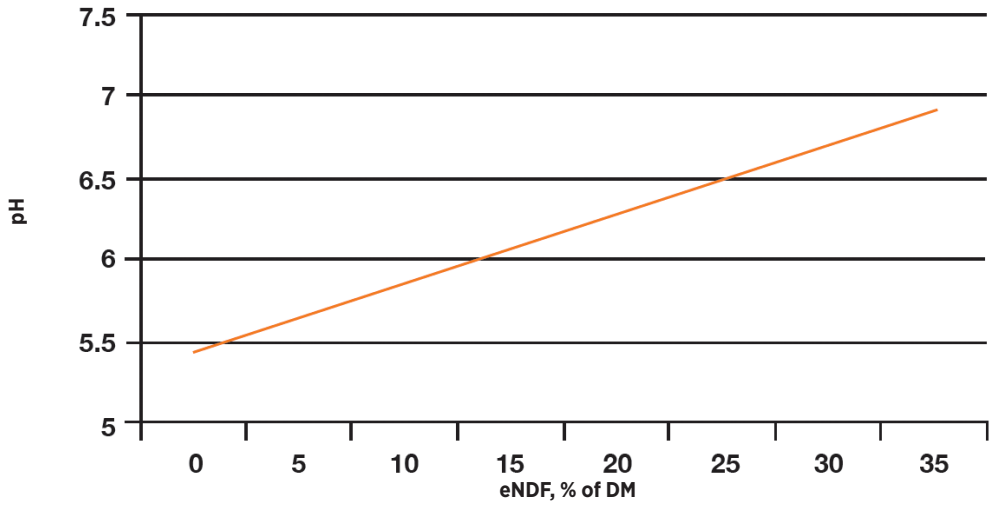


Figure 17.4. The relationship of effective NDF and rumen pH.

NDF concentration is inversely related to the amount of the feed the cattle will eat. Because digestibility of fiber is proportional to the amount of lignin in the plant material, ADF is inversely related to the digestibility of feed ingredients. This relationship explains why some forages and feeds contain high NDF concentrations, but remain high in digestibility, while others may contain moderate or low NDF concentrations, yet are low in digestible energy.

Effective NDF

The physical effectiveness factor (pef) value shown in Table 17.1 is a measure of the feed particle size and an indication of its potential to stimulate chewing. NDF is effective in stimulating rumen motility or churning (Figure 17.4). The physical effectiveness factor ranges from 0 to 1.0. This factor is multiplied by the NDF concentration to determine the physically effective NDF content of the feed (peNDF). Long-stem grass hay has a pef of 1.0 and other feeds are rated relative to grass hay according to particle size. Most of the pef values provided in Table 17.1 are estimates based on particle size and nDF content.

For example, chopped alfalfa haylage has NDF of 42% (dry matter basis) and pef of 0.6. Therefore the peNDF value is 25.2%. From there, average diet peNDF is calculated and used to predict ruminal pH. Diets containing lower peNDF and lower ruminal pH require more intensive management due to increasing risk of acidosis, bloat and founder. Between 12% and 20% peNDF is recommended for growing cattle and for limit-fed diets (NASEM 2016). The layman term for eNDF is the scratch value of the feed. If the rumen stops churning, acidic gases build up causing the pH to drop. The result is bloat, acidosis and/or founder, as well as reduced diet digestibility. Table 17.1 expresses eNDF as a percentage of NDF. This value is determined by several factors including particle size, density, hydration and degree

of lignification. To maintain optimal forage digestion, the diet should contain a minimum of 20% eNDF on a DM basis.

Protein

Requirements for metabolizable, degradable and crude protein (CP) were discussed in chapter 16. Protein values in Table 16.1 reflect CP, which is simply nitrogen concentration multiplied by 6.25. The rumen degradable intake protein (RDIP) column is an estimate of the proportion of the crude protein that is actually degradable in the rumen and is expressed as a percentage of CP. Rumen undegradable protein (percent of CP) can be calculated by subtracting the RDIP value from 100.

Feed Energy Values

Feed energy values are expressed on a DM basis as percent total digestible nutrients (TDN), net energy for maintenance (NEm) and net energy for gain (NEg) units (mega calories per 100 pounds of feed). TDN is determined by carrying out a digestion trial and summing the digestible protein and carbohydrates plus 2.25 times digestible ether extract. Ether extract (EE) is the fat or lipid portion of the feed. The net energy system is generally thought to be more precise in estimating the energy value of feeds, particularly roughages. The net energy of feed is the portion available to the animal for maintenance or various productive purposes. The portion used for maintenance (NEm) is used for muscular work, maintenance and repair of tissues, maintaining a stable body temperature and other body functions. Most of this digested energy will leave the animal's body as heat. Energy used for productive purposes (NEg) may be recovered as growth through retaining energy in tissues. Energy for productive purposes is less efficient than energy used for maintenance. Milk production is unique because its energy efficiency is similar to maintenance uses.

Minerals

Minerals needed by animals in larger quantities are referred to as macro minerals. These minerals are shown in Table 17.1 and feed concentration is expressed on a percent of DM basis. Minerals needed by animals in much smaller quantities are referred to as micro minerals and feed concentration is expressed in parts per million (ppm) in Table 17.1. To convert ppm to percent, simply move the decimal place four places to the left. For example, if a feed contained 12 ppm copper, the copper concentration expressed as a percentage would be 0.0012%.

Conclusion

Producers need to ensure their animals' diets include the proper balance of the six essential nutrients in a physical form that maintains digestive system health and function. To accomplish this, producers must have good knowledge of available feed nutrient composition, physical and digestive characteristics and the animal's nutrient requirements.

Nutrient concentration and digestibility data can be determined by using digestion trials or measuring chemical composition and applying this information to estimate digestibility. It is imperative producers recognize the values published in any table are merely averages and variation among feed commodities, oilseeds and, in particular forages and roughages, can be extreme. For this reason, producers are advised to have their feeds and forages tested for nutrient composition by commercial laboratories.

References

2014 Feed Composition Guide. (2014) Beef. Retrieved from beefmagazine.com/datasheet/2014-feed-composition-table

NRC. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, DC.

National Academy of Sciences, Engineering and Medicine (NASEM). *Nutrient Requirements of Beef Cattle* (8th Revised Edition), 2016.

Table 17.1. Typical composition of feeds and forages.

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
FEEDSTUFF																	
Hay																	
Alfalfa hay, early bloom	88	20	80	63	66	38	45	.7	34	3.0	1.56	0.30	0.41	9	41	24	0.28
Alfalfa hay, midbloom	88	18	80	60	60	34	46	.8	34	2.6	1.89	0.29	0.36	10	41	27	0.28
Alfalfa hay, mature	88	14	75	52	47	22	47	.9	36	1.3	1.52	0.26	0.28	10	44	21	0.28
Barley hay	91	10	59	54	28	58	98	.8	35	—	0.36	0.22	0.16	6.6	38	22	0.09
Bermuda hay, vegetative	90	15	80	57	55	29	69	.7	37	2.3	0.59	0.28	0.30	12	170	36	0.12
Bermuda hay, early bloom	90	10	72	53	49	24	75	.8	37	1.9	0.51	0.20	0.25	8	140	31	0.12
Bermuda hay, full bloom	90	8	68	47	39	15	79	.9	36	1.8	0.43	0.18	0.21	8	110	26	0.05
Bermuda hay, mature	88	6	70	49	42	18	78	.9	39	3.8	0.51	0.24	0.21	6	145	17	0.05
Birdsfoot trefoil, hay	89	16	78	57	57	25	50	.8	38	2.2	1.73	0.24	0.25	—		28	—
Bromegrass hay	89	10	80	55	55	21	66	.8	41	2.3	0.40	0.23	0.19	—	—	19	—
Clover ladino hay	90	21	75	61	62	31	36	.7	32	2.0	1.35	0.32	0.20	—	—	17	—
Clover red hay	88	15	72	55	55	21	51	.7	39	2.5	1.50	0.25	0.17	—	—	17	—
Clover sweet hay	91	16	70	53	53	18	50	.8	38	2.4	1.27	0.25	0.46	—	—		—
Corn stover (stalk hay)	85	6	70	50	44	19	67	1.0	39	1.3	0.57	0.10	0.14	—	—	22	—
Corn, whole hay	88	7.5	61	70	74	46	43	1.0	25	2.8	0.20	0.19	0.10	5.7	0.15	25	0.30
Fescue hay, early bloom	87	15	72	59	59	29	68	.8	31	4.8	0.45	0.37	0.21	11	200	34	—
Fescue hay, full bloom	88	9	68	50	52	16	73	.9	42	3.5	0.40	0.26	0.17	7	100	23	—
Lespedeza hay	92	14	40	54	54	20	65	.8	—	3.0	1.10	0.22	0.19	—	—	29	—
Meadow hay	90	7	77	50	50	12	70	.8	44	2.5	0.61	0.18	0.17	—	—	24	—
Millet hay	92	11	75	53	45	20	63	.8	40	1.7	0.52	0.24	0.19	10	100	38	—
Milo stalk hay	90	4	—	49	50	16	78	1.0	—	—	0.46	0.11	—	—		—	
Milo-soybean hay	90	11	72	55	48	23	58	.9	35	1.5	0.46	0.18	0.17	9	41	27	—
Oat hay	91	9	75	59	53	28	59	.8	38	2.3	0.32	0.21	0.14	8	62	19	0.17
Oat straw	91	4	60	48	48	9	73	1.0	48	2.3	0.24	0.07	0.22	—	—	6	—
Orchardgrass hay	88	10	73	59	59	28	67	.8	40	3.3	0.32	0.30	0.20	—	—	26	—
Old world bluestem hay, early bloom	90	10	—	58	59	34	—	.8	—	2.8	0.38	0.20	0.18	9	60	24	0.12
Old world bluestem hay, mature	90	6	51	52	25	—	—	.8	—	2.4	0.38	0.20	0.18	9	60	24	0.12
Peanut hay	91	11	—	57	54	28	49	.8	39	2.8	1.39	0.16	0.14	14	66	28	—
Peavine hay	91	13	—	57	52	27	47	.9	35	2.1	1.24	0.21	0.16	10	59	29	—
Prairie hay	91	6	63	52	50	12	73	.9	47	2.0	0.40	0.15	0.06	4	59	34	0.05
Rice hay	93	7	70	55	48	23	60	1.0	41	1.8	0.21	0.22	0.15	16	558	60	—
Rice straw	91	4	100	40	42	0	72	1.0	47	1.4	0.23	0.08	0.11	—	—		—
Rye grass hay	90	10	70	58	58	26	65	.9	39	3.3	0.45	0.30	0.18	7	87	27	—
Rye straw	89	4	100	44	44	1	71	1.0	55	1.5	0.24	0.09	0.11	—	—		—
Sorghum hay	91	10	—	55	47	22	62	1.0	40	1.8	0.52	0.22	0.16	11	65	32	—
Sorghum-sudan, hay	92	11	100	54	46	21	64	1.0	40	1.8	0.50	0.24	0.17	11	62	29	—
Soybean hay	92	15	100	60	57	31	47	.9	37	2.3	1.40	0.22	0.19	10	69	32	—
Soybean straw/residue	88	5	100	42	43	0	70	1.0	54	1.4	1.59	0.06	0.26	—		56	—
Sudan hay, boot stage	91	9	70	58	54	26	67	.8	43	2.6	0.40	0.26	0.06	9	41	38	0.12
Sudan hay, mature	91	5	—	52	52	24	68	1.0	44	2.4	0.45	0.20	0.06	9	37	38	0.12
Sugarcane hay	92	6	70	50	38	16	66	1.0	43	1.9	0.48	0.19	0.17	11	77	31	—
Sunflower hay	90	7	70	64	68	41	55	1.0	43	0.0	1.81	0.12	0.00	10	36	10	—
Timothy hay, early bloom	88	11	78	59	59	28	63	.8	39	2.7	0.58	0.26	0.21	—	—	30	—
Timothy hay, full bloom	88	8	75	57	57	25	65	.9	40	2.6	0.43	0.20	0.13	—	—	25	—
Triticale hay	91	11	80	59	53	27	59	.8	38	2.1	0.35	0.23	0.15	7	40	25	—
Wheat hay, immature	87	12	75	58	70	40	66	.8	38	2.2	0.15	0.20	0.22	9	60	23	0.19
Wheat hay, mature	88	9	75	48	56	31	58	.9	42	2.1	0.15	0.20	0.22	9	60	23	0.09
Wheat straw	89	4	40	41	29	5	81	1.0	58	1.8	0.18	0.05	0.19	4	41	29	0.09
Wheat straw, ammoniated	85	9	75	50	50	12	76	.9	55	1.5	0.15	0.05	0.16	5	35	6	—

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
Standing forage/Pasture/Green chop																	
Alfalfa	24	19	82	61	62	31	46	.41	34	3.0	1.35	0.27	0.29	—	—	18	—
Barley forage	38	14		62	60	34	54	—	33	3.3	0.44	0.34	0.19	8	36	40	—
Bermuda, vegetative	30	16	85	65	67	40	68	.80	—	3.0	0.46	0.31	0.33	13	185	32	0.12
Bermuda, boot stage	35	13	75	60	59	33	72	1.0	—	2.7	0.59	0.28	0.30	12	160	36	0.12
Bermuda, fall, mature	80	8	60	48	41	16	77	1.0	—	2.1	0.26	0.18	0.21	9	140	20	0.05
Bermuda, winter, mature	90	5	55	44	34	10	80	—	—	1.5	0.30	0.15	0.15	7	45	15	0.05
Bermuda, stockpiled, Nov.-Dec.	85	11	65	54	50	25	74	1.0	—	2.1	0.52	0.22	0.27	5	117	26	0.05
Bermuda, stockpiled, Sep.-Oct.	35	13	70	57	55	29	70	1.0	—	2.5	0.66	0.24	0.26	6	151	27	0.05
Bermuda, stockpiled, Jan.-Feb.	90	7	60	47	39	15	77	1.0	—	1.5	0.48	0.18	0.25	4	116	26	0.05
Birdsfoot trefoil	22	21	80	66	68	38	47	.8	31	4.4	1.78	0.25	0.25	—	—	31	—
Bluestem, mature	61	6	100	50	50	12		1.0		5.0	0.40	0.12	0.05	—	—	28	—
Brassica, immature	24	19	—	68	71	44	26	.8	21	4.2	1.71	0.39	0.60	8	52	70	—
Brassica, mature	32	13	—	79	88	59	22	.9	20	0.9	0.97	0.33	0.43	4	27	30	—
Bromegrass	30	15	88	64	65	36	54	.8	33	4.1	0.45	0.34	0.21	—	—	20	—
Cheatgrass	21	16	100	68	70	41	68	.9		2.7	0.60	0.28	—	—	—	—	
Clover ladino	19	25	80	69	71	43	35	.6	33	4.8	1.27	0.38	0.20	—	—	20	—
Clover red	24	18	79	64	65	36	44	.6	33	4.0	1.70	0.30	0.17	—	—	23	—
Corn forage	37	8	—	72	75	48	42	.9	24	2.9	0.21	0.22	0.09	6	28	23	—
Corn stalks	39	7	—	53	43	18	67	—	44	1.6	0.33	0.16	0.08	8	57	25	—
Fescue, vegetative	29	18	80	64	65	39	60	.7	32	4.5	0.50	0.40	0.24	13	175	36	—
Fescue, boot stage	33	12	75	57	55	29	65	.8	31	3.8	0.45	0.30	0.21	10	150	32	—
Fescue, mature	70	8	70	49	42	18	74	.9	42	3.2	0.38	0.20	0.18	7	120	26	—
Fescue, stockpiled, Nov.-Dec.	40	13	75	52	47	22	72	.8	36	2.7	0.45	0.30	0.21	12	150	32	—
Fescue, stockpiled, Jan.-Feb.	60	11	68	40	27	3	75	.9	37	2.2	0.38	0.20	0.18	7	120	26	—
Fodder, oat	13	18	82	70	76	49	30	.8	7	7.0	0.28	0.53	—	—	—	—	—
Fodder, wheat	24	18	82	83	92	62	31	.8	6	7.0	0.40	0.40	0.22	—	—	—	—
Fodder, wheat, short germination	12	24	82	68	71	44	31	.7	27	7.0	0.40	0.40	0.22	—	—	—	—
Legume pasture	56	27	—	68	72	44	33	.7	24	3.7	1.24	0.36	0.28	9	53	39	—
Lespedeza	25	16	50	60	60	30	60	.7	—	2.0	1.20	0.24	0.21		—	—	—
Millet forage	38	16	—	60	55	29	60	.8	36	2.5	0.47	0.33	0.22	15	110	41	—
Native range, Jan.-March	85	4	55	49	42	18	80	1.0	—	1.7	0.23	0.07		—	—	—	
Native range, April-June	30	14	75	70	74	47	68	1.0	—	3.2	0.30	0.20	0.15	11	—	—	—
Native range, July-Aug.	35	10	70	64	65	39	71	1.0	—	3.0	0.33	0.15		—	—	—	
Native range, Sept.-Oct.	46	7	65	59	58	32	75	1.0	—	2.5	0.28	0.12	—	—	—	—	—
Native range, Nov.-Dec.	75	5	65	55	52	26	78	1.0	—	2.2	0.25	0.09		—	—	—	
Oat forage	39	17	80	63	62	36	52	.7	33	3.8	0.48	0.35	0.22	8	70	29	—
Orchardgrass	24	14	77	65	66	37	54	.8	32	4.0	0.33	0.39	0.20	—		21	—
Peanut forage	26	20	—	61	60	34	50	.7	36	0.0	1.45	0.30	0.23	8	150	36	—
Peavine forage	42	20	—	65	66	39	43	.8	32	3.4	1.03	0.36	0.21	10	55	38	—
Pineapple forage	38	8	—	59	55	29	57	.9	33	1.9	0.47	0.17	0.14	11	121	48	—
Rye forage	41	20	70	66	67	40	50	.8	30	4.2	0.56	0.40	0.26	10	67	44	—
Sorghum forage	44	9	—	62	58	32	56	.9	34	2.2	0.35	0.22	0.13	8	42	29	—
Sorghum stover	87	5	100	54	54	20	65	1.0	41	1.8	0.50	0.12	—	—	—	—	
Sorghum-sudan forage	67	13	71	63	60	33	60	1.0	35	2.6	0.45	0.29	0.18	9	74	26	—
Soybean forage	74	19	—	62	60	34	44	.8	32	3.8	1.43	0.31	0.26	10	78	28	—
Sudangrass, mature	36	12	72	58	52	27	62	1.0	38	2.7	0.48	0.30	0.18	11	44	36	—
Sudangrass, immature	18	17	100	70	73	44	55	.8	29	3.9	0.46	0.36	0.11			24	—
Sunflower	18	13	—	66	70	43	40	.9	29	6.3	1.33	0.28	0.24	14	148	37	—

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
Timothy	26	11	80	64	65	36	59	.8	36	3.8	0.40	0.28	0.15	—	—	28	—
Triticale forage	34	15	85	63	61	35	55	.8	33	2.9	0.38	0.32	0.18	8	48	30	—
Wheat forage	21	22	84	71	76	48	50	.7	30	4.0	0.35	0.36	0.22	10	85	35	
Silage/Haylage																	
Barley silage	38	12	—	61	59	33	55	.7	35	3.5	0.45	0.30	0.17	8	43	32	—
Bermudagrass silage	39	13	75	56	50	25	67	.8	40	3.3	0.53	0.29	0.24	14	98	43	—
Corn silage, well eared	34	8	72	71	73	46	44	.8	26	3.3	0.25	0.24	0.10	7	31	25	0.09
Corn stalklage	49	6	70	53	45	20	65	1.0	47	1.9	0.90	0.16	0.09	8	82	38	—
Distillers corn stillage	7	22	45	92	103	70	21	.5	10	8.1	0.14	0.72	0.60			60	—
Grass silage	30	11	76	61	62	31	60	.8	39	3.4	0.70	0.24	0.22	11	92	29	—
Legume silage	40	21	75	58	32	44	44	.7	34	3.8	1.41	0.33	0.25	10.3	48.6	27.2	0.17
Millet silage	38	13	75	55	47	22	62	.7	40	2.4	0.54	0.33	0.20	14	130	47	—
Millet/soybean silage	38	12	72	57	52	26	57	.7	40	3.0	0.84	0.32	0.19	9	76	41	—
Milo/soybean silage	31	12	—	60	58	32	44	.7	37	3.4	0.72	0.28	0.16	11	55	34	—
Grass silage, mixed forage	39	16	78	60	56	30	56	.9	35	3.8	1.43	0.33	0.25	9	66	31	—
Legume silage, mixed forage	39	19	78	60	57	31	48	.8	36	3.9	1.25	0.33	0.23	9	44	26	—
Oat silage	35	13	79	60	56	30	59	.8	39	3.7	0.52	0.33	0.19	9	66	28	—
Peanut silage	41	15	60	57	54	28	52	.7	39	4.4	1.25	0.26	0.18	15	176	41	—
Peavine silage	35	17	—	60	58	32	50	.8	36	3.8	1.03	0.33	0.21	12	65	35	—
Corn silage, processed	33	8	—	71	74	47	44	.7	26	3.4	0.23	0.24	0.10	9	28	29	—
Rice silage	62	7	—	55	49	24	53	.7	39	2.5	0.24	0.21	0.12	11	570	34	—
Rye grass silage	32	14	75	59	59	28	59	.7	37	3.3	0.43	0.38	0.23	11	90	36	—
Small grain silage	38	13	—	61	57	31	57	.7	37	3.6	0.54	0.32	0.19	9	78	33	—
Sorghum silage, early bloom	36	10	71	58	53	28	58	.8	37	3.0	0.48	0.24	0.14	10	55	40	0.22
Sorghum Silage, late bloom	26	7	71	61	62	35	59	.9	38	3.0	0.35	0.21	0.11	15	60	32	0.22
Sorghum-sudan silage	45	12	71	58	52	27	61	.8	39	3.3	0.57	0.28	0.17	12	67	34	—
Soybean silage	56	16	65	57	53	28	48	.7	38	4.3	1.36	0.30	0.20	12	81	65	—
Sudangrass silage	31	10	72	58	56	31	64	.8	—	3.0	0.58	0.27	0.14	13	69	29	—
Sugarcane bagasse, silage	68	4	100	42	25	7	75	1.0	62	1.2	0.35	0.06	0.10	8	74	18	—
Sugarcane silage	54	6	—	52	42	18	64	.9	45	1.8	0.36	0.12	0.30	8	77	102	—
Sunflower silage	27	11	—	70	78	50	48	.9	39	14.4	1.42	0.33	0.24	15	33	35	—
Sweet corn silage	23	10	—	67	66	39	64	.8	36	5.3	0.21	0.27	0.12	11	27	39	—
Triticale silage	34	14	100	60	56	30	58	.8	38	3.7	0.50	0.34	0.20	11	50	36	—
Wheat silage	34	13	79	60	56	30	57	.7	37	3.5	0.41	0.34	0.18	10	56	29	—
Pellets/Cubes																	
Alfalfa cubes	91	18	70	57	52	27	44	.4	34	2.3	1.52	0.24	0.26	9	46	24	0.2
Alfalfa pellets	91	18	70	57	53	27	46	.25	34	2.4	1.47	0.28	0.25	11	58	35	0.20
Alfalfa, dehydrated 17% CP	92	19	41	61	61	35	45	.25	34	3.0	1.42	0.25	0.24	9	34	21	0.2
Barley malt pellets with hulls	90	18	64	68	71	44	50	.25		1.9	0.21	0.59	0.32	10	44	61	0.25
Grass cubes	92	12	—	55	48	23	59	.5	40	2.1	0.76	0.22	0.20	22	94	72	—
Grass pellets	91	14	—	59	55	29	54	.3	36	2.8	0.82	0.29	0.20	10	86	48	—
Byproducts																	
Almond hulls, dry	89	6	—	60	58	32	36	.4	30	2.9	0.28	0.12	0.05	5	18	18	—
Almond hulls, wet	80	6	—	61	61	35	34	.3	28	4.0	0.29	0.13	0.04	5	19	16	—
Apple pomace, wet	21	7	—	66	67	40	48	.3	40	6.8	0.18	0.15	0.07	10	15	10	—
Bakery byproduct, dry	90	13	—	91	108	75	11	.2	6	9.8	0.28	0.34	0.16	5	30	38	—
Beet pulp, dry	92	9	56	66	66	39	42	.3	26	1.3	0.94	0.08	0.29	9	61	23	—

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
Beet pulp, wet	23	10	—	63	61	35	48	.25	28	1.1	1.07	0.10	0.21	10	58	24	—
Bread, wet	66	15	—	90	103	72	5	.1	3	8.4	0.19	0.21	0.18	3	13	17	—
Breading	93	13	—	105	131	94	7	.1	4	17.9	0.11	0.20	0.17	2	6	10	—
Breweres condensed solubles	25	26	—	88	100	69	5	.1	2	4.2	0.54	0.71	0.46	27	19	48	—
Brewers grains, dry	93	26	46	73	79	51	51	.25	24	8.7	0.30	0.65	0.31	14	54	90	—
Brewers grains, wet	26	30	—	74	81	53	49	.25	24	9.4	0.35	0.68	0.00	11	52	92	—
Candy byproduct, dry	91	9	100	94	113	80	14	.1	7	15.2	0.25	0.23	0.09	5	18	20	—
Carrots, wet	14	10	—	73	78	50	25	.35	21	4.3	0.86	0.35	0.12	9	30	28	—
Cerial byproduct, dry	91	11	—	84	95	65	12	.1	6	5.2	0.23	0.37	0.13	6	37	84	—
Chocolate byproduct, dry	91	11	80	95	117	83	18	.15	12	20.0	0.24	0.31	0.13	9	25	31	—
Citrus pulp, dry	88	7	—	70	75	47	24	.3	20	2.6	1.88	0.12	0.10	6	13	11	—
Citrus pulp, wet	20	9	—	70	75	47	27	.25	23	3.5	1.50	0.15	0.10	6	13	12	—
Coconut meal, dry	93	22	—	70	78	49	52	.3	31	13.1	0.15	0.61	0.28	38	104	55	—
Cookie byproduct, dry	91	10	—	93	111	78	10	.1	5	11.8	0.20	0.29	0.12	4	24	30	—
Corn cobs, dry	93	5	30	61	56	30	65	.9	35	1.9	0.15	0.14	0.09	7	21	27	—
Corn cobs, wet	66	4	30	59	51	25	80	.8	44	0.7	0.11	0.08	0.05	7	9	25	—
Corn gluten feed, dry	89	24	75	73	78	50	36	.4	11	4.1	0.11	1.04	0.50	6	22	69	0.3
Corn gluten feed, wet	61	22	75	76	84	55	35	.3	12	5.3	0.36	1.26	0.47	6	24	70	—
Corn gluten meal	91	67	40	87	98	67	8	.2	5	3.0	0.07	0.54	0.86	3	7	31	—
Corn steep liquor	41	37	70	84	94	64	3	0	1	3.0	0.08	2.74	1.41	6	50	155	0.30
Cotton gin trash (burrs)	92	11	100	44	34	10	70	.9	51	2.7	0.90	0.12	0.05	10	55	10	0.25
Cottonseed hulls, dry	91	4	55	35	14	2	79	.9	65	4.3	0.35	0.21	0.12	5	28	22	0.30
Cottonseed, whole	91	24	62	77	93	63	53	.8	40	19.9	0.19	0.69	0.23	6	16	34	0.25
Cottonseed, whole, delinted	92	27	61	90	113	80	43	.8	29	22.9	0.34	0.75	0.56	8	25	37	—
Cottonseed, whole, extruded	94	31	50	67	74	46	45	.7	37	9.7	0.29	0.81	0.30	10	20	43	—
Distillers condensed solubles	32	20	100	102	126	90	4	.1	2	17.9	0.10	1.55	1.06	5	32	87	—
Distillers dried solubles	93	31	53	87	96	64	22	.2	7	13.0	0.35	1.20	1.10			91	—
Distillers grain, corn, wet	36	30	53	90	101	69	31	.3	16	12.0	0.09	0.75	0.70	5	21	65	0.42
Distillers grain, sorghum, wet	35	33	45	86	95	63	34	.3	19	12.0	0.20	0.68	0.50	5	21	50	0.42
Distillers grains with solubles, corn, dry	89	31	50	89	100	69	33	.35	18	13.0	0.07	0.87	0.65	5	21	68	0.42
Distillers grains with solubles, sorghum, dry	92	31	47	88	99	68	46	.35	18	10.0	0.25	0.65	0.40	5	21	68	0.42
Fruit byproduct, dry	86	8	—	72	76	48	40	.4	29	4.9	0.36	0.19	0.15	9	56	18	—
Fruit byproduct, wet	28	8	—	72	77	49	35	.35	25	4.9	0.42	0.21	0.12	10	34	19	—
Fuzzpellet	92	23	50	90	102	70	47	.6	39	18.4	0.17	0.52	0.27	9	15	37	0.25
Malt sprouts, dry	92	24	—	68	68	41	43	.4	19	2.1	0.21	0.60	0.31	10	46	64	—
Oat hulls	92	7	75	54	45	20	65	.7	36	3.2	0.16	0.22	0.09	8	50	29	—
Palm kernel meal	90	17	—	68	71	43	64	.6	40	9.1	0.41	0.62	0.20	24	263	43	—
Pasta, dry	90	12	—	92	106	73	3	.25	2	6.2	0.10	0.16	0.12	2	8	10	—
Peanut hulls	93	11	40	39	24	5	65	.5	54	5.3	0.33	0.13	0.11	13	45	21	—
Peanut skins	92	17	100	—	—	0	28	.2	20	22.0	0.19	0.20				—	
Pet food	91	24	—	93	112	79	17	.3	7	14.1	1.63	1.11	0.35	22	63	190	—
Pineapple forage, dry	90	6	—	60	55	29	61	.4	31	1.5	0.37	0.14	0.12	10	155	15	—
Potato byproduct, dry	85	15	—	79	87	58	19	.35	14	4.5	0.30	0.30	0.21	7	23	23	—
Potato byproduct, wet	27	11	—	80	89	60	23	.3	16	6.8	0.46	0.31	0.13	9	30	31	—
Poultry litter, dry	94	25	90	57	53	29	38	.5	26	2.5	2.56	1.44	0.52	291	421	480	—
Poultry manure, wet cage	67	27	90	57	53	29	36	.5	25	3.6	4.12	1.86	0.00	349	483	441	—
Rice bran, full fat	91	14	55	84	100	69	23	.5	17	16.0	0.66	1.70	0.19	12	396	40	—
Rice byproducts	92	8	39	68	68	41	52	.4	45	3.7	0.11	0.27	0.08	16	226	41	—
Rice hulls	92	3	45	13	35	—	81	.6	70	0.9	0.14	0.07	0.08	3	320	24	—

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
Rice mill byproduct	91	7	60	42	43	—	60	.3	50	5.7	0.40	0.31	0.30	—	—	31	—
Rice polishings	90	13	—	83	99	68	24	.2	16	14.1	0.93	1.28	0.15	10	146	80	—
Snack food	48	10	—	86	100	68	20	.2	14	11.1	0.58	0.30	0.15	8	17	25	—
Snack Food, dry	93	9	—	100	125	89	12	.25	7	22.6	0.65	0.21	0.09	3	13	16	—
Soy byproduct, dry	89	34	—	85	99	68	29	.25	20	12.1	0.41	0.44	0.30	12	27	51	—
Soy byproduct, wet	39	31	—	82	97	66	31	.3	22	12.9	0.42	0.32	0.00	20	24	43	—
Soybean hulls	91	14	47	63	60	33	63	.4	44	3.3	0.64	0.18	0.13	9	24	46	0.14
Sugarcane bagasse	39	4	100	43	25	11	75	.9	61	0.9	0.09	0.02	0.04	7	56	9	—
Sugarcane bagasse, dry	93	3	100	48	34	12	80	1.0	62	0.9	0.35	0.04	0.09	7	59	12	—
Sunflower seed hulls	90	4	35	40	42		73	.9	63	2.2	0.00	0.11	0.19	—	—	200	—
Sunflower seeds	92	22	7	113	150	109	38	.8	29	35.2	0.33	0.68	0.00	19	30	57	—
Tapioca (cassava), dry	88	4	62	75	80	52	20	.2	16	0.8	0.30	0.08	0.04	7	58	29	—
Tapioca meal, cassava byproduct	89	1	63	82	89	59	34	.2	8	0.8	0.03	0.05	0.04	7	58	29	—
Vegetable byproduct, wet	27	20	85	62	61	35	43	.3	35	8.8	0.81	0.43	0.34	10	46	35	—
Wheat germ meal	88	29	75	85	99	68	22	.2	6	6.3	0.11	1.23	0.26	7	193	138	—
Wheat midds	90	18	78	73	79	51	38	.3	13	5.9	0.15	1.07	0.19	12	126	84	0.21
Wheat mill run	90	17	72	75	81	53	37	.35	12	4.4	0.12	1.00	0.22	21		90	—
Wheat shorts	89	19	75	78	83	54	30	.3	10	5.3	0.10	0.93	0.20	—	—	118	—
Whey, dry	94	14	85	82	89	59	0	0	—	0.9	0.98	0.88	0.92	4	2	10	—
Whey, wet	23	14	85	82	93	63	1	0	1	3.9	1.10	1.37	0.23	4	2	24	—
Yeast, dry	29	44	—	82	91	62	7	.1	4	3.5	0.42	1.37	0.00	17	20	85	—
Grains/Concentrate																	
Barley, dry	90	12	—	81	89	60	19	.3	8	2.4	0.10	0.40	0.14	6	20	32	0.22
Buckwheat, dry	90	17	—	76	82	54	27	.3	19	3.7	0.13	0.58	0.20	8	38	30	—
Canola seed	94	25	70	—	—	—	28	.3	20	39.7	0.55	0.72	0.43	3	50	60	—
Corn bran	92	13	100	83	95	65	33	.35	10	8.4	0.06	0.51	0.25	5	17	70	—
Corn grain, high moisture	74	9	58	93	104	71	10	.3	4	4.1	0.03	0.31	0.10	2	6	19	—
Corn grain rolled	88	9	46	88	98	65	10	.2	4	4.2	0.02	0.30	0.14	3	9	24	0.15
Corn grain, steam flaked	87	9	41	93	104	71	9	.25	4	3.6	0.03	0.24	0.09	2	5	17	—
Corn grain, whole	88	9	42	88	99	65	9	.35	3	4.3	0.02	0.30	0.12	3	8	18	—
Corn screenings	87	9	48	87	96	64	10	.2	4	3.8	0.04	0.25	0.11	—	—	16	—
Corn snaplage, wet	59	8	70	81	90	61	24	.8	12	3.6	0.06	0.27	0.10	4	11	22	—
Corn, ear	89	9	—	84	94	64	19	.8	8	3.9	0.42	0.31	0.10	4	12	26	—
Corn, high moisture ears	64	8	—	83	93	63	21	.6	10	3.6	0.05	0.29	0.10	3	10	20	—
Fat, animal or vegetable	99	—	100	195	285	230		0	—	99.0	0.00	0.00	—	—		—	
Flax seed	91	29	—	110	144	104	32	.2	19	23.2	0.31	0.71	0.30	15	38	57	—
Glycerol (glycerin)	88	—	100	90	100	68	0	.15	—		—	—	—				
Hominy feed	89	10	52	86	99	68	17	.2	6	6.9	0.04	0.55	0.12	4	13	40	0.11
Lupine beans, dry	91	33	—	81	93	63	28	.25	21	6.5	0.29	0.40	0.22	7	279	36	—
Milk replacer, dry	92	27	—	108	138	100	2	0	—	20.9	0.93	0.77	0.36	10	40	74	—
Milk, dry, skim	94	36	100	87	96	64		0	—	0.9	1.36	1.09	0.34	—	—	41	—
Millet, dry	84	12	43	77	85	56	21	.3	12	3.1	0.83	0.30	0.39	6	22	26	—
Milo/sorghum, dry	90	11	45	84	93	63	16	.35	9	3.4	0.15	0.36	0.11	4	20	22	0.22
Milo/sorghum, steam flaked	82	11	38	90	102	70	20	.1	—	3.1	0.04	0.28	0.14	5	15	18	—
Molasses cane, dried	94	9	100	74	78	49	7	0	3	0.3	1.10	0.15	23	61	30	—	
Molasses cane, wet	73	9	100	72	77	49	1	.1	—	2.3	1.00	0.25	1.00	23	61	71	—
Mung beans	90	23	25	79	87	58	28	.3	8	3.0	1.19	0.68	0.25	—	—		—
Mung bean cracks	90	25	25	88	96	64	20	.2	8	1.3	0.15	0.39	0.25	—	—		—
Oats, rolled	89	12	82	75	77	52	30	.4	15	5.4	0.09	0.33	0.23	7	42	41	0.26
Pearl millet grain	87	13	100	82	89	59	18	.25	6	4.5	0.03	0.36				—	
Peas, dry	89	24	17	79	86	57	14	.2	9	2.0	0.14	0.42	0.18	8	19	38	—

	DM %	CP %	DIP % of CP	TDN %	NEm (Mcal/cwt.)	NEg (Mcal/cwt.)	NDF %	pef[a] %	ADF %	EE %%	Ca %	P %	S %	Cu ppm	Mn ppm	Zn ppm	Se ppm
Potatoes, wet	24	11	—	81	89	60	11	.2	8	3.7	0.14	0.29	0.14	6	15	19	—
Rice	89	8	70	79	85	55	16	.15	12	1.9	0.07	0.32	0.05	5	47	17	—
Rye	89	14	80	80	86	56	19	.2	8	2.5	0.07	0.55	0.17	5	49	36	—
Triticale	89	12		82	91	61	15		.15	1.7	0.08	0.36	0.15	5	42	90	—
Wheat bran	90	18	72	72	76	48	40	.2	14	4.5	0.16	1.08	0.18	12	135	87	—
Wheat grain	89	14	77	84	93	63	13	.15	5	2.0	0.12	0.39	0.15	4	41	31	0.29
Wheat grain sprouted	86	12	82	88	98	65	13	.2	4	2.0	0.04	0.36	0.17	—	—	45	—
Protein Meals																	
Biuret	99	248	100	—	—	—	—	0	—	—	—	—	—	—	—	—	—
Blood meal, dry, non-ruminant	90	100	40	72	77	50	2	.1	1	1.1	0.18	0.2	0.56	5	6	29	
Canola meal, dry	91	40	71	69	73	45	30	.25	21	7.4	0.74	1.1	0.71	6	65	60	—
Corn germ meal	90	23	50	81	92	61	39	.2	14	10.1	0.06	0.8	0.28	3	15	77	—
Cotton seed meal	91	43	73	70	74	47	32	.25	23	5.7	0.31	1.2	0.43	13	27	64	0.32
Feather meal	93	88	27	78	91	61	17	.15	3	10.0	0.56	0.4	1.77	12	10	89	0.9
Fish meal	92	61	40	77	91	62	23	.15	4	12.1	5.04	2.9	0.84	7	37	113	—
Linseed meal, mech. extracted	91	37	60	82	89	59	24	.15	18	6.0	0.42	0.9	0.46	19	50	70	—
Linseed meal, solv. extracted	91	39	64	72	78	53	26	.15	18	1.9	0.43	0.9	0.52	19	50	70	—
Meat meal, dry	96	59	—	67	79	51		.15	29	14.2	7.89	4.40	0.45	19	17	130	—
Peanut meal	94	44	73	79	89	59	24	.15	16	8.8	0.21	0.6	0.27	15	33	51	0.12
Poultry meal, blood & feather	95	67	46	75	91	61	0	.1	0	13.9	4.04	2.4	0.73	16	11	104	—
Safflower meal	95	24	—	58	56	30	53	.3	38	9.1	1.06	0.6	0.26	29	111	140	—
Soybean meal, 44%	89	49	65	84	92	61	15	.15	10	1.5	0.36	0.7	0.41	23	41	62	0.11
Soybean meal, 48%	91	54	64	87	98	67	9	.15	6	1.2	0.28	0.7	0.47	23	41	61	0.11
Soybeans whole	88	41	72	92	103	70	15	.3	11	18.8	0.27	0.6	0.34	15	32	43	—
Soybeans whole, extruded	88	40	65	93	104	71	15	.25	11	18.8	0.27	0.6	0.34	14	34	50	—
Soybeans whole, roasted	88	40	52	93	104	71	15	.3	11	18.8	0.27	0.6	0.34	13	30	44	—
Sunflower meal	92	33	68	66	69	42	41	.1	29	11.5	0.45	1.1	0.00	29	43	87	0.18
Sunflower meal, solvent extracted	91	39	73	64	65	36	36	.1	22	2.0	0.42	1.00	0.37	20	35	70	
Urea 46% N	99	288	100	—	—	—	—	0	—	0.0	0.00	0.00	0.00	—	—	—	—
Minerals																	
Calcium carbonate	99	—	100	—	—	—	—	0	—	—	38.50	0.04	0.00	—		—	——
Calcium iodate	99	—		—	—	—	—	—	0	—	—	—	—	—		—	——
Cobalt carbonate	99	—	—	—	—	—	—	0	—	—	—	—	—	—	—	—	—
Cobalt sulfate	99	—	—	—	—	—	—	0	—	—	—	—	0.15	—	—		
Copper sulfate	99	—	—	—	—	—	—	0	—	—	—	—	0.128	252,000	—	—	——
Dicalcium phosphate	97	—	100	—	—	—	—	0	—	—	22.00	19.30	1.14	10	330	100	—
Limestone, 38%	100	—	0	—	—	—	—	0	—	—	39.40	0.09	0.01	33	281	39	—
Limestone, dolomitic ground	99	—	100	—	—	—	—	0	—	—	22.30	0.04	0.01	33	281	39	—
Limestone, ground	98	—	100	—	—	—	—	0	—	—	34.00	0.02	0.03	33	281	39	—
Monoammonium phosphate	98	70	100	—	—	—	—	0	—	—	0.30	24.70	1.42	—	—	81	—
Mono-dicalcium phosphate	97	—	100	—	—	—	—	0	—	—	16.70	21.10	1.20	—	—	70	—
Potassium chloride	99	—	—	—	—	—	—	0	—	—	0.05	—	0.19	—	—	—	—
Salt	97	—	—	—	—	—	—	0	—	—	—	—	—	—	—	—	—
Sodium Selenite	99	—	—	—	—	—	—	0	—	—	—	—	—	—	—	—	450,000
Zinc oxide	97	—	—	—	—	—	—	0	—	—	—	—	—	—		720,000	—
Zinc sulfate (heptahydrate)	99	—	—	—	—	—	—	0	—	—	—	—	0.177	—	—	223,000	—

a Physical effectiveness factor.

18 Alternative Feeds

Earl Ward, Dana Zook, David Lalman and Chris Richards

Objectives

- **Discuss chemical composition and associated variability of byproduct feeds.**
- **Discuss the origin, nutritional and physical characteristics of various alternative feed sources.**

Forage supplies the majority of dietary nutrients in cow-calf and stocker cattle operations. However, additional nutrients frequently are provided to grazing and pen-fed cattle to correct a nutritional deficiency, increase animal performance or replace forage consumption with another feed source to stretch the forage supply. Supplemental protein and energy traditionally are provided in several different sources.

Examples of common protein and energy supplement sources include alfalfa hay, cottonseed meal, soybean meal, corn, sorghum and wheat. However, numerous alternative feeds can be used to meet supplemental protein and energy needs of beef cattle. By far, the most common alternative feeds are byproducts of the grain and/or oilseed milling industries. Examples include wheat middlings and corn gluten feed. Numerous less common alternative feeds can be used to meet the nutritional needs of cattle in a cost-effective manner. Examples of these less common feed sources include bakery waste products, bean sprouts and peanut skins.

This chapter provides cow-calf and stocker operators with nutritional information and other considerations for the use of conventional and alternative feeds available in the Midwest Southern Plains.

Variability and Mineral Content

Conventional feed grains, such as corn, are a common feed source for producers in much of the Midwest ans Southern Plains. Although varieties and management of these crops have varied through the years, the nutrient content of the grain has remained relatively the same. Due to the nature of alternative or byproduct feed production, nutrient concentration and moisture content can vary a great deal. Moisture content of 11% or more for most byproduct feeds can create significant storage and spoilage problems. For this reason, it is a good idea to obtain a laboratory feed analysis from the supplier for each load of feed. If an analysis is not available specifically for the feed already purchased or being considered for purchase, collect and send off a sample for analysis. Awareness of the physical and nutritional characteristics of byproduct feeds can prevent possible toxicity or reductions in performance.

Once the nutrient concentration of the feed has been determined, an appropriate feeding rate or feed blend must be determined. Very few feed ingredients can be fed as a single ingredient in complete rations. Thus, it is imperative to consult a nutritionist and have feeds tested for nutrient composition, then balanced with other ingredients in the ration.

Mineral nutrition is a very important part of a comprehensive supplementation program and will vary depending on stage of production. In dry and wet milling processes, starches are removed from these grains, which concentrates nutrients two to three times in the resulting byproduct feed compared to the original grain product. Depending on degree of processing, phosphorus content of conventional feed grains such as corn, milo and wheat will range in phosphorus content from 0.27% to 0.44% (Table 17.1). With the exception of soybean hulls, all of the byproduct feeds discussed are relatively high in phosphorus. Beef cattle diets should be balanced to provide a recommended calcium-to-phosphorus ratio of two parts calcium to one part phosphorus. In many cases, a calcium source, such as limestone, will need to be added to the supplement or mineral mix to achieve this ratio. Many of the byproduct feeds also are good sources of potassium as well as trace minerals. As a result, depending on the level of the alternative feed in the diet, a lower cost mineral supplementation program can be adopted.

Due to processing procedures, alternative feeds may contain toxic levels of some minerals. Usually, this is only a concern if cattle consume too much of one feed containing a high concentration of a specific mineral. When the feed source is provided in relatively small daily amounts as a supplement, this generally does not create an animal health

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

problem.

One good example of a potentially toxic mineral is sulfur. Cattle require approximately 0.15% sulfur in the diet, while the maximum tolerable level is between 0.3% to 0.5%, depending on the percentage of forage in the diet (NRC, 2016). Several feeds common to Oklahoma contain relatively high concentrations of sulfur, including corn gluten feed (0.43%), distillers grains (0.4%), cottonseed meal (0.44%) and soybean meal (0.47%). It is important to note these values are averages and variation in sulfur concentration can be dramatic. Excess sulfur intake can lead to a condition called polioencephalomalacia (PEM), often referred to as sulfur-induced polio.

Corn

To gain a better understanding of alternative and byproduct feed sources, it is important to first recognize how traditional grain sources are utilized in beef rations. Corn is one of the most utilized energy sources and thus, many other energy-type ingredients are marketed based on the energy value of corn. Corn typically contains 9% to 10% crude protein and 84% to 90% TDN (Table 17.1). Compared to other grain sources, corn is lower in crude protein but higher in energy. The degradable protein (DIP) fraction of corn ranges from 40% to 50%. The remaining 55% to 60% of protein in corn makes up the undegradable intake protein fraction (UIP).

A kernel of corn has five primary constituents: starch, gluten, hull, water and germ. Starch makes up a majority of the kernel at approximately 70% and processing increases the accessibility of starch, therefore increasing energy availability. Previous research shows that although starch in whole kernel corn can be utilized by beef cattle, processing to maximize surface area of starch increases its digestibility from 5% to 10%. Although processing may not necessarily improve average daily gain, research has shown corn processing will likely improve feed efficiency.

Corn can be utilized in virtually all stages of beef production. In growing and finishing diets, corn can be the primary grain source within the diet. However, in diets with high inclusion of corn, a protein supplement should be utilized to make up for the low level of protein. In diets primarily made of forage, corn can be utilized to provide supplemental energy to beef cows in times when energy content of forage is low. However, due to the high starch level, corn can reduce forage digestion if included in the diet above recommended levels. For this reason, with rations high in forage and balanced to include adequate protein, using whole corn at inclusion levels of 0.2% to 0.4% of body weight is recommended.

Corn Byproduct Feeds

Within the last decade, huge strides have been made in the byproduct feeds sector. Milling industries have utilized corn as a major source for both ethanol production and food manufacturing. In turn, the byproducts of these processes have become major ingredients in the cattle feeding industry. Each part of a kernel of corn is utilized specifically in each of the corn milling processes and the remaining fractions are those utilized as byproducts. The two major milling industries are dry milling and wet milling, each having separate byproducts.

Dry Milling Byproduct Feeds

The first process is dry milling, which is utilized primarily for ethanol production. Starch, making up two-thirds of corn grain, is utilized in dry milling fermentation to produce ethanol. Distillers grains are the byproduct of ethanol production and are made up of the remaining one-third of the corn grain (protein, fat and fiber). The resulting nutrient concentration of distillers grains is increased three-fold compared to whole corn. A majority of distillers grains are made from corn, however certain areas of the U.S. also will produce this product from milo or sorghum. Sorghum contains more fiber and protein and less fat than corn grain, which results in sorghum distillers grains that are greater in fiber and protein and lower in fat than corn distillers grains (NRC, 2016). Distillers grains are identified by the type of grain from which they are made, for example, corn distillers, milo or sorghum distillers or other grains (NRC, 2016).

Currently, distillers grains can be broken down into four main feed products: dry distillers grains (Figure 18.1), modified distillers grains, wet distillers grains (Figure 18.2) and condensed distillers solubles (CDS). Currently, a majority of CDS are added back to wet, modified and dry distillers grains, resulting in products called wet distillers grains with solubles (WDGS), modified distillers grains with solubles (MDGS) and dry distillers grains with solubles (DDGS). Wet distillers grains with solubles are typically 30% to 35% DM and contain 30% to 35% crude protein and 9% to 12% fat (Table 17.1). Modified distillers grains with solubles, a partially dried version of WDGS (50% to 55% DM), contains similar levels of protein and fat in WDGS (Erickson et al., 2006).

Dried distillers grains with solubles (corn and sorghum) contain 31% crude protein. The drying process decreases protein degradability, which increases undegradable or bypass protein. Due to the drying process, the degradable protein fraction will vary considerably in DDGS, with an average of 40% to 50%. This variation is due to a range of temperatures the feed is subjected to during the drying process. Most analytical laboratories report acid detergent insoluble nitrogen (ADIN), which is commonly used as an index to estimate heat-damaged protein in forages. Recent research with non-forage proteins indicates ADIN is not a good indicator of protein digestibility or energy value of DDGS. However, ADIN is a reasonably good indicator of bypass protein. As ADIN increased, the bypass protein value of DDGS increased. In MDGS, the drying process is not as extensive; therefore, minimal reductions in protein degradability are realized in MDGS similar to WDGS. Although WDGS, MDGS and DDGS vary in moisture content and protein degradability, energy values are relatively similar. Performance and feed intake data of yearling feedlot steers on WDGS, MDGS and DDGS are shown in Table 18.1.

In a study at OSU (Winterholler et al., 2008), newly

weaned steer calves were fed increasing levels of DDGS and free-choice prairie hay for a 56-day preconditioning period. Daily weight gain continued to increase with increasing amounts of DDGS, although prairie hay intake declined. Improvements in feed efficiency were dramatic at the levels from 0.75% and 1.2% of body weight. These data demonstrate that DDGS is an excellent source of energy and protein for growing cattle.

Because of the higher protein content of distillers byproducts, and resulting higher price relative to other energy sources, distillers byproducts are generally considered protein sources. However, when economically feasible, these products can be an excellent source of energy. A meta-analysis calculated feeding values of various corn byproducts relative to dry-rolled corn. At a 30% inclusion rate in dry rolled corn and high moisture corn based ration, WDGS was 136% the value of corn. At the same dietary inclusion, MDGS was 120% and DDGS was 112% the value of corn with solubles.

Researchers (Nuttelman et. al., 2011) compared the effect of the drying process on various distillers byproducts on feedlot performance. Within this study, three types of distillers grains—WDGS, MDGS and DDGS—were included in the diet and compared to a rolled corn control. Feeding WDGS to feedlot steers resulted in reduced dry matter intake compared to MDGS, DDGS and rolled corn. As a result, steers fed WDGS had lower feed efficiencies compared to those fed MDGS, DDGS and rolled corn (Table 18.2). When carcass traits were summarized for steers fed WDGS, MDGS or DDGS, no differences were observed.

The final byproduct of the dry milling industry is Condensed Distillers Solubles (CDS). Condensed distillers solubles contains 20% to 25% crude protein and 15% to 20% fat (Table 17.1). As mentioned previously, CDS has been typically added back to WDG, MDG and DDG. However, fractionation of the corn kernel in dry milling plants and centrifuging (removal) of a portion of the oil has been recently adopted by many ethanol plants, which will lead to a greater variation in oil or fat content of all distillers grains products across plants (NRC, 2016). The resulting de-

Figure 18.1. Dried distillers grains with solubles in meal and pellet form compared to corn.

Figure 18.2. Wet distillers grains with solubles.

oiled CDS has slightly greater crude protein (25% to 28%), fiber and minerals compared to normal fat CDS, due to the increased concentration of nutrients when oil is removed. Dry matter of de-oiled CDS is relatively similar to normal fat CDS. In many cases, de-oiled CDS are still combined in WDGS, MDGS and DDGS. When this occurs, the resulting distiller byproducts with CDS have approximately 4% less oil than normal fat distillers byproducts (7% to 8%). Like de-oiled CDS, crude protein values are slightly higher in de-oiled WDGS, MDGS and DDGS. Numerically, feeding value of de-oiled products is reduced slightly but research indicates this does not affect performance. As dry milling plants continue to introduce new technologies, byproducts will be further fractioned, changing the nutrient composition and feeding value of byproducts. When utilized alone, CDS are typically mixed with low-quality forages as an energy and protein supplement for cow-calf operations.

Recent technological advancements have led to the creation of a DDGS extruded pellet, making it more available to cattle producers. Distillers pellets and cubes are now on the market, offering cattle producers another supplement and feed option for all levels of beef production. In the past, many producers who supplement cows on the ground could not feed the traditional fine-textured DDGS due to the potential waste. A cube form makes this ingredient more versatile for producers who don't use feed bunks. As a supplement, the higher level of fat makes it favorable over other traditional manufactured supplements. However,

Table 18.1. Performance and feed intake of yearling feedlot steers fed three types of corn distillers byproducts.[6]

	Type of distillers grains[1]		
	WDGS	*MDGS*	*DDGS*
Performance			
Initial BW, lb	767.0	767.0	768.0
Final BW lb[2]	1,400.0	1,409.0	1,392.0
DMI[3], lbs per day	24.8[a]	26.4[b]	27.1[b]
ADG[3], lbs	4.11	4.17	4.05
F:G[4]	6.06[a]	6.33[b]	6.67[c]
Carcass Characteristics			
HCW[3], lbs	882.0	887.0	877.0
12th rib fat, inches	0.63	0.64	0.60
Marbling Score[5]	610.0	599.0	602.0
LM[3] area, inches[2]	13.3	13.2	13.4

a,b,c Means with different superscripts differ (P < 0.05).

1 WDGS = wet distillers grains with solubles; MDGS= modified distillers grains with solubles; DDGS = dried distillers grains with solubles.
2 Calculated from hot carcass weight, adjusted to a common dressing percentage of 63.0%
3 DMI = Dry Matter Intake: ADG = Average Daily Gain; HCW = Hot Carcass Weight; LM = *Longissimus* Muscle.
4 Analyzed as gain:feed, reciprocal of feed conversion (F:G).
5 Marbling score: 400 = Slight0; 450 = Slight50; 500 = Slight0, etc.
6 Data presented are from Nuttelman et al., (2001).

the increased fat affects the pellet quality and producers should expect some fines or broken cubes, like other pelleted byproducts. The storage of cubed DDGS also is much improved over the traditionally finer-textured products. The texture of cubes or pellets improve flow of the DDG product, allowing storage in overhead bulk bins and gravity wagons.

Wet Milling Byproduct Feeds

The other primary process of the milling industry is wet milling. The wet milling industry produces a variety of food-grade products such as corn oil and high fructose corn syrup. The main byproduct of this industry is corn gluten feed (CGF). Corn gluten feed (Figure 18.3) is made is from the portion of the corn kernel remaining after extraction of starch, gluten and germ. The major component in CGF is the hull or bran, so it is relatively high in fiber (Table 17.1).

Figure 18.3. Wet corn gluten feed.

CGF is available in wet (60% to 65% DM) and dry (89% to 90% DM) forms. The dry form is usually marketed after being pelleted. Although CGF pellets generally contain considerable fines and tend to be dusty, pelleting improves the product's density and handling characteristics.

Corn gluten feed also is high in protein (22% to 28%). Like soybean meal, most of this protein (65% to 80%) is degradable in the rumen. According to producer testimony, palatability is variable when grazing cattle are fed CGF as a stand-alone supplement. Blending CGF with other more consistently palatable feedstuffs should reduce this problem. When CGF is included in a forage diet at 0.5% of body weight or less, the energy value is approximately equivalent to that of corn grain. Energy value of CGF relative to corn grain decreases as the forage component of the diet decreases. In one study, CGF was compared to ground, pelleted corn grain fed at 1% of body weight to steers grazing fescue pastures (Hannah et al., 1989). Forage intake was 8% greater for steers supplemented with CGF. Forage digestibility was decreased by 19% with ground, pelleted corn, but unchanged by CGF supplementation. Conversely, in high-concentrate diets, CGF has 85% to 95% the energy value of corn grain.

Hominy Feed

Hominy feed is a byproduct from the manufacturing process of pearl hominy, hominy grits or table meal from corn. Hominy contains at least a portion of the corn bran, corn germ and a portion of the starch. It is similar in appearance to finely ground corn, although it has slightly more energy (primarily due to the higher fat content), protein, fat and fiber. Hominy feed is very palatable to cattle. Hominy should be analyzed for its fat content, which can vary considerably due to the type of manufacturing process. As fat content drops, so does TDN. For example, hominy containing 1.5% fat will have 82% TDN.

Hominy feed can be used to replace all or part of the grain portion of supplements and feeds. However, because hominy feed is highly palatable, it frequently contains a moderate concentration of fat. Because the highly digestible starch is in the form of extremely small particles, overconsumption can lead to digestive upset in cattle. Therefore, cattle consuming a forage-based diet should be limited to approximately 0.5% of their body weight in hominy feed per day. Higher levels of hominy feed can be fed safely in blended rations containing adequate effective fiber (Hannah, et al.,1989).

Sorghum - Milo

In 2019, Oklahoma was the fourth largest producer of grain sorghum or milo in the U.S. with 13.26 million bushels of production. Milo can be a viable option for feeding cattle. Agronomically, it can be grown in dryer climates, but has a similar feeding value to corn. Milo possesses higher amounts of crude protein (12.4%) and lower amounts of TDN (76%) than corn (9.8% CP and 88% TDN). Whole milo (Figure 18.4) is difficult for cattle to digest, therefore it is recommended to roll, crack or steam flake milo to increase the digestibility. Another difference between corn and milo is the crude fat content. Corn tends to have a higher percentage of crude fat

than milo (4.3% and 3.1%, respectively). It takes 1.05 pounds of milo to get the same amount of energy as 1 pound of corn.

Figure 18.4. Sorghum grain compared to corn.

Rice Bran

Rice bran (RB) (Figure 18.5) results from the physical abrasion and separation of the hull from rice grain, which is used for human consumption. Rice bran is produced when hulls and fragments of the hulls are blended with some of the germ. Rice bran contains more fat than most other byproducts (12% to 16%), which makes it more susceptible to rancidity during summer storage. Due to processing, RB is finely ground and has a powdery texture, which makes mechanical handling and storage in bins difficult due to vertical stacking and bridging. Blending with other concentrates, such as grain, improves flow characteristics. Small particle size, starch and fat content all add to the risk of digestive upset and potential for nutritional imbalances. In general, beef cattle diets should not exceed 6% fat on a dry matter basis.

Figure 18.5. Rice bran compared to corn.

Research evaluated RB as a supplement to forage-based diets for grazing steers (Table 18.2) and cows receiving hay diets. Research results indicate when RB is supplemented at 0.4% of body weight, it has approximately the same energy value compared to corn grain fed at the same level. Increasing the inclusion above 0.4% will decrease the RB feeding value compared to corn.

It should be noted that several companies offer a defatted rice bran product. Since rice bran gets a good deal of its energy from fat, this defatted product would obviously be of less nutritional value and, therefore, lower market value.

Table 18.2. Weight gain of steers fall grazing fescue/clover pastures and supplemented with corn or rice bran.

Weight gain, lb/day	*Control*	*.3% BW Corn*	*.6% BW Corn*	*.38% BW RB*	*.76% BW RB*	*.3% BW Corn .38% BW RB*
Day 0-42	1.56	1.54	2.03	1.54	1.06	1.87
Day 42-84	1.56	1.78	2.25	2.20	2.27	2.27
Day 0-84	1.56	1.67	2.14	1.87	1.67	2.07

Source: Forster et al.

Wheat

Wheat grain (Figure 18.6) has long been recognized as an excellent energy feed resource for livestock. Because wheat generally is used for human food consumption, it is typically priced higher than feed grains, such as corn and milo, on an equal weight basis. Higher prices result in modest use as a feed grain during most years. However, during periods when the wheat market is depressed or feed grains are scarce and high priced, wheat can be used as an economical feed source for beef cattle. Other situations that increase the use of wheat grain in cattle rations are low test weight and sprout-damaged wheat. Market discounts for low test weight and sprout-damaged wheat can be substantial enough to encourage cattle producers to consider this feed resource in

Figure 18.6. Wheat grain and wheat middlings compared to corn.

their beef cattle rations.

Wheat generally contains less moisture and higher protein compared to corn grain. Another advantage wheat may have over corn is wheat protein has higher degradability in the rumen compared to the protein in dry rolled corn (77% verses 45%, respectively). The energy (TDN and NE values from Table 17.1), calcium and phosphorus concentrations are very similar for wheat and corn. Like most feed grains, with the exception of soybean hulls, wheat contains a relatively low concentration of calcium and a high concentration of phosphorus. Corn provides approximately one-half the vitamin A requirement of growing cattle, if fed as the major component in the ration, whereas wheat provides no vitamin A.

Wheat grain must be rolled or coarsely ground to optimize utilization by ruminant animals. In one experiment, digestibility of starch in mixed diets containing whole-wheat was only 60% compared to 86% for the same diet when the wheat was either rolled or crushed.

The starch contained in wheat grain is more rapidly fermented compared to the starch in corn grain. Consequently, wheat grain should be limited to 30% to 50% of the complete ration for beef cattle to minimize the risk of acidosis and bloat. Finely ground wheat should be avoided in beef cattle diets to prevent acidosis. Extremely fine grinding results in separation of fines in dry rations, which causes reduced intake and increased secondary fermentation in the feed bunk. When adapting cattle to wheat-containing rations, producers should gradually increase the grain portion of the diet during a 25- to 30-day period. During this period, intakes should be consistent through a three- to four-day span of time before increasing wheat inclusion in diet. This is a good rule when adapting cattle to any new ration.

The energy density of wheat and corn is much higher compared to that required by growing cattle. Consequently, these feeds must be blended with other feeds containing more fiber or roughage and less energy to minimize digestive problems such as acidosis and founder. Whole shelled corn grain may be limit- or program-fed to achieve similar rates of gain with little or no roughage, but this practice is not recommended for wheat grain.

Wheat can be fed as a supplement to increase rate of gain for stocker cattle receiving hay or silage-based rations. It is recommended that no more than 1% of body weight be used in these situations. Wheat does not contain enough protein to replace protein supplements commonly used in combination with moderate- to low-quality roughages. Whereas wheat contains only 14% protein (dry matter basis), beef cow and stocker cattle supplements used in these situations generally contain 20% to 40% protein.

Wheat Middlings

Wheat middlings (WM) (Figure 18.6) refers to one of several byproducts resulting from the flour-milling process. Other products include wheat bran, wheat germ meal, wheat mill run, wheat shorts and wheat red dog. Wheat mill run and WM often are used interchangeably in the industry because their official definition is nearly identical.

This alternative feed has been used for many years in ruminant diets and often is incorporated in commercial supplements, as are many of the other alternative feeds, as a protein and energy source. Wheat middlings are a good source of protein ranging from 16% to 19% (Table 17.1). Numerous studies have been conducted at OSU and other universities to determine the value of WM as a protein and energy supplement to grazing cattle. Most research suggests protein and energy in WM is highly degradable and effective in improving animal performance, similar to supplements formulated using soybean meal and corn grain. In one series of studies using gestating cows, animal performance was nearly identical when 5 pounds to 6 pounds of WM replaced 3 pounds of soybean meal.

The energy available in WM is in the form of both starch and highly digestible fiber. Recent research reported starch ranged from 25% to 36% of WM dry matter in samples collected from seven different mills. Because of the variation in starch content, WM may vary more than other byproducts in terms of their nutrient value in a given feeding situation.

The rapid rate of fermentation of both the highly digestible fiber component and the starch component in WM leads to the potential of bloat, acidosis and founder when WM are over-consumed by cattle. Little data is available, however, based on producer testimony, a relatively safe feeding limit for WM appears to be around 1% of the animal's body weight (5 pounds for a 500-pound calf or 12 pounds for a 1,200-pound cow).

WM usually are marketed in the pelleted form, although loose WM can be purchased. WMs seem to be particularly susceptible to molding when the moisture content is more than 11%. Therefore, producers should inquire about the moisture content before purchase and occasionally check the moisture content when the feed is received.

Soybeans

High-quality soybeans and damaged soybeans can serve as an excellent source of energy and protein in beef cattle rations and supplements. All too frequently in Oklahoma, late-summer heat and drought results in a significant proportion of the soybean crop being damaged in terms of size, color, weight and nutrient content. This damaged grain may not be merchantable at many grain elevators. Even moderate damage can result in a very significant market discount. Consequently, beef cattle producers should consider the opportunity to incorporate soybeans into their feeding programs when the soybean market is depressed or when drought- or frost-damaged soybeans are available at low prices.

Whole soybeans typically contain 38% to 42% crude protein and 16% to 20% fat (dry matter basis). However, drought-damaged soybeans, and particularly green-colored beans, generally have lower protein (between 25% to 38%) and fat (14% to 18%). Consequently, as in most animal feeding situations where uncommon or variable feedstuffs are used, a nutrient analysis from a commercial laboratory is advised.

Whole raw soybeans have been shown to be an effective protein supplement compared to soybean meal in a low-quality hay diet (6.5% protein) for growing steers, according to one Oregon study (Albro et al., 1993). In a Kentucky study,

growing steers were fed whole soybeans or soybean meal as the protein source in corn silage rations. Weight gain and feed efficiency was similar for both protein sources.

In research conducted at OSU, soybeans have been an effective protein and energy source for gestating beef cows. Because soybeans contain estrogenic activity, they should not be fed to beef females within 60 days of the breeding season. Some research indicates this estrogenic activity from soybeans may impair ovarian function, thus disrupting the estrous cycle.

One OSU study where drought-stressed soybeans were compared to soybean meal, weight gain was reduced in whole soybean fed cattle (Steele et al., 2002). The reduced performance was attributed to small beans passing through the digestive tract undigested. Therefore, cracking or course grinding drought-stressed soybeans is advised.

Whole soybeans also have been shown to be an effective protein and fat supplementation source for feedlot cattle. In a Missouri study, whole raw soybeans were included at the rate of 0%, 8%, 16% or 24% of the ration dry matter (Felton et al., 2004). Soybean meal was used to achieve equal crude protein supply for each treatment. No differences were found in rate of gain, feed efficiency or carcass characteristics among the treatments.

Raw soybeans should not be fed to calves less than 4 months of age or weighing less than 300 pounds. Nor should they be fed to nonruminant animals. The primary concern is a trypsin-inhibiting compound that renders dietary protein indigestible. Trypsin is a digestive enzyme vital for the digestion and utilization of dietary protein. The inhibitor found in raw soybeans is rendered inactive in larger ruminants because of the detoxifying ability of ruminal fermentation. The trypsin-inhibiting compound also is destroyed through heating or cooking of the soybeans, as is done in the soybean milling process.

Raw soybeans should not be fed to animals receiving a diet containing urea. Soybeans contain the enzyme urease, which breaks down urea into ammonia at a very rapid rate. Toxicity occurs when the rate of ammonia entry into the blood stream overrides the capacity of the liver to detoxify the ammonia.

The amount of soybeans fed should be limited to around 0.3% of the animal's body weight. For example, a 500-pound steer should receive no more than 1.5 pounds of whole soybeans per day. This will ensure total fat concentration in the diet does not hinder digestion of other ingredients and create digestive scours due to excessive fat in the total diet. Fat content of beef cattle diets should not exceed 6%. Most other feed grains and forages contain between 1% and 3% fat.

Remember to consider the vitamin and mineral balance in the total ration. High fat rations tend to slightly hinder calcium and magnesium absorption. If soybeans are fed at their near maximum rate (0.3% of body weight), feed or free-choice mineral supplements should be formulated to contain slightly higher-than-normal calcium and magnesium.

Soybean Hulls

During processing, soybeans are rolled or cracked to break the whole bean into smaller pieces so the hulls can be removed. Soybean hulls (SH) are separated from the cracked seeds by an air stream, and the seeds are extracted with hexane to remove oil, leaving high protein bean meal (48%). Next, SH pass through a toaster to destroy the urease activity. Finally, the hulls are ground to the desired particle size and stored until added back to the 44% bean meal or shipped as soybean hulls. Grinding the hulls decreases particle size and increases density for mixing and shipping purposes (Figure 18.8).

Crude protein concentration of SH ranges from 10% to 16%, with an average of around 14% (Table 17.1). This concentration is very similar to the needs of beef calves gaining around 2 pounds per day. They are an excellent energy source in the form of highly digestible fiber. Depending on the processing plant, soybean hulls often are available in both meal and pelleted forms.

Like other highly digestible fiber byproducts, the energy value of SH depends upon the amount fed and type of diet (concentrate versus forage or roughage). In a two-year study, steers were fed fescue hay and received 0.7% of body weight in corn, WM or SH (Table 18.3). Feeding 0.7% body weight SH, WM or corn reduced hay intake an average of 13% with no difference due to supplement type. Hay digestibility was not measured; however, ADG was higher for SH and WM supplemented cattle. This indicates greater utilization of the hay, supplement or both when cattle were supplemented with SH or WM compared to corn.

Figure 18.7. Soybean hulls compared to corn.

Table 18.3. Performance of steers receiving fescue hay supplemented with corn, soybean hulls or wheat middlings.

Item	*Control*	*Corn*	*SH*	*WM*
Hay DM Intake (% BW)	2.09	1.79	1.85	1.82
Sup DM Intake (% BW)	0	0.7	0.7	0.7
ADG, lbs	0.66	1.32	1.5	1.52
Feed cost/lb of gaina	$0.42	$0.31	$0.28	$0.28

a Fescue hay valued at $45 per ton and corn, SH and WM valued at $80 per ton.

Source: Crawford and Garner.

In another series of studies, 400- to 500-pound grazing steers and heifers were supplemented with 3 pounds per day of ground corn or SH (Anderson et al. 1988a). Two trials were conducted with cattle grazing brome grass pastures and two trials were conducted with cattle grazing cornstalks. Regardless of the forage source, daily gain was equivalent when cattle were supplemented with SH or ground corn. These results indicate SH have equivalent energy value, compared to corn when fed as a supplement to forage diets at 0.5% body weight or less.

However, when higher levels of SH are fed, energy value is reduced. When SH alone were fed, 61% of SH dry matter was digested, compared to the percentage of SH dry matter being digested when two parts SH were fed with one part hay. This reduction in SH digestibility is caused by faster passage rate of small particles when little or no long-stem forage is included in the diet. The forage serves to slow passage and ruminal retention time, thereby increasing digestibility of SH.

Because soybean hulls have a similar nutrient profile to the requirements of growing calves, research at OSU has evaluated the possibility of using soybean hull pellets as a sole or major ingredient in self-fed growing rations. Although SH are high in neutral detergent fiber (Table 17.1), the fiber is ground into a very small particle size. Additionally, SH fiber is rapidly and extensively fermented in the rumen. This suggests the potential for bloat when cattle consume large quantities of SH. In a 112-day experiment (Table 18.4), growing steers were fed in a dry lot with no access to hay or pasture (Shriver et al). Cattle were fed soybean hulls as the sole ration ingredient or fed SH plus 2 pounds of a 32% protein pellet that included vitamins and minerals. Both supplement and hay increased total dry matter intake and average daily gain. Hay supplementation did reduce the incidence of bloat substantially, although it did not eliminate the problem. Moreover, several of these steers foundered, indicating a deficiency of effective fiber in the rations. Most of the bloat and marginal acidosis problems were observed after the cattle had been on feed for 56 days and performance declined substantially for all groups after 84 days. Dry matter intake peaked for all three treatment groups between day 56 and day 84, before declining substantially through day 112.

Other experiments have demonstrated intake of SH for pen-fed cattle gradually increases and reaches exceptionally high levels at 45 days to 60 days on feed (Shriver et al. and Lalman et al.). At about the same time, weight gain begins to decline from 2.25 pounds to 2.75 pounds per day to lows of around 1 pound to 1.5 pounds per day. A minimum of 3 pounds to 4 pounds of additional effective fiber such as long stem hay, peanut hulls, cotton seed hulls or sunflower hulls is necessary to minimize the risk of bloat, acidosis and founder when cattle consume a self-fed diet that consists of 90% or more soybean hulls. When offered soybean hulls in a self-feeder and good-quality prairie or alfalfa hay in a dry lot situation, growing cattle only consume 1.5 pounds to 2.5 pounds of hay. Bloat has not been a problem for cattle consuming SH free choice with abundant access to standing forage in a nonconfined pasture situation.

Phosphorus and vitamin A will need to be provided in a free choice mineral supplement, if not blended in the feed or included in the protein supplement. Research has demonstrated that supplemental vitamins, minerals and feed additives improve animal performance and reduce the risk of digestive upset in cattle consuming high levels of SH for more than 45 days (Lalman et al 2022). Interestingly, one study indicated that the risk of bloat was reduced when a blend of 80% SH and 20% corn grain was fed. Similar to other high-fiber byproducts, SH have a lower energy value compared to corn grain when fed at a level greater than 20% of diet dry matter in high concentrate finishing rations for 120 days or more.

Table 18.4. Nutrient content of solvent extracted sunflower meal based on amount of hulls retained (dry matter basis).

	No hulls removed	*Partially dehulled*	*Dehulled*
Crude Protein	28	32	38
Fat	2.5	2.5	3.0
Crude Fiber	25	20	15
TDN	60	64	68

Source: Adapted from Anderson and Lardy; Blasi et al.

Sunflower Meal

Sunflower meal (Figure 18.8) is produced from byproducts of the sunflower oil production process. Whole sunflower seeds are dehulled and the oil is extracted from the remaining kernel. The sunflower hull, germ and starch are then blended back together and pelleted to produce sunflower meal.

The nutrient concentration of sunflower meal varies considerably depending on several factors, including oil content of the seed, extent of hull removal and efficiency of oil extraction. Table 18.6 demonstrates the impact the extent of hull removal can have on protein fat and fiber content of sunflower meal.

Figure 18.8. Pelleted sunflower meal with hulls compared to corn.

Sunflower meal is an excellent protein source for beef cattle. The rumen degradability of sunflower protein is

higher (74%) than the rumen degradability of cottonseed meal (58%) and soybean meal (64%). The energy value of sunflower meal is lower than the energy value of most other oilseed meals primarily due to hulls that are low in digestibility.

Table 18.5. Performance of growing cattle consuming corn silage rations and supplemented with soybean meal or sunflower meal.

Item	*Soybean meal*	*Sunflower meal*
No. of pens of cattle	6	6
Feed intake, lbs DM	18.1	17.8
Daily gain, lbs	1.76	1.71
Feed: gain	10.6	10.5
Feed cost/lb gain	$0.49	$0.41

Source: Blasi et al.

Several experiments indicate sunflower meal is an excellent protein supplement for beef cows and growing cattle consuming protein deficient diets. Table 18.5 shows the results of an experiment where growing cattle were fed corn silage containing 6.8% protein (DM basis) and supplemented with either soybean meal or sunflower meal. Results from this experiment and others suggest decisions regarding the purchase of sunflower meal can be made on a cost per unit of protein basis.

Whole Cottonseed

Areas of high cotton production allow for cattle producers to take advantage of whole cotton seed (WCS), a byproduct of the cotton ginning process. WCS can be purchased from cotton gins prior to having the lint removed or after being delinted. WCS are high in energy, fat, protein and fiber (Table 17.1) as well as being relatively palatable to cattle. Seldom are all these nutritional characteristics found in one feed.

Due to high fat content (20%) of WCS, feeding should be limited to prevent reductions in forage digestibility. Diets exceeding 6% fat on a dry matter basis can reduce forage digestibility, which ultimately reduces the value of the supplement. Whole cottonseed is a very versatile feed that can be utilized for cows or stocker calves. In situations where cottonseed is being supplemented to cows in good body condition, no more than 0.5% of body weight would need to be provided. In situations where cows need to make up body condition, a slightly higher level is warranted at 0.75% of body weight. For example, a 1,200-pound cow in good condition would be safely fed 6 pounds of WCS daily. WCS also can be fed to stocker calves, but the feeding level should be no more than 0.3% of body weight. This would equate to 2 pounds daily for a 600-pound stocker calf.

Quality of cottonseed varies. It should be clean, free of foreign debris and white to whitish gray in color. Good-quality WCS should rattle when shook. Storing cottonseed that is too wet at harvest may result in heating and/or molding, as evidenced in a dark or black seed. This can result in protein being heat-damaged and may cause lypolysis, which is the breakdown of fat into fatty acids, both of which may lower quality. To minimize losses, store seed that is less than 10% moisture in an area sheltered from rain.

One big disadvantage of WCS is its handling characteristics. It is very bulky and does not flow in most mechanical systems. Even though new technologies have emerged that allow some producers to feed WCS with a mechanical feeding system on a pickup or feed truck, most WCS must be handled manually with a shovel or with a front-end loader.

Cottonseed Meal

Cottonseed Meal (CSM) (Figure 18.9) is the by-product of oil extraction from cotton seeds. Each ton of crushed cotton seeds yield approximately 900 pounds of CSM. There are several processes of making CSM, each resulting in different nutrient contents. The most common CSM used in Oklahoma is a 41% crude protein solvent extracted CSM. Because of its high protein digestibility, it is a good protein supplement for low nutritive value forages.

Figure 18.9. Cottonseed meal compared to corn.

Although CSM is a great option for a protein and energy source for growing cattle and mature cows, some precaution must be taken when feeding certain animals WCS or CSM due to gossypol toxicity. Non-ruminants and pre-ruminant calves (less than four months of age) are unable to tolerate much gossypol before toxicity signs begin to show. Gossypol is a natural toxin present to protect the plant from insects. Ruminant animals with fully functioning rumens are able to detoxify gossypol because the microorganisms in the rumen bind the toxin so it cannot be absorbed. Supplementing lactating cows with CSM does not pose a problem with nursing calves because the calves usually do not consume enough CSM to be harmful.

It is not recommended to feed WCS or CSM to breeding bulls 60 days to 90 days prior to the breeding soundness exam or breeding season. The high levels of gossypol has shown a histological change in testicular tissues, which can be reversed after removing WCS and CSM from the diet for two months.

Figure 18.10. Cottonseed hulls and pellets compared to corn.

Cottonseed Hulls

Cottonseed Hulls (CSH) (Figure 18.10) are the outer covering of a cottonseed and are removed before cottonseed oil is extruded from the kernels. CSH are used as a roughage source for cattle because of their high fiber content and palatability. Although high in fiber, CSH are low in crude protein, TDN, calcium and phosphorus.

Loose CSH, much like WCS, are extremely bulky and hard to handle and store. CSH pellets are much easier to handle but you lose some "scratch factor" to the rumen. Scratch factor simply means that it scratches the papillae in the rumen to maintain surface area for the animals to absorb volatile fatty acids.

Conclusion

Producers must continually monitor supplemental needs and feed prices to take advantage of alternative feed sources to reduce the cost of production. This requires advanced planning, not only to have storage available, but also to know how feeds might be incorporated into the system.

To assist beef and dairy producers in locating byproduct feeds and monitor prices, a Byproduct Feed Prices Bulletin has been published since 1987 by the University of Missouri. This weekly bulletin lists companies, phone numbers, addresses, contact persons, feeds, current prices and other purchasing information. The Byproduct Feed Prices Bulletin can be found online at agebb.missouri.edu/dairy/byprod/bplist.asp and is available through the Agriculture Electronic Bulletin Board (AGEBB).

References

Albro, J.D., D.W. Weber and T. Del Curto. (1993) Comparison of Whole Raw Soybeans, Extruded Soybeans, or Soybean Meal and Barley on Digestive Characteristics and Performance of Weaned Beef Steers Consuming Mature Grass Hay. *Journal of Animal Science* 71:26-32.

Anderson, S.J., J.K. Merrill and T.J. Klopfenstein. (1988a) Soybean Hulls as an Energy Supplement for the Grazing Ruminant. *Journal of Animal Science* 66:2959.

Anderson, V. and G. Lardy. (1988b) Sunflower Meal in Beef Cattle Diets.

Arensdorf, A. et al. (1995) Nutritional Variability of Wheat Middlings and Wheat Grain Screenings. *Journal of Animal Science* 73 (Suppl. 1):94 (Abstr.).

Blasi, D.A., K.K. Kreikemeier and T.P. Eck. An Evaluation of Sunflower Meal in Grower Diets. Southwest Research-Extension Center Report, Kansas State University, 18-20.

Bremer, V.R., K.J. Hanford, G. E. Erickson and T.J. Klopfenstein. 2011. Meta-Analysis of Feeding Calf-Feds or Yearlings Wet Distillers Grains with Different Corn Processing Types. *Nebraska Beef Report* pp. 40 - 41

Crawford, R.J., Jr. and G.B. Garner. (1993) Ammoniation of Endophyte-Infected Tall Fescue Hay and Supplementation with By-Product Feeds to Improve Steer Performance. *Journal of Animal Science* 71(Suppl. 1):378 (Abstr.).

Erickson, G.E., T.J. Klopfenstein, D.C. Adams and R.J. Rasby. 2006. *Corn Processing Co-products Manual.* General Overview of Feeding Corn Milling Co-Products to Beef Cattle. Pp. 3 – 12

Felton, E.E.D. and M.S. Kerley. (2004) Performance and Carcass Quality of Steers Fed Whole Raw Soybeans at Increasing Inclusion Levels. *Journal of Animal Science* 82:725-732.

Forster, L.A., Jr. et al. (1993) Feed Intake, Digestibility, and Live Weight Gain by Cattle Consuming Forage Supplemented with Rice Bran and/or Corn. *Journal of Animal Science* 71:3105.

Galyean, M. L., D. G. Wagner and F. N. Owens. 1979. *Journal of Animal Science*. 49:204-210

Ham, G.A. et al. (1994) Wet Corn Distillers By-Products Compared with Dried Corn Distillers Grains with Solubles as a Source of Protein and Energy for Ruminants. *Journal of Animal Science* 72:3246.

Hannah, S.M. et al. (1989) Influence of Energy Supplemenation on Forage Intake, Digestibility, and Grazing Time by Cattle Grazing Tall Fescue. *Nutrition Reports International* 40:1153.

Highfill, B.D. et al. (1987) Effects of High Fiber Energy Supplements on Fermentation Characteristics and In Vivo and In Situ Digestibilities of Low Quality Fescue Hay. *Journal of Animal Science* 65:224.

Hintz, H.F. et al. (1964) Effects of Processing and of Feeding Hay on the Digestibility of Soybean Hulls. *Journal of Animal Science* 23:43.

Jolly, M.L., B.L. Nuttelman, D. Burken, C.J. Schneider, T.J. Klopfenstein and G.E. Erickson. 2014. Effects of Increasing Inclusion of Wet Distillers Grains Plus Solubles with and Without Oil Extraction on Finishing Performance. *Nebraska Beef Report*. Pp. 81- 82.

Lalman, D.L., D.E. Williams and J.D. Steele. (2002) Vitamin and Mineral Supplementation for a Self-Fed Soybean Hull Growing Diet. Animal Science Research Report, Oklahoma Agricultural Experiment Station, Oklahoma State University. Retrieved June 7, 2004 from ansi.okstate.edu/research/2002rr/18/index.htm

Nakamura, T., T.J. Klopfenstein and R.A. Britton. (1994) Evaluation of Acid Detergent Insoluble Nitrogen as an Indicator of Protein Quality in Nonforage Proteins. *Journal of Animal Science* 72:1043.

National Research Council. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, D.C.

National Research Council. ((2016) *Nutrient Requirements of Beef Cattle* (8th Edition). National Academy Press, Washington, D.C.

Nuttelman, B.L, W.A. Griffen, J.R. Benton, G.E. Erickson and T.J. Klopfenstein. 2011. Comparing Dry, Wet, or Modified Distillers Grains Plus Solubles on Feedlot Cattle Performance. *Nebraska Beef Report* pp. 50-52

Shriver, J.A. et al. (2000) Effects of Hay and Protein Supplementation on Performance of Growing Steers Fed Pelleted Soybean Hulls. Oklahoma Agricultural Experiment Station Research Report ansi.okstate.edu/research/2000rr/10.htm

Steele, J.D. et al. (2002) Drought Stressed Soybean Supplementation for Gestating Beef Cows Grazing Native Tall Grass Prairie. Oklahoma Agricultural Experiment Station Research Report P-993. Retrieved from ansi.okstate.edu/research/2002rr/index.htm

Stern, M.D. et al. (1995) Protein Contributions from Alternative Feeds. Proceedings: 2nd National Alternative Feeds Symposium, 31.

Weigel, J.C. (1991) Wet Corn Milling: the Industry. Proceedings: 1st National Alternative Feeds Symposium.

Winterholler, S. J., B. P. Holland, T. K. Dye, C. R. Krehbiel, G. W. Horn and D.L. Lalman. 2008. Effects of Dried Distiller's Grains during Preconditioning on Subsequent Wheat Pasture and Finishing Performance of Fall-weaned Beef Steers. *Journal of Animal Science* 86(Suppl. 2): 9.

19 Vitamin and Mineral Nutrition of Grazing Cattle

David Lalman

Objectives

- **Present vitamin and mineral composition of common Oklahoma forages.**
- **Discuss specific mineral requirements, deficiencies and potential antagonists.**
- **Provide guidelines to evaluate potential mineral deficiencies.**

Proper mineral and vitamin nutrition contributes to strong immune systems, reproductive performance and calf weight gain. A properly balanced mineral program requires consideration of previous cow and calf mineral nutrition, hay or pasture forage intake and mineral concentration and feed or mineral supplement intake and mineral concentration. Diets with mineral imbalances may cause poor animal performance, resulting in reduced profitability.

Mineral requirements are dependent on forage mineral content, animal age and stage of production. However, simply knowing the animal's requirement is only one component in evaluating an animal's mineral status. Mineral needs also tend to be area specific and change with soil type, fertilization rates, rainfall and other factors. An understanding of the need for minerals is necessary for making decisions about what and how much to feed. This chapter will give major attention focusing on those minerals most likely to pose a problem in Oklahoma.

Typical Mineral Composition of Common Oklahoma Forages

As a general rule, Oklahoma forages do not have severe mineral deficiencies or high levels of mineral antagonists compared to forages in many other states. When excessive amounts of antagonistic minerals are consumed, the availability of other minerals is reduced or completely blocked. Specific antagonists are discussed more extensively in the next section. However, forage mineral concentration is extremely variable and site-specific mineral problems in Oklahoma have been identified.

Table 19.1 shows average mineral concentration in four types of forages common to Oklahoma, and compares these averages with requirements of growing cattle. More extensive data on nutrient requirements was provided in chapters 16 and 17. The data shown in Table 19.1 was summarized from two large data sets through a period of several years. These data represent forage mineral concentration when samples were harvested during mid-summer. Forage will contain much higher concentration of most minerals when it is immature and rapidly growing compared to more mature, weathered forage.

From these data, several general principles are evident relative to supplementing minerals to grazing beef cattle in Oklahoma.

Table 19.1. Average mineral concentration of common Oklahoma forages and dietary requirements of beef cattle.

	Forage type					*Dietary requirements*
Mineral	*Alfalfa/clover*[a]	*Bermudagrass*[a]	*Fescue*[a]	*Native*[a]	*Small grain forage*[b]	*of beef cattle*[c]
Phosphorus, %	0.27	0.21	0.23	0.08	0.31	0.15 to 0.3
Sodium, %	0.08	0.04	0.02	0.01	0.03	0.06 to 0.1
Iron, ppm	198.0	114.0	110.0	190.0	886.0	50.0
Copper, ppm	12.4	6.3	5.0	5.7	4.8	10.0
Zinc, ppm	23.0	22.4	17.8	22.5	23.5	30.0
Selenium, ppm	0.3	0.15	0.09	0.21	0.2	0.10
Manganese, ppm	47.6	83.9	122.0	51.6	176.0	40.0

a Adapted from Mineral Nutrition of Grazing Cattle, Circular E-861, OSU Extension.
b Beck.
c Adapted from NASEM (2016)

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

1. Almost all forage requires salt supplementation as a source of sodium.
2. Summer native range and prairie hay require phosphorus supplementation.
3. Most grasses common to Oklahoma are marginal to deficient in copper and zinc.
4. It is apparent that good-quality legume-based forages require very little, if any, mineral supplementation with the exception of zinc and salt, depending on the amount of this type of hay provided in the total diet.
5. In addition, fescue forage is usually marginal to deficient in selenium, while Bermudagrass forage is marginal.

These values represent averages and the variation from location to location can be quite extreme. As discussed in the next section, each of these marginal to deficient minerals has been shown to impact immune function, reproduction or both. Therefore, it is recommended producers ensure beef cows receive supplemental sources of these elements at least 60 days prior to calving through breeding and 30 days to 60 days prior to weaning. Similarly, weaned calves and purchased stocker cattle should receive adequate copper, zinc and selenium through a concentrate feed supplement or free-choice mineral.

Macro Mineral Considerations

Calcium

Calcium is an important mineral for beef cattle, both in terms of the relative requirement and the diversity of functions in the body. It is a major component of the skeleton, which also serves as a calcium storage site. In fact, about 99% of the total calcium in the body is found in the bones and teeth.

Calcium is involved in blood clotting, muscle contraction, transmission of nerve impulses, regulation of the heart, secretion of hormones and enzyme activation and stabilization. Fortunately, calcium is available in adequate amounts in high quality forages, although calcium can be deficient in weathered or mature forage. The most frequently observed cases of calcium deficiency occur in cattle fed high amounts of concentrate feed and in cattle grazing small-grain forages. Availability of dietary calcium is also quite variable. Consequently, the National Research Council assumed dietary calcium availability was only 50% when calcium requirements were calculated. Signs of calcium deficiency include:

- **Rickets:** weak, soft bones in young cattle; retards bone growth and performance of young growing cattle.
- **Osteomalacia:** weak brittle bones caused by demineralization of bones in adult animals.
- **Urinary calculi:** hard masses of mineral salts and tissue cells that form in the kidney or bladder and can cause water belly in growing steers and bulls.

Problems may arise due to low calcium content of grains, small-grain forage and many byproduct feeds. While forages tend to be adequate in calcium and deficient in phosphorus, the opposite is true of small-grain forage and grains such as corn, milo, barley, oats and wheat. These grains typically will contain about 0.03% calcium and 0.3% phosphorus. Similarly, corn gluten feed, wheat middlings, distillers' grains, barley malt sprout pellet products and many other concentrate feeds contain 0.5% to more than 1% phosphorus. The phosphorus content is adequate for most cattle, but the calcium content is extremely low compared to the animal's requirement. In this situation, the problem of low dietary calcium is compounded by the low ratio of calcium to phosphorus.

When dietary phosphorus exceeds dietary calcium, absorption of calcium from the digestive tract is further reduced. Therefore, when significant amounts of these concentrates are fed without supplemental calcium, the animal will metabolize bone calcium to meet the body's requirement. However, the calcium in the bone is stored in combination with phosphorus and both must be mobilized at the same time. Therefore, both calcium and phosphorus in the bone will be depleted.

Another nutritional disease that can develop in growing male cattle with adequate or high phosphorus and low calcium is water belly or urinary calculi. The most effective method to prevent urinary calculi development in growing male cattle is to maintain total dietary calcium:phosphorus ratio between 1.5:1 and 3:1. Most nutritionists formulate rations and mineral supplements to achieve a ratio of around 2:1. Calcium is an inexpensive mineral to add and a general rule of 1% added limestone will balance the calcium requirement in most grain-based rations.

A second method to minimize the risk of this disease is to make certain the cattle have access to salt or the total diet contains 0.5% up to 4% salt. Salt increases water intake, which increases mineral solubility and dilutes the urine.

Cattle can tolerate calcium-to-phosphorus ratios of up to 7:1. However, excessive calcium has been shown to reduce absorption of phosphorus and many of the essential trace minerals. Therefore, producers should strive to maintain dietary calcium:phosphorus ratios of less than 3:1 and more than 1.5:1.

The other calcium deficiency occasionally observed in Oklahoma occurs when pregnant and lactating cows graze lush, cool-season forage such as small grains, brome and fescue. These cool-season forages are high in phosphorus and low in calcium during immature stages of growth. When cows in late pregnancy and early lactation graze this type of forage, grass tetany is frequently observed. Originally, the problem was thought to be solely the result of magnesium deficiency. However, more recent studies have shown tetany may result from calcium deficiency as well as from magnesium deficiency. Symptoms of tetany from deficiencies of both minerals are indistinguishable without blood tests and the treatment consists of intravenous injections of calcium and magnesium gluconate, which supplies both minerals. Cows grazing lush small-grains pastures should be fed mineral mixes containing both calcium and magnesium.

Phosphorus

Phosphorus often is discussed in conjunction with calcium because these minerals interact in many bodily functions and because they are both stored in bone tissue. Phosphorus, along with calcium, is a major component in bone structure with more than 80% of the phosphorus in the body residing in bone and teeth. However, phosphorus has many other important physiological roles, including cell growth and differentiation; energy utilization and transfer; cell membrane structure, primarily as phospholipids; and acid-base and osmotic balances. Phosphorus also is required by ruminal microorganisms for growth and cellular metabolism. Signs of phosphorus deficiency include:

- Osteomalacia: weak, brittle bones caused by demineralization of bones in adult animals.
- Infertility.
- Reduced feed intake, growth and feed efficiency.
- Reduced milk production.

Phosphorus may be deficient in Oklahoma forages during several months of the year, with great apparent variation from area to area. As shown in the tables included in chapter 16, high-quality, immature forage typically contains adequate phosphorus for most classes of beef cattle. However, forage phosphorus concentration and digestibility declines with advanced maturity and weathering. Figure 19.1 shows the decline of phosphorus concentration in stockpiled Bermudagrass forage through the winter months. In this and subsequent figures, the box represents the range in phosphorus requirements for most classes of beef cattle, according to the National Academy of Sciences, Engineering and Medicine (NASEM). It is apparent this forage resource contained adequate phosphorus during the early fall months, although phosphorus would need to be supplemented for all classes of cattle during late winter because forage phosphorous declined by 39%.

The wide range in phosphorus content of forages in the state highlights the need for forage testing. A forage test including calcium and phosphorus will cost around $30. Considering the potential cost of overfeeding phosphorus when it is not needed, or the potential lost performance when phosphorus is underfed, the advantages of sampling are obvious. It should be remembered that phosphorus-deficient cattle may show varying degrees of unthriftiness long before classical signs such as bone and joint deformities appear. The rumen likely will be phosphorus deficient before the animal's body has mobilized bone reserves. Phosphorus-deficient animals will appear malnourished.

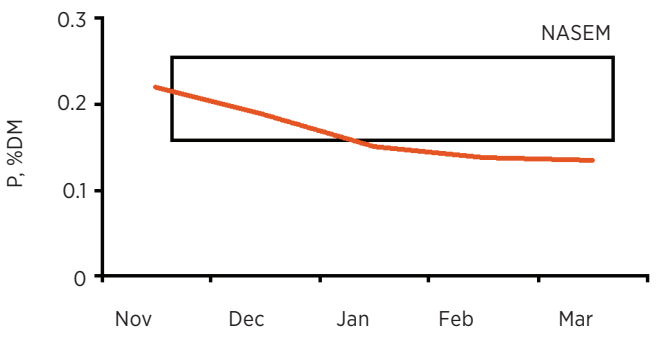


Figure 19.1. Effects of weathering on phosphorus concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

Potassium

Potassium is the third most abundant mineral in the body. It is important in acid-base balance, regulation of osmotic pressure and water balance, muscle contractions, nerve impulses and certain enzyme reactions. Signs of potassium deficiency include:

- Reduced feed intake and weight gain.
- Pica (chewing and gnawing wood and other objects).
- Rough haircoat.
- Muscular weakness.

When forage is growing and immature, potassium concentration is high and generally exceeds the requirements of all classes of cattle. However, potassium is soluble in plant tissue and is rapidly depleted in standing forage or hay that has been rained on after cutting and before baling. Figure 19.2 shows a 76% decline in potassium concentration in standing forage from November to March. Nebraska research showed winter supplements should contain about 2% potassium when fed at rates of 1.5 per pound per head per day to 2.0 pounds per head per day, or about 10 grams of supplemental potassium per head per day.

Common sources of supplemental potassium include potassium chloride and potassium carbonate (K_2CO_3). The carbonate form is more palatable than the chloride form.

Because soybean meal and cottonseed meal both contain more than 1.5% potassium and sunflower meal and peanut meal contain more than 1.2% potassium, the requirement for potassium is met when natural protein supplements are fed. Alfalfa hay, cubes and dehydrated pellets also are excellent sources of potassium, containing between 1.5% to 3%. If grain-based urea supplements that do not contain substantial amounts of the oilseed meals are

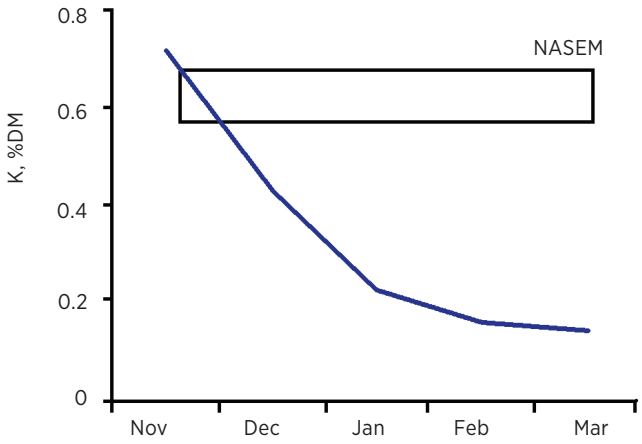


Figure 19.2. Effects of weathering on potassium concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

fed, potassium will need to be added. Potassium chloride is the most common source used in livestock rations.

Magnesium

Magnesium is closely related to calcium and phosphorus in function and distribution in the body. This mineral is known to activate at least 300 different enzymes. Magnesium is essential in energy metabolism, transmission of the genetic code, membrane transport and nerve impulse transmissions. Magnesium is available in several common forms, with the most common being magnesium oxide and magnesium sulfate (epsom salts). Signs of magnesium deficiency include:

- Excitability.
- Anorexia.
- Hyperemia.
- Convulsions and muscular twitching.
- Frothing at the mouth.
- Profuse salivation.
- Calcification of soft tissue.
- Grass tetany.

Figure 19.3 shows standing forage magnesium concentration reduction can be substantial during the winter months. In fact, in this experiment, Bermudagrass forage magnesium concentration declined about 50% from November through March.

Grass tetany typically occurs in beef cows during early lactation and is more prevalent in older cows. Older cows are thought to be less able to mobilize magnesium reserves from bone compared to younger cows. Grass tetany most frequently occurs when cattle are grazing lush immature grasses or small grains pastures and tends to be more prevalent during periods of cloudy weather. Symptoms include uncoordination, salivation, excitability (cows may charge humans) and, in the final stages, tetany, convulsions and death. Grass tetany is occasionally encountered on fescue pastures, but the incidence is much lower than seen on small grains.

It is known factors other than simply the magnesium content of the forage can increase the probability of grass tetany. Some of these factors are discussed in the phosphorus section. High levels of potassium in forages can decrease absorption of magnesium, and many lush, immature forages

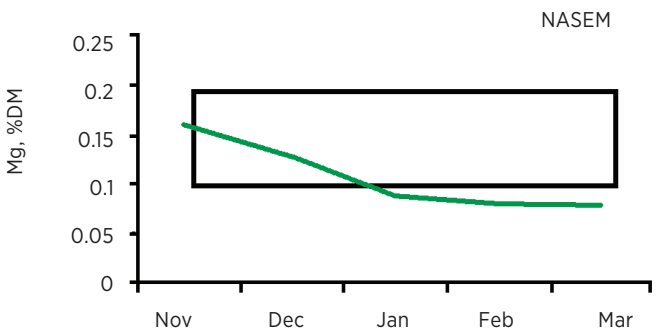


Figure 19.3. Effects of weathering on magnesium concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

are high in potassium. Consequently, the incidence of grass tetany on wheat pastures often occurs in central and western Oklahoma on soils that are quite high in potassium. High levels of nitrogen fertilization also have been shown to increase the incidence of tetany, possibly because an insoluble precipitate of magnesium-ammonium-phosphate forms in the digestive tract and is excreted by the animal. Feeding supplements containing high concentrations of nonprotein nitrogen to cattle grazing lush forage also would increase the risk of grass tetany. Feeding oilseed meal-based protein supplements has not been shown to increase the incidence of tetany, although this could contribute to the bloating problem, especially with stocker cattle.

Other factors, such as the presence of certain organic acids in tetany-prone forages, have been linked with tetany. It is likely that a combination of factors, all related to characteristics of lush forage, are involved.

When conditions for occurrences of tetany are suspected, cows should be provided a mineral supplement containing between 6% and 30% magnesium with daily mineral intake ranging from 2 ounces to 4 ounces per day. The higher inclusion rate and level of intake is appropriate for high-risk situations. In high-risk situations, cows should consume around 1 ounce of magnesium oxide per day. This is difficult because magnesium oxide is very unpalatable to cattle. Most commercial products formulated for the purpose of minimizing the risk of grass tetany contain between 6% and 15% magnesium. It is best for the high-magnesium supplements to be provided at least one month ahead of the period of tetany danger so the proper intake can be established. Because tetany can occur when calcium is low as discussed in the phosphorus section, calcium supplementation also should be included. Examples of high-magnesium mineral supplements are shown in Table 19.5.

Magnesium supplementation does not cure or prevent bloat in cattle grazing wheat pasture. Tetany and bloat are two different problems, with tetany affecting older cows and bloat being a major problem with younger stocker cattle. While calcium and magnesium may be very effective in preventing tetany, they are ineffective for preventing bloat.

Sulfur

Sulfur is needed for synthesis of methionine and cystine, which are sulfur-containing amino acids, as well as the B vitamins, thiamin and biotin. Sulfur is required by ruminal microorganisms for normal growth and metabolism. In fact, ruminal microorganisms are capable of synthesizing all organic sulfur-containing compounds required by the animal from inorganic sulfur. Although sulfur deficiency is very uncommon in Oklahoma, signs of sulfur deficiency include:

- Anorexia, weakness, dullness emaciation.
- Excessive salivation.
- Death.

Sulfur concentration was above that suggested by NRC as the dietary requirement and declined only slightly (16%) in standing Bermudagrass forage through the winter (Figure 19.4).

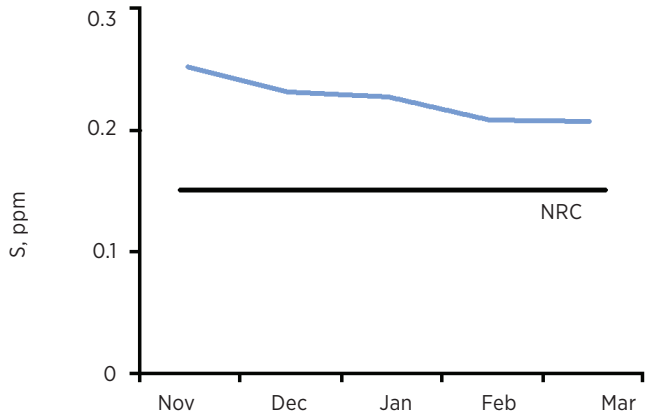


Figure 19.4. Effects of weathering sulfur concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

Marginal deficiencies would be expected to result in reduced feed or forage intake and digestibility due to reduced ruminal microorganism growth and metabolism. Sulfur supplementation might be considered when urea-based protein supplements containing little natural protein are fed. Otherwise, supplemental sulfur will not likely be needed.

Cattle are sensitive to excessive sulfur intake through water and feed. The maximum tolerable concentration of dietary sulfur has been estimated to be 0.35% of diet dry matter for cattle consuming a diet with less than 15% roughage and 0.5% of diet dry matter for cattle consuming a diet with 40% or more forage. Sulphate sulfur in drinking water should not exceed 500 milligrams per liter. Diets high in sulfur can cause polioencephalomalicia (PEM). Signs of PEM include restlessness, diarrhea, muscular twitching, dyspnea (labored breathing), blindness and, in prolonged cases, inactivity followed by death. It is important for cattle producers to recognize some common feed commodities, such as soybean meal, distillers grains, corn gluten feed and barley malt sprout pellets, may contain between 0.4% and 1% sulfur. Therefore, if feeds high in sulfur make up a high percentage of the animal's daily dry matter intake, PEM is a real threat. Generally, if forage, water and other feed sources are low in sulfur concentration, feeding up to 1% of body weight of high sulfur-containing supplements will not cause a problem. Obviously, if there is a concern or a question about the sulfur concentration of any feed source, a representative sample should be submitted to a commercial feed testing laboratory for analysis.

Diets containing 0.35% or more sulfur and water with a high sulfur concentration have been implicated in initiating copper deficiency in cattle. High levels of forage sulfur are likely when ammonium sulfate or other fertilizer sources high in sulfur are used.

Trace Mineral Considerations

Trace minerals are those that are required only in extremely small amounts. Because such small daily quantities of trace minerals are needed, dietary requirements are generally expressed in parts per million (ppm), rather than percent. Trace mineral requirements are not well defined and deficiencies are frequently difficult to pinpoint due to the inconspicuousness and overlap of deficiency symptoms among minerals.

Cobalt

Cobalt's primary role in ruminants is a building block for vitamin B-12. This essential vitamin can be manufactured in the rumen by the microorganisms when cobalt and other precursors are available. Vitamin B-12 catalyzes enzymes essential in energy metabolism and methionine (an amino acid) metabolism. Very little cobalt is stored in body tissues. Therefore, cobalt status in cattle is assessed using blood serum concentrations of vitamin B-12. Cattle with 200 nanograms per milliliter or higher serum B-12 concentration are thought to have adequate ruminal B-12 synthesis. Signs of cobalt deficiency include:

- Reduced appetite.
- Reduced growth rate or failure to moderate weight loss in cows.
- Pale skin and mucous membranes.
- Reduced ability of neutrophils to kill yeast.
- Reduced disease resistance.

Young, rapidly growing cattle seem more susceptible to cobalt deficiency than mature cattle. Feed-grade sources of cobalt include sulfate, carbonate and chloride forms as well as commercial products containing organic forms of cobalt. In 2016, the NASEM increased the estimated dietary requirements for beef cattle to 0.15 ppm.

Copper

Copper is an important cofactor in many enzyme systems including those involved in hemoglobin formation, iron absorption and mobilization, connective tissue metabolism and immune function. Copper status in cattle is quite susceptible to a number of antagonists, including molybdenum, sulfur, iron and zinc. When total intake (dietary and water) of these potential antagonists is within the normal or adequate range, copper status is likely not affected. However, when daily intake of one or more of these antagonists is higher than needed to meet the animal's requirements, reduced copper status can occur. In these cases, copper supplementation must be increased accordingly to gradually restore the animal to normal copper status. Signs of copper deficiency include:

- Anemia.
- Reduced growth rate.
- Depigmentation (dulling) of hair and rough hair coat.
- Diarrhea.
- Reduced fertility.
- Increased incidence of abomasul ulcers in newborn calves.
- Reduced immune function; increased bacterial infections.

Copper concentration of stockpiled Bermudagrass forage was well below the NRC suggested requirement, and

concentration declined by 20% between November and March (Figure 19.5).

Copper status is best assessed by collecting liver tissue via biopsy and analyzing the wet tissue for mineral concentration. Copper oxide is extremely low in terms of its availability to the animal, whereas the sulfate and various organic forms are much higher in availability. Copper oxide should not be used to supplement cattle when a copper deficiency has been determined to exist.

Molybdenum and sulfur in the rumen combine to form thiomolybdates, which form a complex with copper that is essentially unavailable to the animal. Most nutritionists agree the dietary copper-to-molybdenum ratio should be maintained between 4-to-1 and 10-to-1 to minimize the risk of molybdenum-induced copper deficiency. Therefore, when forage copper concentration is adequate (around 10 parts per million) and forage molybdenum concentration is high, a supplemental source of copper will still be needed.

Copper and zinc are absorbed through similar pathways, creating a competition for absorption sites. Therefore, mineral supplements should be formulated with a copper-to-zinc ratio of around 1-to-2 or 1-to-3.

Forage-based diets containing 250 parts per million to 1,200 parts per million iron in the form of iron carbonate reduces copper status in cattle. For some reason, iron-induced copper deficiency has yet to result in typical clinical signs associated with copper deficiency, particularly growth rate and reproduction effects. However, iron-induced copper deficiency has resulted in pancreatic damage and impaired neutrophil function, suggesting reduced function of the immune system.

Iodine

Iodine is an essential component of the thyroid hormones thyroxine (T_4) and triiodothyronine (T_3), which regulates the rate of energy metabolism in the body. Iodine requirements may be elevated in cattle consuming goitrogenic or goiter-causing substances, which interfere with iodine metabolism. The cyanogenetic goitrogens include the thiocyanate derived from cyanide in white clover and the glucosinolates found in some forages such as kale, turnips and rape. These goitrogens impair iodine uptake by the thyroid, and their effect can be overcome by increasing dietary iodine. Signs of iodine deficiency include:

- Swelling of the thyroid gland, particularly newborns.
- Hairless, weak calves at birth.
- Low reproductive rate in cows.
- Retained placenta.
- Decreased libido and semen quality in males.

Clinical signs of iodine deficiency may not be apparent for up to one year after the iodine deficient diet is initiated. Iodine supplementation is inexpensive and easily provided through iodized salt. Iodine is usually provided in supplements in the form of calcium iodate or ethylinediamine dihydroiodide (EDDI), an organic form of iodine. High temperatures, high humidity and rain volatilize and leach iodine in salt and mineral mixtures.

Iron

Iron is an essential component in the structure of proteins involved in transportation and utilization of oxygen. Examples include hemoglobin, myoglobin, cytochromes and iron-sulfur proteins involved in the electron transport chain. Additionally, as with many other trace minerals, several enzymes either contain or are activated by iron. Signs of iron deficiency may include:

- Anemia.
- Anorexia.
- Reduced growth rate or increased rate of weight loss.
- Listlessness.
- Pale mucous membranes.
- Atrophy of the papillae of the tongue.

Iron deficiency in grazing cattle is unlikely because most forages contain more iron than necessary to meet that requirment for cattle (Figure 19.6). Additionally, most feed grains and oilseed meals contain significant amounts of iron. Cattle also can ingest iron through the water source and soil ingestion. In fact, many soils in Oklahoma contain high concentrations of iron oxide, which gives it the red or reddish-brown appearance. This high soil concentration

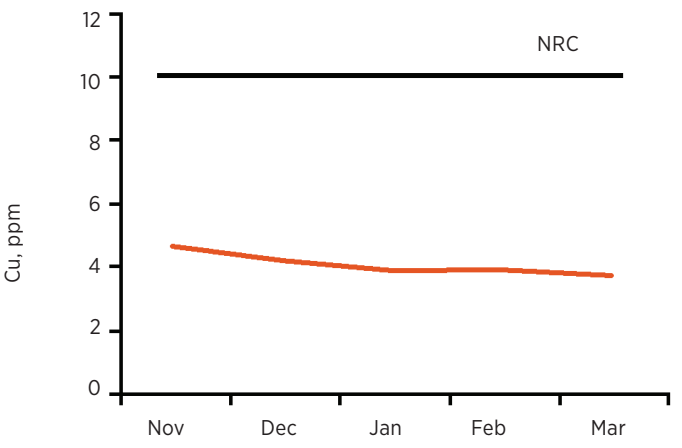


Figure 19.5. Effects of weathering on copper concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

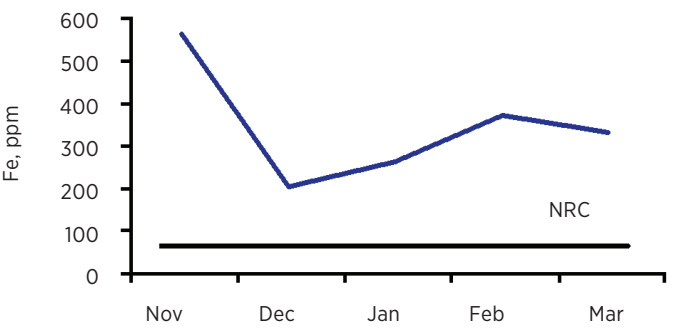


Figure 19.6. Effects of weathering on iron concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

leads to high forage iron concentration. Heavy parasite infestations or other diseases causing chronic blood loss can lead to an iron deficiency.

Supplemental iron sources include ferrous (iron) sulfate, ferrous carbonate and ferric oxide. Availability of ferrous sulfate is high, while ferric oxide is very low in availability. Many commercial mineral mixes include ferric oxide to give it the traditional red appearance.

Dietary iron concentrations as low as 250 parts per million to 500 parts per million have caused copper deficiency in cattle. Many water sources and forages in Oklahoma are high in iron concentration. In these situations, copper supplementation may be needed to prevent copper deficiency. High iron intake also has been implicated in reducing manganese absorption in cattle.

Manganese

Manganese is important in bone growth and formation in young animals and in maintaining optimum fertility in female cattle. The role of manganese in metabolism includes a component of the enzymes pyruvate carboxylase, arginase, superoxide dismutase and several others. Signs of manganese deficiency include:

- Skeletal abnormalities in young cattle resulting in stiffness, twisted legs, enlarged joints and reduced bone strength.
- Low reproductive performance in mature cattle.
- Abortions.
- Stillbirths.
- Low birth weights.

The necessity for manganese supplementation in grazing cattle remains unclear. Forage and feed manganese concentrations are generally more than the concentration suggested for the dietary requirement of cattle (20 parts per million to 40 parts per million) as shown in Figure 19.7. In this study, Bermudagrass forage manganese concentration was more than twice the dietary requirement throughout the winter.

However, limited research suggests the availability of forage manganese is quite low (less than 20%). Until more research is available, and considering the importance of manganese in cow fertility and young calf development, it seems logical to focus supplementation and diet evaluation efforts prior to and immediately following calving.

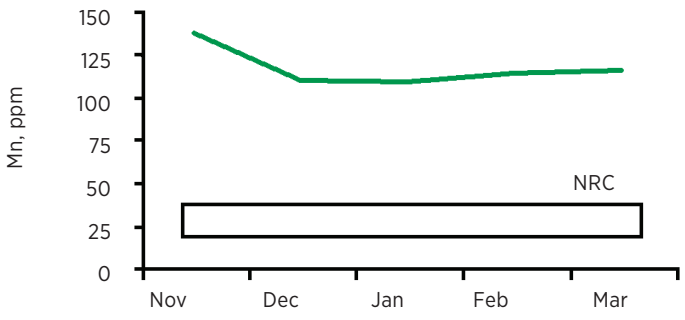


Figure 19.7. Effects of weathering on manganese concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

Effective manganese sources include manganese sulfate, manganese oxide and various organic forms of manganese. Relative availability of organic sources of manganese is approximately 120% of manganese sulfate, with manganese oxide having lower availability than manganese sulfate. High intake of phosphorous, calcium and iron results in reduced manganese absorption.

Selenium

Early attention was drawn to selenium because of severe selenium toxicity in grazing cattle in some parts of the U.S. More recently, forage selenium concentration has been shown to be marginal to deficient in several areas. Unlike many other trace minerals, the range between dietary toxicity and deficiency is quite narrow. In fact, the USDA regulates the inclusion rate of selenium in feeds and supplements with levels not to exceed 3 milligrams per day or about 0.14 milligrams per pound of total diet (0.3 parts per million). This amount is equivalent to only 0.27 gram of total selenium per ton of feed.

Selenium is required in the body for synthesis of an enzyme that breaks down harmful oxidizing agents. Selenium and vitamin E are somewhat related because vitamin E acts to protect cells from the harmful effects of the oxidizing agents. Vitamin E also acts as an antioxidant. Therefore, a deficiency of either selenium or vitamin E will increase the requirement for the other. Early analysis suggested selenium supplementation may moderate the negative effects of fescue toxicosis. Unfortunately, initial positive claims for beneficial effects of selenium against fescue toxicity have not been substantiated in studies at the University of Missouri. However, on average, fescue forage is marginal to low in selenium concentration, suggesting that a low level of supplementation may improve animal performance. Signs of selenium deficiency include:

- White muscle disease: degeneration and necrosis of skeletal and cardiac muscle.
- Reproductive failure.
- Increased incidence of retained placenta in dairy cows,
- Increased calf mortality and reduced calf weaning weights.
- Immune suppression.

Sodium selenite is the most common form of selenium supplementation, although several organic forms of selenium have recently been developed.

Producers should be cautioned against attempting to mix their own formulation with selenium. The toxic level for selenium is only 5ppm and any math error or mixing mistake can lead to serious consequences.

Zinc

Zinc is an essential component of a number of important metabolic enzymes and serves to activate numerous other enzymes. Enzymes that require zinc are involved in protein, nucleic acid and carbohydrate metabolism as well

as enzymes associated with immune function. Signs of zinc deficiency include:

- Reduced feed intake and growth rate.
- Listlessness.
- Excessive salivation.
- Reduced testicular growth.
- Swollen, cracked hooves.
- Skin lesions (parakeratosis).
- Failed or slowed wound healing.
- Reduced fertility in cows and bulls.

Most forages are marginal to low in zinc concentration compared to the suggested requirement (30 parts per million). Figure 19.8 shows the zinc concentration in stockpiled Bermudagrass forage throughout the winter. Although zinc concentration was below the requirement, forage zinc concentration did not decline as the winter grazing season progressed.

It was previously noted that mineral supplements should contain a copper-to-zinc ratio between 1-to-2 and 1-to-3. Zinc sulfate, zinc oxide and organic forms of zinc are common supplementation sources. Absorption or availability is lower for the oxide compared to the sulfate and organic forms.

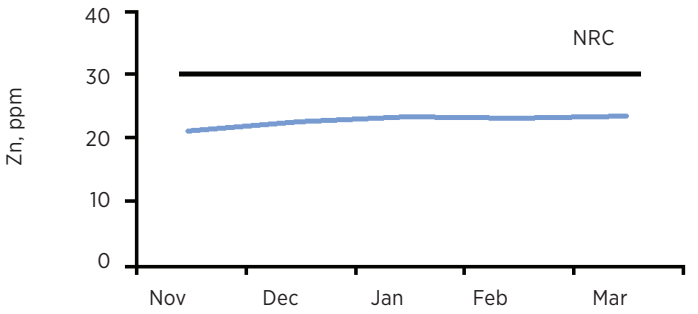


Figure 19.8. Effects of weathering on zinc concentration of stockpiled Bermudagrass forage. Source: Lalman et al.

Vitamins

Vitamins and vitamin precursors are organic components of forage and feeds, although they are distinct from carbohydrates, protein, fat and water. Vitamins are essential for the development and maintenance of different tissues and they are involved in numerous metabolic activities. Vitamins also differ from other essential nutrients because they do not enter into the structural portions of the body.

Vitamins are classified as either fat-soluble (A, D, E and K) or water-soluble (B, thiamin, niacin and choline) based upon their structure and function. Fat-soluble vitamins contain only carbon, hydrogen and oxygen, whereas the water-soluble B-vitamins contain these elements and either nitrogen, sulfur or cobalt. Fat-soluble vitamins may occur in plant tissues as a provitamin (a precursor to the vitamin). A good example is carotene in forages, which is readily converted to vitamin A by ruminant animals. No provitamins are known to exist for the water-soluble vitamins. However, rumen microorganisms have the ability to synthesize water-soluble vitamins. As a result, the supplementation of water-soluble vitamins is generally not necessary in ruminants. Only the vitamins thought to be of significant concern for grazing cattle in Oklahoma will be discussed.

Thiamin

Thiamin functions in all cells as a coenzyme cocarboxylase. Thiamin is the coenzyme responsible for all enzymatic carboxylations of keto-acids in the tricarboxylic acid cycle, which provides energy to the body. Thiamin also plays a key role in glucose metabolism.

Synthesis of thiamin by rumen microflora makes it difficult to establish a ruminant requirement. Generally, animals with a functional rumen can synthesize adequate amounts of thiamin.

In all species, a thiamin deficiency results in central nervous system disorders, because thiamin is an important component of the biochemical reactions that break down the glucose supplying energy to the brain. Other signs of thiamin deficiency include weakness, retracted head (head back and cannot look down) and cardiac arrhythmia. As with other water-soluble vitamins, deficiencies can result in slowed growth, anorexia and diarrhea.

Vitamin A

Vitamin A is considered by many to be the most important vitamin regarding the need for supplementation. Vitamin A is necessary for proper bone formation, growth, vision, energy metabolism (glucose synthesis) and skin and hoof tissue maintenance. Deficiency symptoms include:

- Night blindness.
- Reproductive failure.
- Skeletal deformation.
- Skin lesions.

Plant materials contain the provitamin carotene. Green leafy forage, green hay, silages, dehydrated alfalfa meal, yellow corn, whole milk and fish oils are rich sources of carotene. In cattle, 1 milligram of beta-carotene is converted to the equivalent of about 400 international units (IU) of vitamin A. Lush immature forage contains high concentrations of carotene, although carotene is destroyed rapidly as the plant matures and with exposure to sunlight, air and high temperatures (Figure 19.9).

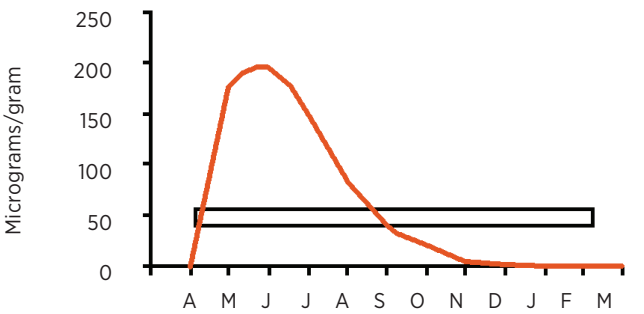


Figure 19.9. Concentration of carotene in native range forage. Source: Wuller et al.

The liver stores vitamin A, and these stores can serve to prevent deficiency in times when carotene or vitamin A intake is low. Generally, it is thought vitamin A stores could last only two months to four months if a severe dietary deficiency exists. Situations where cattle are particularly susceptible to vitamin A deficiency includes times when cattle consume:

- high-concentrate diets,
- winter pasture, crop residues or hay grown during drought conditions,
- feeds receiving excess exposure to sunlight, air and high temperature,
- feeds that have been heavily processed or mixed with oxidizing materials, such as minerals and
- forages that have been stored for long periods of time.

Vitamin B-12

B vitamins are abundant in milk and other feeds. B vitamins are synthesized by rumen micro-organisms, soon after a young animal begins feeding. As a result, B vitamin deficiency is limited to situations where an antagonist is present or the rumen lacks the precursors to make the vitamin.

Vitamin B-12 is the generic descriptor for a group of compounds having vitamin B-12 activity. One feature of vitamin B-12 is it contains 4.5% cobalt. The naturally occurring forms of vitamin B-12 are adenosylcobalamin and methyl cobalamin. These are found in both plant and animal tissues. The primary functions of vitamin B-12 involve metabolism of nucleic acids, proteins, fats and carbohydrates. Vitamin B-12 is of special interest in ruminant nutrition because of its role in propionate metabolism, as well as the practical incidence of vitamin B-12 deficiency as a secondary result of cobalt deficiency. Primarily, cobalt content of the diet is the limiting factor for ruminal microorganism synthesis of vitamin B-12.

A vitamin B-12 deficiency is difficult to distinguish from a cobalt deficiency. The signs of deficiency may not be specific and can include poor appetite, retarded growth and poor condition. In severe deficiencies, muscular weakness and demyelination of peripheral nerves occurs. In young ruminant animals, vitamin B-12 deficiency can occur when rumen microbial flora have not reached adequate populations or are depleted due to stress.

Vitamin D

Vitamin D is essential for bone growth and maintenance. It is directly involved in calcium absorption as well as phosphorus absorption from the kidney and it is involved in osteoblast (bone cell) formation and calcification. It also plays an important role in phosphorylation of carbohydrates, which is part of the energy metabolism process, and has a regulatory role in immune cell function. There are two primary forms of vitamin D: ergocalciferol (vitamin D-2) derived from the plant steroid ergosterol, and cholecalciferol (vitamin D-3), which is found only in animal tissues or products and derived from the precursor 7-dehydrocholesterol. One IU of vitamin D is equivalent to 0.025 microgram of vitamin D-2 or vitamin D-3. Similarly, 1 milligram of either source contains 40,000 IU activity.

Sun-cured hay, irradiated yeast and certain fish liver oils contain high concentrations of vitamin D. However, because vitamin D is synthesized by beef cattle when exposed either to sunlight or fed sun-cured forages, they rarely require vitamin D supplementation.

Examples of situations conducive to moderate vitamin D deficiency would include cattle housed indoors for long periods of time and fed a high-concentrate ration (little or no sun-cured forage), and cattle consuming extremely low-quality forage during long periods with little or no sunlight.

Severe vitamin D deficiency results in a disease referred to as rickets, which is caused by the bones failure to assimilate and use calcium and phosphorus normally. Accompanying evidence frequently includes a decrease in calcium and inorganic phosphorus in the blood, swollen and stiff joints, anorexia, irritability, tetany and convulsions. Osteomalacia is a related disease that affects older animals with vitamin D deficiency, resulting in weak, fragile bones.

Vitamin E

Vitamin E occurs naturally in feedstuffs as a-tocopherol. Vitamin E is not stored in the body in large concentrations, although small quantities can be found in the liver and adipose tissue. This vitamin serves several functions including a role as an inter- and intra-cellular antioxidant and the formation of structural components of biological membranes. Vitamin E is important in muscle growth and structure.

The vitamin E requirement for cattle was revised in 2016 by the NASEM beef cattle committee to indicate the dietary requirement is about 16 international units per pound of fed dry matter (16 IU/lb) for all classes of cattle. A much higher concentration (180 to 225 IU/lb) is recommended for highly stressed receiving cattle (NASEM, 2016).

Vitamin E deficiencies can be initiated by the intake of unsaturated fats. Examples of common sources of unsaturated fats include whole cottonseed, soybeans and whole sunflowers, among others.

Signs of deficiencies in young calves are characteristic of white-muscle disease including general muscular dystrophy, weak leg muscles, crossover walking, impaired suckling ability caused by dystrophy of tongue muscles, heart failure, paralysis and hepatic necrosis.

Diagnosis of Mineral Deficiencies

Diagnosis of mineral deficiencies is difficult due to extreme variation in current and historical dietary mineral supply, the presence of potential antagonists, differences in the availability of minerals in various supplement sources and only a cloudy view of specific dietary mineral requirements, particularly for trace minerals. An effective diagnosis may include several of the following evaluations: clinical signs, soil analysis, forage analysis, water analysis, mineral concentrations in feed or supplement, mineral concentrations in tissue (primarily blood, blood components and liver tissue), as well as the animal's response to treatment.

Estimated dietary requirements for various minerals were provided in the tables of chapter 16. Average dietary availability of minerals was considered when these requirements were determined. Although availability of forage mineral varies with the specific mineral, soil mineral concentrations and forage maturity and weathering, most data indicate minerals of forage origin are between 50% and 90% available to the ruminant animal. The exception to these higher absorption values is manganese, which may be considerably lower.

Perhaps the most useful starting point in evaluating mineral status is obtaining a complete mineral profile of all forages, feeds and supplements provided to the cattle. An estimate of average daily intake of each component also will be necessary. Once a mineral balance profile (daily supply minus daily requirement) has been constructed, marginal and severe deficiencies can be identified. If this exercise does not reveal the potential cause of severe or even marginal deficiency signs, such as low pregnancy rates or high morbidity and mortality rates in weaned calves, tissue and water source evaluations may be necessary.

Liver concentrations of copper, manganese, selenium and zinc provide the best indication of trace mineral status (Table 19.2). Unfortunately, obtaining liver samples is somewhat expensive, invasive and time consuming compared to blood samples. Liver iodine and iron concentration are not indicative of nutritional status.

Concentrations of minerals in whole blood or blood components are frequently used because they are correlated to nutritional status, particularly for iodine, iron, selenium and zinc (Table 19.3). However, blood concentrations of most minerals change rapidly and are influenced by many factors other than dietary supply, such as calving, lactation and other sources of stress or disease. Therefore, blood concentrations of any mineral should be interpreted with caution and in conjunction with other assessment criteria.

Concentration of various blood enzymes and metabolites also are used as indicators of mineral status in cattle. For example, glutathione peroxidase is an indicator of selenium status, while alkaline phosphatase, superoxide dismutase and metallothionein are indicators of zinc status. Similarly, ceruloplasmin, superoxide dismutase and metallothionein are used as indicators of copper status. Vitamin B-12 and methylmalonic acid are used as indicators of cobalt status.

Water intake and water mineral concentration also can provide instructive information when assessing mineral status of cattle. Table 19.4 provides recommended maximum levels of minerals and mineral compounds in livestock drinking water.

Supplementing Minerals

The most common method of providing supplemental minerals to cattle is through a protein/energy supplement or through a free-choice mineral supplement. Free-choice supplementation requires additional equipment for delivery to cattle. Mineral waste and spoilage from moisture can be minimized with a number of commercially available mineral feeders designed to minimize mineral exposure to wind and rain (Figure 19.10). Animal-to-animal variation in intake is greatest with free-choice mineral supplements. Some cattle consume no supplement, while others may consume

Table 19.2. Criteria for classification of mineral status in cattle using liver mineral concentrations.

	Deficient	*Marginal*	*Adequate*	*High*	*Toxic*
Cobalt	<0.005		0.020 to 0.085	0.085 to 8.70	5.0 to 300
Copper	< 33	33 to 125	125 to 600	600 to 1,250	> 1,250
Iodine	<0.094		0.094 to 2.0	>0.781	
Iron	<40		45 to 300	53 to 700	
Magnesium	<40-200		100 to 250		
Manganese	< 5	5 to 10	10 to 15	15 to 25	
Phosphorus	6-14	6 to 14			
Potassium					
Selenium	< 0.5	0.6 to 1.25	1.25 to 2.50	> 2.5	
Zinc	<20	20 to 40	25 to 200	300 to 600	> 1000

Source: Puls and Kincaid.

Table 19.3. Criteria for classification of trace mineral status in cattle using whole blood, plasma or serum mineral concentrations.

	Deficient	*Marginal*	*Adequate*	*High*	*Toxic*
Copper, plasma, microgram/mL	< 0.5	0.5 to 0.7	0.7 to 0.9	0.9 to 1.1	> 1.2
Iodine, serum, microgram/100 mL	< 5		10 to 40	70 to 300	
Iron, serum, microgram/100 mL	< 120		130 to 250	400 to 600	
Manganese, whole blood, ng/mL	< 20	20 to 60	70 to 200		
Manganese, serum, ng/mL	< 5	5 to 6			
Selenium, whole blood, ng/mL	< 60	60 to 200	210 to 1,200	> 1,200	
Zinc, plasma, microgram/mL	<0.4	0.5 to 0.8	0.8 to 1.4	2 to 5	3 to 15

Source: Puls and Kincaid.

Table 19.4. Recommended maximum levels of minerals and mineral compounds in livestock drinking water (all units are mg/L except pH).

Aluminum	<5.0	Manganese	<0.05
Arsenic	<0.05	Mercury	<0.003
Barium	<1.0	Molybdenum	<0.06
Boron	<5.0	Nitrogen (from NO_2+NO_3)	<23.0
Cadmium	<0.01	Nitrate (NO_3)	<100.0
Calcium	<1,000.0	pH, units	5.5–8.3
Chloride	<1,000.0	Phosphate	<0.7
Chromium	<0.05	Potassium	<20.0
Cobalt	<1.0	Residue-total	<7,000
Copper	<1.0	Residue-total fixed	<7,000
Cyanide	<0.20	Residue-filterable	<7,000
Fluoride	<1.2	Selenium	<0.01
Hardness ($CaCO_3$)	<2,000.0	Sodium	<800
Iodine	<1.0	Sulphate	<500
Iron	<0.4	Vanadium	<0.1
Lead	<0.05	Zinc	<5.0
Magnesium	<1,000.0		

Source: Puls.

Figure 19.10. Cattle consuming mineral from a protected free-choice mineral feeder.

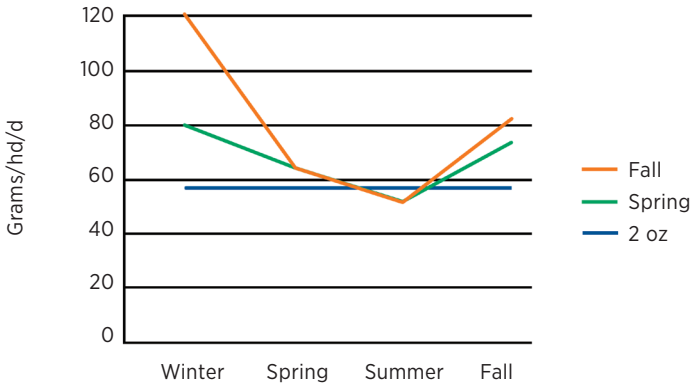


Figure 19.11. Average mineral disappearance by cow herd and season.

as much as four or five times the intended daily amount. This variation is reduced considerably when minerals are incorporated into protein/energy supplements that are provided on a regular basis.

It is important to monitor and record average daily intake of free-choice supplements so the supplement formula can be adjusted if necessary to increase or reduce intake. Cattle will consume salt in excess. This is why salt is used as the base ingredient in free-choice supplements. Phosphorus and magnesium sources are unpalatable and may reduce mineral supplement consumption. When providing a complete free-choice mineral supplement, all other sources of salt should be removed from the pasture.

Mineral supplements disappearance (which is an estimate of intake) has been tracked for both spring- and fall-calving cow herds at the Range Cow Research Center, North Range Unit for five years. The free-choice mineral supplement shown in Table 19.5 was used. Average mineral disappearance by the cow herd and season is shown in Figure 19.11. Lactating fall calving cows had higher mineral consumption during the winter months compared to dry spring calving cows during that same time period. Regardless of calving season, cows consumed more mineral during the fall and winter months with much lower mineral disappearance during the spring and summer (Figure 19.11).

The mineral formulas provided in Table 19.5 are provided as examples of relatively simple free-choice mineral mixes designed for beef cows grazing native range during late summer and winter in Oklahoma. These formulas also would be appropriate for cows consuming other low-quality forage, such as dormant Bermudagrass and fescue during late summer or mid-winter. An example of a magnesium-fortified mineral supplement and a high-magnesium supplement also is provided. Producers should not attempt to mix mineral supplements containing small amounts of trace minerals at home due to potential mixing errors and the potential to cause mineral toxicity.

Lush growing forage and forage with a substantial legume component contains significantly higher concentrations of most minerals. For example, in the study of Lalman et al., mineral concentration of fertilized, stockpiled Bermudagrass forage contained relatively high concentrations of phosphorous, potassium, sulfur, iron and manganese during the month of November, when the forage regrowth was lush (high quality). Therefore, mineral supplements should contain lower concentrations of these

Table 19.5. Free-choice mineral supplements for beef cows grazing low-quality forage.

Ingredient	*Free-choice mineral for beef cows*[a]	*Magnesium-fortified mineral for beef cows*[b]	*High-magnesium mineral for beef cows*[c]
		Pounds per ton (as fed basis)	
Dicalcium phosphate	900.0	700.0	250.
Salt	570.4	435.4	500
Cottonseed meal	150.0	200.0	500
Limestone, 38%	140.0	140.0	250
Dried molasses	75.0	100.0	
Selenium	600.0	40.0	40
Magnesium oxide	30.0	300.0	500
Vitamin A-30,000 IU/g	30.0	30.0	
Mineral oil	20.0	20.0	
Zinc sulfate	16.6	16.6	
Potassium chloride	10.0	-	
Manganous oxide	8.0	8.0	
Copper sulfate	8.0	8.0	
Vitamin E-50% 227,600 IU/lb	2.0	2.0	
		Nutrient composition (as fed basis)	
Calcium, %	12.0	10.0	7.0
Phosphorus, %	8.0	6.0	2.5
Magnesium, %	1.0	8.0	15.0
Sulfur, %	0.5	0.5	-
Copper, ppm	1,000.0	1,000.0	-
Iron, ppm	6,250.0	5,000.0	-
Manganese, ppm	2,500.0	2,500.0	-
Selenium, ppm	12.0	12.0	-
Zinc, ppm	3,000.0	3,000.0	-

a Example of a free-choice mineral for beef cows grazing native range or Bermudagrass pasture. Do not feed this mineral to sheep. Daily intake should range from 2 ounces to 4 ounces per day.

b Magnesium mineral supplement should be provided when beef cattle, particularly cows, graze rapidly-growing cool-season grass or small-grain pasture. Do not feed this mineral to sheep. Daily intake should range from 2 ounces to 4 ounces per day.

c This mineral formula does not contain micro minerals and thus can be safely mixed at the home operation. Part or all of the cottonseed meal can be replaced with dried molasses.

d Do not add iron oxide or other ingredients high in iron since most Oklahoma forages contain excessive iron.

minerals during times when cattle have access to high-quality forage. Mineral supplementation for cattle grazing wheat pasture and other cool-season annuals is discussed in chapter 18. As a general rule, free-choice mineral supplements for high quality, fresh forage should contain greater than 12% calcium and less than 6% phosphorus.

Some producers have fed very simple free-choice mineral supplements to beef cows with excellent growth, animal health and reproductive performance year after year. For example, one popular homemade mineral supplement includes 50% trace-mineralized salt and 50% dicalcium phosphate. A simple formula for supplying supplemental magnesium in high-risk situations is included in Table 19.5. Obviously, the major advantage of these simple formulas is they are inexpensive and can be mixed at home. If a simple program like this has been used with success (animal health, growth and reproduction meets or exceeds the expectations of the producer), a more complicated and expensive program may not be needed. However, producers should keep in mind the potential for a production-limiting deficiency to develop. As discussed above, the greatest potential deficiencies in Oklahoma include vitamin A, phosphorus, copper and zinc. These deficiencies may be revealed through reduced animal health and performance through a long period of time.

Salt is the most effective and economical supplementation program in some situations. This is particularly true when cattle consume high-quality lush forage, legume based forage and/or substantial concentrate supplementation. For example, when stocker cattle are shipped into Oklahoma for dry wintering followed by summer grazing, little is known about their previous dietary mineral status. Additionally, since many loads of cattle represent more than one previous owner and origin, previous dietary mineral status will be quite variable. Some, if not most of these cattle may be deficient in one or several vitamins and minerals when they arrive in the fall. However, if the cattle are wintered with a well-formulated supplement designed to improve vitamin and mineral status, it is unlikely these cattle would respond to mineral supplementation during the 90- to 150-day spring and summer grazing season. Forages contain considerably higher concentrations of highly available provitamins, vitamins and minerals during lush growing periods compared to forage in more mature stages of growth or dormancy. If well-managed stockers on high-quality forage start the grazing season with adequate mineral status, supplements should not be necessary for about 90 days. Many producers feed minerals because they either do not know how animals have previously been

managed or they have another objective, such as delivery of an ionophore.

Conclusion

Forage mineral concentration varies considerably and is dependent on many factors including forage species, soil mineral concentrations, fertilization, climatic conditions, season of the year and weathering. Even though forage mineral concentration data are not difficult or expensive to obtain, this information must frequently be combined with additional assessment criteria because forage mineral availability also is variable and unknown in many cases. Numerous mineral interactions exist to influence the availability of dietary minerals. In fact, some minerals, such as copper and manganese, may need to be provided beyond the suggested requirement when high concentrations of antagonists are present. Deficiency signs for various minerals have been provided. Many of these clinical signs are not evident until a severe deficiency exists because bone, blood, liver and other organs provide a substantial pool from which cattle can draw during times of dietary inadequacy. The minerals most likely to be deficient for cattle grazing moderate to low-quality Oklahoma forage are phosphorous, potassium (for cattle grazing dormant standing forage), copper and zinc. Supplementation of manganese and selenium may also be necessary in many cases and magnesium supplementation is frequently necessary during spring.

References

Arthington, J.D. (2002) Essential Trace Minerals for Grazing Cattle in Florida. AN086. Animal Science Department, University of Florida.

Beck, P.A. (1993) Development of a Self-Limited Monesin-Containing Energy Supplement for Growing Cattle on Wheat Pasture. Master's Theses. Department of Animal Science, Oklahoma State University.

Corah, L.R. and S. Ives. (1991) The Effects of Essential Trace Minerals on Reproduction in Beef Cattle. *Veterinary Clinics of North America: Food Animal Practice*. Vol. 7, No. 1.

Graber, R.W. et al. (1985) Mineral, Rumensin®, and Chlortetracycline Supplementation for Steers on Native Bluestem Pasture. Cattlemen's Day Report, Kansas State University.

Greene, L.W. et al. (1998) Role of Trace Minerals in Cow-Calf Cycle Examined. Feedstuff,. Vol. 70, No. 34.

Greene, L.W. (1999) Designing Mineral Supplementation of Forage Programs for Beef Cattle. Proceedings: *American Society of Animal Science.*

Harper, H.J. and L.W. Reed. (1964) Effect of Chemical Composition of Soil on Micronutrients and Other Elements in Oklahoma Forage Plants. Processed Series P-486, Oklahoma State University.

Horn, F.P. (1983) Chemical Composition of Wheat Pasture. Proceedings: National Wheat Pasture Symposium. MP-115:47-54. Oklahoma Agricultural Experiment Station, Oklahoma State University.

Karns, J.F. and D.C. Clanton. (1976) Potassium in Range Supplements. Nebraska Beef Cattle Report, E.C. 76-218. University of Nebraska.

Kilgore, G.L., F.K. Brazle and M.R. Fausett. (1980) Tall Fescue Production and Utilization. Cooperative Extension Bulletin C-622, Kansas State University.

Kincaid, R.L. (1999) Assessment of Trace Mineral Status of Ruminants: A Review. Proceedings: American Society of Animal Science.

Lalman, D.L. et al. (2002) Effects of Harvest Date and Late-Summer Fertilization Rate on Stockpiled Bermudagrass Forage Mineral Concentrations. P-993: Article 14. Oklahoma Agricultural Experiment Station, Oklahoma State University, Retrieved from ansi.okstate.edu/research/2002rr/15/index.htm

Nelson, A.B. et al. (1955) Supplemental Phosphorus Requirement of Range Beef Cattle. Technical Bulletin T-54.

Nelson, A.B. et al. (1956) Feeding Trace Minerals to Beef Cattle in Oklahoma. Bulletin B-470, Oklahoma State University.

National Research Council. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, D.C.

Puls, R. (1988) Mineral Levels in Animal Health. Sherpa International. Clearbrook, B.C., Canada.

Rasby, R. et al. (1988) Minerals and Vitamins for Beef Cows. EC97-277. University of Nebraska.

Spears, J.W. (1994) chapter 7. Minerals in Forages. Forage Quality, Evaluation and Utilization. *American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America*, 281.

Waller, G.R., R.D. Morrison and A.B. Nelson. (1972) Chemical Composition of Native Grasses in Central Oklahoma From 1947 to 1962. OSU Agricultural Experiment Station Bulletin B-697.

20 Body Condition Scoring of Cows

David Lalman, Glenn Selk and Daniel Stein

Objectives

- **Explain the body condition scoring system for beef cows.**
- **Provide visual examples of body condition scores.**
- **Explain the importance of body condition as it relates to rebreeding efficiency.**

Condition Scores

The body condition scoring (BCS) system is used to assess body energy stores in beef cows. Energy stores are reflected primarily by the relative amount of fat available to metabolize as an energy source. When dietary energy is inadequate to meet the animal's energy need, fat is mobilized along with some muscle and organ tissue. Said another way, when cows lose weight, they burn fat and some protein tissue (muscle and organ weight). When cows gain weight, they gain primarily fat tissue with minimal gain in protein tissue.

Body condition is important because there is a close relationship between BCS at calving and the first 90 days after calving to reproductive success. In addition, cow body condition influences the calf's ability to develop a strong immune system.

Current BCS is a snapshot in time of the balance between recent nutrient supply and recent nutrient requirements. Many different management factors influence this balance of supply vs demand. Overgrazing, for example, often leads to a situation where inadequate nutrient supply is available to meet the animal's requirements, eventually leading to weight loss. Body condition is a good reflection of the match or mismatch of a cow's genetic potential to the forage and management system.

The BCS system used for beef cows range from 1 to 9, with a score of 1 reflecting cows that are emaciated and a score of 9 reflecting cows that are obese. Thin cows should receive a lower score and fat cows should receive a higher score. A description of each score follows and the appearance of key areas of the body are provided in Figure 20.1.

Cattle descriptions by the nine condition scores are:

BCS 1. The cow is severely emaciated and physically weak with all ribs and bone structure easily visible. Cattle in this score are extremely rare and are usually inflicted with a disease and/or parasitism.

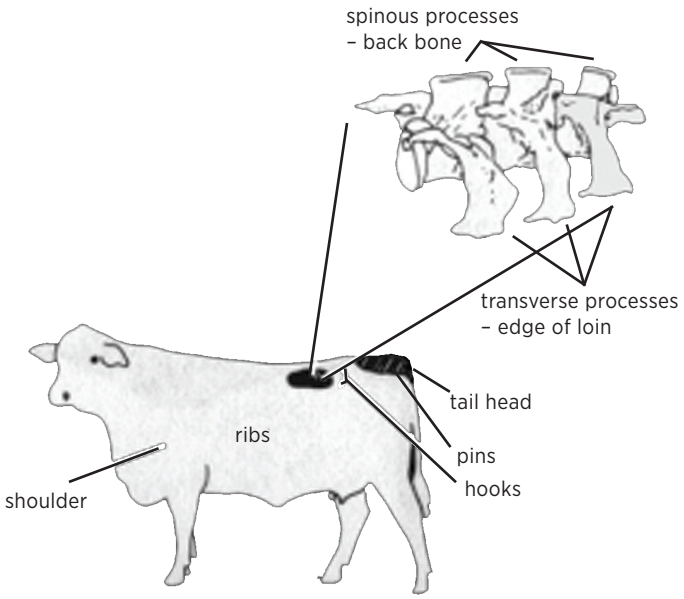


Figure 20.1. Key areas to examine for body condition scoring.

BCS 2. (Figure 20.2) The cow appears emaciated, similar to BCS 1, but not weakened. Muscle tissue seems severely depleted through the hindquarters and shoulder.

BCS 3. (Figure 20.3) The cow is very thin with no fat on ribs or in brisket and the backbone is easily visible. Some muscle depletion appears evident through the hindquarters.

BCS 4. (Figure 20.4) The cow appears slightly thin, with several ribs easily visible and the backbone showing. The spinous processes (along the edge of the loin) are still sharp and barely visible individually. Muscle tissue is not depleted through the shoulders and hindquarters.

BCS 5. (Figure 20.5) The cow may be described as moderate to thin. The last two ribs can be seen and little evidence of fat is present in the brisket, over the ribs or around the tail head. The spinous processes are smooth and difficult to identify.

BCS 6. (Figure 20.6) The cow exhibits a smooth appearance throughout. Some fat deposition is present in the brisket and over the tail head. The back appears rounded and fat can be palpated over the ribs and pin bones.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Figure 20.2. BCS 2.

Figure 20.3. BCS 3.

Figure 20.4 BCS 4.

Figure 20.5. BCS 5.

Figure 20.6. BCS 6.

Figure 20.7. BCS 7.

BCS 7. (Figure 20.7) The cow appears in very good flesh. The brisket is full, the tail head shows pockets of fat and the back appears square due to fat. The ribs are not visible and appear smooth due to fat cover.

BCS 8. The cow is obese. Her neck is thick and her back appears flat or square due to excessive fat. The brisket is distended and large pockets of fat are evident around the tail head.

BCS 9. These cows are extremely obese and may have problems with mobility due to excessive weight and restriction of limbs. The animal's topline will be square and flat with large dimples or pockets due to excessive fat cover. The front leg set will be wide due to a bulging brisket. The entire underline will bulge with fat, including the udder and naval. The tail head will not be visible as it will be covered in a large mass of fat.

When condition scoring cows, the technician should disregard (or look beyond) age, frame size, rib depth, body length, pregnancy status and hair coat. Condition scoring is intended to provide a consistent system to quantify relative fatness regardless of these other factors that create differences in cows' appearance.

There is a strong relationship between weight and body condition score. For each one-unit change in BCS, cows should gain or lose approximately 7% of their BCS-5 weight (NASEM, 2016). For example, a cow that weighs 1,200 pounds when she is in BCS 5 should reach a BCS 6 at 1,284 pounds and a BCS 4 at 1,116 pounds.

Why Body Condition Is Important

One of the major constraints in the improvement of reproductive efficiency of beef cows is the duration of the post-calving anestrous period. If cows are to maintain a calving interval of one year, they must conceive within 80 days to 85 days after calving. Body condition at calving time determines the rebreeding performance of beef cows in the subsequent breeding season to a great extent (Selk).

Figure 20.8 represents the rebreeding percentage of six research herds in four states and includes mature as well as young cows. It clearly shows the body condition at calving greatly determines the rebreeding percentage of cows during the subsequent 60- to 90-day breeding season. Based on research with mature and young cows, those maintaining body weight, therefore, having ample energy reserves before parturition, exhibited estrus sooner than cows that lost considerable body weight and consequently had poor energy reserves. Body weight change during pregnancy is confounded with embryo and placenta growth. Therefore, the estimation of body fat by use of body condition scores is more useful in quantifying the energy status of beef cows. The numeric system of body condition scoring is an excellent estimator of percentage body fat in beef cows. Body condition score accounted for 85% to 91% of the variation in stored body energy (percent fat) in cows.

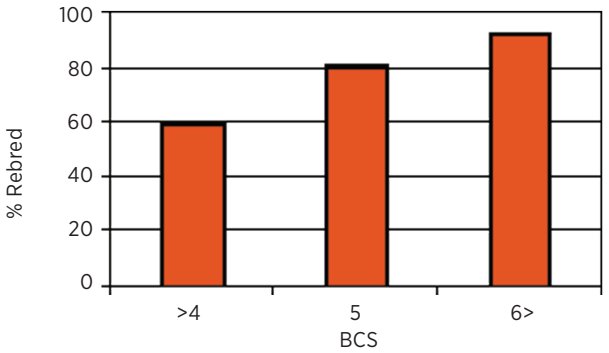


Figure 20.8. Percent rebred at next breeding season per day, according to body condition at calving (summary of six trials in four states) BCS 4 or less, BCS 5, BCS 6 or more. Source: Field and Sands.

The processes of fetal development, delivering a calf, milk production and repair of the reproductive tract all are physiological stresses. These stresses require the availability and utilization of large quantities of energy to enable cows to be rebred in the required 85 days. Add to these physiological stresses the environmental stress of cold, wet weather on spring calving cows and the nutritional stress of energy intake that is below body maintenance needs. As the intake falls short of the energy utilized, the cow compensates by mobilizing stored energy or adipose tissue, and through a period of several weeks, a noticeable change in the outward appearance of the cow takes place.

This is a change in the body condition and can be monitored by assigning body condition scores to cows and quantifying the degree of change. Cows in a thin body condition at calving return to estrus slowly. Postpartum increases in energy intake can modify the length of the postpartum interval. However, increases in the quality and quantity of feed to increase postpartum body condition can be very expensive.

Improvement in reproductive performance achieved by expensive postpartum feeding to thin cows may not be adequate to justify the cost of the additional nutrients. Oklahoma scientists used 81 Hereford and Angus x Hereford heifers to study the effects of body condition score at calving and postpartum nutrition on rebreeding rates at 90 days and 120 days postpartum (Bell et al.). Heifers were divided into two groups in November and allowed to lose body condition or maintain body condition until calving in February and March. Each of those groups was then divided and fed to gain weight and body condition postpartum or to maintain body condition postpartum.

Figure 20.9 illustrates the change in body weight of heifers that calved with a greater than BCS 5, or those that calved with a BCS less than or equal to 4.9. The same pattern has been illustrated in the other experiments is manifest clearly with these heifers. Thin heifers that were given ample opportunity to regain weight and body condition after calving actually weighed more and had greater body condition by eight weeks than those heifers that had good body condition at calving and maintained their weight through the breeding

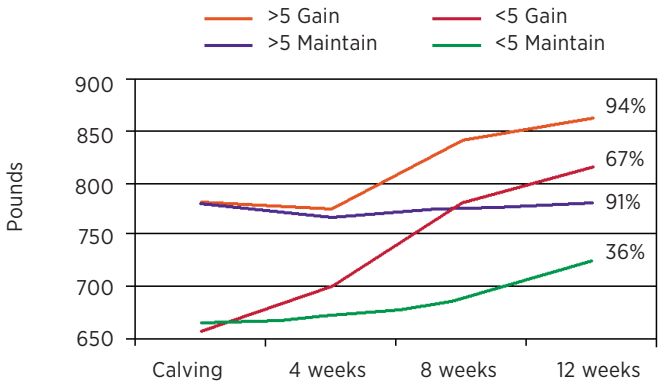


Figure 20.9. Postpartum body weight of heifers with body condition less than 5 or greater than or equal to 5 at calving and fed to gain or maintain weight. Pregnancy rates are indicated on the right side of the legend. Source: Bell et al.

season. However, the rebreeding performance (on the right side of the legend of the graph) was significantly lower for those that were thin (67%) at parturition compared to heifers that were in adequate body condition at calving and maintained condition through the breeding season (91%). Postpartum increases in energy therefore, weight and body condition gave a modest improvement in rebreeding performance, but the increased expense was not adequately rewarded. The groups that were fed to maintain postpartum condition and weight received 4 pounds of cottonseed meal supplement (41% crude protein; $.13 per pound) per day.

The supplement cost for the 69-day feeding period was approximately $36 per cow. The cows in the gain groups were fed 28 pounds of a grain mix (12% CP; $.073 per pound) at a total supplement cost of $141. Both groups had free choice access to grass hay (Wettemann). The improvement in reproductive performance (67% pregnant versus 36% pregnant) of the thin 2-year-old heifers was not enough to offset the large investment in feed costs in most cases.

Other data sets have shown conclusively cows that calve in thin body condition, but regain weight and condition going into the breeding season, do not rebreed at the same rate as those that calve in good condition and maintain that condition into the breeding season. Table 20.1 from Missouri researchers illustrates the number of days between calving to the return to heat cycles depending on body condition at calving and body condition change after calving.

This data clearly shows young cows that calve in thin body condition (BCS 3 or BCS 4) cannot gain enough body condition after calving to achieve the same rebreeding

Table 20.1. Predicted number of days from calving to first heat as affected by body condition score at calving and body condition score change after calving in young beef cows. (body condition score scale : 1 = emaciated; 9 = obese).

BCS at calving	*Condition score change after calving to day 90*						
	-1	*-0.5*	*0*	*0.5*	*1*	*1.5*	*2*
3	189	173	160	150	143	139	139
4	161	145	131	121	115	111	111
5	133	116	103	93	86	83	82
5.5	118	102	89	79	72	69	66

Source: Lalman et al.

performance as cows that calve in moderate body condition (BCS 5.5) and maintain or lose only a slight amount of condition.

Cows must be rebred by 85 days after calving to calve again at the same time the next year. Notice that none of the averages for cows that calved in thin body condition were recycling in time to maintain a 12-month calving interval.

Conclusion

Producers should manage their calving season, genetics, grazing system, supplementation program and herd health to achieve herd average BCS of 5 to 6 in mature cows at calving time and BCS 6 in first-calf heifers at calving time. Subsequently, producers should manage their operation with the goal of minimizing the amount of weight and BCS loss between the time of calving and breeding. Early management to meet these goals are important because drastic changes in BCS during late-pregnancy and early lactation are extremely difficult and costly to achieve.

References

Bell, D. et al. (1990) Effects of Body Condition Score at Calving and Postpartum Nutrition on Performance of Two-Year-Old Heifers. *OSU Animal Science Research Report* MP-129.

M.J. Field and R.S. Sand, Eds. Factors Affecting Calf Crop (1994). CRC Press, Inc., Boca Raton, FL.

Lalman, D.L. et al. (1997) Influence of Weight and Body Condition Change on Duration of Anestrus by Undernourished Suckled Beef Heifers. *Journal of Animal Science* 75.

Selk, G.E. et al. (1988) Relationships among Weight Change, Body Condition and Reproductive Performance of Range Beef Cows. *Journal of Animal Science* 66:3153.

Vizcarra, J.A. et al. (1995) Body Condition Score is a Precise Tool to Evaluate Beef Cows. *OSU Animal Science Research Report* P-943.

Wettemann, R.P. (2004) Personal Communication.

21 Supplementing Beef Cows

David Lalman

Objectives

- **Present method and tools necessary to identify supplemental needs.**
- **Discuss supplementation priorities, nutrient sources and delivery methods.**
- **Provide standard protein supplementation programs for various situations.**

On average, nearly 40% of total operating costs in cow-calf enterprises are associated with nutrition because purchased and harvested hay and concentrate feeds make up the majority of that cost. Consequently, the nutritional program represents a major target to trim cost of production. However, it is widely recognized that nutritional status of the cow is closely related to reproductive performance. If too many corners are cut in the nutritional program, pregnancy and calving rate dramatically suffer.

A ranching operation can appropriately be considered a forage production and utilization enterprise. Ranchers are in the business of converting sunlight, water and carbon dioxide into a high-quality human food resource; namely beef. With good management, forage is an extremely valuable renewable resource. As such, it represents the least expensive feed resource to maintain animal health and production in cow-calf and many stocker operations. A combination of excellent forage production and grazing management practices, cattle genetics that match the forage resources and a well-timed calving season results in minimum reliance on purchased and harvested feeds. Nevertheless, specific nutrients must be supplemented at times. While special emphasis is placed on supplementing beef cows in this section, much of the discussion and data presented are relevant to all grazing cattle.

Occasionally, cow-calf producers need to feed a concentrate or harvested forage to further increase body condition of the cows or to replace pasture forage due to limited pasture forage availability (see chapter 20 for body condition scores and chapter 12 for hay production). This practice, known as feeding or substitution, is in contrast to supplementation because the alternative feed or forage actually replaces consumption of the original forage resource. In general, consumption of the original forage resource declines when cattle are fed concentrate feeds at the rate of 0.5% of body weight (6 pounds for 1,200-pound cows) or more. Substitute feeding is more frequently used for growing cattle than for mature beef cows. Therefore, the practice of substituting concentrate feeds for forage is dealt with in more detail in chapter 22.

Identifying a Supplemental Need

The first step in implementing and maintaining an efficient supplementation program for grazing or forage fed cattle is to identify specific supplementation needs. In other words, the producer must identify specific forage nutrients not provided in adequate quantity to meet the animal's nutrient requirements. For grazing cattle, this is a difficult task because forage quality is constantly changing and so are the animal's nutrient requirements. Knowledge of these two factors is the basis for effective and efficient supplementation. Even though the task may seem difficult, years of research and current technology provides guidance in developing an effective supplement development and evaluation plan. The following steps provide a logical approach in identifying a supplemental need and evaluating supplement alternatives.

1. Determine the nutrient requirements for the appropriate stage of production.
2. Estimate the amount of nutrients cows will receive from forage.
3. Subtract item No. 1 from item No. 2 to determine if a nutrient deficiency or excess exists.
4. Evaluate supplement alternatives.

Nutrient requirements for cattle of various stages of production, mature size, age and productivity are discussed and presented in tabular form in chapter 16. It should be noted that all possible combinations of the above factors are not available in the tables, simply because there are infinite possibilities. Computer software, such as OSU Cowculator, can better pinpoint an animal's nutrient requirement at a specific time and in a specific situation. These and other useful tools can be found at beef.okstate.com.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Average nutrient composition of various feeds and forages common to Oklahoma are presented in Table 17.1. Anticipating nutrients supplied by the forage base is the most difficult task in grazing cattle nutrition. The formula for nutrient intake is simple: forage intake multiplied by concentration of available nutrients in the forage.

However, many factors influence both components in this formula. Forage intake is dramatically influenced by forage quality as well as forage availability and both of these factors can vary dramatically from year to year and month to month. General estimates of forage intake are given in Table 16.1. In addition, estimates of forage consumption based on the animal's energy requirements are provided in Table 16.2.

The next step is to estimate nutrient content of standing forage or hay. As mentioned earlier, these values also vary, depending on forage type, maturity and weathering. The most accurate method to determine supplemental needs for cows that will primarily receive a hay diet is to have the hay analyzed for nutrient concentration. This will cost from $15 to $70 per sample, but can save hundreds, even thousands of dollars in some cases. As a starting point, Table 17.1 includes average nutrient values for a few common feeds and forages found in the Southern Plains.

Once nutrient requirements have been established and a reasonable estimate of the nutrient contribution of the forage has been made, determining supplemental needs is simply a comparison of the two. Again, this comparison is easily and perhaps more accurately made using computer software, such as OSU Cowculator. For this example, it is assumed cows will graze winter range with little to no hay supplementation.

Average cow weight will be 1,100 pounds and average calving date is March 15. Consequently, these cows would be grazing low-quality winter range throughout the last one-third of gestation. Table 21.1 shows that a 1,100-pound cow requires about 1.62 pounds of protein and 11.7 pounds of total digestible nutrients (TDN) per day. Table 17.1 indicates late winter native range would be expected to contain only around 4% protein and be around 49% digestible. Table 16.2 suggests these cows would be expected to consume around 2% of their body weight, or 22 pounds of diet dry matter (1,100 pounds x 2%), assuming adequate supplemental protein is provided.

By using this information, supplemental needs can be calculated as shown in Table 21.1. Without supplementation, this group of cows would be deficient in both protein and energy and would be expected to lose considerable body condition before calving. Here, beef cows are used in the example. However, the process to determine supplemental needs for growing cattle is the same.

Once the supplemental need is determined, various supplement alternatives are relatively easy to compare. In this example, all three supplement alternatives provide adequate protein when fed at the daily amount shown. Energy or TDN is provided in considerable excess (compared to the supplemental need) with the 20% supplement option. Therefore, this strategy might be desirable if increased weight gain or body condition were desired. However, if the cows were in good body condition, this strategy would simply be more expensive than one of the other strategies given in the example because of the increased feeding rate. Feeding just under 2 pounds (1.95 pounds) of 38% supplement provides adequate protein and energy to maintain bodyweight and condition during this stage of production.

Producers can make these calculations using this approach or a computer software program, then evaluate the costs, necessary feeding rate, convenience and expected animal performance outcome for each possible alternative.

In cases where one supplemental nutrient is needed, a very effective method to evaluate cost of nutrient sources is on a cost-per-unit-of-nutrient basis. In the example, the primary nutrient needed is protein. Assuming the 20% supplement cost $300 per ton, the cost per pound of protein is $.75 ($300 per ton divided by 400 pounds of protein per ton). If the 38% supplement costs $380 per ton, the cost per pound of protein is $.50 ($380 per ton divided by 760 pounds of protein per ton).

In this example, the cows can maintain their current weight and body condition (assuming it is adequate) with a supplementation program that costs about $.37 per head per day. Had the producer chosen the 20% supplement program, not recognizing the higher feeding rate, therefore higher

Table 21.1. Nutrient supply compared to requirements for an 1,100-pound beef cow grazing native range during last one third of pregnancy.

	Crude protein (lbs per day)	*TDN (lbs per day)*	
Required	1.62	11.7	
Supplied by forage[1]	0.88	10.78	
Supplemental need	0.74	0.92	
	Feed protein concentration		
	20%	25%	38%
Amount to feed, lb	3.70	3.00	1.95
Cost per ton	300.00	340.00	380.00
Cost per day	$0.55	$0.51	$0.37
Protein supplied, lb	0.74	0.75	0.74
TDN supplied, lb[1]	2.78	2.25	1.46

1 All supplements are assumed to contain 75% TDN.

energy intake was not necessary, the producer would spend about $.55 per head per day or approximately $18.00 more per cow in a 100-day period.

Additional Considerations for Supplementing Low-quality Forage

Supplementation Priorities

If supplementation is the goal for cattle grazing low-quality forage, priority should first be placed on meeting the protein requirement to maximize forage intake and digestion. Many years of research have consistently shown protein supplementation is extremely effective for cattle grazing protein-deficient forage (Table 21.2). In fact, energy supplementation will not be effective if dietary protein is deficient.

Once the producer ensures the supplementation (or feeding) program will meet the protein requirement, energy intake should be evaluated, similar to the example given in Table 21.1. The decision must be made whether the cattle need to maintain body weight and condition, gain weight and condition or can be allowed to lose some weight and condition. This decision will dictate how much supplemental energy should be provided.

Table 21.2. Influence of winter protein supplementation on performance of beef cows grazing native range.

	Treatment	
Item	*2 lbs/day of 40% protein supplement*	*No supplement*
Cow weight change during late gestation	23	-153
Cow BCS[a] change during late gestation	-.33	-1.61
Calf birth weight	88.5	77.5
Calf weaning weight	484	448

a Body Condition Score
Source: Steele.

Lastly, vitamin and mineral requirements should be compared to expected intake, have potential deficiencies identified and have supplemental alternatives evaluated. This does not mean vitamins and minerals are not important. Priority is given to protein and energy nutrition first because these items are needed in much greater quantities and they have the potential to have much greater impact on animal performance and efficiency of forage utilization. Vitamin and mineral nutrition of grazing cattle is discussed in detail in chapter 19.

Protein Sources

Protein from plant origin (such as soybean meal, cottonseed meal, corn gluten feed, wheat middlings or alfalfa hay) generally results in better utilization of low-quality roughages compared to nonprotein nitrogen sources such as urea and biuret. This is particularly true when a small amount of supplement is fed (0.5% of body weight or less). Nonprotein nitrogen sources are more effective in stimulating diet utilization and animal performance under one or more of the following conditions:

- When greater than 0.5% of body weight concentrate is being fed.
- When larger, more mature animals are being supplemented (greater than 600 pounds).
- When the protein deficiency in the diet is marginal (1% to 3% more protein needed in diet compared to 4% to 8% needed).
- When a blend of plant protein and nonprotein nitrogen sources are used.
- When it is provided in a form for animals to access more than one time per day.

Generally, when three or more of these conditions exist, studies have shown that nonprotein nitrogen sources are from 75% to 95% as effective compared to an all-natural plant protein source.

Alfalfa hay and alfalfa pellets are excellent supplements for moderate- to low-quality roughage growing programs. Alfalfa has long been known to have very favorable effects on rumen fermentation and is so common in most regions of Oklahoma it is often overlooked as an ingredient or stand-alone supplement. Studies at Kansas State University show alfalfa is equal to mixtures of grain and soybean meal containing the same percentage of protein when used to supplement roughages.

Interval Feeding

Significant costs in wintering cows and stockers on dry grass are the labor and transportation required to feed supplements. Adequate research has shown cows do not need to receive protein supplements every day. In one experiment using cottonseed meal as the protein source, cows were fed the same weekly amount of supplement on two-, four- and six-day intervals (Table 21.3). Although cow weight loss was slightly less when cows were fed on four-day intervals, there was no difference in cow weight loss between two- and six-day intervals. Calf weaning weights were similar among all treatments. In a more recent study, cows were fed the same amount of cottonseed meal-based protein supplement weekly, although the feeding intervals were three times per week or six times per week (Table 21.4). In this study, there was no difference in cow weight loss, body condition score or pregnancy rate due to supplement feeding interval. Many ranchers follow the practice of feeding two times the daily

Table 21.3. Performance of beef cows fed supplement at different time intervals.

	Interval between feeding, days		
	2	*4*	*6*
Supplement, lb/feeding (41% cottonseed meal)	5	10	15
Cow weight change, lb	-185	-148	-170
Calf weaning weight, lb	433	440	428

Source: Pope.

Table 21.4. Performance of beef cows fed supplement three or six times per week.

	Days supplement fed per week	
	3	*6*
Cow weight in Nov., lb	1,187	1,211
Cow weight loss, Nov. to Apr., lb	242	255
Body condition score, Nov.	5.4	5.4
Body condition score, Apr.	4.4	4.3
Pregnancy rate, %	98	94

Source: Wettemann and Lusby.

allowance on alternate days or feeding three times per week to eliminate Sunday feeding. With interval feeding, timid cows are more likely to receive their share of supplement. Even if cows are not fed daily, they should be observed as often as necessary, especially during the calving season.

It should be noted these results were obtained using dry supplements formulated with oilseed meals. These supplements had a high concentration of plant-based protein, which has a slower rate of degradation compared to supplements containing significant amounts of nonprotein nitrogen. Cows would not be expected to perform as well if dry supplements containing significant amounts of nonprotein nitrogen were fed at extended intervals, similar to these experiments.

Interval feeding does not work as well for higher feeding rates of low to moderate protein feed (energy feeds). For example, if the producer determines that 7 pounds per day of a 20% protein supplement (moderate protein concentration) should be provided, then 49 pounds of feed would need to be delivered each week. With three feedings per week, 16 pounds of feed would have to be delivered at each feeding. With four feedings per week, slightly more than 12 pounds per feeding would need to be provided. These large quantities of feed provided on an interval basis can lead to digestive upset, founder and reduced forage intake and digestibility. Therefore, the maximum recommended amount to provide during any one feeding event is 1% of body weight (11 pounds for an 1,100-pound cow). Using this rule of thumb and the 1,100-pound cow example, the maximum feed a producer should provide on a daily equivalent would be 4.7 pounds using three feedings per week (11 x 3 = 33 pounds per week; 33 ÷ 7 days per week = 4.7 pounds per day equivalent). The maximum daily equivalent provided using a four-days-per-week schedule would be 6.3 pounds (11 x 4 = 44 pounds per week; 44 ÷ 7 days per week = 6.3 pounds per day equivalent).

Supplemental Programs for Common Situations in Oklahoma

When hay or pasture nutrient concentration can actually be measured (samples collected and analyzed) and monitored, the methodical approach presented previously will be the most cost-effective way to determine the type and amount of supplement to feed. However, many low-cost producers do not feed hay and prefer to use their cows to harvest standing forage. If forage type and conditions are relatively constant from year to year, producers can develop a consistent supplementation program and fine-tune it when necessary. For example, when cattle graze native tallgrass prairie pastures, forage quality consistently declines through the summer, fall and winter months. Protein supplementation needs are quite predictable and may vary more from changing genetics or time of calving than forage conditions. Table 21.5 shows supplementation schedules for this type of forage with different calving seasons and winter weather conditions. Notice the feeding rate of the high-protein supplement gradually increases to offset the declining forage protein.

More energy is necessary when wet, cold weather conditions persist for long periods of time. Therefore, feeding higher daily amounts of a moderate-protein supplement is advised when these conditions exist or anytime cows are observed to be losing weight and condition too rapidly.

The goal for a spring-calving herd is to strive for a BCS 5 in mature cows by the time they calve in order to achieve optimum rebreeding during the spring and early summer months. Fall-calving cows usually calve in very good body condition (BCS of 6 to BCS 8) and the producer can allow these cows to gradually lose some condition through the winter. The main objective for a fall-calving cow is to prevent her from losing too much condition before the end of the breeding season. Once she is pregnant, additional weight and condition loss and lower rates of supplementation, will not hinder the established pregnancy.

Table 21.5. Common supplementation strategies for cows grazing native warm-season forage[a] during winter.

Month	*Spring-calving cows*		*Fall-calving cows*	
	Good cow condition and/or moderate weather	*Marginal cow condition and/or severe weather*	*Good to moderate cow condition and/or moderate weather*	*Thin cow condition and/or severe weather*
October	None	1 lb HP	2 lb HP	3 lb HP
November	1 lb HP[b]	2 lb HP	3 lb HP	4 lb HP
December	2 lb HP	3 lb HP	4 lb HP	6 lb MHP[d]
January	3 lb HP	4 lb MP	6 lb MHP[d]	7 lb MHP
February	3 lb HP	5 lb MP[c]	6 lb MHP[d]	7 lb MHP
March	3 lb HP	6 lb MP	5 lb MHP[d]	6 lb MHP
April	2 lb HP	4 lb MP	3 lb MHP[d]	3 lb MHP

a Forage protein declines to a low of around 3% to 4% during mid winter.
b HP = high protein supplement, containing 35% to 40% protein, as fed basis.
c MP = moderate protein supplement, containing 20% protein, as fed basis.
d MHP = moderate-high protein supplement, containing 25% protein, as fed basis.

When gestating cows consume hay or pasture that remains above 8% protein, low to moderate protein (energy) supplements, such as corn grain, soybean hulls, wheat middlings or milo can be used at about the same feeding rates as shown in Table 21.5. However, after calving, a moderate protein supplement may be necessary to offset the protein requirement for lactation. The amount or concentration of protein in the supplement will depend on the protein concentration in the forage base.

Using High-quality Pastures to Supplement Low-quality Forage

In many parts of Oklahoma, small grains pastures can be used to supplement cow herds in winter. Because these are high-quality forages, full-time grazing by beef cows results in considerable waste of valuable nutrients. A dry cow grazing continuously on small grain pasture consumes up to 10 times her requirement in protein. A more efficient use of these forages is accomplished by limit-grazing, restricting access to green pasture to a few days or hours each week and providing low-quality harvested or standing forage during the remaining time.

Small grain forages such as wheat pasture are high in protein, containing 15% to 30% digestible protein on a dry matter basis. Recent work at the Samuel Roberts Noble Foundation indicated mature steers consumed an average of 2.7 pounds of wheat forage dry matter in a 45-minute period. Since the wheat forage contained 30% crude protein, the steers consumed 0.8 pound of crude protein during this short period of time. This would be approximately equivalent to 4 pounds of a 20% protein supplement. Other research suggested beef cows consume between 0.5% to 1% of their body weight in rye forage dry matter during one fill-up grazing bout (Table 21.6). The fill-up period was approximately four hours in this study. Data suggest small grains forage dry matter intake is at the lower end of this range during the first few days of limit-grazing. Eventually, small grains forage intake increases substantially during the fill-up grazing bout after the cows have adjusted to the limit-grazing program. After about three weeks, these cows were consuming enough forage to supply about 3 pounds of crude protein; the equivalent of 7.5 pounds of a 40% protein supplement or 15 pounds of a 20% protein supplement.

Labor availability, location of the small grains pasture, the low-quality forage resource and weather conditions frequently limit the use of limit-grazing systems. For these reasons, producers frequently use an interval limit-grazing approach. Rather than giving cows access to small grains pasture for a few hours each day, cows are provided access to small grains pasture for one fill-up grazing bout (three to five hours) for every two days to six days grazing the low-quality forage or consuming the low-quality harvested forage. A three- to five-hour grazing bout limits the loss of valuable forage due to trampling, bedding down and manure deposits.

The limit-grazing schedule shown in Table 21.7 is provided as a guideline for limit-grazing intervals necessary to provide adequate supplemental protein and energy to beef cows at different stages of production. For example, in January spring calving, cows would graze native range or consume hay with low protein content for three days, followed by one day (three to five hours) grazing small grains pasture before being returned to the low-quality forage source.

Replacement heifers will require approximately one day shorter intervals between small grains grazing bouts to continue growing, maintain or improve body condition and have a reasonable chance of rebreeding for their second calf. Remember that the appropriate time spent grazing the small grains pasture is likely to vary considerably depending on the situation. Factors such as low -quality forage protein and content and digestibility (energy content), small grains forage standing crop, cow size, stage of production, genetic potential for milk production, body condition score and age will have a substantial impact on this decision.

With average weather conditions in central and western Oklahoma, enough small grains forage should be accumulated by early December to supply the protein needs of about 1 to 1.5 cows per acre through the middle of February, assuming that a limit-grazing program is used. After the small grains forage begins to grow rapidly during late February or early March, protein needs can be met for 1.5 cows to three cows per acre, again, assuming a limit-grazing program is used.

Table 21.6. Beef cow rye forage intake during one fill-up period (approximately 4 hours).

Days relative to initiation of limit-grazing	*Forage dry matter intake, lbs*	*Crude protein intake, lbs*
Day 1	5.0	1.25
Day 2	7.2	1.80
Day 23	11.9	2.98

Source: Altom and Schmedt.

Table 21.7. Approximate interval between small grains grazing bouts necessary to meet supplemental protein and energy needs of beef cows[a,b].

	Number of days consuming low quality forage per fill-up grazing bout	
Month	*Spring calving cows*	*Fall calving cows[c]*
December	4	2
January	3	2
February	3	3
March	2	3
April	2	3
Total days grazing small grains pasture (12/1 – 4/15)	38	42

a These suggested intervals assume that abundant low quality forage is provided at all times when the cows are not grazing small grains forage.
b Reduce the suggested interval by one day for first-calf heifers.
c Calves should be provided free-choice access to the small grains forage using creep gates.

While not as abundant in protein as small grain forage, tall fescue in winter will meet the protein needs of a dry cow with less than full-time grazing. An efficient system for wintering cows on fescue is to accumulate fall growth in the pasture for grazing after Dec. 1. When pastures are adequately fertilized with nitrogen, the accumulated forage contains from 9% to 14% protein. Similarly, fertilized, stockpiled Bermudagrass pasture can contain 9% to 14% protein through the month of December.

Limiting Feed Intake with Salt

Occasionally, it is desirable to self-feed supplements to cows in winter. For example, rough and inaccessible pastures limit a producer's ability to deliver supplements on a timely basis. In these situations, salt can be used to control intake of the supplement. The ratio of salt-to-supplement can be varied to achieve any desired supplement intake.

Self-feeding of supplements tends to allow timid, slow-eating cows to get their share. Vitamin A, minerals and other feed additives can be provided through the supplements.

There are disadvantages to feeding salt-concentrate mixes. Salt is not a precise regulator of intake since certain individuals will tolerate more salt than others. Additionally, salt is destructive to metal storage bins, feeders and farm vehicles.

The daily salt requirement for mature cattle is less than 1 ounce per head per day; however, voluntary intake often exceeds minimum needs. Maximum daily voluntary intake of salt is approximately 0.1 pound salt per 100 pounds body weight for most classes of cattle.

Effects of High Salt Intake

Salt toxicity is seldom seen in cattle because of their high tolerance for salt. The one-time lethal dose for mature cattle is 4 pounds to 5 pounds of salt. Salt is rapidly absorbed from the intestinal tract into the bloodstream. It is then excreted by the kidneys through urine. However, the animal is able to eliminate excess salt only when adequate clean water is available. Therefore, an abundant, clean water supply is a must when this method is used.

Salt toxicities are most likely to occur:

1. Where cattle have been deprived of salt for extended periods of time and suddenly have readily available salt.
2. When cattle eat excessive salt with an inadequate water supply.
3. When cattle drink water containing a high concentration of salt.

As a rule of thumb, cattle on salt mixtures drink 50% to 75% more water than normal, or approximately 5 gallons of additional water for each pound of salt. If only salty water is available, cattle will often refuse the supplement or may be forced into a toxicity situation. Salt content of water is usually measured by total dissolved solids (TDS) which includes calcium, magnesium, sodium chlorides, sulfates and bicarbonates. In general, caution is necessary in using salt-limited supplements when water contains more than 5,000 parts per million TDS. This analysis can usually be obtained through the Soil, Water and Forage Analysis Laboratory (SWAFL) of OSU (check with your local county Extension educator).

Salt used in self-fed supplements should be coarse, plain white salt. Cost alone prohibits the use of trace-mineralized salt; however, this should be avoided since forced feeding high levels of trace-mineralized salt could result in toxicity or mineral imbalances due to excessive intake of certain trace elements. If cattle need trace-mineralized salt, the amount consumed daily should not exceed 0.02% of the animal's body weight.

Controlled experiments in several states have failed to show any harmful effects upon cattle production from proper use of salt-concentrate mixes. High salt intake with adequate water has had no effect on fertility, calf crop percentage, weaning weight or appearance of animals.

Adjusting Salt Levels

Several factors influence the concentration of salt required in a mix to achieve a certain feed intake. Where large amounts of salt are naturally present in drinking water or forage, the amount of salt in the mix must be reduced to get satisfactory feed intake. On the other hand, it usually is necessary to increase the salt content of the mix through a period of time, as cattle become accustomed to the high salt level. Cattle also tend to consume more of a salt-limited supplement when forage is scarce or unpalatable. Extra precautions should be taken with these and other emergency conditions to ensure water supplies are adequate.

Estimates of salt needed to limit feed intake are shown in Table 21.8. Actual salt intake occasionally varies from the indicated values. Forage intake, palatability of supplement ingredients, salt content of the water and animal adaptation influence salt intake.

When cattle are accustomed to eating supplements but unaccustomed to self-feeding, prevent overeating by starting with a high salt level (50-50 or even 60-40 ratio of salt to meal). Then, the salt level should be reduced to obtain the desired level of intake. If cattle have not eaten concentrates before, a training period of a week or more of daily hand feeding of meal without added salt may be necessary.

If grain is included in a self-fed supplement, it should be cracked or coarsely ground and mixed with salt of similar

Table 21.8. Estimated salt intake of cattle fed salt limited supplements[a].

	Salt consumption, lbs/day		
Body weight, lbs	*Low*	*Average*	*High*
300	0.3	0.5	0.6
500	0.5	0.6	0.7
700	0.6	0.7	0.9
900	0.7	0.9	1.1
1,100	0.8	1.1	1.3
1,300	0.9	1.3	1.5

a Assumes drinking water is low in total dissolved solids (TDS).

particle size. This prevents separation of the salt from the grain and aids in preventing overeating. Adequate grass or hay must be available so the cattle are not forced to eat a salt-limited supplement to survive.

Example: A producer wants to self-feed cottonseed meal at the rate of 2 pounds per head per day to a group of 1,100-pound cows. Table 21.8 indicates that the daily salt consumption of 1,100-pound cattle averages 1.1 pounds when salt is used to limit supplement intake. Therefore, the producer's feed blend should include 1.1 parts salt and 2 parts cottonseed meal. Total intake would be approximately 3.1 pounds per day and the blend would contain 35%salt. The producer will need to monitor intake and adjust these percentages slightly to achieve the desired feed intake.

Assume that in addition to 2 pounds protein supplement, it is desired that the cow also consumes 3 pounds of grain (corn, milo, etc.) for a total nonsalt consumption of 5 pounds. In this case, the blend would contain 1.1 parts salt, two parts cottonseed meal and three parts corn grain for a total of 6.1 pounds intake per day. This blend would contain 18% salt.

Conclusion

Reducing feed costs, while maintaining performance is a must for Oklahoma cow-calf producers. By using a systematic approach to evaluating beef cow nutritional requirements, forage nutrient contribution and alternative supplemental sources, an optimal winter nutrition program can be designed. The lowest cost alternative will not always be the best program, due to the relative value of convenience, labor availability and feeding system. The most effective way to evaluate alternatives is to first determine the cost of the total supplementation program, then compare differences in cost with other factors.

References

Aljoe, H. (2000) Limit Winter Grazing as a Protein Supplement. Ag News and Views, Noble Foundation. Retrieved fromnoble.org/Ag/Forage/WinterGrazing/Index.htm

Altom, W. and T.F. Schmedt (1983) Limit Grazing of Small Grain Pastures. Proceedings: National Wheat Pasture Symposium. Oklahoma Agricultural Experiment Station MP-115: 297-315.

Gill, D.R. et al. (1989) Feeding the Cow Herd. Oklahoma Beef Cattle Manual, (3rd Edition) Oklahoma Agricultural Experiment Station E-913:1-8.

Hibberd, C.A. and T.A. Thrift (1992) Supplementation of Forage-Based Diets: Are Results Predictable? *Journal of Animal Science* 70 (Suppl. 1):181. (Abstr.).

National Research Council. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, D.C.

Pope, L.S., Nelson, A.B. and Campbell, W.D. (1963) Feeding protein supplements to range beef cows at 2, 4, or 6-day intervals. Feeder's Day Report. Oklahoma Agricultural Experiment Station Pg. 49:51.

Steele, J.D. et al. (2002) Drought Stressed Soybean Supplementation for Gestating Beef Cows Grazing Native Tall Grass Prairie. Oklahoma Agricultural Experiment Station Research Report P-993. Retrieved February 4, 2004 fromansi.okstate.edu/research/2002rr/index.htm

Wettemann, R.P. and K.S. Lusby (1994) Influence of Interval of Feeding Protein Supplement to Spring Calving Beef Cows on Body Weight and Body Condition Score During the Winter. Oklahoma Agricultural Experiment Station Research Report P-939:123-125.

22 Supplementing and Feeding Calves and Stocker Cattle

Paul Beck and David Lalman

Objectives

- **Define supplementation and substitution.**
- **Discuss summer supplementation strategies.**
- **Discuss winter supplementation strategies.**
- **Explore various feeding programs.**
- **Describe changes in forage nutritive quality altering supplementation responses.**

Overview

The stocker industry is an important economic enterprise in Oklahoma because of the abundant forage resources that can be utilized for low-cost weight gain on cattle. In addition, an abundant supply of oilseed meals, cereal grains, silages and grain milling and ethanol byproducts are produced in the Midwest and High Plains. These feed resources can be used in growing programs as a major portion of the diet or used as supplements to enhance the performance of grazing cattle. Because of the numerous options available and variables involved, producers who do a good job of tailoring their supplementation or feeding program to fit their situation are much more likely to be profitable compared to producers who do not.

When cattle consume forages as their only energy source, intake may not be adequate to meet desired rate of gain. When forage alone is not adequate for desired animal performance goals supplements are often provided, an in-depth understanding of the nutrition requirements of the animal, desired gain response and forage quality are necessary for the optimization of supplementation programs for maximum profitability.

There are five basic reasons for supplementation:

1) Correct nutrient imbalances for animal and ruminal microbes
2) Increased daily gains
3) Increase carrying capacity
4) Carry feed additives and minerals
5) Dilute forage toxins

Forage digestion in ruminants depends on microbial fermentation of the fiber. Microbial populations depend on availability of protein (rumen degradable proteins and nitrogen; chapter 15) and energy for microbial growth. Byproducts of fermentation of roughages (volatile fatty acids – acetate, propionate, butyrate etc.) are a source of energy to other microbes and the host animal. Microbes are then used as a source of protein to the host animal. So, supplementation of grazing cattle is complicated because there are feeding two systems, 1) the rumen environment and 2) the host animal.

Protein requirements of growing calves varies substantially with rate of gain and other genetic factors. For instance a steer weighing 600 pounds requires a diet supplying 9.3% crude protein (CP) and is 59% digestible. If the steer is gaining 1.5 pounds per day, the diet needs to be 10.5% CP and 64% digestible; and at 2 pounds per day the diet needs to be 11.9% CP and 69% digestible.

Forage TDN:CP ratio

Microbial protein production is limited by the amount of energy and the efficiency of energy use in relation to the amount of rumen degradable protein (RDP). If there is insufficient rumen degradable crude protein in the rumen in relation to the energy available, the imbalance results in low forage intake and digestibility and reduced performance. Nitrogen (N) that is not used for microbial growth is absorbed through the rumen wall as ammonia and recycled through the liver and back to the rumen. Some of the nitrogen in high-quality forages is so rapidly degraded in the rumen that it is not incorporated into microbial protein and will be excreted from the animal in the urine. This impacts the types of supplements used for cattle grazing high-quality pasture which will be discussed in chapter 23.

Often, the performance response to supplementation is not what was expected. The difference between expected and actual performance response to supplementation are explained by associative effects of supplements on the rumen environment and the level of available energy in the total diet. Increased response compared to expected performance are known as "positive associative effects" with increased forage intake with added supplement. A decreased response to supplement compared to an expected response is known as a "negative associative effect" with forage intake decreasing when supplements are provided. Even though forage is the least expensive feed resource for

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

cattle, the nutritive value of forage is not sufficient to meet the animal's dietary requirements at times. In these cases, supplementation of the deficient nutrient or nutrients will usually increase forage intake and digestibility, improve health status and/or maintain a higher level of productivity. When the provision of one or more nutrients in the form of a supplement increases forage intake and digestibility, the supplement is said to have a positive associative effect on forage utilization (Figure 22.1). Supplementation can also result in no change in forage intake and digestibility, with the end result being greater total nutrient intake, relative to the control (0). Too much supplement leads to substitution for forage. (Figure 22.1).

The ratio of rumen degradable energy to crude protein is expressed as the total digestible nutrients to crude protein ratio (TDN:CP). At a TDN:CP ratio of >7:1 there is a deficiency of nitrogen in relation to available energy, providing a small amount of RDP (cottonseed meal supplement for instance) will result in increased forage intake and digestibility. When TDN:CP is less than 4:1, there is not enough available energy to incorporate nitrogen into microbial protein and a small amount of supplemental energy (corn or byproduct feeds) can reduce nitrogen loss and improve forage nitrogen incorporation into microbes. The TDN:CP between 4:1 and 7:1 are considered balanced and supplemental nutrients should be provided to correct nutrient deficiencies for the animal without expectation of positive associative effects. Table 22.1 has examples of forage TDN:CP ratios in common Oklahoma forages throughout the year.

Forage Nutritive Quality of Warm Season Grasses

Table 22.1 has the seasonal nutritive quality of warm-season forages common to Oklahoma. These forage analysis are only examples and the actual forage conditions varies from ranch to ranch, and on each ranch, forage conditions vary considerably across years. Tallgrass prairie sampled by collecting forage actually selected by grazing steers starts its growth in May during the late spring with crude protein levels that are adequate for high levels of performance but a deficiency in energy (TDN) for high rates of growth. In June, the CP concentrations decreased substantially but TDN declined only slightly. Samples from August and September show large reductions in both CP and TDN. When tallgrass prairie species stop growth in the fall, forage CP and TDN continue to decline with significant deficiencies in CP and an unbalanced TDN: CP. This indicates CP of tall grass prairie is deficient to the animal and provides unbalanced TDN:CP, limiting forage digestibility and forage intake during the late summer and fall. In western Oklahoma, native prairie species are a mixture of tallgrass, midgrass and short grass species. The growth habit and conditions are different and this results in differences in forage nutritive value. In Table 22.1, forages sampled in western Oklahoma at the Marvin Klemme Range Research Station are more often deficient in energy (TDN) or deficient in both TDN and CP throughout the year. Old World bluestems are an introduced forage species that, when managed with fertilizer and grazing, contain high levels of CP and are highly digestible in the early summer. This quality can be maintained through the summer until energy deficiencies become an issue in August. During the winter, Old World bluestems decrease in CP and will have an unbalanced TDN:CP ratio until regrowth starts in the spring. Bermudagrass managed with fertilizer and rotational grazing maintains adequate protein concentrations even late into the winter but digestibility becomes limiting during the late summer and continues to decline through the fall and winter after it goes dormant.

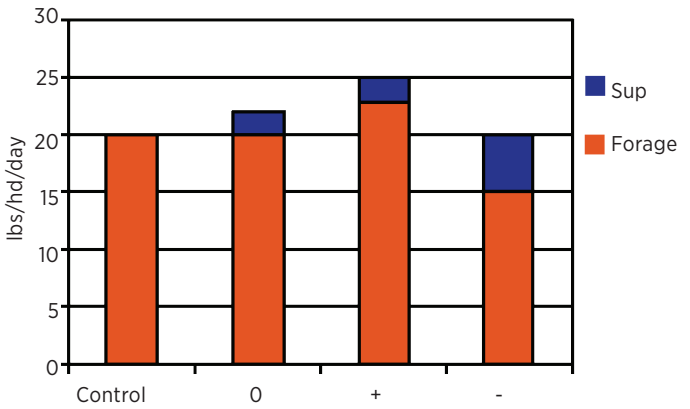


Figure 22.1. Influence of supplemental feed on forage intake (lbs/hd/day); positive (+) or negative (-) associative effects.

The low CP and unbalanced TDN:CP ratio of tall grass prairie in the late summer and fall and for Old World bluestems in the winter indicate a small amount of rumen degradable protein (RDP) supplement during the late summer and fall will have positive associative effects by increasing forage digestibility and intake. This supplementation program is not universal for all seasons or forage species.

Supplement and Feed Types

A list of commonly available feedstuffs is provided in Table 17.1. Becoming knowledgeable of feed nutrient values is important, particularly if the producers intend to purchase feed commodities or mix their own feed. It is important to be aware the nutrient values listed in Table 17.1 are averages, and energy values apply to mixed roughage and concentrate diets formulated for moderate rates of growth. These values are based on data from the National Research Council and other sources. Unfortunately, energy values for many feeds change, as the amount in the diet changes. This issue is commonly referred to as associative effects. Each feedstuff has different characteristics that allow it to be matched with the intended production goals and forage characteristics.

Supplements for Pasture-based Growing Programs

Spring and Early Summer

Most forages in the spring and early summer provide adequate CP and digestibility to reach practical production

Table 22.1. Seasonal nutritive quality of common warm-season forages.

Forage/Month	*Component*		
	Crude protein	*Total digestible nutrients*	*TDN:CP*
Tallgrass prairie		Campbell, 1989; Average of forage collected in 1987 and 1988	
May	13.4	57.3	4.3
June	9.9	55.4	5.6
August	7.2	52.3	7.3
September	7.8	50.5	6.5
		Bodine, 2003; Average of collected 2001 and 2002	
October	6.1	56.1	9.2
November	5.8	50.6	8.7
December	5.7	50.9	8.9
Midgrass prairie		Gunter, et al., 1991	
May	13.1	58.6	4.5
June	8.8	54.2	6.2
August	10.0	54.2	5.4
October	10.6	53.7	5.1
		Marston et al., 1993	
December	10.0	46.1	4.6
February	11.2	42.6	3.8
April	17.4	66.4	3.8
Old World bluestem		Ackerman, 1999; Average of collected 1997 and 1998	
May	14.5	60.1	4.1
June	15.5	62.8	4.1
July	12.4	67.6	5.4
August	10.6	67.6	6.4
		Marston et al., 1993	
December	6.8	50.5	7.4
February	6.8	50.9	7.5
April	13.9	55.9	4.0
Bermudagrass		Beck et al., 2016	
May	13.6	56.3	4.1
June	14.9	61.4	4.1
July	12.5	59.2	4.7
September	12.0	60.9	5.1
October	15.5	63.3	4.1
November	12.3	54.3	4.4
January	10.5	52.4	4.8
February	11.2	50.8	4.5
March	11.0	52.1	4.7

goals (Table 22.1). Therefore, supplementation to provide additional nutrients is usually not practiced. Using supplements as a carrier for feed additives, vitamins, and minerals is often practiced, as well as using supplements to increase carrying capacity which will be described later. In most cases, a high protein supplement is not required during the spring and early summer. Mid-protein (14% to 30% CP) supplements based on grain milling byproducts (wheat middlings, soybean hulls, corn gluten feed and dried distiller's grains) have less negative impacts on forage intake and digestion than grains. The grain milling byproducts are made up primarily of fiber that is digestible in the rumen and contains very little starch that would decrease ruminal pH and upset microbial populations if fed at high rates.

Late-summer Pasture

Tallgrass native range species, less intensively managed Bermudagrass and cool-season perennial pasture forage quality rapidly declines as they mature. This occurs during the mid- to late-summer for warm-season grasses and during the late spring for cool-season pastures. As a consequence, stocker cattle gains on warm-season pastures can fall from performance highs of 2 pounds to 3 pounds per day during spring and early summer, to below 1 pound per day through the late-summer grazing period. Table 22.1 indicates that protein concentration in native range forage rapidly declines after May. The result is realized in late summer weight gains of around 1 pound per day.

In several trials conducted at OSU with prairie hay harvested in mid-summer, forage intake was increased by 20% to 30% and digestibility was improved by 15% to 20% when cattle were supplemented with 1 pound of a 38% to 41% rumen degradable protein supplement. This improvement in forage utilization for hay-fed cattle also applies to stocker cattle grazing summer pastures.

Logically, this assumes forage availability is adequate. A small quantity of high-protein supplement will not improve weight gain if pastures are overgrazed. Table

22.2 summarizes research trials in which weight gain of nonsupplemented calves was compared to weight gain of calves supplemented with 0.9 pound to 1.2 pounds per day of 38% to 41% protein feed.

In seven research trials conducted with late summer native or mature Bermudagrass pasture, cattle supplemented 0.9 pound to 1.2 pounds per day of a similar protein supplement gained an average of 0.38 pound per day faster than nonsupplemented cattle. This efficient response to supplement provided the basis for the development of the Oklahoma Gold and SuperGold supplementation programs. The Oklahoma Gold program consists of feeding the equivalent of 1 pound per head per day of a 37% to 40% all-natural protein supplement containing vitamin A, added trace minerals and one of three feed additive alternatives: Bovatec®, Rumensin® or Gainpro®. Numerous other studies indicate when grazing cattle receive one of these feed additives, the weight gain response ranges from 0.13 pound to 0.28 pound per day. Adding an average response of 0.2 pound to the 0.38 pound from the protein results in an average increased weight gain of 0.57 pound per day. Therefore, the average supplement conversion calculates to 1.8 pounds of feed per pound of added weight gain. These supplementation programs also would be appropriate for calves grazing mature Bermudagrass pasture. However, calves grazing mature native grass pasture during this time of the year can be expected to gain faster compared to cattle grazing mature Bermudagrass pasture.

Super Gold feed contains 25% protein and should be fed at the rate of 2.5 pounds per day. Much like Gold, the Super Gold feed product supplies supplemental protein, vitamins, minerals and a feed additive. With this program, weight gains have been improved an average of 0.76 pound per head per day when cattle graze abundant native grass pastures during late summer or early fall. This is an average supplement conversion efficiency of 3.3 pounds of feed per pound of added weight gain. The SuperGold program is a good choice for calves with high nutrient requirements, such as lighter weight calves or when economic conditions support pushing calves for higher rates of gain. The SuperGold program fits forage systems with more balanced TDN:CP ratio, such as well managed Bermudagrass, Old World Bluestem or short- and mid-grass native range. A mid-protein, high energy supplement, similar to the SuperGold formulation, is the better choice in situations where feed prices are moderate to low, or a faster rate of gain is necessary to achieve a predetermined market weight. Relative costs of alternative grain milling byproduct feeds can have a large impact on the most economical supplement choice.

These supplementation programs were specifically designed for growing cattle grazing abundant native pasture during late summer and early fall. Because these supplements are provided in relatively small amounts, they can be fed daily or every other day.

Adequate forage is a necessity to make these supplementation programs successful because they are designed to enhance forage intake and digestion. They are NOT designed to stretch pasture or increase stocking rate.

Table 22.3 shows typical formulations for Oklahoma Gold and SuperGold feeds. Similar results should be attainable with free-choice supplements designed to deliver approximately the same amount of degradable protein, minerals and the feed additive. Examples of these small-package supplement delivery systems include pressed and cooked block products as well as liquid feed products. Some of these products will contain at least some nonprotein

Table 22.3. Typical formula for Oklahoma Gold and Oklahoma Super Gold feeds.

	Composition, % (as fed basis)	
Ingredient	*Oklahoma Gold*	*Oklahoma SuperGold*
Cottonseed meal	86.0	17.0
Soybean meal	-	15.0
Wheat middlings	7.0	56.0
Molasses (pellet binder)	4.0	4.0
Vitamin and mineral premix	3.0	3.0
Feed additive	Variable	Variable
Crude protein, % as fed	38.0	25.0
Feeding rate, lbs per day	1.0	2.5

Table 22.2. Summary of trials evaluating response of grazing cattle to protein supplement[a].

Initiation date	*Trial length, days*	*Initial cattle weight*	*Control ADG, lbs*	*Supplement ADG, lbs*	*Added gain, lbs/day*	*Supplement conversion, lb sup/lb added gain*	*OSU Animal Science Research Report Reference*
7/16	96	580	1.44	1.88	0.44	1.8	MP - 112, 1982
7/20	56	350	1.35	1.72	0.37	2.2	MP - 114, 1983
7/20	62	616	1.06	1.39	0.33	3.2	MP - 117, 1985
8/16	56	490	0.83	1.32	0.49	2.0	MP - 117, 1985
8/16[b]	57	440	0.95	1.25	0.30	3.3	MP - 117, 1985
7/16	84	645	0.83	1.25	0.42	2.9	MP - 118, 1986
5/25	84	365	1.48	1.75	0.27	3.7	P - 939, 1994
7/28	84	622	1	1.5	0.5	2	P - 1014
7/16	68	699	1.33	1.59	0.26	3.8	P - 1014
Average	72	531	1.14	1.52	0.38	2.77	

a Supplement amount ranged from 0.9 pound to 1.2 pounds per day and contained 38% to 41% crude protein on a dry matter basis. All supplements were formulated with soybean meal and/or cottonseed meal as the protein source.

b Forage base was Bermudagrass pasture. All other studies utilized native range pastures.

nitrogen. While nonprotein nitrogen can be used effectively by grazing cattle under certain conditions (see chapter 21), a high percentage of nitrogen (protein) from plant sources will likely give better results in this situation, compared to a feed product containing a high proportion of nonprotein nitrogen.

During Winter

Stocker cattle often are purchased ahead of the period when high-quality forage, such as spring grass or grazeout wheat pasture, will be available. Many of these holding/growing programs are based on moderate- to low-quality forages and roughages, such as grass hay and stockpiled native range, Bermudagrass or cool-season perennial pasture. This approach allows producers to take advantage of seasonal stocker cattle availability and market trends. If hay or standing forage is available, the normal strategy is to target gains at a rate that at least covers daily cash and overhead costs, but does not reduce subsequent performance when cattle graze high-quality forage or when placed in the feed yard. Target weight gains between 0.5 pound and 1.5 pounds per day are common.

Supplements for this situation should achieve one or more of the following:

- Supply protein to enhance roughage intake and digestion (for roughages not meeting protein requirements).
- Supply additional energy above that obtained from the roughage; this is critical with lightweight calves (less than 350 pounds).
- Supply other important items in the diet such as vitamins, minerals and additives (ionophores or coccidiostats).

Protein requirements vary depending on animal age, weight and rate of gain. For example, a 450-pound steer gaining 1 pound per day requires approximately 10% crude protein on a dry matter (DM) basis. A 450-pound steer gaining 2 pounds per day requires approximately 12% DM protein. Consequently, the appropriate amount of total protein in the diet, therefore, the correct protein concentration in the supplement depends on the target gain and the amount of energy available in the diet.

Dormant native range is almost always low in protein; at 3% to 5% DM. Standing Bermudagrass forage is more variable, depending on forage quality at the end of the growing season, fertilization history and the amount of deterioration from rainfall. If forage quality is high at the time of first frost, it is not uncommon for protein concentration to be more than 8% through the month of January. However, if Bermudagrass forage is more mature at the time of first frost and significant rainfall occurs during late fall and early winter, protein content will likely be low and comparable to native winter range. Similarly, cool-season grass hay protein concentration is extremely variable and depends on maturity at harvest, species, fertilization program and harvest conditions. A typical range for protein concentration is 6% to 14% for Bermudagrass hay and 4% to 8% for prairie hay. The only way to be sure of nutrient concentration and the most appropriate supplementation program is to have hay samples analyzed for nutrient content by a commercial laboratory. See OSU Extension fact sheets PSS-2589, *Collecting Forage Samples for Analysis* and PSS-2117, *Forage Quality Interpretations* for more information regarding hay testing and analysis interpretation.

Supplementation vs Forage Substitution

When forage supply is not adequate to sustain the number of animals grazing a land area for a given time period, forage dry matter intake declines in accordance to the extent of the limitation and the quality of the remaining forage. A supplementation experiment was conducted at the Marvin Klemme Range Research Station in western Oklahoma. This station has forage resources that are mixed-grass or short-grass prairie species. Steers were fed 1 pound per day of a 33% CP soybean-meal-based cube from June through the end of grazing in September. When steers were stocked at 7.5 acres per steer, they gained 0.5 pound more per day compared to unsupplemented controls, yet when steers were stocked at 5.7 acres per steer gains were only increased by 0.2 pounds per day. The increased stocking rate decreased forage availability during the late summer and supplemented steers were unable to increase forage consumption because of this forage deficit. The forage production potential and stocking rate must be included in the decision about supplementation programs. In times of plenty of low-quality forages (late summer tall grass prairie or winter grazing programs), a small amount of a high-protein RDP supplement may be the solution to increase forage intake and digestibility and, as a result, increase animal performance very efficiently.

If forage production is limited or stocking rates are high, animals have less forage to select from, so diet quality declines. As a result, animal performance frequently declines when forage availability is significantly limited. One unfortunate (although frequently observed) example is stocker steers being maintained in an overgrazed pasture during a drought. During times of drought or necessary short-term overstocking, some ranchers choose to replace forage with other feed resources. This practice is referred to as substitution or substitute feeding. The objective can be two-fold: limit or eliminate the potential decline in animal performance due to a shortage of forage, or reduce the rate and/or extent of forage disappearance to maintain a higher stocking rate. This objective also is referred to as stretching the forage with feed. Substitution can have a negative associative effect on forage utilization because forage intake is reduced and, in certain cases, forage digestibility may be reduced (Figure 22.1). Total nutrient intake by the animal may not change, or it may slightly increase, resulting in improved animal performance.

The distinction between supplementation and substitution, regarding the amount of feed provided, is not well defined for cows or growing calves. However, most studies indicate forage intake declines when more than 0.5% of body weight supplemental feed is provided.

The substitution rate (decline in forage intake) is variable and depends on the amount of feed provided, protein concentration of both the base forage and the feed, and the type of supplemental feed being provided. In general, each pound of additional feed beyond the 0.5% of body weight rule of thumb can reduce forage intake by 0.5 pound to 2 pounds. The substitution rate and negative associative effects are greater when feed grains are fed in combination with low-quality forage with inadequate supply of ruminally degradable protein.

An example of this in action is research conducted in central Oklahoma on Old World Bluestem pastures (Reuter et al., 2015) shown in Table 22.4. Each summer for four years, stocker steers grazed

1) unfertilized pastures stocked at 280 pounds of steer per acre;
2) fertilized (80 pounds of actual nitrogen from urea per acre) and stocked at 565 pounds of steer per acre;
3) fertilized with N and P (80 pounds of actual nitrogen per acre and 35 pounds of phosphorous per acre) and stocked at 565 pounds of steer per acre; and
4) unfertilized and steers were supplemented with dried distiller's grains with solubles (DDGS) at 0.75% of steer body weight/day and stocked at 565 pounds of steer per acre.

Fertilization increased stocking rates without reducing steer performance, so total bodyweight gains per acre were increased by 85% to 99% with fertilization (1 to 1.25 pounds of gain per pound of fertilizer N applied). Feeding DDGS at 0.75% of steer bodyweight daily allowed for increased stocking rates and increased steer ADG by 0.25 pounds per day over Control (which were fed 1 pound per day of a high-protein supplement during the late summer) and increased total bodyweight gain per acre by 126 pounds. Based on the economic conditions at the time of the experiment using DDGS to increase stocking rates increased net returns by $85 per acre compared with control and by $38 per acre over nitrogen fertilization.

Balancing Forage and Supplement Nutrients to Meet Production Goals

To maximize forage intake and digestion, protein requirements must be met. Energy supplementation will not be effective if protein is deficient. Table 22.5 gives general guidelines for the amount of supplemental protein needed, based on forage protein content and expected rate of gain. The first step is to choose the expected rate of weight gain from the table—0.5 pound, 1.0 pound or 1.5 pounds per day. The next step would be to choose the column with the forage protein concentration closest to the forage protein concentration in your situation—4%, 6%, 8% or 10%. The value in the table where the appropriate line and column intersects represents the approximate amount of protein needed to on a daily basis. This value represents the supplemental protein needed. To determine the amount of actual supplement that would need to be provided, divide the supplemental need by the protein concentration (as-fed basis) of the supplement. For example, a 400-pound steer receiving prairie hay containing 6% crude protein needs 0.6 pound of supplemental protein in order to gain 1 pound per day. If the supplement contains 20% crude protein on an as-fed basis, 3 pounds would need to be fed (0.6 ÷ 0.2 = 3). A supplemental protein requirement is not indicated for 1.5 pounds per day gain with forages containing less than 6% crude protein, simply because this level of gain with extremely low-quality forage is not practical.

Once the protein requirement has been met, weight gain usually is limited by energy availability. Therefore, producers may choose to feed additional supplemental energy to further increase animal performance. As mentioned above, feeding below 0.5% of body weight total supplement has a high probability of ensuring maximum forage utilization. Beyond that threshold, intake may decline, particularly for low-quality forage, resulting in substitution or feeding rather than supplementation. Given a situation dealing with 500-pound calves and an overall goal of maintaining maximum forage utilization, the upper limit for the amount of supplement would be 2.5 pounds per day. From Table 22.2, if it is assumed forage provides 8% protein and available energy to support 1 pound per day gain, about 0.45 pound of supplemental protein is required. This need could be met by feeding 1 pound per day of a 40% protein supplement. On the other hand, by feeding 2.5 pounds of supplement, weight gain may be increased by 0.2 pound to 0.3 pound per day. Increased weight gains result in increased daily protein requirement. Reading between the lines in Table 22.3, the daily supplemental protein requirement for 1.25 pounds per day gain (8% protein forage) would be about 0.55 pound. Therefore, the supplement would need to contain approximately 22% protein [(0.55 x 2.5) x 100]. Commercial feed companies provide supplements containing a wide

Table 22.4. Effect of feeding distiller's grains (DDGS) with solubles as a substitute for fertilizer in summer grazing Old World Bluestems.

Item	*Treatment*			
	Control	*N Fertilizer*	*N+P Fertilizer*	*DDGS*
ADG, lbs/day	1.90	1.76	1.90	2.16
Gain per acre, lbs	101	186	201	227
Net Return, $/acre	39	86	79	124

Table 22.5. Supplemental protein required (pounds per day) for 300- to 500-pound stockers with varying protein content in forage grass hay[a].

Daily gain, lbs	*Forage crude protein content (DM basis)*			
	4%	*6%*	*8%*	*10%*
0.5	0.60	0.4	0.25	0.10
1.0	0.75	0.6	0.45	0.25
1.5	-	0.8	0.65	0.50

a Calculated using equations from NRC.

range of protein concentration to fit specific situations, such as the one described in this example.

Energy from grain is primarily in the form of starch or nonstructural carbohydrate. The majority of forage energy is in the form of fiber or structural carbohydrate. When a small amount of starch-based energy supplement is fed (0.25% of body weight or less), forage intake and digestibility are either not affected or slightly improved. This assumes forage protein concentration is adequate to meet the degradable protein requirement. However, when grain is supplemented at higher levels and protein concentration in the diet is marginal or deficient, forage intake and digestibility generally decline. This is why feed grains are not thought of as being ideal supplements for cattle receiving a low-quality forage diet. Cattle receiving low-quality roughage diets make better use of feed grains if they are coarsely rolled or cracked. Consequently, formulas with high grain content are usually fed in bunks to minimize waste.

Feed grains are primarily used to provide energy to cattle because grains are energy rich and moderate to low in protein concentration (8% to 11% protein). In this sense, they are not complementary to low-quality roughages containing a low protein concentration (3% to 7% protein). Research has shown starchy feeds can reduce fiber digestion and intake of low quality roughage.

Recent research has shown the real key in efficiently using grain in low-quality forage diets is to include adequate protein along with the grain. Intensive studies looking at the amount of soybean meal necessary to overcome the negative associative effects have been conducted recently. Table 22.6 shows the performance of steers grazing dormant range during winter and supplemented with nothing, corn, soybean meal or an 80/20 blend of corn and soybean meal (16.5% crude protein, as fed basis). This demonstrates that straight corn, fed at 1.25% of body weight, resulted in very disappointing weight gains, relative to the amount of feed provided. This is an excellent example of the negative associative effect grains can have on forage intake and digestion when the degradable protein supply is deficient. However, weight gain was increased by nearly 1 pound per day when 2.5 pounds of soybean meal was fed alone. When soybean meal was blended with the corn, the cattle were much more efficient in utilizing the energy in the grain.

An alternative method to determine the appropriate amount of protein to include in a feed is to calculate the degradable protein requirement. Average protein degradability for each feed is shown in Table 16.1 (page 135). In general, degradable protein supply should be a minimum of 11% of total digestible nutrients (TDN) intake when less than 0.5% of body weight concentrate is being fed (true supplementation) to cattle consuming low-quality roughages and forages.

When greater than 0.5% of body weight concentrate is fed, or when higher-quality forages are provided, degradable protein should be fed to approximate 13% of TDN intake. For example, if a 60% TDN diet were being fed at the rate of 15 pounds per day, the animal would consume 9 lbs of TDN. Degradable protein supply should be 0.13 x 9 = 1.17 pounds per day, which is equivalent to 7.8% of the diet on an as-fed basis (1.17 x 15 x 100). However, if target gains of 1.5 pounds or more are desired, the concentrate will need to be fed at higher levels compared to true supplementation programs. In this situation, the grass or hay actually becomes a minor portion of the diet, and the feed provides most of the nutrients.

Table 22.6. The effect of protein and energy supplementation on performance of steers grazing dormant native pasture[a].

	No supplement	*Corn*	*SBM*	*Corn + SBM*
Amount fed, lbs/day	-	8.2	2.5	8.2
ADG, lbs/day	0.12	0.64	1.06	1.7

a Initial weight of steers = 631 pounds corn + soybean meal mix contained 16.5% protein, as fed basis.
Source: Bodine.

When supplement amount exceeds 0.5% of body weight, several factors need to be considered. First, care must be taken to ensure all cattle have an equal opportunity to eat the desired amount of supplement. Some cattle may choose a diet of mostly supplement, while other cattle consume roughage only. This leads to greater variation in performance, and if livestock consuming only roughage ingest a concentrate, digestive disorders can occur. Additionally, if cattle are not nearby when feed is delivered, some may overconsume supplement, while others receive none. Such shifts in feed intake are a serious concern if the supplement contains a high level of starch, with acidosis as a possible result, regardless of why the shift occurs. Highly digestible fiber from grain milling byproduct feeds provide more safety when large amounts of supplement are fed.

The final objective of a supplement for grazing cattle is to deliver other nutrients or feed additives, such as vitamins, minerals, ionophores or coccidiostats. chapter 19 discusses in detail vitamin and mineral nutrition for grazing cattle, so consequently, those concepts will not be dealt with here. However, it should be mentioned that most ingredients included in protein and energy supplements contain substantial amounts of minerals. For example, most feed grains and grain milling byproducts contain high concentrations of phosphorus and very little calcium, while alfalfa and other legume forage resources contain high concentrations of calcium. Few feeds, other than green forage, contain substantial amounts of vitamins. Therefore, total dietary vitamin and mineral supply should be calculated and evaluated any time a supplementation or feeding program is being considered

Beyond Supplementation— Feeding Programs

In many farm situations and during some years, the high-quality pasture alternative may not be available. In these cases, hay coupled with supplementation or concentrate-feeding programs can be implemented. The number of nutrition program alternatives is virtually unlimited.

Table 22.7 includes several rations for calves receiving free-choice grass hay, with target gains between 1, 1.5,

Table 22.7 Rations for supplementation of growing calves fed free-choice hay in dry lot.

	Level of performance		
	1.0 lbs/day	*1.5 lbs/day*	*2.0 lbs/day*
Mid-bloom alfalfa (17% CP and 58% TDN)			
Supplementation rate, lbs/day	-	1.0	3.5
Supplement composition, % as-fed basis			
Cracked corn	-	97.0	99.6
Dicalcium phosphate	-	3.0	0.4
Salt/mineral mix	Free choice salt only	Free choice salt only	Free choice salt only
Grass hay (10% CP and 56% TDN)			
Supplementation rate, lbs/day	0.6	3.5	5.2
Supplement composition, % as-fed basis			
Cottonseed meal	100	14.3	32.8
Soybean hulls		-	36.1
Cracked corn		85.7	31.1
Salt/mineral mix	Free Choice Complete Mineral	Free choice salt only	Free choice salt only
Grass Hay (7% CP 52% TDN)			
Supplementation rate, lbs/day	2.3	4.0	6.6
Supplement composition, % as-fed basis			
Cottonseed meal	66.4	26.7	32.8
Soybean hulls	33.6	27.0	40.3
DDGS	-	46.3	26.9
Salt/mineral mix	Free Choice Complete Mineral	Free Choice Complete Mineral	Free Choice Complete Mineral

and 2.0 pounds per day. Separate rations are suggested for alfalfa hay (mid-bloom, 17% CP and 58% TDN), and grass hays > 10% CP (56% TDN), and grass hay containing 7% CP and 52% TDN. High quality hays like alfalfa usually have adequate minerals to meet animal requirements, thus only free choice salt is indicated in the proposed diets. As hay quality decreases, mineral levels also tend to decline, but often byproduct feeds supply needed minerals to meet requirements. Mineral content of forages is quite variable, so unless mineral content is analyzed it is recommended to supply trace minerals and vitamins via a balanced mineral and vitamin premix. The producer has the option of providing calcium and phosphorus sources such as limestone and dicalcium phosphate; micro minerals such as copper, zinc and selenium; vitamins A and E; and additives in the feed or in a free-choice mineral mix. The formulas shown in Table 22.7 assume the calcium and phosphorus sources will be provided in the feed mix and the other supplemental nutrients and feed additive will be provided through the mineral mix.

Silage Growing Programs

Silage production is an expensive process requiring considerable labor and equipment overhead costs. As a result, fewer cattle enterprises rely on silage as a major forage source compared to 20 years ago. Many operations using silage in growing rations use custom harvesting services rather than owning all of the necessary equipment. The majority of silage harvested for growing programs in Oklahoma is corn, sorghum or small grain silage. Corn silage contains the highest energy content (Table 17.1), but is less frequently used because of production expense and water requirements to grow the corn. The advent of baled silage wrapping technologies in recent years has increased the availability of grass silages (cool-season annuals, sorghums, etc). These forage products are often high in quality, but often are fed the same way as long-stem hay thus, supplementation programs would be the same as recommended for high quality hay products.

One advantage of a silage-based ration instead of dry mixed rations is a tremendous reduction in dust. Several ration combinations are show in Table 22.8 using four common silages in combination with wheat or corn grain and cottonseed meal as the protein source. Rations are designed to provide about 2 pounds per day gain for 400-pound calves.

These rations are formulated using the dry matter percentages from Table 16.1. It is critical that the dry matter content of particular silage be known before formulating a ration from the percentages shown in Table 22.8. Other nutrient values from Table 16.1 were used in these formulations. Naturally, more accurate feeding programs can be designed with nutrient analysis information from any batch of silage.

Limit Fed High-Concentrate Rations

A somewhat more aggressive strategy is available for producers who find themselves with calves, but no pasture and too few other roughage sources for a traditional growing/holding program. This strategy involves growing cattle at moderate rates of gain using a limited amount of a higher-concentrate ration. In times of drought or high roughage prices, limit-feeding concentrates may be more economical. However, limit fed high-concentrate diets require skilled management, compared to roughage-based diets. Many commercial feed yards have used this approach successfully for a number of years as an alternative growing program for light calves.

Table 22.8. Silage based growing rations for 400-pound steers gaining two pounds per day[a].

Ration No.	1		2		3		4	
	%AF[b]	%DM[c]	%AF	%DM	%AF	%DM	%AF	%DM
Wheat silage	80	60.3						
Sorghum silage, grain type			84	63.5				
Corn silage					92	81.5		
Forage sorghum silage							78.5	53.25
Ground or rolled:								
Wheat			11	25				
Corn	15.4	30.4					16	34.5
Cottonseed meal	4	8	4.5	10.3	7	16	5	11
Limestone	0.6	1.3	0.5	1.2	1	2.5	0.5	1.25

a An ionophore or coccidiostat should be added.
b AF = As-fed basis.
c DM = Dry matter basis.

When limit fed, producers must calculate the amount of feed to achieve competitive but restricted gains on growing cattle. OSU Cowculator is a ration-balancing program that can be used for this purpose. This program is available at: beef.okstate.edu. The daily amount of feed varies with cattle weight, diet dry matter content, energy density in the diet and the desired rate of gain.

Further critical steps are diet formulation and purchasing, if a commercial product will be used. An experienced nutritionist familiar with limit feeding should be consulted. Rations used for limited intake growing programs require special formulation. The levels of protein, vitamins and minerals must be increased over the levels used in ad libitum-fed diets.

Feeding Management

Limit feeding of cattle requires special skills and facilities. Minimum requirements are:

- Adequate bunk space so all cattle can eat at one time.
- Pens small enough so cattle can come up to the bunk when fed.
- Scales or other methods of weighing out the daily feed.
- Skill on the part of the manager.
- Roughage feeds to gradually raise the limit fed diet.
- Sufficient business management skill to evaluate the economic limitations and opportunities in limit feeding of cattle.
- A sound plan for the use or sale of the cattle following limit growing.

Table 22.9 is an example ration for a 450-pound steer to gain about 2.25 pounds per day. This is a high-concentrate ration and requires cattle be gradually adapted from a forage-based diet. At gains of about 2 pounds per day, the daily amount of feed is sufficient to keep the calves comfortable. For gains below 2 pounds per day, additional roughage may need to be added to increase total feed intake and keep calves from becoming dissatisfied and restless.

Programmed feeding will only work with cattle uniform in weight, size, age and background. Sorting cattle into similar groups may be necessary before starting.

Table 22.9. Feedstuff and nutrient composition of a limit fed ration (as-fed basis).

Ingredients	% As-fed	Nutrient	Concentration
Alfalfa pellets	7.88	Nem, Mcal/lb.	0.82
Calcium carb	0.87	Neg, Mcal/lb.	0.52
Bovatec® 68	0.02	Crude prot, %	14.05
Cane molasses	4.18	Fat, %	3.23
Rolled corn	65.91	Crude fiber, %	7.18
CSM	13.47	K, %	0.81
Salt	0.28	CA, %	0.50
SBM 48	2.38	Phos, %	0.37
Vitamin A-30	0.02	TDN, %	71.02
Cottonseed hulls	4.98	Dry matter, %	89.67

Apparent gains of cattle through short periods of time often are distorted by changes in fill. Limit-fed animals have less fill than ad-lib-fed animals.

Limit feeding can be readily adapted to operations already growing cattle in a drylot on complete rations containing traditional roughage levels. Once cattle are on full feed of the traditional ration, the roughage level can be reduced gradually until cattle are consuming the desired amount of high concentrate ration. Silages, chopped hay or other roughage sources can be used.

Feedlot research shows that calves grown on limit fed rations perform at least as well during subsequent finishing than calves grown at the same rate as on forage or on traditional growing programs in confinement (Table 22.10).

Table 22.10. Limit fed schedule for calves.

Week	Average weight	Per animal per day		Feed/only cost of gain
		lbs DM[a]	lbs AF[b]	
1-2	390.8	9.19	10.21	$0.35
3-4	422.3	9.74	10.82	$0.37
5-6	453.8	10.28	11.42	$0.39
7-8	485.3	10.81	12.01	$0.41
9-10	516.8	11.33	12.59	$0.43
11-12	548.3	11.85	13.17	$0.45

a DM = Dry matter basis.
b AF = As-fed basis.

Conclusion

A variety of options are available for producers to develop supplementation programs for their cattle. In addition to supplementation programs, some producers may decide to use a forage replacement program. In either case, careful consideration of all the elements of the programs must be given. Producers should use the resources mentioned in this chapter to determine which programs will work best for their operations.

References

Ackerman, C. J. (1999) Performance of light vs heavy weight steers grazing Plains Old World bluestem at three stocking rates. Oklahoma State University Ph. D. Dissertation.

Beck, P., T. Hess, D. Hubbell, M. S. Gadberry, J. Jennings, and M. Sims. (2017) Replacing synthetic N with clovers or alfalfa in bermudagrass pastures. 2. Herbage nutritive value for growing beef steers. *Animal Production Science* 57: 547-555

Bodine, T.N., H.T. Purvis II and D.A Cox. (2000) Effects of Supplemental Energy and Degradable Intake Protein on Grazing Behavior, Forage Intake, Digestion and Performance of Steers Grazing Winter Range. Oklahoma Agricultural Experiment Station Research Report. Retrieved February 4, 2004 from ansi.okstate.edu/research/ 2000rr/07.htm

Bodine, T. N. (2003) Influence of corn and degradable intake protein supplements on digestion, performance, and ruminal ecology of beef steers. Oklahoma State University Ph. D. Dissertation.

Bogle, L.A., D.M. Engle and F.T. McCollum (1989) Nutritive Value of Range Plants in the Cross Timbers. Oklahoma State University.

Campbell, R. R. (1989) The influence of advancing season on diet quality, intake and rumen fermentation of cattle grazing tallgrass prairie. Oklahoma State University Ph. D. Dissertation.

Cantrell, J., G. Bryan and K.S. Lusby (1985) Effect of Protein Supplementation on Stockers Grazing Native Grass in Southeastern Oklahoma. Oklahoma Agricultural Experiment Station Research Report MP-117:252-253.

Cantrell, J., G. Bryan and K.S. Lusby (1985) Effect of Different Management Practices on Weight Gains of Stocker Calves Grazing Bermudagrass. Oklahoma Agricultural Experiment Station Research Report MP-117:254-256.

Fleck, A.T., K.S. Lusby and F.T. McCollum (1986) Corn Gluten Feed or Soybean Meal as Summer Supplements for Growing Beef Cattle Grazing Native Range. Oklahoma Agricultural Experiment Station Research Report MP-118:214-217.

Gunter, S. A., F. T. McCollum and R. L. Gillen. (1991) Chemical composition of diets consumed by cattle grazing native range or plains bluestem pasture. Oklahoma Agricultural Experiment Station Research Report MP-134:122-128.

Lusby, K.S. (1994) Performance of Beef Calves Supplemented with Protein or Energy With or Without Smartamine-M. Oklahoma Agricultural Experiment Station Research Report MP-939:173-178.

Lusby, K.S. and G.W. Horn (1983) Energy vs Protein Supplementation of Steers Grazing Native Range in Late Summer. Oklahoma Agricultural Experiment Station Research Report MP-114:209-211.

Lusby, K.S., G.W. Horn and M.J. Dvorak (1982) Energy vs Protein Supplementation of Steers Grazing Native Range in Late Summer and Early Fall. Oklahoma Agricultural Experiment Station Research Report MP-112:36-39.

Marston, T. T., S. A. Gunter, F. T. McCollum and R. L. Gillen. (1993) A comparison of midgrass prairie and Old World Bluestem during winter and early spring. Oklahoma Agricultural Experiment Station Research Report P-933:363-368.

McCollum, F.T., D.R. Gill, and R.L. Ball (1985) Corn Gluten Feed or a Conventional Protein Cube for Stockers on Summer Native Range. Oklahoma Agricultural Experiment Station Research Report MP-117:215-217.

National Research Council. (2000) *Nutrient Requirements of Beef Cattle* (7th Edition). National Academy Press, Washington, D.C.

OSU Cowculator at extension.okstate.edu/programs/cowculator.html

Reuter, R., P. A. Lancaster, G. W. Horn, B. D. Wallis and P. A. Gunter. (2016) Distiller's grains as a substitute for fertilizer in summer grazing systems: performance, nitrogen recovery, and profit. *Journal of Animal Science* 94 (Suppl. 1):29 (ABSTR).

23 Supplementation of Stocker Cattle on Small Grain Forage

Paul Beck, Ryan Reuter and Gerald Horn

Objectives

- **Understand the unique nutrient content of wheat pasture and other small grains.**
- **Discuss supplementation of cattle grazing high-quality pastures.**
- **Discuss frothy bloat in cattle and how to reduce its incidence.**
- **Present different strategies for providing supplemental nutrients to cattle grazing small grain pastures.**

Winter wheat pasture is a unique and economically important renewable resource in Oklahoma and the southern Great Plains. Income is derived from both grain and the increased value added as weight gain, to growing cattle grazed on wheat pasture. The potential for profit from grazing stocker cattle on wheat pasture is exceptionally good because of the high quality of the forage and the very favorable seasonality of prices for stocker and feeder cattle that favor price appreciation of the cattle. As more producers have opted to forgo grain harvest for graze-out, there has been adoption of planting other small grains (oats, cereal rye, triticale and barley) and cool-season annuals (turnips, radishes, other brassica species and annual ryegrass). These alternative cool-season annuals have similar quality attributes to wheat pasture, so the supplementation recommendations are similar.

Supplementation of cattle grazing cool-season annuals is of interest to:

1. Provide a more balanced nutrient supply plus feed additives such as ionophores and bloat preventive compounds.
2. Substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and/or marketing decisions.
3. Substitute supplements for forage with conditions of low-forage standing crops.

It is usually said the higher the risk, the higher the rewards for the value of cattle. Predicting performance of stocker cattle grazing cool-season annuals is particularly challenging because of potentially large variations in weather and forage production. If weight gains of growing cattle cannot be predicted with some degree of accuracy, realistic breakevens, a prerequisite to sound marketing decisions, cannot be calculated. The ability to predict cattle performance will become more important as the feedlot and stocker segments of the industry compete for supplies of stocker/feeder cattle, and as coordinated beef production systems come to fruition.

Forage Nutritive Characteristics of Wheat and Other Cool-Season Annuals

In the fall and early spring, cool-season annual grasses planted into dedicated crop fields or interseeded into warm-season grass sod have been used extensively for grazing stocker cattle to improve net-farm income in the Southern High Plains and Southeastern U.S. Improvements in net income are achieved with the availability of high-quality forages at a time of year when weaned cattle are at a seasonally low price and other predominant forages are dormant and of low nutritive quality. Figure 23.1 shows the nutrient content of wheat pasture often seen during the fall and spring. Cool-season annual grass forages are extremely high in CP (> 25% DM basis) and low in fiber (40% to 49% NDF and 19% to 29% ADF, DM basis) during the fall and early spring prior to stem elongation. Even though increases

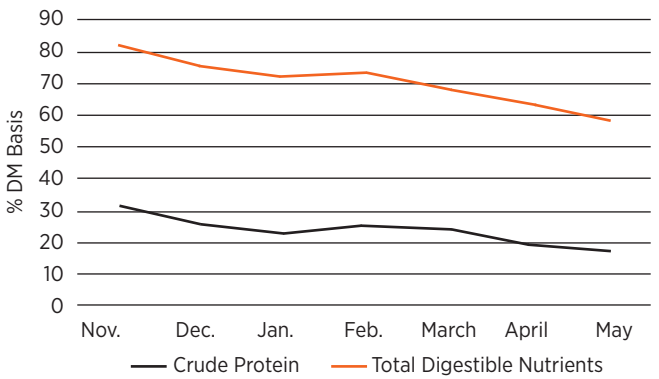


Figure 23.1 Crude protein and total digestible nutrient content of wheat forage. (Adapted from Beck et al., 2014)

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

in fiber content (increasing to more than 50% NDF) and reductions in CP content (decreasing to less than 20% on DM basis) are noted during April and May, CP content and estimated energy content of the forages were greater than animal requirements for a 500-pound growing steer to gain in excess of 2.5 pounds per day until the end of the spring grazing season each year. This indicates that cool season annuals provide a nutrient-dense diet for grazing cattle and any differences in animal performance from the expected levels are likely due to restrictions in forage availability.

Mineral Content of Wheat Forage

Wheat pasture poisoning is a noninfectious metabolic disorder of cows grazed on wheat pasture. It occurs most frequently in mature cows that have been grazing wheat pasture for 60 days or more and are in the latter stages of pregnancy or are nursing calves. Cows with wheat pasture poisoning have low blood concentrations of both calcium and magnesium. While a similar tetany like condition may occur in stocker cattle, its incidence is extremely low. Considerable variation occurs in the mineral composition of wheat forage. The data in Table 23.1 have been selected to indicate the calcium, phosphorus, magnesium and potassium content of wheat forage in relation to the requirements for the same minerals of a 400-pound steer calf gaining 2 pounds per day.

The values indicate that wheat forage contains marginal to sufficient phosphorus and magnesium, excess potassium that is characteristic of small grains forages in general and inadequate amounts of calcium for growing cattle. Therefore, calcium is the macromineral of primary concern in many wheat pasture-grazing situations. In these situations, wheat pasture stockers should be supplemented with an additional 10 grams of calcium per day. While this may seem like a very small amount of calcium, therefore perhaps not important, the total calcium requirement of a 400-pound steer calf gaining 2 pounds per day is 28 grams. The additional calcium could be included as calcium carbonate in other supplements or a mineral mixture. Mineral mixtures will not be effective if desired amounts are not consumed. Intake of mineral mixtures must be monitored.

The lower values for phosphorus content of wheat forage (Table 23.1) are from Bushland, Texas (Stewart et al. 1981). In that area, and perhaps the Oklahoma Panhandle and southwestern Kansas, wheat pasture stocker cattle also should receive supplemental phosphorus, depending on soil type and actual mineral analysis of wheat forage. More recently, a case of phosphorus deficiency was encountered in a group of growing steers grazing wheat pasture near Loyal (north-central Oklahoma). The farm had been in alfalfa for about six years prior to planting wheat. The application of phosphorus fertilizer for the wheat crop was less than recommended from soil test results. Phosphorus, calcium, magnesium and potassium contents of wheat forage samples collected Jan. 14 were, respectively, 0.16%, 0.26%, 0.16% and 1.72% of dry matter (DM). The Angus steers appeared healthy and were fairly fleshy, but seemed to crave bones, which were present in native grass adjacent to the wheat pasture from carcasses of cows that had died in previous years. Depraved or decreased appetite is a classical sign of phosphorus deficiency in beef cattle. The mineral mixture fed was changed from a low-phosphorus mineral (4.0%) to a mineral mixture containing 12% calcium, 12% phosphorus and 12% salt. The owner reported this resolved the bone-chewing problem.

Table 23.1. Mineral composition of wheat forage.

Item	*Calcium*	*Phosphorus*	*Magnesium*	*Potassium*
Composition, % DM	0.35	0.25 - 0.40	0.15	3-5
Requirement[a]	0.55	0.26	0.10	0.6

a For a 496-pound, 10-month-old Charolais x Angus steer gaining 2.2 pounds per day and consuming 12.43 pounds of wheat forage dry matter.

Source: 1996 Beef Cattle NRC.

Feeding Minerals to Cattle Grazing Small Grain Pastures

Figure 23.2 shows the response of steers grazing wheat pasture to mineral supplementation in experiments from two locations in Oklahoma (OSU Marshall Wheat Pasture Research Unit and USDA ARS Southern Plains Range Research Unit) and one in Arkansas (University of Arkansas Livestock and Forestry Research Station). In each of these experiments, the control steers were offered plain white salt, while a balanced complete mineral designed to match the deficiencies for growing calves grazing wheat pasture was offered. At the MWPRU site, a complete mineral supplying the ionophore monensin (Rumensin®) was offered as well. From these six experiments in three locations, it is apparent that feeding a balanced complete mineral increased gains of steers grazing wheat pasture by 0.34 pounds per day. This increase in gains occurred whether the calves were restricted in growth (baseline gains of around 1 pound per

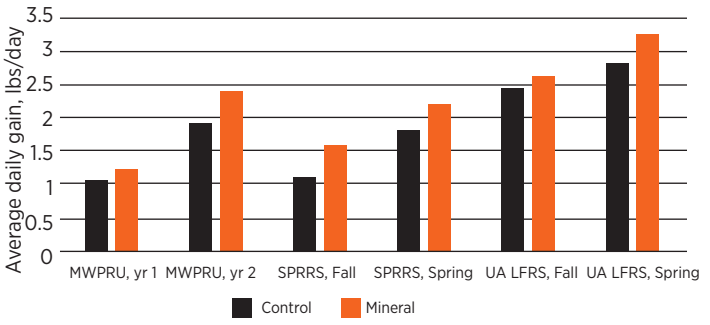


Figure 23.2 Response of steers grazing wheat pasture to supplemental free-choice mineral supplements compared with white salt. (Adapted from Fieser et al., 2007, Gunter et al., 2019, and Beck et al., unpublished.)

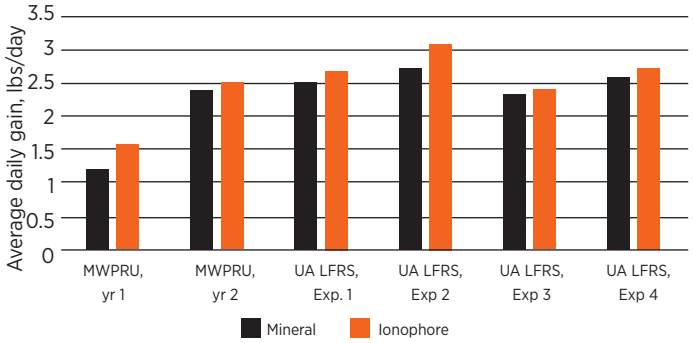


Figure 23.3 Response of steers grazing wheat pasture to free-choice mineral mixture containing the ionophore monensin compared with non-medicated mineral mixture. (Adapted from Fieser et al., 2007; Beck et al., 2014; Weiss et al., unpublished.)

day) or calves were gaining rapidly (baseline gains of 2.8 pounds per day). Furthermore, this increased performance with cattle grazing wheat pasture in both the fall and winter and during spring grazeout.

Figure 23.3 shows the performance advantage of including an ionophore (monensin) in self-fed minerals for steers grazing wheat pasture in six experiments in Oklahoma (OSU Marshall Wheat Pasture Research Unit) and Arkansas (University of Arkansas Livestock and Forestry Research Unit). The average gain response to the ionophore was a 0.2-pound-per-day increase in average daily gain, the range of response was from 0.1-pound-per-day to 0.4 -pound-per-day increase across these experiments. These experiments were conducted with both fall and spring wheat pasture and with wheat pasture that had limited forage availability and had supplemental silage on offer, which highlights the consistent response to this technology.

The question relative to the effect of feeding mineral mixtures (often high-magnesium mineral mixtures) to wheat pasture stockers on the incidence of bloat is commonly raised. Supplemental magnesium has not been shown to decrease the incidence and/or severity of bloat in stocker cattle on wheat pasture. There may be a relationship between ruminal motility and the ability of stocker cattle to eructate ruminal gases and the calcium status of the cattle. Ruminal and gut motility is greatly compromised by subclinical deficiencies of calcium. Therefore, the concern of providing additional calcium to growing cattle on wheat pasture is two-fold: to meet requirements for growth and to perhaps decrease the bloat problem by an effect on ruminal motility. Of interest would be whether dry bloat problems sometimes observed in wheat pasture stocker cattle are related to a subclinical deficiency of calcium.

Frothy Bloat

Frothy bloat is a major cause of deaths in wheat pasture stocker cattle in Oklahoma. Death losses from wheat pasture bloat are believed to be about 2% annually and sometimes are much higher on individual pastures. Bloat can strike suddenly and without warning. Some basic points relative to the causes and prevention of frothy bloat in wheat pasture stockers are:

1. Bloat occurs when the rate of eructation or removal of rumen fermentation gases is less than the rate production. This may result from an increased rate of production of gases or from impaired function of the rumen, cardia or esophagus.
2. Rumen fermentation gases may become entrapped in ruminal fluid froth or foam and cannot be eructated regardless of the functionality of the rumen and/or other digestive organs.
3. The chemical composition of wheat forage changes, depending upon environmental growing conditions, the stage of wheat plant growth or maturity and fertility level; therefore, it affects the likelihood that stable ruminal foam will be formed when wheat forage is grazed.

Factors Contributing to Wheat Pasture Bloat

Some of the factors involved in the occurrence of frothy bloat of wheat pasture stocker cattle include:

1. Wheat forage intake, on an as-grazed basis, is very high to support the high rates of weight gain commonly observed for wheat pasture stocker cattle. High forage intake (dry matter basis) has been measured of 2.8% to 3% of body weight of steers grazed on wheat pasture (for example, 44.8 pounds to 48 pounds of forage containing 25% dry matter for a 400-pound steer). High forage intake and the fact that wheat forage ferments (digests) very rapidly in the rumen are conducive to the production of extremely large volumes of rumen fermentation gases which, if not eructated normally, can lead to bloat.
2. Wheat forage is high in crude protein with reported values of 18% to 34% of forage dry matter. A possible relationship exists between the incidence of bloat in stocker cattle and the crude protein content of wheat forage. The protein content of wheat forage is influenced by plant growth stage and level of nitrogen fertilization. Results of analyses of wheat forage samples collected many years ago from pastures in Oklahoma where bloat did or did not occur are shown in Table 23.2. Forage samples from bloat-provocative pastures contained less dry matter and total fiber [neutral-detergent fiber (NDF)]. The concentration of crude protein and soluble nitrogen fractions in forage

Table 23.2. Chemical composition of wheat forage where bloat was not observed and bloat-provocative pastures.

Wheat Pasture	*No bloat*	*Bloat (2%-5% death loss)*
Number of samples	9	7
Dry matter (DM), %	28.48	22.31
Neutral-detergent fiber	44.59	35.02[a]
Crude protein, % DM	25.40	31.75[a]
Soluble nitrogen, % DM	1.85	3.24[a]

a (P<.05).
Source: Horn et al., 1977.

samples from bloat-provocative pastures were all significantly higher.

The extent to which the analyses in Table 23.2 reflect stage of wheat forage growth or age of accumulated forage growth (maturity) is not known. The data do suggest, however, that a subtle relationship exists between climatic growing conditions, soil fertility management and stocking rates as they affect wheat forage maturity and the incidence of bloat (Figure 23.4).

Wheat forage of several days' accumulated growth may be more fibrous and less succulent than wheat forage of only a few days growth. Stockers grazing the more fibrous, less succulent wheat forage may secrete greater quantities of saliva during the chewing associated with eating and during re-chewing of regurgitated boluses. The increased amounts of saliva may have an anti-foaming effect, thus reducing the incidence of frothy bloat. The significantly decreased total fiber content (NDF, Table 23.2) supports this rationale. In general, one would expect higher incidences of bloat during periods of rapid forage growth and in small forage standing crops. These periods often occur during fall and mid-winter grazing periods through early February, as day length increases and active plant growth begins. Frosts tend to increase fragility of leaf surfaces and rate of fermentation of the soluble carbohydrate fractions of forage, changing in the behavior of grazing cattle, increasing bloat. From a practical standpoint, wheat pasture stockers that are frequently seen chewing their cuds may be less likely to bloat than those that do not. Also freeze-burned (brown to whitish), dormant wheat forage is not likely to cause bloat.

Another contributing factor to the bloating of stockers on wheat pasture is the marked changes in grazing behavior occurring in stocker cattle in response to the movement of weather fronts through the southern Great Plains. Horn et al. (1976) reported that there is a period of little or no grazing prior to weather fronts, and the front is followed by a period of very active grazing. This change in rate of intake of highly fermentable forage is conducive to bloat.

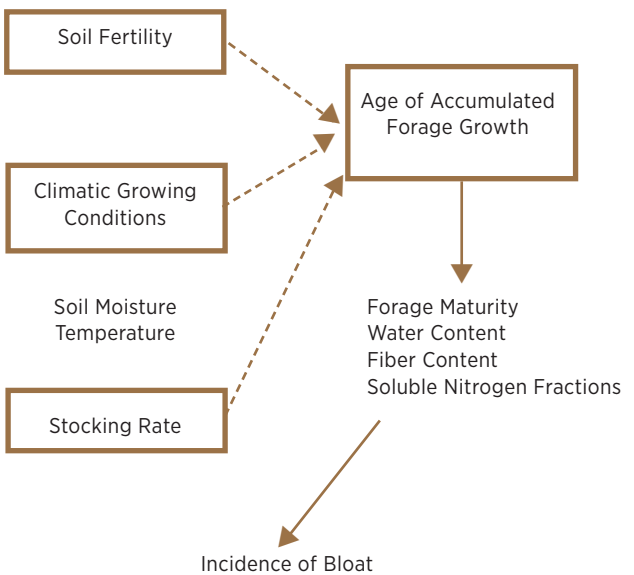


Figure 23.4. Some variables affecting forage maturity and possibly the incidence of bloat in wheat pasture stockers.

Management Practices to Reduce the Incidence of Bloat

Producers should separate animals with predisposition of bloat. Often, marked differences exist among animals within herds regarding their predisposition or susceptibility to bloat. Where physical facilities and labor management permits, animals identified as having a predisposition to bloat should be managed differently to minimize bloat issues.

Another way to control bloat is to feed poloxalene. The feed additive poloxalene was developed in the early 1960s (Bartley and Bassette, 1961) and it markedly decreases the incidence and severity of both alfalfa and wheat pasture bloat of cattle. In the event of a bloat outbreak, poloxalene is the product of choice to administer to cattle at a dosage of 1 gram to 2 grams per 100 pounds of body weight per day. Poloxalene is a surfactant that reduces the surface tension of foam, decreasing foam formation in the rumen and entrapment of fermentation gases. There are several poloxalene-containing products available for use in grazing programs, including feed additives, top dresses for pastures, mineral supplements, blocks and liquid feeds. It is important to remember that to be effective, adequate amounts of poloxalene must be consumed on a daily basis. Since bloat outbreaks can occur very quickly, producers may want to consider having a small emergency supply of poloxalene-containing supplement on hand throughout the bloat season. Guaranteed consumption of a sufficient amount of poloxalene may require feeding a palatable supplemental feed containing poloxalene each day. Because of cost, it is generally not economical to feed poloxalene continuously throughout the wheat pasture-grazing period. Producers need to evaluate each pasture, looking for a history of bloat issues occurring on that pasture, the number of cattle bloating and the severity of the bloat in making the decision to feed poloxalene-containing products. Breakeven death loss percentages can be easily calculated for different scenarios, daily cost of product and days of feeding poloxalene.

Feeding monensin also can help reduce bloat. Although monensin (Rumensin®) is not a true bloat-preventive compound like poloxalene, studies have shown that it does decrease the incidence and severity of wheat pasture bloat. The Oklahoma Green Gold supplement is a monensin-containing energy supplement designed to be hand fed daily at the rate of 2 pounds per animal or every other day at the rate of 4 pounds per animal. The research in support of this supplementation program, its effect on cattle performance and potential effects on bloat are discussed later. The strategy of using this supplementation program is to feed it throughout the wheat pasture grazing period and to substitute poloxalene for monensin during times of bloat outbreaks. With this approach, cattle are accustomed to going to a feeder and the increased weight gain from the Oklahoma Green Gold program will improve the economics of the total supplementation program.

Mineral supplements were discussed earlier in this chapter. Additional calcium is needed to meet the requirements of calcium for growth and perhaps to prevent a subclinical deficiency of calcium, which could compromise ruminal motility and contribute to bloat. For a long time, it has been recommended that wheat pasture stocker cattle be given free-choice access to a high-calcium mineral mixture. The one typically used contains 16% calcium, 4% phosphorus, 5.5% magnesium and about 20% salt. In a two-year study that used a negative control (that is cattle that grazed wheat pasture and received no mineral or any other supplement), the mineral supplement increased weight gain in only one year by 0.26 pounds per day. However, from a management standpoint, feeding the mineral supplement provided a means of getting poloxalene into the cattle when bloat was a problem. Hand mixing of Bloat Guard® Medicated Premix (52% poloxalene) into the mineral mixture (25% Bloat Guard® and 75% mineral mixture) resulted in good, efficacious intakes of poloxalene for bloat prevention.

The question relative to the effect of feeding high-magnesium mineral mixtures on the incidence of bloat is commonly raised. There is no data to support the suggestion that supplemental magnesium will decrease bloat of wheat pasture stocker cattle.

Feeding Low-quality Roughages to Wheat Pasture Stocker Cattle

Low-quality roughages such as wheat straw are commonly fed free-choice to stocker cattle on wheat pasture. Producers often say they will feed low-quality roughages on wheat pasture to slow the rate of passage, thereby increasing the utilization of wheat forage and reduce the incidence of bloat.

A very important question relative to feeding low-quality roughages to wheat pasture stockers is what effect they may have on wheat forage intake and stocker weight gains. Intakes of 2 pounds to 3 pounds of straw dry matter per day, if substituted for wheat forage, could decrease weight gains of stockers by as much as 0.46 pounds per day (2.11 pounds versus 1.65 pounds) as indicated in Table 23.3. These gains were estimated by calculating the effect of substituting wheat straw for wheat forage, taking into account the much lower energy value of wheat straw.

A three-year study was conducted in which fall-weaned steer calves (initial mean weight of 378 pounds) grazed clean-tilled wheat pasture (Nov. 23 to March 24, plus or minus three days to seven days) and were fed no supplemental feed or had free-choice access to wheat straw (WS) or sorghum-sudan hay (SS) (Mader et al., 1983 and Mader and Horn, 1986). Results were as follows:

- Daily consumption of low-quality roughage was low and ranged from:
  WS — 0.15 pounds to 0.4 pounds per head per day
  SS — 0.35 pounds to 0.9 pounds per head per day
- Live and carcass weight gains of steers were not affected by offering low-quality roughage.
- Feeding steers two times the amount of low-quality roughage as listed in the first bullet did not affect intake, digestibility or rate of passage of wheat forage.
- Bloat was observed only during the last two weeks of the period of lush spring growth of wheat forage of the first year. The incidence and severity of bloat of the control, wheat straw and sorghum-sudan fed steers were not different among treatments. Intake of wheat straw and sorghum-sudan hay was only about 5% to 12% of roughage intakes reported in the literature to effectively control or aid the prevention of bloat. Therefore, it seems unlikely that low-quality roughage consumed in amounts similar to those of this study will control bloat of stocker cattle on wheat pasture.

Significant positive or negative responses to feeding low-quality roughage to stocker cattle on wheat pasture have not been seen. It appears to be a practice of little consequence other than the cost of the low-quality roughage and the labor required. However, if cattle on wheat pasture do not have a dry place to lie down, availability of low-quality roughages may improve performance by providing bedding and aiding maintenance of normal body temperature during severe storms.

Table 23.3. Effect of straw consumption on calculated daily weight gains of wheat pasture stockers[a].

Item	*All wheat forage*	*Wheat forage +2 lbs straw*	*Wheat forage +3 lbs straw*
Daily gains, lbs	2.11	1.80	1.65
Change from all wheat forage, lb/day	–	-0.31	-0.46

a Calculated for a 440-pound steer with a total dry matter intake (wheat forage alone or wheat forage plus straw) of 3% of body weight.

Source: Mader et al., 1983 and Mader and Horn, 1986.

Setting Stocking Rates Based on Forage Allowance

The forage DM production of cool-season annual grasses follows a biphasic production curve, in which productivity during the fall and winter is at a much lower level than during the spring. Thus, stocking rates should be much less in the fall and winter from early November to late February, ranging from 2 acres to 3 acres per steer up to 1 acre per steer with excellent forage growth conditions. In the spring from late February to early May, generally 2 acres to 2.5 steers per acre is typical. Stocking rate is a fundamental variable for managing pastures and there is a distinct relationship between stocking rate and animal performance for each forage type. In order to determine the forage allowance that would result in the optimal stocking rate for fall and winter grazing of cool-season annual pastures, the forage production and steer performance from the experiments reported in several experiments [Bowman et al. (2008) and Morgan et al. (2012)] were used to determine the response of ADG to initial forage allowance expressed as pounds of forage dry matter per pound of steer

bodyweight. The response of ADG to forage allowance was fit to find the average forage allowance during the fall and winter grazing season to reach maximum performance for growing steers. This data set used pasture means for cattle grazing small-grain pastures during the fall and winter from 2003 to 2009 and included 117 records. In this analysis, the average forage allowance during the fall and winter ranged from 0.8 pounds to 8.2 pounds of forage DM per pound of average steer bodyweight. The response of ADG to the average forage allowance (average pound forage DM per pound average bodyweight; Figure 23.5) indicates that the maximum ADG is expected at 3.5 pounds forage DM per pound average bodyweight with expected performance of 2.7 pounds per day. It is interesting to note that an ADG of approximately 2 pounds per day would be expected at forage allowance of approximately 1.8 pounds of forage per pound steer bodyweight. This level of performance (i.e., 2 pounds per day) is the level that many stocker producers set as the goal for the period of stocker cattle ownership, which allows the fixed and variable costs of stocker ownership to be spread over multiple units of gain.

Managers are faced with decisions regarding stocking rate at the beginning of the grazing season with only the forage produced up to that point to consider in setting the stocking rate. Analysis of the forage DM available at turnout in these experiments indicates the initial forage DM yield is highly correlated with average forage DM yield (r = 0.94), so the analysis was conducted only considering the initial forage allowance (pounds initial forage DM per pound initial bodyweight) on ADG during the fall and winter (Figure 23.6). The response of ADG to the initial forage allowance indicates that a maximum ADG of 2.7 pounds per day could be expected at 5.0 pounds of forage DM per pound initial bodyweight and ADG of 2 pounds per day could be expected at an initial forage allowance of approximately 2.4 pounds forage DM per pound initial bodyweight. So, if forage mass at initial turnout is 1,200 pounds of forage DM per acre (about 6 inches to 7 inches of average plant height), stocking rates should be set at 2 acres per 500-pound steer to reach

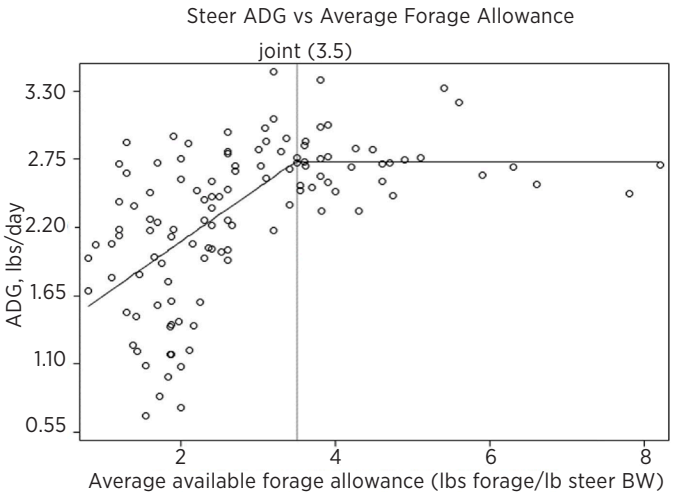


Figure 23.5 Effect of average wheat forage allowance (expressed as pounds of forage DM per pound of steer bodyweight) during the fall and winter on performance of grazing stocker steers. (Adapted from Beck et al., 2013.)

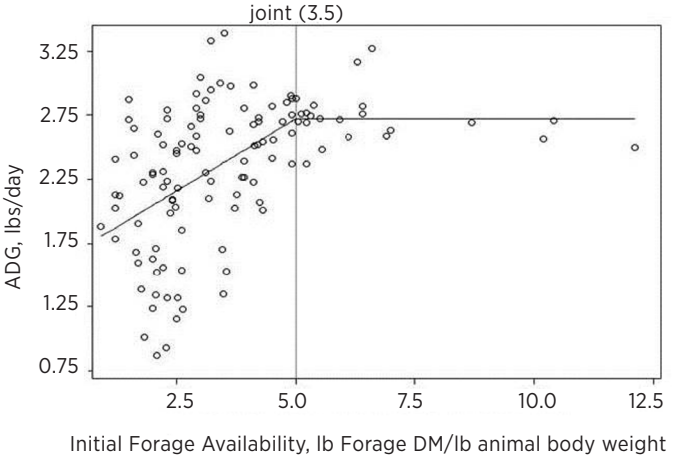


Figure 23.6 Effect of initial wheat forage allowance (expressed as pounds of forage DM per pound of steer bodyweight) during the fall and winter on performance of grazing stocker steers. (Adapted from Beck et al., 2013.)

maximum steer performance. During the spring graze-out period, forage growth is rapid and the forage allowance at that time can be reduced to 1.5 pounds of forage DM per pound of steer bodyweight or less without negatively impacting steer performance, in fact if forage allowance is too high (stocking rates are too light) wheat forage will mature rapidly and reductions in forage quality with excess maturity will reduce potential steer performance.

Energy Supplementation

Because the protein levels in this highly digestible forage are so high during the fall and early spring, the TDN:CP ratio (see discussion in chapter 22) often is less than 3:1 or 4:1. This indicates there is not adequate ruminally available energy present for maximal microbial growth, so proteins are not fully incorporated into microbial proteins and nitrogen is excreted. This impacts the type of supplements that should be used for cattle grazing wheat and other cool-season annual pastures.

Steers would then respond to small-package energy supplements (Oklahoma Green Gold supplement program described below), designed to supply required minerals and vitamins, carry growth-promoting ionophores and provide energy to correct ruminal TDN:CP ratio imbalances (see discussion below).

Oklahoma Green Gold Supplementation Program

Two ionophores (monensin and lasalocid) are available for wheat pasture stocker cattle. Both, if delivered in the proper dosage, increase weight gains of growing cattle on wheat pasture by 0.18 pounds to 0.24 pounds per day more than that of the carrier supplement and improve the economics of supplementation programs. In addition, producer experience and research indicate that monensin decreases the incidence and severity of bloat from wheat pasture (Branine and Galyean 1990). Other characteristics of the two ionophores are listed in Table 23.4. The plus sign

Table 23.4. Characteristics of ionophores.

Weight gain response	*Monensin*	*Lasalocid*
	Equal if proper dosage of ionophore achieved	
Bloat protection	+	
Palatability		+
Potential for toxicity	+	
FDA clearance for every-other-day feeding	+	

indicates a more favorable or greater response of one over the other.

While some producers prefer self-limiting supplements that can be fed free-choice, others prefer to hand-feed supplements. Hand-feeding obviously allows much better control of supplement intake, and monensin has FDA approval for every-other-day feeding to stocker cattle.

The Oklahoma Green Gold supplement is a monensin-containing energy supplement for growing cattle on wheat pasture. It is designed to be hand-fed daily at the rate of 2 pounds per animal or every other day at the rate of 4 pounds per animal. The supplement contents are shown in Table 23.5.

Potential benefits of the Oklahoma Green Gold supplementation program include:

- Provide additional digestible energy and help balance the energy-to-crude-protein-ratio of wheat forage.
- Provide monensin to improve the economics of the supplementation program and decrease the incidence and severity of bloat.
- Provide additional calcium for growth of stocker cattle.
- Provide a means from a management standpoint of getting other feed additives into the cattle when needed, for instance, Bloat Guard® (poloxalene) in cases of severe or protracted bloat outbreaks.

A summary of five trials conducted during three years showing the effect of the supplementation program of live weight gain of stocker cattle grazing wheat pasture is shown in Table 23.6. In four of the five trials, the mean (± standard deviation) response to the hand-fed supplement (excluding the negative gain from Marshall in 1998-1999, which was considered an outlier) was: Daily gain: + 0.42 ± 0.10 and Supplement conversion: 4.72 ± 0.50.

Table 23.5. Contents of the Oklahoma Green Gold supplement.

Ingredient	1992/93[a]	1997/98[b]
Ground milo	66.65	62.15
Wheat middlings	21.00	21.00
Sugarcane molasses	4.80	5.00
Limestone	4.00	4.30
Dicalcium phosphate, 21% P	2.55	2.55
Magnesium mica (Smectite)		4.00
Fine mixing salt[c]	0.50	0.50
Magnesium oxide	0.35	0.22
Rumensin® 60 premix		0.15[d]
Rumensin® 80 premix		0.125[e]
Vitamin and trace-mineral premix		0.10
Vitamin A-30		0.05

[a] Source: Andrae et al., 1994.
[b] Source: Paisley et al., 1998.
[c] Fine mixing salt (99.5% NaCl).
[d] To provide 90 mg monensin per pound of supplement.
[e] To provide 100 mg monensin per pound of supplement.

Because the incidence of bloat was not large enough during the five trials previously listed, the effect of this supplemntation program on bloat is unknown. However, Branine and Galyean reported that monensin decreased the incidence and severity of bloat from wheat pasture. In a study reported by Paisley and Horn, 12 rumen cannulated steers that grazed the same wheat pasture near Stillwater were randomly allotted to three experimental groups. Gelatin capsules containing nothing, monensin or lasalocid were placed directly into the rumen of each steer each day. Dosage of the ionophores was 300 milligrams per day because the steers weighed 1,164 ± 67 pounds. After a preliminary period of 16 days, the steers were assigned a bloat score each morning from March 15 through March 28 (14 days). The wheat was in a rapid growth stage during this time and was fairly immature. Hard freezes on the mornings of March 14, 15 and 16 increased the incidence of bloat and slowed the rate of wheat growth. Monensin decreased

Table 23.6. Summary of effect of monensin-containing energy supplement (hand fed every other day) on weight gain and supplement conversion by wheat pasture stocker cattle.

Year/location	*Daily gain, lbs*		*Gain response*	*Mean supplement intake, lbs/hd/day*	*Supplement conversion[d]*
	Control	*Supplement*			
1992-1993					
Stillwater	2.31	2.87[a]	+.56	1.55[b]	4.16
1997-1998					
Stillwater	2.56	2.94[a]	+.38	1.74[c]	4.55
Marshall	2.50	2.90[a]	+.40	1.92[c]	4.80
1998-1999					
Stillwater	2.56	2.90[a]	+.34	1.82[c]	5.35
Marshall	2.55	2.53	-.02	1.78[c]	–

a Different from control (P<.05).
b Contained 90 mg monensin/lb as-fed.
c Contained 100 mg monensin/lb as-fed.
d Pounds of as-fed supplement per lb of increased weight gain.
Source: Andrae et al., 1994 and Paisley et al., 1998.

(P<.05) both the incidence and severity of bloat and was more efficacious for prevention of bloat than lasalocid. In addition to increasing rate of weight gain, the Oklahoma Green Gold supplementation program should decrease bloat.

The rate of feeding the supplement is not high enough to allow stocking rate to be increased more than normal stocking rates for the area in which it is fed. Supplement specifications include:

Sources of Energy. About 82% to 90% of the as-fed formula should consist of corn, milo, wheat middlings and/or soybean hulls as the source(s) of energy. Corn gluten feed should not be used because of concerns that the additional sulfur may accentuate the incidence of polioencephalomalacia, sometimes occurring in wheat pasture stocker cattle. No roughage products other than soybean hulls should be included in the supplement.

Form. It is recommended that the supplement be manufactured as a small pellet because intake data was obtained with pelleted supplements. Pellets also decrease the potential for segregation of ingredients.

Mineral content. The supplement should contain 2.25% to 2.75% calcium, 1% phosphorus, 0.7% magnesium, 60 parts per copper and 0.75% to 1.25% salt for the as-fed formula. No additional iron or potassium should be added to the supplement.

Vitamin content. The supplement should contain a minimum of 10,000 IU of added vitamin A.

Monensin concentration. The as-fed supplement should contain 90 milligrams to 100 milligrams of monensin per pound.

This supplementation program requires close management. Monensin in large amounts will kill cattle. However, if one considers the lethal dose for monesin (1% deathloss) to be 5.5 milligrams per kg body weight (or 1,250 milligrams per head per day for a 500-pound steer), then there is a theoretical safety ratio of 6.25 for 500-pound cow consuming 200 milligrams monensin per day. Feeding the supplement every other day may increase the likelihood that some cattle could eat more than the desired amount of supplement. The primary challenge in using this supplementation program is one of having good management and enough time to be a good observer of what the cattle are doing. While this supplementation program worked well, the studies were with small numbers of cattle on pastures of 18 acres to 24 acres in size. Feed bunk space was adequate for all cattle to eat the supplement during a single feeding. Producers have to be good observers of cattle feeding behavior in relation to location of feed bunks in the pasture. Care has to be taken that there is adequate bunk space so some cattle do not overconsume the supplement. Equines should not be allowed access to this supplement. Ingestion of monensin by equines has been fatal.

Feeding moderate amounts of energy supplement to growing cattle on wheat pasture increases the stability of the enterprise and improves the predictability of cattle performance, which decreases production risk. It also increases stocking rate and flexibility by having more cattle on hand during fall/winter grazing for subsequent grazing during the graze-out period, if desirable. Because of the seasonality of stocker/feeder cattle prices and the dynamics of breakeven selling prices in stocker cattle budgets, the latter of these can be particularly important to the economics of growing cattle on wheat pasture.

Energy Supplements to Stretch a Shortage of Wheat Pasture

If forage allowance falls below 3 pounds to 5 pounds of forage DM per pound of steer bodyweight or stocking rates are increased to offset requirements to purchase additional cattle for grazeout in less favorable economic conditions, other alternative supplementation strategies can be considered to stretch wheat forage resources.

Silage

Silage is used very successfully to stretch available wheat forage and allow initial stocking densities on wheat pasture to be increased in some areas of the southern Great Plains. In studies reported by Vogel et al. (1987 and 1989), use of supplemental silage allowed initial stocking density on wheat pasture to be doubled without decreasing weight gains of stocker cattle. Supplemental silage decreased wheat forage intake linearly (P<0.10). Each pound of added silage DM decreased DM intake of wheat forage by 0.66 pounds. The extent of ruminal digestion of DM and NDF of wheat forage was increased by feeding silage, indicating that silage had a positive associative effect on utilization of wheat forage (Vogel et al., 1989).

Table 23.7 shows the gain response of feeding free choice round bale Bermudagrass silage to steers grazing wheat pasture in north-central Arkansas. The Bermudagrass round bale silage was 40% dry matter and 14% crude protein (DM basis) and 55% TDN (DM basis). The silage was offered free-choice to calves on wheat pasture stocked at 1, 1.5 or 2 steers per acre during the fall and 2.25 steers per acre in the spring grazeout period; and was replaced as needed (when 20% of previous bale was remaining) about every seven to 14 days depending on silage intake. The negative control (not offered silage) was stocked at one steer per acre in the fall and winter and 2.25 steers per acre in the spring. Forage allowance (pounds foraged per pound steer bodyweight) at the start of fall grazing was 2.2 for steers stocked at one steer per acre, 1.6 for steers stocked at 1.5 steers per acre and 1.3 for steers stocked at two steers per acre. Because there was less forage remaining at the end of the winter grazing season for the heavier-stocked pastures, forage allowance at turnout for the spring grazeout period were 1.0 for steers stocked at one steer per acre during the fall, 0.7 for steers stocked at 1.5 steers per acre during the fall and 0.5 for steers stocked at two steers per acre during the fall. During the fall, feeding silage to steers stocked at the low rate did not affect animal performance with gains right at 3 pounds per day. As stocking rate increased during the fall and winter grazing season, gains decreased even though silage was fed, but the reduction in performance was not a big as would be expected had supplemental forage were not offered. During spring grazeout, feeding silage to steers that were placed on

Table 23.7. Using round bale silage to increase stocking rate of steers grazing wheat pasture in the fall.

	Control	*Silage 1x*	*Silage 1.5x*	*Silage 2x*
Fall and winter				
Forage mass at turnout, lbs DM/acre	1,214	1,188	1,309	1,361
Forage allowance at turnout, lbs forage/lb bodyweight	2.25	2.19	1.62	1.27
Stocking rate, steers per acre	1.0	1.0	1.5	2.0
Average daily gain, lbs/day	3.09	2.95	2.53	2.12
Spring grazeout				
Forage mass at turnout, lbs DM/acre	1,559	1,557	990	762
Forage allowance at turnout, lbs forage/lb bodyweight	1.11	1.11	0.70	0.54
Stocking rate, steers per acre	2.25	2.25	2.25	2.25
Average daily gain, lbs/day	1.43	2.03	1.56	1.83
Total gain per acre	451	561	597	683
Silage DM offered per acre	0	326	636	816
Pounds silage DM per added gain per acre	-	2.96	4.38	3.52

pastures previously stocked at the lower stocking rate did increase gains by 0.6 pounds per day. This is because the poor growing conditions during the spring grazing season in this experiment limited forage production, which limited performance of the control calves. Total bodyweight gain per acre increased when silage was fed at the low stocking rate compared with the control, and as stocking rate increased, bodyweight gain per acre increased. As stocking rate increased, silage fed per acre increased as well. Even though more silage was fed with increasing stocking rates, the feeding silage was quite efficient in increasing total weight gain per acre, requiring only 3 pounds to 4 pounds of silage dry matter per pound of increased gain per acre.

High-starch Versus High-fiber Byproduct Feed-Based Energy Supplements

The response of growing cattle on wheat and other small grain pastures to supplemental grain has been variable. To prevent potentially adverse effects of starch on ruminal fermentation, high-fiber byproduct feeds offer alternatives in formulating energy supplements with fairly high energy densities. Examples include wheat middlings, soybean hulls and corn gluten feed. The potential for using these byproduct feeds in supplementing growing cattle on wheat pasture is particularly good because of the rapid rate of ruminal degradation of wheat forage and the resultant relatively low ruminal pH.

Research at the Wheat Pasture Research Unit near Marshall was conducted to evaluate types of energy supplements for growing cattle on wheat pasture. A corn-based, high-starch supplement was compared to a high-fiber byproduct feed-based energy supplement. The high-fiber energy supplement contained about 47% soybean hulls and 42% wheat middlings (as-fed basis), and all supplements contained 40 milligrams per pound of monensin. The supplements were hand fed six days per week at a level of about 0.75% of body weight (for example, 4 pounds per day for a 533-pound steer) and stocking rate was increased 22% to 44%. Nonsupplemented, control cattle had free-choice access to a high-calcium (16%) commercial mineral mixture throughout the study. Details of the studies have been reported by Horn et al. (1995). In general, results were:

Supplementation Response. During the three-year period, weight gains during the fall/winter grazing and early spring grazing period (up to time of first hollow stem stage of maturity of wheat) were increased by energy supplementation, regardless of type of energy supplement, by an average of 0.33 pounds per day. Weight gains were 2.02 pounds, 2.33 pounds and 2.38 pounds per day for the control, high-starch and high-fiber supplemented steers, respectively. The gain response was similar at all stocking rates. Mean consumption of the supplements was 0.65% of body weight, which was a little less than the target of 0.75%.

Type of Energy Supplement. The type of energy supplement (high-starch versus high-fiber) did not affect weight gains of the cattle. The difference in response by cattle to high-fiber versus high-starch energy supplements is expected to decrease as the amount of supplement fed decreases and as crude protein content of the forage increases. The level of supplement fed in these studies was relatively small, and wheat forage contains excess crude protein. Substitution of supplement for wheat forage did not differ for the two types of supplements. Wheat forage intake was decreased by 0.91 pounds for every pound of supplement consumed (Cravey, 1993).

Supplement Conversion. Mean conversion of the supplements (expressed as pounds of as-fed supplement per pound of increased gain per acre) was about 5:1 for both types of supplement. This is substantially less than conversions of nine to 10 traditionally used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle.

Cattle Preference for Supplements. Cattle seemed to like the high-fiber supplement and consumed it much more readily than the corn-based high-starch supplement. Generally, the cattle consumed the high-fiber supplement in a matter of 10 minutes to 30 minutes in the morning. In contrast, the corn-based supplement was eaten during at least two feeding periods during the day (morning and mid-afternoon). From a feed and bunk management standpoint, this difference in the supplements is extremely important on days of inclement weather (rain, snow, etc.) and in situations of bird predation. Contamination of feed bunks by bird excrement was substantial for the corn-based supplement.

In addition, the potential for acidosis is much less for the high-fiber supplement, provided that the wheat middlings used in the high-fiber supplement do not contain a lot of fine starch.

Feedlot Performance. Because wheat pasture cattle are some of the more fleshy cattle placed on feed, the potential effect of energy supplementation on subsequent feedlot performance is of interest. Cattle were followed through the feedlot in two of the three years. Supplementation did not affect feed intake or feed conversion in year one, but average daily gain was decreased by about 0.20 pounds ($P<0.05$). In another year, daily gain of the cattle in the feedlot was not affected by two supplementations on wheat pasture.

The 1991-1992 wheat pasture year was very dry, and many pastures were extremely short of forage at the time of traditional turnout. Some pastures had as little as 300 pounds of forage dry matter per acre. While this was a problem, it presented an opportunity to compare some different types of energy supplements for stretching this severe shortage of wheat pasture. The objective was to compare limited amounts (1% of mean body weight) of whole shell corn, dry-rolled corn, or a 50/50 mix of pelleted wheat middlings/soybean hulls. The supplements were hand-fed six days per week. The target gain for the cattle was 2 pounds per day. Nine pastures were used in the study and initial stocking density was 3.5 acres per steer to provide an initial forage allowance of 1,050 pounds of forage DM per steer (2.4 pounds of forage DM per pound steer bodyweight). Because of the very mild winter and continued growth of wheat forage, cattle in three pastures were distributed by treatment through the other six pastures on Jan. 30, 1992, in an attempt to provide equal or lesser amounts of forage to all cattle. Forage availability in each of the pastures on Jan. 21 was about 1,500 pounds DM per steer, greater than was preferred for the initial objective of the trial. Forage growth after Jan. 30 was excellent. Because wheat jointed so early, the cattle were removed on Feb. 28. Performance of the steers is shown in Table 23.8.

Weight gain of all steers was about 2.2 pounds per day during the 84-day trial and was not different ($P>0.62$) among treatments, which is in general agreement with other results. No difference in gain was observed between steers supplemented with a high-starch, corn-based supplement versus a high-fiber byproduct feed-based supplement on wheat pasture. Steers consumed the whole corn much more readily than the rolled corn and usually had slick bunks by midafternoon. Two steers on the rolled corn treatment foundered and showed signs of lameness throughout most of the trial. Because of the small numbers of pastures and steers in this trial, this data should be considered only preliminary. However, from a feed and bunk management standpoint, the whole corn was clearly more desirable than the rolled corn.

The 1995-1996 wheat pasture year presented another opportunity to evaluate a limit-feeding program with whole shelled corn for steers on wheat pasture. Three pastures with 10 to 13 steers per pasture were used. Wheat forage standing crops on Dec. 7, 1995 (date of turnout), Jan. 17, 1996 and March 12, 1996 were 511 pounds, 376 pounds and 251 pounds DM per acre, respectively. Forage allowances on these same dates were 1,024 pounds; 749 pounds and 725 pounds DM per steer (1.9, 1.4 or 1.3 pounds of forage DM per pound per steer bodyweight, respectively). Steers had free-choice access to a high-calcium (16%) mineral mixture. While the target level of intake of whole corn was 1% of body weight, the cattle did not achieve this level of intake until about Jan. 17, 1996 (day 41). Corn intake was very consistent among pastures and averaged 0.75% of body weight from Dec. 7, 1995 to March 15, 1996 (98 days). Mean weight of the steers at the start of the trial was 540 pounds, and they gained 1.86 ± 0.11 (standard deviation) pounds per day.

Table 23.8. Energy supplements for stretching wheat pasture.

	Whole corn	*Dry-rolled corn*	*Wheat middlings/ soybean hulls*
No. pastures	2	2	2
No. steers	10[a]	12	12[b]
Initial weight, lbs (12/5/91)	438	438	439
Final weight, lbs (2/28/92)	622	630	625
Daily gain, lbs[c] (84 days)	2.17	2.25	2.19

a Increased to 14 on Jan. 30.
b Increased to 18 on Jan. 30.
c Add-on steers of Jan. 30 were not included in calculation of mean daily gains. Differences among treatments are not significant ($P>.62$).
Source: Horn and Paisley, 1999.

Economic Analysis

Several levels of economic analyses can be used in evaluating supplementation programs and other management decisions in stocker cattle programs. One approach is to simply compare cost of the additional weight gain to the gross value of weight gain in the stocker program. An estimate of the value of weight gain can be calculated by determining the gross value of the cattle at the time of purchase and again at the time of sale. The difference in the gross values represents the total value of weight gain. One simply needs to divide the total difference in gross value by the difference in initial and final weight to determine the value of each pound of weight gain. In recent years, value of weight gain for cattle purchased in the fall and sold during spring have ranged from about $0.75 to $1.25 per pound.

Value of weight gain is generally higher for heifers compared to steers. This is due to the fact that heifers gain at a slower rate and are not as efficient at converting forage or feed to weight gain compared to steers and therefore, their gain is more expensive to produce.

If the cost of the additional weight gain from supplementation is less than the value of weight gain, supplementation will be profitable. At a supplement conversion of 5 pounds of supplement per pound of increased gain per acre and a feed cost of $270 per ton, supplement cost per pound of increased gain would be $0.68. This is valid only

if stocking rate is increased since supplement conversion is expressed on an increased gain per acre basis. Also, any additional costs incurred in feeding the supplement (e.g., fuel, labor, etc.) should be included in the evaluation.

Conclusion

Supplementation of cattle grazing wheat pasture is of interest to:

- Provide a more balanced nutrient supply and feed additives such as ionophores and bloat preventive compounds.
- Substitute supplement for forage where it is desirable to increase stocking rate in relation to grazing management and/or marketing decisions.
- Substitute supplement for forage with conditions of low-forage standing crops.

Three different strategies for providing energy supplements to growing cattle on wheat pasture were presented. One strategy was to develop a hand-fed small package (a target intake of 2 pounds per day or 4 pounds every other day) monensin-containing energy supplement to provide a more balanced dry organic matter-to-crude protein ratio in the total diet. This supplementation program (Oklahoma Green Gold) consistently increased daily gain by 0.42 pound with a supplement conversion (pound supplement per pound of increased weight gain) of 4.72, which often will be profitable. Increased profits of $15 per steer to $31 per steer depended on supplement cost and profit potential of the cattle.

A second strategy was to develop energy supplements that could be fed in larger amounts (about 0.75% of body weight) to increase stocking rate during the fall/winter grazing period and to have more cattle on hand for spring graze-out of wheat. Two types of supplements, a high-starch, corn-based supplement and a high-fiber byproduct feed-based supplement, were compared. During the three-year study, mean daily supplement consumption was 0.65% of body weight. This energy supplementation program increased daily gain by 0.33 pounds and allowed stocking rate to be increased by one-third. The type of supplement did not influence daily gain, supplement conversion or the substitution ratio of supplement for forage. Supplement conversion was about 5 pounds of as-fed supplement per pound of increased gain per acre, and was substantially less than conversions of 9 pounds to 10 pounds traditionally used in evaluating the economics of energy supplementation programs for wheat pasture stocker cattle.

The third strategy was to limit-feed energy supplements in amounts of 1% of body weight in situations of very low initial wheat forage standing crops (less than 300 pounds DM per acre). Weight gain of steers stocked on wheat pasture to provide initial forage allowances of 1,000 pounds to 1,300 pounds DM per steer and limit fed whole shelled corn at a level of 0.75% to 1% of body weight were about 2 pounds per day during two separate wheat pasture years.

References

Andersen, M.A. and G.W. Horn (1987) Effect of Lasalocid on Weight Gains, Ruminal Fermentation and Forage Intake of Stocker Cattle Grazing Winter Wheat Pasture. *Journal of Animal Science* 65:865.

Andrae, J.G., G.W. Horn, and G. Lowrey (1994) Effect of Alternate-Day Feeding of a Monensin-Containing Energy Supplement on Weight Gains and variation in Supplement Intake by Wheat Stocker Cattle. Animal Science Research Report P-939:158-161. Oklahoma Agricultural Experiment Station, Oklahoma State University.

Bartley, E.E. and R. Bassett (1961) *Journal of Dairy Science* 44:1365.

Beck, P., M. Anders, B. Watkins, S. Gunter, D. Hubbell and S. Gadberry. (2013) Invited: Improving the production, environmental, and economic efficiency of the stocker cattle industry in the Southeastern United States. *Journal of Animal Science*. 91:2456-2466

Beck, P. A., T. Hess, D. Hubbell, D. Hufstedler, B. Fieser and J. Caldwell. (2014) Additive effects of growth promoting technologies on performance of grazing steers and economics of the wheat pasture enterprise. *Journal of Animal Science*. 92:1213-1227

Branine, M.E. and M.L. Galyean (1990) Influence of Grain and Monensin Supplementation on Ruminal Fermentation, Intake, Digesta Kinetics and Incidence and Severity of Frothy Bloat in Steers Grazing Winter Wheat Pasture. *Journal of Animal Science* 68:1139.

Cravey, M. D. (1993) Influence of High-Starch vs. High-Fiber Energy Supplements on Performance and Forage Intake and Utilization by Stocker Cattle Grazing Wheat Pasture. Ph.D. Thesis. Oklahoma State University.

Fieser, B. G., G. W. Horn and J. T. Edwards. (2007) Effects of energy, mineral supplementation, or both in combination with monensin on performance of steers grazing winter wheat pasture. *Journal of Animal Science*. 85:3470-3480.

Gunter, S. A., and F. F. Combs. (2019) Efficacy of mineral supplementation to growing cattle grazing winter –wheat pasture in northwestern Oklahoma. *Translational Animal Science*. 3(4):1119-1132

Horn, F.P. et al. (1976) Influence of Periods of Starvation on Blood Ammonia and Plasma Urea Concentrations of Steers Grazing Wheat Pasture. Animal Science Research Report MP-96. p. 48.

Horn, G.W. and S.I. Paisley (1999) Developments in the Management and Supplementation of Stocker Cattle on Wheat Pasture. Proceedings: Plains Nutrition Council Spring Conference. San Antonio, TX. Publication No. AREC 99-9. Texas A&M Research and Extension Center, Amarillo. p. 48-73.

Horn, G.W., B.R. Clay and L.I. Croy (1977) Wheat Pasture Bloat of Stockers. Animal Science Research Report MP-101. Oklahoma Agricultural Experiment Station. p. 26.

Horn, G.W. et al. (1981) Effect of Monensin on Ruminal Fermentation, Forage Intake and Weight Gains of Wheat Pasture Stocker Cattle. *Journal of Animal Science* 52:447.

Horn, G.W. et al. (1995) Influence of High-Starch vs. High-Fiber Energy Supplements on Performance of Stocker Cattle Grazing Wheat Pasture and Subsequent Feedlot Performance. *Journal of Animal Science* 73:45.

Mader, T.L. and G.W. Horn (1986) Low-Quality Roughages for Steers Grazing Wheat Pasture. II. Effect on Wheat Forage Intake and Utilization. *Journal of Animal Science* 62(4):1113-1119.

Mader, T.L. et al. (1983) Low-Quality Roughages for Steers Grazing Wheat Pasture. I. Effect on Weight Gains and Bloat. *Journal of Animal Science* 56(5):1021-1028.

Paisley, S.I. and G.W. Horn (1998) Effect of Ionophore on Rumen Characteristics, Gas Production, and Occurrence of Bloat in Cattle Grazing Winter Wheat Pasture. Animal Science Research Report MP-965:141.

Paisley, S.I. et al. (1998) Alternate Day Feeding of a Monensin-Containing Energy Supplement on Weight Gains of Steers Grazing Winter Wheat Pasture. Animal Science Research Report P-965:132-135. Oklahoma Agricultural Experiment Station, Stillwater.

Potter, E.L. R.L. VanDuyn and C. O. Cooley (1984) Monensin toxicity in cattle. *Journal of Animal Science* 58:1499.

Stewart, B.A. et al. (1981) Chemical Composition of Winter Wheat Forage Grown Where Grass Tetany and Bloat Occur. *Agronomy Journal* 73:337.

Trapp, J.N. (1998) Seasonal Price Index Updates for Oklahoma Livestock and Livestock Products. Oklahoma Agricultural Experiment Station *Current Farm Economics* 71(3):56.

Vogel, G.J. et al. (1987) Influence of Supplemental Silage on Performance and Economics of Growing Cattle on Wheat Pasture. *The Professional Animal Scientist* 3:50.

Vogel, G.J. et al. (1989) Effects of Supplemental Silage on Forage Intake and Utilization by Steers Grazing Wheat Pasture or Bermudagrass. *Journal of Animal Science* 67:232.

24 Preconditioning Nutrition and Management

Jeff Robe; Paul Beck; Rosslyn Biggs, DVM; John Gilliam, DVM and David Lalman

Objectives

- **Outline several alternatives for reducing cattle stress during the first few days following weaning.**
- **Discuss important nutrition factors for calves during weaning and receiving times of stress.**
- **Present dietary recommendations for cattle of different situations during and after receiving.**

Receiving and weaning times represent the most stressful periods during a beef animal's life. Taking action to ensure minimal stress during the weaning or receiving period is a critical step to minimize the risk and cost of disease. The process of weaning calves prior to shipment has been shown to have a significant impact on the health performance of calves in the stocker and feedlot phases. Weaning calves for 45 days prior to shipment, even without vaccination, has a significant positive impact on calf health (Step et al 2008). Management steps taken around the time of weaning to ensure optimum health and performance of cattle is often referred to as preconditioning in the cattle industry. In a small, growing percentage of cases, some or all of these management steps are executed at the ranch of origin by the cow-calf producer. In many more cases, these management steps are taken after the sale or shipment of the calves by the stocker producer or cattle feeder. Examples of preconditioning management steps include a comprehensive animal health program including vaccinations, deworming, coccidiostat, etc.; balanced nutrition before and after weaning; training calves to eat from a bunk; and a growing or preconditioning period that usually lasts 45 days. However, the demand for long weaned calves, preferably 60 days or more, is increasing indicating opportunity for producers to capture additional value.

With a variety of cattle types, feed resources, operation sizes and environmental conditions, no one health program for receiving cattle can be recommended for all Oklahoma producers. However, research and experience have provided scientists and cattlemen with information that can be used to minimize cattle stress and improve health and weight gain during this critical period.

Preweaning and Weaning Management

Developing a strong immune system in beef calves begins with key management factors that must be acted upon prior to calving. Passive transfer of colostral (first milk) antibodies is vital to short-term health as well as lifetime immune function. For example, in one experiment, calves that did not have adequate blood concentrations of immunoglobulins from the dam's colostrum within 24 hours after birth were three times as likely to be treated for Bovine Respiratory Disease during the feedlot phase (Selk).

A variety of vaccination schedules can be used and producers are encouraged to work with their veterinarian to develop a vaccination program customized to the needs of the individual operation. All calves benefit from vaccination prior to weaning. This can be done at two months to three months of age, or what also may be known as branding time. Typically, calves are vaccinated, identified, castrated and dehorned then returned back to the dam. One of the key factors if calves are going to be shipped at weaning is getting calves vaccinated prior to weaning so effective immunity is in place at the time of weaning. Even when using modified live vaccines, there is a lag period of about two weeks between vaccination and the development of protective immunity. Calves also may be less likely to respond well to a vaccine if the vaccine is administered concurrent with the stress of weaning.

For the best health protection, cattle should receive two rounds of vaccinations prior to sale. At a minimum, calves should be vaccinated for diseases such as infectious bovine rhinotracheitis (IBR), bovine parainfluenza virus, bovine respiratory syncytial virus, bovine viral diarrhea virus and clostridial organisms (commonly referred to as blackleg and tetanus). Other vaccinations may be needed depending on the producer's goals. Understanding that each ranch's management may be different, producers should consult with their veterinarian on the best health protocol for their operation.

If cattle are not vaccinated at a younger age, it is essential vaccinations are provided at weaning or receiving in an attempt to protect them against future disease exposure. Two series of vaccinations is needed if there is no known or

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

doubtful vaccination history. Many stocker producers will receive cattle that have had no or little previous management and will add value by vaccinating, castrating, dehorning and improving health of calves prior to selling or turning out on high-quality forage. Cattle with no vaccinations or unknown vaccination history prior to shipment to a backgrounding yard are considered high risk and receive a discount at the time of sale. Please refer to chapter 36 for more specifics on vaccinations and herd health.

Any practice reducing stress on cattle during the first few days after weaning will reduce the risk of health problems, improve calf weight gains and minimize wear and tear on facilities and people. Performing procedures such as castration and dehorning at the time of weaning also has a negative impact on calf health. To alleviate this impact, these procedures should be performed as early as possible to allow the calf to fully recover before it experiences the stress of weaning. When these procedures have to be performed at weaning, provision of medications to alleviate as much pain as possible should be administered under the direction of a veterinarian. Providing pain relief for castration at feedlot entry has been shown to have a positive impact on calf health.

Many cattlemen prefer to isolate calves in a corral, drylot or small grass trap with good fencing during the bawl-out period. It is helpful to familiarize calves with their weaning area by giving them access to it for a few days prior to weaning. If a drylot or corral is used, smaller pens are preferable to reduce fence walking or pacing. Feed bunks and hay or water troughs can be strategically placed along the fence line to discourage fence walking.

If the weaning corral is well designed and solidly constructed, the cows can be allowed adjacent access to the calves. However, the corral must be constructed so calves are unable to nurse. Another helpful practice, but is not always practical, is to leave the calves in the familiar weaning area and move the cows far enough away so they cannot hear their calves bawling. Probably the least ideal situation is to move the cows to another pasture where they can hear and see the calves, but do not have close contact. This method can work, but requires a good fence because cows will be aggressive in their efforts to get back to their calves.

Some producers subscribe to the practice of leaving one or more older cows with the calves, thinking that the presence of at least one adult female will calm the calves. However, this practice has not proven to improve calf health, time spent at the feed bunk or overall performance according to research settings.

Another practice that seems to be growing in popularity is one of leaving cows and calves in adjacent pastures, using electric fence on either side of a barbed or woven wire fence to keep the cattle apart. This practice, referred to as fence-line weaning, makes it easier to utilize high-quality pasture, rather than a dusty drylot. Previous and recent exposure to electric fencing is necessary to train the calves to respect it. Initially, cows will graze and rest close to the fence, but gradually begin to graze farther and farther away. Recent research conducted at OSU during a two-year period compared fence-line weaning to traditional abrupt weaning, the use of anti-suckling nose flaps or temporary separation of calf and dam prior to weaning. Through both years of the study, calves weaned by the fence-line method had the greatest average daily gain of a preconditioning period of 28 days to 42 days (Taylor et al., 2020).

During the initial weaning period, a concentrate-feeding program should be implemented. This practice trains the cattle to come to feed, eat from a bunk, aids in health monitoring and handling and provides a method to incorporate supplemental nutrients in the diet. A minimum of 14 days of concentrate feeding is recommended to ensure all the cattle have been trained to eat from the bunk.

Treatment

Due to the high stress of separating the cow and the calf, special attention needs to be placed on quick treatment of sick animals, regardless if cattle are being preconditioned at the ranch or have been received from outside sources. At this point, respiratory disease often will be a major contributor in decreased calf health. With time and experience, many cattle producers excel at identifying sick cattle quickly and are able to remove them from their herd mates to treat very efficiently with very little stress. That being said, slow recognition of disease and application of treatment is the primary reason for treatment failure.

Knowing the signs of illness in cattle is essential. Reduced intake, indicated by a lack of rumen fill, lethargy or a calf separating itself from the rest of its pen, may be the first of several signs a calf may exhibit. These clinical signs often are associated with an increase in rectal temperature. A thermometer is a necessary tool to determine sickness. If the temperature is more than 103 F, cattle are considered sick and need immediate treatment. Other signs of illness include labored breathing, coughing and eye or nasal discharge. Depression also is a major sign of illness and is indicated by drooping head and ears, very slow movement or a reluctance to get up or be moved as seen in Figure 24.1. Once calves reach this point, successful treatment is often difficult.

Monitoring the consistency of manure of cattle can also indicate sickness or digestive upset. Loose manure or manure with blood may be an indication of acidosis, injury

Figure 24.1 Signs of illness in cattle.

or other problems causing a decrease in immune response or a decrease in feed efficiency. Establishing a treatment protocol plan with a veterinarian prior to the beginning of the preconditioning program will give specific guidelines on how to identify and treat sick animals in the operation.

Deworming

Many forage systems in Oklahoma are favorable for the proliferation of internal and external parasites. In contrast to adult cattle, calves do not acquire full immunity to gastrointestinal parasites until about a year after weaning, thus weaned calves are very susceptible to internal parasites (worms). Cattle infected with internal parasites will have reduced appetites and suppressed immune function, as well as reduced ability to respond to vaccination. Producers should consult veterinarians for assistance in identifying the most appropriate deworming strategy to use for their area and current conditions.

Many preconditioning programs requiring certification include deworming as one of the health management requirements. In these programs, producers usually have the option of deworming calves two weeks to six weeks prior to weaning, at weaning or two weeks to three weeks after weaning. Deworming at the earliest possible date within the program's guidelines will ensure weight gain is not limited by parasite infestation and digestive tract damage. Additionally, the early application should improve the efficacy of the vaccine products used. In effect, applying the deworming product as early as possible (preferably two weeks to six weeks prior to weaning) may improve the efficiency, profitability and effectiveness of the entire preconditioning effort. Chapter 38 has a more detailed discussion on internal parasite control in beef cattle.

Implanting

Few, if any, beef cattle management practices are more cost effective or have a higher return on investment than properly used growth-promoting implants. Pellets are implanted just under the skin, on the backside of the ear of growing calves. Be sure to implant pellets to avoid blood vessels and the placement of future ear tags. Care should also be made to avoid crushing pellets upon insertion. The pellets release extremely low concentrations of various hormones or hormone-like substances that improve average daily gain 7% to 17% and feed efficiency 4% to 12%.

Stocker producers and feedyards prefer that calves do not have an active implant present when they arrive at their operation. This allows the stocker producers or cattle feeders to uniformly initiate their own implant strategy and minimize problems associated with overlapping implants. These problems can include a higher incidence of buller steers, advanced carcass maturity and lower quality grade. Implants approved for suckling calves generally have an active payout period of 70 days to 90 days. Therefore, cattlemen who wish to participate in certified preconditioning programs requiring a minimum of a 45-day weaning period should:

- Consider implanting steers and heifers that will NOT be retained as replacements at branding time (45 days to 90 days of age).
- Reimplant (if implanted at branding) or initially implant steers destined for the certified preconditioning program two weeks to six weeks prior to weaning.
- If calves cannot be implanted during the two- to six-week window prior to weaning, they should not be implanted at all, other than at branding.
- If there is any possibility that heifers could be purchased or retained for replacements, they should not be implanted more than one time under any circumstance.

Some implants approved for suckling calves are designed to provide longer payout periods of up to 400 days, these would not be recommended for use in a short-term preconditioning program. A veterinarian should be consulted to determine the most appropriate implant for a particular program. Refer to chapter 13 for more information regarding the proper implant selection.

Post-weaning Preconditioning Nutrition

Since the nutrition program can take 50% to 70% of the preconditioning budget, careful consideration, planning and preparation are warranted. Several nutritional management options are available for weaning and preconditioning calves, and vary considerably within regions of the state. In selecting an effective program, producers should first define and prioritize the objectives of the nutritional management program. Objectives might include:

- Optimizing condition and health of the cattle for the next phase.
- Producing added weight gain at a low cost.
- Marketing home-raised feed resources through the preconditioning program.
- Minimizing the risk of digestive disorders and disease during the weaning and preconditioning phase.
- Achieving a specific target weight for the cattle by sale or shipping date.
- Accomplishing the above objectives in a way that requires minimal labor and equipment investment.

Producers must be cautious not to over-condition cattle that might be destined for a moderate to low plane of nutrition, such as dry wintering on native pasture or hay with minimal supplementation. Much of the weight and condition (flesh) gained during preconditioning will be lost, resulting in poor overall production efficiency. Cattle buyers with orders for cattle to go to this type of situation will not be interested in paying very much for fleshy calves. However, if the cattle are more likely to go directly to high-quality pasture or to a feed yard where a high concentrate ration is fed, a higher rate of gain and increased fleshiness is justified. Cattle considered to be fleshy (BCS 7 or greater) can receive discounts of up to $20 per cwt. Excessively fat or fleshy calves will be discounted because of reduced potential for gain. Overly thin cattle may (or may not) receive premiums because of the possibility of compensatory gains, but these premiums are never enough to make up for the reduced

pounds of sale weight. Moderate flesh (body condition score of 4 to 6) should be the targeted condition at marketing. Body fat accretion rate occurs at different rates depending on the animal's frame score, sex, post-weaning backgrounding gains and growth promoting technologies used (for instance, implants and beta agonists). The percentage of body fat is consistent for animals at the same stage of maturity, or at the same percentage of their expected weight at 28% body fat (or low Choice quality grade). In other words, the body composition of cattle will vary despite having the same body weight when frame size and gender differ. For example, an implanted medium-framed steer would have a lower percentage of body fat at any given weight than a non-implanted heifer. Fleshy cattle with condition scores of 7, 8 and 9 have 26%, 30% and 34% body fat, respectively, which are close to the target body fat content of finished cattle ready for slaughter.

Table 24.1 shows the predicted gains and fat accretion of steers and heifers with differing mature size. A medium-framed heifer finishes at a lower bodyweight than a steer, so bodyweight gain has more fat than a steer of the same frame size or larger-frame cattle. Thus, these medium frame heifers could be fed to gain 2 pounds per day without getting too fleshy and being discounted. If these heifers are fed for 2.5 pounds per day they would reach more than 19% bodyfat and likely receive discounts for excess flesh. Whereas, a large-framed steer or heifer could be fed to gain 2.5 pounds per day without becoming excessively fat.

Preconditioning feeds must be highly palatable. Freshly weaned calves will be more concerned about the absence of their mothers than eating hay or processed feeds. Consequently, feed intake will be low for three to four days, especially if the calves had not been previously exposed to feed in bunks or creep feeders. Providing highly palatable and/or familiar feeds minimizes the length of this fasting period, resulting in improved weight gain and reduced stress during the first week after weaning.

Actual weight gain is difficult to accurately predict because it can be influenced by many factors. Some of the major factors determining weight gain during this period are:

- Health of the calves during weaning and pre-conditioning. Sick or parasite-infested calves obviously will not gain well.
- How quickly the calves increase their feed intake after weaning.
- Amount of feed or forage consumed.
- Energy level of the total diet, assuming that protein, minerals and vitamin requirements are met to sustain the energy for allowable gain.
- Presence of growth-promoting implants and/or other feed additives.
- Length of the feeding period.
- Previous level of nutrition, such as cows' milk production and preweaning pasture conditions, and the resulting flesh condition of the calves. Fleshy calves generally do not gain as rapidly as thin to moderately fleshed calves.
- Genetic potential for growth, which is inherited from the calves' sire and dam.
- Weighing conditions and gut fill. Since young calves can consume between 0% and 4% of their body weight, unequal fill conditions from one weigh date to the next can cause weight swings of up to 20 pounds to 30 pounds through short time periods.

Table 24.1. Estimated gain, fat gain and final condition score of growing calves with differing mature weights and rates of gain for a 60-day preconditioning period for medium- and large-framed calves.

	MF heifer		*MF steer*		*LF heifer*		*LF steer*	
Mature body weight	1,100		1,200		1,180		1,280	
Beginning weight	400		440		480		520	
Gain, lb/day	1.0	2.0	1.0	2.0	1.5	2.5	1.5	2.5
Total gain, lbs	60	120	60	120	90	150	90	150
Beginning body fat, %	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
Body fat in gain, %	5.9	26.7	3.3	23.7	13.5	34.8	11.9	31.8
Ending body fat, %	12.6	16.6	12.3	15.8	13.6	18.6	13.3	17.7
Ending BCS	3.3	4.4	3.3	4.2	3.6	5.0	3.5	4.7

Grazing Programs and Supplements

In many cases, the cheapest and most convenient preconditioning nutrition program is to turn calves back out on high-quality pasture four to seven days after they have been weaned. The pasture should be within easy access to a corral and chute where any sick calves can be restrained for treatment, if necessary. Forage quality and availability will vary dramatically depending on species, growing conditions, previous grazing management and time of year.

The calves should be given access to the highest-quality pasture available. Ensuring high-quality pasture at the time of weaning requires considerable planning and pasture management for months ahead of time. An excellent method to ensure the highest-quality pasture possible is to utilize the rotational grazing technique. For the purpose of this discussion, rotational grazing will simply serve to stage an area for the calves to graze that represents immature (high-quality) forage or forage regrowth. A second approach is to stage the production of high-quality forage to match the timing of the preconditioning period. For example, if calves are to be sold in a special auction during late October, calves could be weaned in early September and turned out on native pasture until adequate stockpiled Bermudagrass or fescue is available. Another example would be to turn calves out on stockpiled Bermudagrass in mid-October followed by a move to an overseeded rye pasture in mid-November. Refer to chapters 22 and 23 for more information regarding supplementation and feeding programs for growing calves.

Access to Water and Feed

There is no evidence to support any advantage in withholding either water or feed from cattle upon arrival. The water source should be fresh, clean and easily located by the cattle. Many cattlemen prefer to place good-quality grass hay in bunks for the first 24 hours after arrival before offering the receiving diet. A Texas Tech University study showed that when long-haul cattle (720 miles, 6.6% shrink) were deprived of water for six hours to eight hours after

arrival, but were immediately offered feed, feed intake was reduced during the first week.

Feeding and Bunk Management

Newly received or weaned cattle should be fed at approximately the same time each day to establish a consistent eating time. As a result, sickness is much easier to detect because sick cattle are slower to come to the feed bunk. Twice-a-day feedings during the first one week to two weeks may be advisable for young, lightweight or highly stressed cattle. Bunks should be kept clean of manure, stale feed and silage trash.

Feed Intake

After a period of water and feed removal, which often occurs during weaning and shipping, rumen fermentation is greatly reduced and remains low for several days after cattle are put back on feed. These changes lead to decreased appetite and feed intake. Calves that remain healthy often return to a normal appetite and steady feed intake within two weeks after arrival. However, when calves are sick upon arrival or develop a respiratory disease after arrival, feed intake is reduced further, and the length of time for an animal to return to normal is extended, as shown in Table 24.2.

A wide range in crude protein and energy concentration is indicated in Table 24.3 because the level of these nutrients largely depends on animal weight, level of stress, expected feed intake and desired weight gain.

Receiving Diet Nutrient Concentration

With dry matter intake low during the weaning or receiving period, preconditioning rations should be designed to maximize intake and provide greater concentrations of required nutrients. Refer to Table 24.3 for current nutrient recommendations for receiving rations intended for highly stressed calves.

Protein Source

The protein in receiving diets should be from a plant protein source, such as soybean meal, cottonseed meal, alfalfa or wheat middlings. Stressed calves have a lower tolerance for nonprotein nitrogen (urea) than do nonstressed calves. Nonprotein nitrogen is not recommended in receiving diets for cattle weighing less than 600 pounds and certainly should not be used in diets for calves weighing less than 350 pounds.

Table 24.2. Dry matter feed intake of newly arrived calves (percent of body weight).

Days from receiving	*Healthy*	*Sick*
0 to 7	1.55	0.90
8 to 14	1.90	1.43
15 to 28	2.71	1.84
29 to 56	3.03	2.68

Source: Hutcheson and Cole.

Table 24.3. Suggested dietary nutrient concentrations for stressed calves (dry matter basis).

Nutrient	*Unit*	*Suggested Range*
Dry matter	%	80 to 85
Crude protein	%	12.5 to 14.5
Net energy for maintenance	Mcal/lb	0.6 to 0.73
Net energy for gain	Mcal/lb	0.35 to 0.41
Calcium	%	0.6 to 0.8
Phosphorus	%	0.4 to 0.5
Potassium	%	1.2 to 1.4
Magnesium	%	0.2 to 0.3
Sodium	%	0.2 to 0.3
Copper	ppm	10 to 15
Iron	ppm	100 to 200
Manganese	ppm	40 to 70
Zinc	ppm	75 to 100
Cobalt	ppm	0.1 to 0.2
Selenium	ppm	0.1 to 0.2
Iodine	ppm	0.3 to 0.6
Vitamin A	IU/lb	2,000 to 3,000
Vitamin E	IU/lb	20 to 50

Source: Adapted from National Academy of Sciences, Nutrient Requirements of Beef Cattle.

Feed Additives

The occurrence of subclinical coccidiosis during receiving is well known; therefore, all receiving rations should contain a coccidiostat. Coccidiosis appears to play a role in the immune response, and coccidiostats have been shown to improve feed efficiency and rate of gain during the receiving period. Feed additives approved for aiding in the prevention of coccidiosis include: decoquinate (Deccox®), lasalocid (Bovatec®) and monensin (Rumensin®). Another method to control coccidiosis is to treat the water source with amprolium. A veterinarian should be consulted to determine the most effective coccidiostat for a particular program.

Research at several locations has shown that adding vitamin E to receiving diets can improve gain and may reduce sickness. Vitamin E should be fed between 400 IU and 500 IU per head per day during the receiving and starting period. In general, responses to vitamin E additions in the diet have been positive. However, injections of vitamin E at processing have often been noneffective and even detrimental.

Light Calves

Calves weaned early (six weeks to 16 weeks of age), and those weighing less than 350 pounds require nutrient-dense diets. Calves cannot efficiently digest moderate- and low-quality roughage. As a result, receiving diets for young, light calves should be highly palatable and higher in protein and digestible carbohydrates than receiving diets for calves weighing more than 350 pounds. Programs utilizing free-choice hay as the major ingredient will not be as effective as mixed rations higher in concentrates. According to New Mexico State research (Lofgreen and Kirksey), young calves do not seem to be as prone to acidosis as yearlings, and prefer concentrate to roughage when stressed and sick.

Two suggested receiving diets for very young calves are shown in Table 24.4. These diets were developed for

Table 24.4. Suggested diets for receiving very light calves or early weaning.

Ingredient	*Diet A*	*Diet B*
	% of diet, as-fed	
Cottonseed hulls	29.0	14.9
Alfalfa pellets	-	15.0
Rolled corn	46.0	46.0
Cane molasses	4.0	4.7
Soybean meal (47%)	18.5	17.7
Calcium carbonate	1.2	0.8
Dicalcium phosphate	0.5	0.5
Salt	0.3	0.3
Magnesium oxide	0.1	0.1
Zinc oxide	0.008	0.008
Vitamin A	2500 IU/lb	2500 IU/lb
Vitamin E	40 IU/lb	40 IU/lb
Coccidiostat	As per veterinarian's preference	
	Nutrient content (DM basis)	
Dry matter, %	88.7	88.5
NEm, Mcal/lb	0.82	0.84
NEg, Mcal/lb	0.48	0.50
Crude protein, %	16.0	17.5
Potassium, %	1.24	1.3
Calcium, %	0.80	0.82
Phosphorus, %	0.40	0.43

the purpose of early weaning (six weeks to eight weeks old) and have proven to be extremely palatable to newly received calves. Diet A has the advantage of requiring fewer commodities and no alfalfa pellets. However, Diet B is less bulky, resulting in better handling characteristics, and should flow better in self-feeders. These diets can be blended as shown; or soybean meal, minerals and additives can be pelleted before being mixed with the cottonseed hulls, alfalfa pellets and corn. Pelleting the supplement improves the physical characteristics of the diet and may help stimulate intake. Cottonseed hulls are an effective fiber source and appetite stimulant. Because of their low nutrient value and relatively high cost, cottonseed hulls are hard to justify in most diets. Even so, cottonseed hulls are very palatable to cattle and calves will often consume unfamiliar feeds more readily when cottonseed hulls are added.

The protein and energy content of these diets is much higher than would be required in yearling programs. However, these levels are necessary for small calves with high protein and energy needs, but with a relatively low feed intake. Consumption of the diets shown in Table 24.4 should be 3% of body weight within two weeks, and calves should gain between 1.75 pounds and 2.25 pounds per day.

Both diets shown in Table 24.4 are intended to be fed as complete rations. Other roughage sources should not be provided. If hay is offered, some calves may only consume hay. The result is a nutrient-deficient diet. Energy deficiency in lightweight calves can severely depress the immune system and increase the incidence of sickness.

Calves Weaned at Normal Age

For calves weaned at six months to eight months of age or weighing more than 350 pounds, receiving programs based on either roughage diets or high concentrate diets can be effective. The decision about which nutritional program to use often will depend on the availability of resources on the farm or ranch and the advantages and disadvantages of the programs.

Trade-offs exist between rate and efficiency of weight gain and sickness in concentrate-based versus roughage-based receiving programs. Research from New Mexico State University (Lofgreen and Kirksey) indicates weight gain and feed efficiency is improved, but incidence of sickness is slightly increased with receiving diets containing high concentrate (75%) in comparison to a prairie hay diet supplemented with a high-protein pellet as shown in Table 24.5. Other research has shown a trend of increased sickness as concentrate in the diet is increased from 25% to 75% of diet dry matter.

Concentrate diets that are moderate to low in starch content and formulated with highly digestible fiber sources, such as distillers grains, wheat middlings and soybean hulls, may reduce the incidence of sickness as well as the risk of acidosis. At the same time, rate and efficiency of gain should be similar to that of receiving diets based on grain.

Table 24.6 includes three suggested weaning or receiving diets for calves and yearlings weighing 400 pounds or more. All of these diets use cottonseed hulls as the fiber source or scratch factor, which is important in stimulating rumen motility and reducing acidosis. As mentioned before, cottonseed hulls do not contribute a great deal from a nutrient standpoint, but are very palatable to cattle and can be justified during the critical receiving period. Diet C in Table 24.6 is a more traditional mix based on corn and alfalfa pellets and has been used in Oklahoma for several years with success. Diets D and E are based on the palatable byproduct feeds of corn distillers grains, wheat middlings and soybean hulls, respectively.

Such feeds provide a greater proportion of digestible fiber with moderate to low starch content. These formulations also may provide an opportunity to cut costs when byproduct feeds are underpriced relative to other commodities.

For Diets C and E, a supplement pellet can be made from soybean meal, minerals, vitamins and additives. If a

Table 24.5. Performance of calves received 28 days on alternative feed programs.

	75% Concentrate Ration			
	Alfalfa hay, first week only	*Native hay, first week only*	*Native hay, four weeks*	*40% Protein supplement + native hay four weeks*
No. of calves	31	31	31	32
Treated, %	26	23	32	16
Days treated	3.5	4.1	4.0	4.4
Milled feed or supp intake, lbs	9.7	10.4	9.5	1.93
Hay, intake, lbs	1.5	1.1	3.5	8.83
Daily gain, lbs	1.85	1.94	2.01	1.23
Feed:Gain	6.04	5.95	6.44	8.75

Source: Lofgreen and Kirksey.

Table 24.6. Receiving rations for 400- to 600-pound calves.

Ingredient	*Diet C*	*Diet D*	*Diet E*
	% in Ration (as-fed)		
Cottonseed hulls	14.0	20.0	15.0
Alfalfa pellets	19.0	-	-
Rolled corn	51.0	30.5	22.0
Corn distillers grains	-	43.0	-
Wheat middlings	-	-	25.0
Soybean hulls	-	-	25.0
Cane molasses	4.2	4.5	4.5
Soybean meal (47%)	10.3	-	7.5
Calcium carbonate	0.6	1.2	1.0
Dicalcium phosphate	0.6	-	-
Potassium chloride	-	0.5	-
Salt	0.25	0.25	0.25
Magnesium oxide	0.1	0.1	-
Zinc oxide	0.008	0.008	0.006
Vitamin A	2,500 IU/lb	2,500 IU/lb	2,500 IU/lb
Vitamin E	40 IU/lb	40 IU/lb	40 IU/lb
Coccidiostat	As per veterinarian's preference		
	Nutrient Content (DM basis)		
Dry matter, %	88.5	90.0	89.0
NEm, Mcal/lb.	0.83	0.87	0.83
NEg, Mcal/lb.	0.49	0.54	0.51
Crude protein, %	14.5	14.8	14.5
Potassium, %	1.22	1.2	1.18
Calcium, %	0.79	0.66	0.71
Phosphorus, %	0.42	0.42	0.45

Table 24.7. Forty percent protein pellet for receiving programs with hay.

Ingredients	*Percent (as-fed)*
Soybean meal	88.9
Salt	3.0
Premix[a]	0.18
Vitamin A-30,000 IU/gm[b]	0.11
Vitamin E-222,800 IU/lb[c]	0.089
Cottonseed Meal	5.0
Dicalcium PO_4	2.75

a To provide desired dosages of decoquinate, lasalocid or monensin.
b To provide 15,000 IU vitamin A per pound.
c To provide 200 IU vitamin E per pound.
Source: Gill, D.R. and R.A. Smith.

supplement is desired for Diet D, a portion of corn can be mixed with the minerals, vitamins and additives. Because corn does not make a good quality pellet, this supplement should be mixed and blended as a meal with the remaining ingredients of the diet.

Roughage-based programs often require more labor and covered storage space, as in the case of small square bales. However, if an abundance of high-quality hay is produced on the farm or ranch, producers often prefer a hay-based receiving program rather than purchasing expensive concentrate feeds. Weight gain will be considerably lower compared to concentrate programs. However, added gain during receiving, resulting from a high concentrate receiving program, is often lost before the end of a low-input dry winter grazing program. Conversely, if cattle are to be placed on high-quality pasture or enter the finishing phase immediately after the receiving period, higher rates of gain during receiving may be apparent.

In situations where 0.5 pound to 1.5 pounds per day gain during the receiving period is acceptable, high-quality grass hay, which is clean, palatable and free of mold, plus 2 pounds of a high-protein supplement has worked well in research trials and for many producers. The supplement should contain the necessary protein, minerals, vitamins and feed additives needed to meet the recommended nutrient levels indicated in Table 24.3. Research and producer experience indicate that although this receiving program does not promote rapid gain, it does minimize health and digestive disorders. A high-protein supplement that has worked well with native hay receiving programs in Oklahoma is shown in Table 24.7.

Conclusion

It is important for producers to help reduce cattle stress during both the weaning and receiving phases. Taking action to ensure minimal stress during the weaning or receiving period is a critical step to minimize the risk and cost of disease. A good preconditioning program will allow for the optimum health and performance of cattle. Because the usefulness of a program depends on the individual operation, producers should use the information presented here to develop a specific preconditioning plan that will likely be beneficial to their businesses.

References

Gill, D.R. and R.A. Smith (1988(. Nutrition, Health and Management of Newly Arried Stressed Stocker Cattle. *Oklahoma Beef Cattle Manual* (2nd Edition) pp85-105.

Hutcheson, D.P. and N.A. Cole (1986) Management of Transit-Stress Syndrome in Cattle: nutritional and Environmental Effects. *Journal of Animal Science* 62:555.

Lofgreen, G.P. and R.E. Kirksey (1982) Effect of Receiving Rations on Subsequent Performance on Grass. Livestock Research Briefs. New Mexico State University. p. 17-23.

Lofgreen, G.P. et al. (1980) Effects of Dietary Energy, Free Choice Alfalfa Hay and Mass Medication on Calves Subjected to marketing and Shipping Stresses. *Journal of Animal Science* 50:590.

National Academies of Sciences, E. M., D. E. L. Studies, B. A. N. Resources, and C. N. R. B. Cattle. 2016. *Nutrient Requirements of Beef Cattle*: 8th Revised Edition. National Academies Press.

Selk, G. (2002) Disease Protection for Baby Calves. Extension Fact Sheet AFS-3358, Cooperative Extension Service, Oklahoma State University. extension.okstate.edu/

Step. D. L. et al. (2008) Effect of commingling beef calves from different sources and weaning protocols during a forty-two day receiving period on performance and bovine respiratory disease. *Journal of Animal Science* 86:3146-3158.

Taylor, J. D. et al. (2020) Comparison of four weaning methods on health and performance of beef calves. *Animal* 14:161-170.

25 Performance Recording Guidelines

Mark Johnson and Daniel Stein

Objectives

- **Identify key factors for genetic improvement.**
- **Review the application of different selection methods.**
- **Summarize information available through the Beef Improvement Federation.**

Beef production takes place in diverse environmental and management situations. Accordingly, the genetic diversity of many excellent breeds must be exploited as effectively as possible to optimize profit potential. Fortunately, the Beef Improvement Federation (BIF), established in 1968 as a forum for producers, breed associations and scientists, has established many standardized measures of beef cattle performance. The 9th edition of the BIF guidelines are the definitive source of information on performance recording and can be accessed online at beefimprovement.org/library-2/bif-guidelines or a web-based Wiki format, which can be found at guidelines.beefimprovement.org. Breed associations also are an excellent source of information on performance recording. Cattle producers can utilize these measures to make selection decisions within and between breeds of beef cattle. Many beef breed associations have been very aggressive in adopting and utilizing the newest technologies for genetic improvement, leading to more criteria and information than ever before for producers to consider in making mating decisions. The following is an overview of the fundamentals of animal breeding and performance recoding and provides some general guidelines on recording and evaluating phenotypic performance.

Phenotype = Genotype + Environment

The animal's genotype is determined at conception. One-half of an animal's genome is inherited from each of its parents, and the subset of genes it inherits is randomly determined by independent assortment (the random segregation of genes into gametes). The effect of an animal's genotype is a combination of both additive (the effect of individual alleles on phenotype) and non-additive (gene combination effects, for example, heterosis) effects. Generally, one can think about these two types of effects as being either selected for (additive) or managed through mating systems (non-additive). This is because additive genetic effects are passed from parent to offspring since a sperm or egg carries only individual genes, not gene pairs.

Environmental factors, such as management, feed and weather conditions, can have a huge impact on whether or not an individual animal reaches its full genetic potential for a particular trait. For example, even though an animal has a genetic potential for large weaning weights, this animal must receive proper care, nutrition and a favorable environment to realize this potential.

All physical traits of beef cattle can be referred to as phenotype. Phenotype is the result of the animals inherited genotype and the environment in which the animal lives. Phenotype can be measured objectively, by a scale or other objective measurement tools, or subjectively, by using a scoring system. Objective measures of phenotype, like birth and weaning weights, serve as the basis for most standardized performance recording. However, subjective evaluation is currently the only means by which to evaluate several economically important traits, such as structural soundness.

Heritability and Selection

Heritability

Because it is known genetics and environmental conditions work together to result in a particular phenotype or level of performance, it is useful to know what proportion of the phenotype is due to genetic influences versus environmental factors. Heritability is the metric used to describe these influences, and is not constant between different populations. It may be helpful to think of heritability as how easy it is to make genetic improvement through selection. Heritabilities for a trait generally can be classified as lowly, moderately or highly heritable. Estimates for two breeds of beef cattle are shown in Tables 25.1 and 25.2. As a rule of thumb, most reproductive traits tend to have low heritability (< 0.20), growth traits tend to have moderate heritability (.20 to .40) and carcass traits tend to have fairly high heritability (>0.40). Consider Figure

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 25.1. Angus trait heritabilities and genetic correlations.

Trait	*CED*	*BW*	*WW*	*PG*	*RADG*	*DMI*	*YH*	*SC*	*Doc*	*HP*	*CEM*	*MILK*	*MW*	*MH*
Calving ease direct (CED)	**.22**[1]	-.65												
Birth wt direct (BW)		**0.44**												
Weaning direct (WW)			**0.20**	0.15[2]										
Post-weaning gain (PG)					0.20		0.48[3]	0.28[4]						
Residual average daily gain (RADG)					**0.36**									
Dry matter intake (DMI)						**0.36**								
Yearling height (YH)							**0.50**							
Scrotal circumference (SC)								**0.47**						
Docility (Doc)									**0.37**					
Heifer pregnancy (HP)										**0.14**				
Calving ease maternal (CEM)											**0.11**[5]			
Maternal milk												**0.14**		
Mature weight (MW)													**0.37**	0.75
Mature height (MH)														**0.61**

1 Heritability estimates are on the diagonal.
2 Upper off-diagonals are genetic correlations.
3 Genetic correlation between 365-day yearling weight and SC or YH.
4 Dry Matter Intake heritability.
5 Maternal component only.
Genetic parameters for carcass traits are published at *Journal of Animal Science* 2008, 86:2518-2524.
Source: American Angus Association.

Table 25.2. Charolais trait heritabilities and genetic correlations.

												Ultrasound Measurements (Correlated Traits)				
Trait	*BWT*	*WWT*	*PWG*	*MAT*	*SC*	*REA*	*HCW*	*FAT*	*MARB*	*CE*	*MCE*	*IMF*	*REA*	*SCAN WT*	*FAT THICK*	*RUMP FAT*
Birth weight (BWT)	**0.49**	0.47	0.22							-0.76	0.16					
Weaning weight (WWT)		**0.25**	0.49	-0.32	0.28	0.35	0.45	-0.10	-0.07							
Post-weaning gain (PWG)			**0.31**		0.35											
Milk (MILK)				**0.14**												
Scrotal circumference (SC)					**0.31**											
Ribeye area (REA)						**0.34**	0.40						0.70			
Hot carcass weight (HCW)							**0.21**							0.75		
Fat thickness (FAT)								**0.26**	0.15						0.70	0.48
Marbling score (MARB)									**0.36**			0.68				
Calving ease (CE)										**0.24**	-0.06					
Maternal calving ease (MCE)											**0.16**					
Intramuscular fat (UIMF)												**0.23**				
Ultrasound ribeye area (UREA)													**0.39**			
Scan weight (SCAN WT)														**0.27**		
Fat thickness (UFAT)															**0.35**	
Rump fat (URUMP)																**0.38**

Source: American International Charolais Association.

25.1, where each circle represents an animal's phenotype and the components that contribute to that phenotype. For a trait with a low heritability (Figure 25.1, right side), the environment has more influence on phenotype than genetic components. For a highly heritable trait (Figure 25.1, left side), genetics influence the phenotype more than environmental contributions.

Heritability also reflects the ease with which genetic changes can be realized in a population. It is easier to select for highly heritable traits than for lowly heritable traits. However, it is easier to improve the performance of an animal for a lowly heritable trait by using good management practices. This does not mean lowly heritable traits should not be included in a selection program, because often these

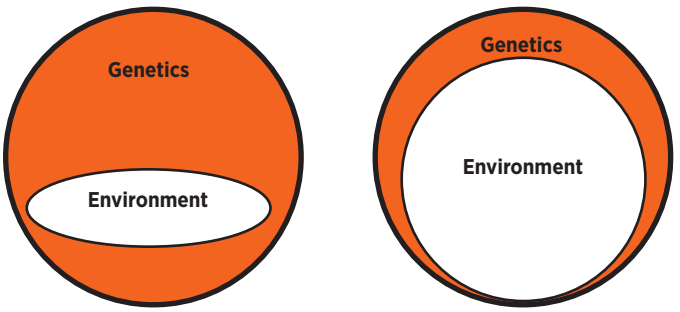


Figure 25.1 Schematic representation of lowly heritable traits (right) and highly heritable traits (left).

traits (such as fertility) are so economically important, that even a small selection advantage can dramatically influence profitability. However, it is useful to be cognizant of the influence of management practices on these traits.

Until recently, the only genetic selection tools available for female fertility were indicator traits. In some studies, larger scrotal circumference in sires has been linked to earlier puberty in heifers, therefore scrotal circumference Expected Progeny Differences (EPDs) have been used as an indicator of fertility in heifers. Several breeds now have published heifer pregnancy EPDs, which better describe female fertility than the use of an indicator trait. Several beef breeds also publish stayability EPDs, which provide a selection tool for another lowly heritable trait, longevity.

Genetic Correlations

Genetic correlations are found between traits that are controlled by many of the same genes. One can think of genetic correlations as the amount one trait is influenced by selection on another trait. The amount of genetic variation one can select for that is independent of the variation present in the other trait is equal to 1 minus the genetic correlation. For example, the genetic correlation between weaning weight and birth weight in Charolais (Table 25.2) is 0.47. This means that if birth weight is held constant, one can select for higher weaning weights using 53% (1 - 0.47 = 0.53) of genetic variation for weaning weight not tied to birth weight. Knowledge of traits with genetic correlations allows the use of indicator traits in selection. Indicator traits, like ultrasound measures of carcass characteristics, allow measurement of performance in a trait that is genetically correlated to an economically important trait, but usually is cheaper or easier to measure. If two traits are genetically correlated, one can change a trait that is difficult to measure (such as feed efficiency) by selecting a trait that is easier or cheaper to measure (such as growth). The downside of using an indicator trait is that it only allows selection on those genes which have shared effects on the two traits, and the variation independent of the correlated trait remains unselected.

Knowledge of the magnitude of the genetic correlation between various traits is useful in a selection program. This is important to note because genetic correlations are not always favorable. To choose a logical example, selection to increase weaning and yearling weight can have an adverse effect on mature weight because many of the same genes that influence growth also will cause cattle to weigh more at maturity. Selecting for increased growth also can have adverse effects on birth weight as seen in Figures 25.2 and 25.3 for genetic trend in birth weight from 1985 to 1993. However, since about 1994, breeders have successfully held birth weights in check (and in some cases lowered birth weights), while simultaneously continuing to make progress in selecting for increased weaning weights by being mindful of the unfavorable genetic correlation and selecting for growth genes independent of birth weight.

One example of an unfavorable genetic correlation frequently mismanaged in the cow herd is the unfavorable genetic correlation between direct calving ease (commonly abbreviated as CED) and maternal calving ease (commonly abbreviated as CEM). Direct calving ease refers to the ease with which progeny of that animal are born. Maternal calving ease refers to the calving ease of progeny in the next generation. For example, if a sire with a high CED EPD is selected, it would be expected that a large proportion of his calves would be born unassisted, which is an important selection criterion when selecting bulls to breed to first-calf heifers. However, if a bull with a high CEM is selected, it would be expected that a higher proportion of the replacement heifers retained would calve unassisted during their lifetime. In a terminal system where only the direct calving ease of animals is important (not keeping replacements), selection solely on CED is logical. However, when replacement heifers are being kept, CEM should be considered for potential sires of those replacement heifers.

Response to Selection

Response to selection is the genetic change that occurs as a result of selection and allows certain individuals a greater opportunity to reproduce than others. The key to successful selection is identifying the genetically superior animals in the current generation to serve as parent stock for the next generation. The amount of genetic change realized each year is a function of selection intensity, accuracy, genetic standard deviation (a function of the heritability) and the generation interval.

The formula for response to selection is:

$$\text{Genetic change/year} = \frac{\text{Selection intensity x Accuracy x Genetic standard deviation}}{\text{Generation interval}}$$

The selection intensity can be described as the difference between the average performance of the individuals selected to be parents and the average performance of the entire population (Figure 25.4 and Table 25.3). Generally, the fewer traits actively selected, the larger the intensity for each trait. However, it is important to remember single-trait selection is almost universally undesirable. The intensity will be different between heifers and bulls, because a larger number of heifers are saved as replacements than typical or purchase males for bulls. For example, we may choose to keep 30% of heifer calves (with a final goal of 25% retained, 5% culled due to poor performance or failure to breed) as replacements (an intensity of 1.14 from the Table 25.4) with a target of replacing 12.5% of the herd per year (25% of heifers retained times 50% of the herd that had heifer calves).

Considering the same heifers used in the previous example, genetic change per year in weaning weight with a heritability of 0.32 (genetic variance of 230 ◎◎ 723 phenotypic variance = a heritability of 0.32), a generation interval of approximately five years, a low accuracy of 0.3 and a genetic standard deviation of 15.2 leads to the following equation:

$$\text{Genetic change per year} = \frac{1.14 \times 0.30 \times 15.2}{5} = 1.0$$

where we see approximately a 1-pound increase in weaning weight per year. Increasing accuracy and selection intensity

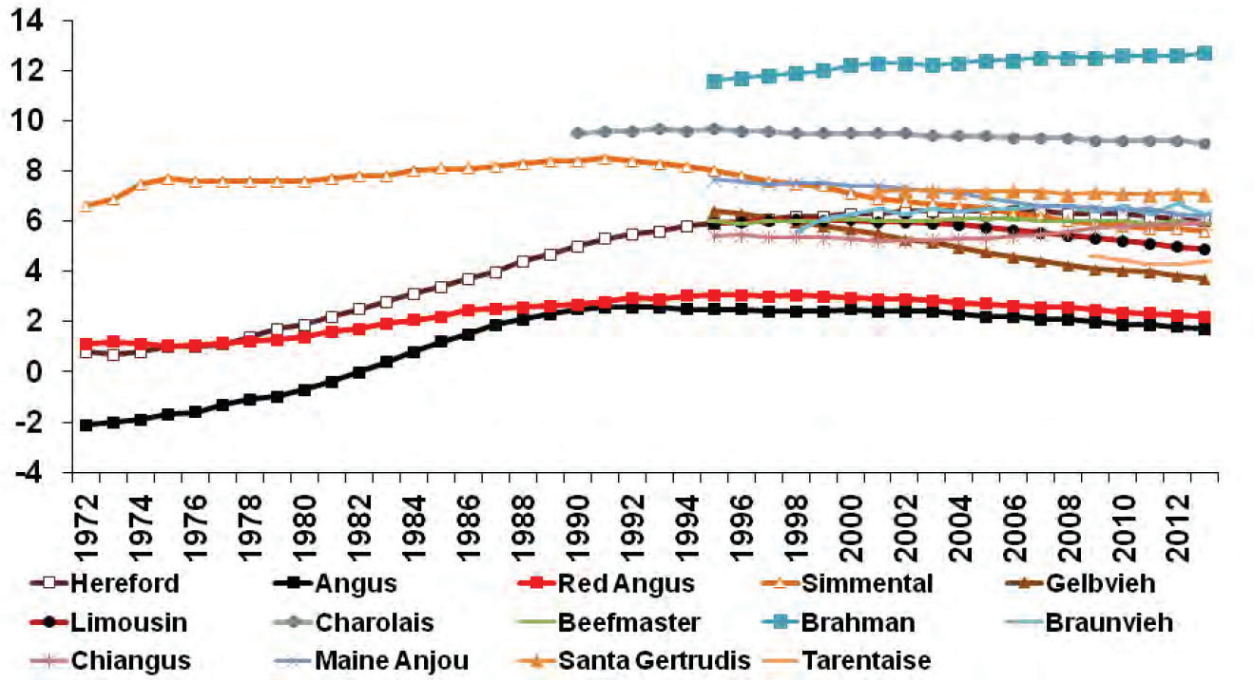


Figure 25.2. Across-breed genetic trends for birth weight EPD. Source: Kuehn and Thallman 2015.

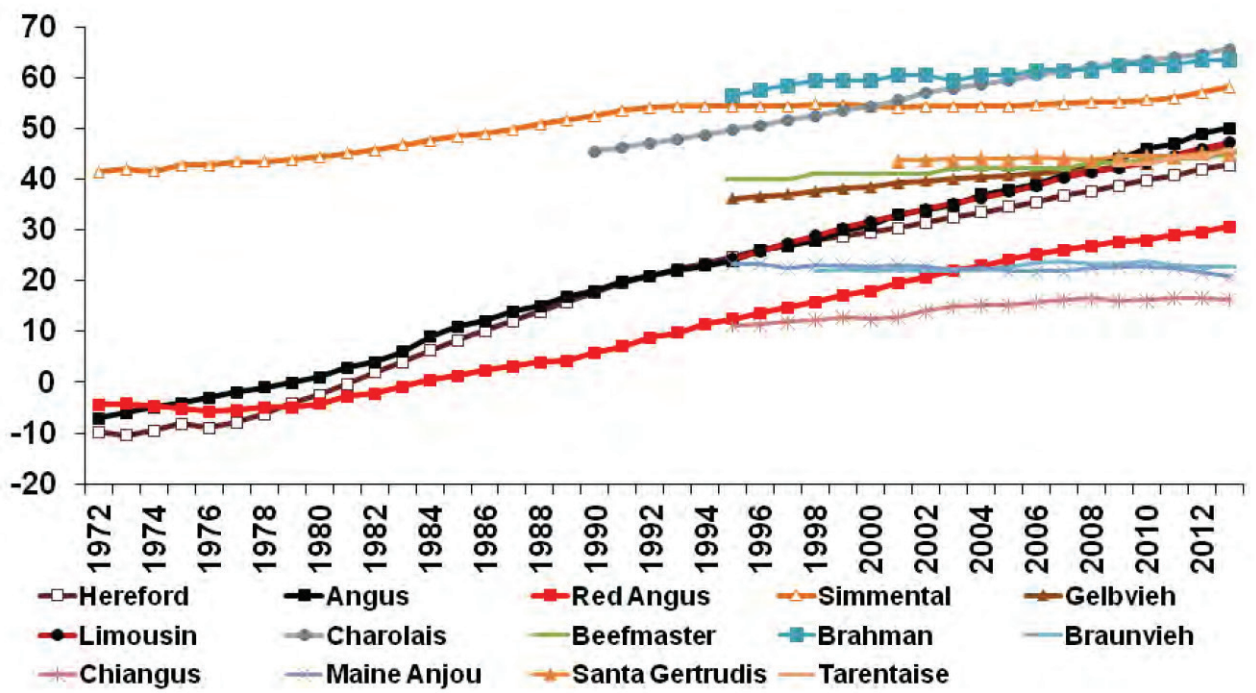
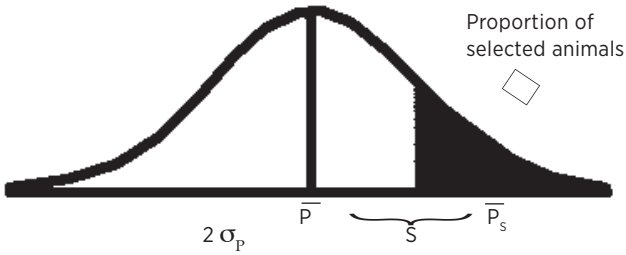


Figure 25.3 Across-breed genetic trends for weaning weight EPD. Source: Kuehn and Thallman 2015.



S= Selection differential

$$i = \frac{S}{\sigma_P} = \text{selection intensity (see Table 25.4)}$$

Figure 25.4. Selection differential between the population average (P) and the selected animals (P_s, black)

Table 25.3. Intensity calculated on the basis of the proportion of animals selected for breeding.

Proportion of animals for breeding	*Intensity i*	*Proportion of animals for breeding*	*Intensity i*	*Proportion of animals for breeding*	*Intensity i*
1.00	0				
0.90	0.20	0.09	1.80	0.008	2.74
0.80	0.35	0.08	1.85	0.006	2.83
0.70	0.50	0.07	1.91	0.004	2.96
0.60	0.64	0.06	1.98	0.002	3.17
0.50	0.80	0.05	2.06	0.001	3.38
0.40	0.97	0.04	2.15	0.008	3.43
0.30	1.14	0.03	2.27	0.0006	3.51
0.20	1.40	0.02	2.42	0.0004	3.61
0.10	1.76	0.01	2.67	0.0002	3.79

and decreasing the generation interval are all methods that can increase genetic change per year.

The length of time to turn over a generation is highly variable between herds. It is a function of the reproductive rate of the animals and how long a producer keeps individuals in the herd. Generation interval is the length of time it takes to replace the members of one generation in a herd. The generation interval in many beef cattle herds will fall in the range of three years to four years for males and four and a half years to six years for females. Generally speaking, decreasing the generation interval increases the genetic progress made by "turning over" old genetics for presumably superior newer genetics. The generation interval could be decreased to two years if, for example, bulls were mated to yearling heifers, then all of these animals in the herd were replaced immediately. However, this scenario to decrease the generation interval is not practical or economically feasible. The generation interval can be decreased by increasing the rate at which older animals are culled and replaced with younger animals or by using strategic genomic testing to utilize younger, more superior bulls in the herd. Decreasing the generation interval will lead to greater genetic change.

One of the primary opportunities to apply selection pressure is through sire selection. The herd sire has a direct impact on progeny performance, and in many cases, his daughters become replacement females in the herd. Combining the ability to be highly selective when choosing bulls due to the need for fewer males in the herd, combined with keeping replacement females, a high percentage of all genetic improvement within a herd is due to sire selection. An additional opportunity to increase genetic change through selection of herd sires is through an artificial insemination (AI) program. Using high-accuracy AI sires can help to decrease risk and increase genetic change per year by increasing selection intensity and accuracy, at the expense of slightly increasing generation interval.

Applications of Selection

Individual breeders can and should obtain and use performance information on as many of the animals in their herd as possible. Computers are prevalent and data management software is available and easy to use, making this information readily utilized. Even without sophisticated equipment, many economically important traits can be measured and used in selection programs with minimum labor. Many producers can take advantage of breed association or Extension programs, which obtain information of various types and supply summaries to their clientele. Additionally, producers also can take advantage of software packages specifically designed for management of beef cattle data. Some of these programs interface with financial management programs.

One of the best sources of information for animal improvement is from National Cattle Evaluation (NCE). Most beef cattle breed associations have genetic evaluation programs. Each breed organization publishes an online listing of the bulls in the evaluation with pertinent breeding value estimates (expressed as expected progeny differences, or EPDs, which are one-half of a breeding value), information on a variety of traits. The internet is a valuable tool breed associations use to disseminate information to their members and commercial clients. For example, producers are able to electronically search a breed's genetic evaluation database and access current information and updates about their breed as well as access other vital information from the sire summary such as percentile rank tables, breed average EPDs and possible change values for EPDs.

Selection should be exercised vigorously in all seedstock herds. Commercial herds need to develop programs for culling inferior animals, selecting young replacements and selecting quality herd sires, but the major improvement should be taking place in seedstock herds that supply breeding stock for commercial herds. The improvement seen through performance-recording programs where data is more widely available and the breed associations work diligently to provide the most advanced selection tools will trickle down to the other sectors of the industry. Because of the wider availability of information and tools in the seedstock sector, a commercial producer often is dependent upon their suppliers of breeding stock for most of the improvement that will occur. However, commercial producers can still achieve selection progress through utilization of EPDs on herd sires as well as recording performance information. The following discussion will outline examples of the various programs that are available for improvement of beef cattle.

On-Farm Testing

Performance-recording programs may be very complex with many traits measured and may require a sophisticated recordkeeping system. In contrast, some are very simple with only a few traits evaluated and animals can be classified into general groups instead of keeping specific records. The complexity of the system will depend on several factors, including the need for making improvement as opposed to simply eliminating inferior animals. A commercial producer who obtains breeding stock from other sources may be able to utilize a less complex system, since selection will be primarily practiced though culling of animals with inferior performance and sire selection. A seedstock producer will need to have very complete records so the increase in genetic merit will progress as rapidly as possible.

Any performance-testing program begins with identification of individual animals and recording the birth date. There are many systems: ear tags, notches or tattoos can be used to identify animals at birth. The date of birth is important, since adjustments will need to be made for age differences, even if other measurements are not obtained. The conditions of birth and birth weights, if taken, also should be recorded as soon as possible after birth. This includes any unusual aspects concerning the birth, such as degree of calving difficulty. Commercial producers may be interested in collecting only economically important data, such as recording calving ease scores instead of birth weight. Whether seedstock or commercial producer, it is useful to weigh both the cow and calf at weaning time to make decisions regarding both mature cow size and weaning performance.

It is best to use EPDs wherever possible and for all traits for which they are provided. In the absence of a standardized NCE and EPDs for a performance trait, it is very important to maintain uniform management of the animals to be compared. It also is important to evaluate as many of the animals in a herd as possible and accuracy of measurement is critical. Scales and other measuring devices should be appropriate for the animals being tested. It is impossible to make fair comparisons of individuals based on phenotypic data if all animals are not managed alike, which is why NCE and EPDs are so important. Most, if not all, of the individuals in a herd should be tested so an accurate assessment of the merits of the herd can be obtained. The process whereby seedstock producers report all data for all animals in their herd is called whole-herd reporting and is a major asset not only to the breed association which receives the data, but also to the producer submitting the data and their customers. It is permissible to make intermediate removals of obviously inferior animals, such as culling animals between the dates when weaning and yearling weights are taken, but predictions will be more accurate if comparisons are made with as large a portion of the herd as is possible. The importance of whole-herd testing will have to be weighed against the practical problems of testing large numbers of individuals.

In the absence of EPDs, the performance of an individual should be considered relative to the performance of its contemporaries. However, it is important to remember that an above-average individual in one herd may not be above average in other herds. A large part of the differences in performance of animals between herds is due to management variations. The use of a ratio will help a manager or a prospective buyer understand the performance of the individual relative to others managed similarly, but should not take the place of EPDs for selection decisions. A ratio is calculated as follows:

$$\text{Ratio} = \frac{\text{Individual record}}{\text{Average of animals in contemporary group}} \times 100$$

An average animal will have a ratio of 100, while above-average animals have ratios greater than 100, and below-average animals have ratios less than 100. Ratios are useful tools within a herd; however, more advanced tools, such as expected progeny difference (EPD), are superior and allow comparison of animals across herds and different management systems. The reliability of the selection decision is greater using EPDs.

There are organizations that have on-farm testing programs for their clientele. Most major breed associations, as well as some private companies and state or national Extension groups provide recordkeeping and genetic evaluation systems for different groups of producers. It is vital all seedstock producers participate in such a program, both to provide a service to their customers as well as to ensure genetic improvement tools can be accurately used for both themselves and their commercial customers. Centralized performance records provide the basis for national evaluation programs, so individuals can be compared fairly between farms and ranches. It is important for commercial producers to remember when purchasing bulls or replacement females, they are purchasing an animal for its genetic potential to produce exceptional progeny, and not the superiority of someone else's management decisions. Therefore, it is important to consider EPDs in selection decisions, not just weights and ratios, which cannot be easily compared outside of a contemporary group.

Central Test Stations

Several central bull test stations in the U.S. evaluate bulls from different herds for post-weaning performance with uniform conditions. Test stations assist in:

- Locating and evaluating breeding stock belonging to individual producers.
- Demonstrating effective testing of post-weaning performance.
- Providing a source of performance-tested bulls for both commercial and purebred breeders.
- Assisting in the improvement of economically important traits for beef cattle.
- Providing access to advanced technology, such as ultrasound (ribeye area, backfat thickness and intramuscular fat percentage), especially for smaller producers that would otherwise not have groups large enough to effectively scan cattle.

- Providing an educational forum for producers to receive updates on current issues related to the beef cattle industry. Central test stations should be considered as a supplement to good on-farm programs, not as a replacement for them.

Numerous bull testing stations are located in the U.S. and primarily serve as a facility where bulls from different herds are assembled in an effort to jointly evaluate their performance with uniform environmental conditions. Bull test stations can add value through performance evaluation for smaller producers unable to have an on-farm test and also can be a good source of education on use of performance information and EPDs. BIF recommends the following procedures and policies for all central bull tests:

- Bulls should meet realistic qualifications related to age, weaning performance and soundness.
- Age of calves at delivery to test stations should be at least 180 days old and not more than 270 days old, and bulls within a single testing group should have no more than a 90-day age spread.
- All ratios should be calculated only within contemporary groups containing animals of the same breed and of a similar age.
- Herds from which bulls are consigned should be members of their respective breed associations, or alternatively, their state beef cattle improvement association's performance programs. Calves should have completed the weaning phase with the rest of the members of their contemporary groups.
- Initial and final test weights may be either full or shrunk weights. If full weights are taken, they should be the average of two weights taken on successive days to minimize fill effect.
- The nutrition program should meet the growth requirements of bulls on test. Therefore, it is important for the ration to provide adequate levels of protein and energy for growing bulls. This is vital so the bulls are allowed to express their true genetic differences and their genetic potential can be fairly evaluated.
- Sire group testing (at least five sons of any particular size) is more beneficial than individual progeny testing because it provides a greater amount of information to the breeder and to prospective buyers.
- All bulls sold in a test should be examined by competent personnel for reproductive and structural soundness. A qualified veterinarian or reproductive physiologist should conduct a breeding soundness examination.
- Yearling ultrasound and scrotal measurements should be recorded at the end of the test or on the first weigh date after the bulls' average age is 365 days.
- Expected progeny differences and their accuracies should be reported on final test reports and in sale catalogs for traits available. At a minimum, birth weight, weaning weight, yearling weight and milk should be provided. If available, scrotal circumference, direct calving ease, maternal calving ease and carcass EPDs also should be provided.
- Breed average EPDs for non-parent bulls born in the same year as the bulls on test should be included in the sale catalog for the buyer's information and for comparative purposes.
- Differences in environmental conditions and testing procedures among different testing stations render direct comparison of results from animals tested at different stations, in different contemporary groups or at different times invalid.

Additional guidelines are available through BIF that reflect whether cattle will be evaluated in a forage-based bull test facility or in a full-feed testing program. Many test stations will provide a weighted index used to rank the bulls and this index may be used to determine sale order. Care should be taken when using these indices to make sure the traits emphasized in the index are appropriate and coincide with selection goals. It may be more useful for many producers to consider multiple individual traits and EPDs rather than using the station's index as the sole selection criteria.

Performance Programs

Adjustment Factors

Some sources of environmental variation can be adjusted out of raw data. These sources include age of dam and age of all other animals when the trait was measured. For example, any herd has females of varying ages. Generally, enough is known about differences due to age of dam that the records of individuals with very young or very old dams can be adjusted so they can be compared fairly. The two main categories of beef cattle adjustment factors are:

- Adjustment to common age.
- Adjustment to common age of dam.

The beef cattle adjustment factors and formulas are from the Guidelines for Uniform Beef Improvement Programs and published by BIF, found at beefimprovement.org. Adjustment factors and formulas have been developed from large sets of data that were obtained under a wide variety of environmental conditions. Also, many breed associations have developed specific adjustment factors for their breed. A purebred producer should use the adjustment factors developed for the breed of interest, instead of the general adjustment factors.

Beef Cattle Performance Testing procedures are found in Guidelines for Uniform Beef Improvement Programs, which can be found online at guidelines.beefimprovement.org/index.php/Guidelines_for_Uniform_Beef_Improvement_Programs. The guidelines recommend procedures for on-farm and central test performance programs and describe the techniques for National Cattle Evaluation. Much of the following discussion is paraphrased from the current BIF Guidelines.

Whole Herd Reporting

The concept of Whole Herd Reporting (WHR) has been around for several years. A WHR system requires

collection of complete and unbiased production data on all animals within a herd, including animals without a calf and those performing below expectations. The WHR system requires information to be collected on all animals in the breeding herd, which is called the breeding herd inventory, whether it is a performance record or a disposal code. Using this approach, producers are submitting data on every animal within the herd, which helps inform NCE and leads to better EPD estimates. This is an advantage to both the breeder and the breeder's customers. A producer is not necessarily obligated to register every calf, but WHR requires submission of required data on each calf. Some breed associations require participation in whole herd reporting as a part of membership, and other associations allow producers to opt-in to these programs. Yet other associations have no official system of whole herd reporting at all. Incentives for participation in these programs remove financial deterrents to submitting complete performance data and promote registration and transfer of animals.

In addition to informing NCE in a general sense, WHR allows associations to better track reproductive performance of males and females in those herds through maintaining records on heifer exposure (breeding season, exposure status, management codes, mating practices and disposal codes). The information from these systems also can be used to identify genetic, environmental and management areas where improvement can be focused. Information also can assist in selection and culling decisions and generate data for the generation of new selection tools and EPDs.

The BIF guidelines have a complete description of WHR; Table 25.4 is a brief overview of the disposal and reason codes typically available for reporting.

Table 25.4. Codes recommended for recordkeeping systems.

Disposal codes: Birth to weaning
1 = Stillborn/full term
2 = Died at birth – defect
3 = Died at birth – other
4 = Born alive, died before weaning – disease
5 = Born alive, died before weaning – other
Disposal codes: Weaning to two years of age
10 = Died after weaning – disease
11 = Died after weaning – other
12 = Culled – feet and legs
13 = Culled – performance
14 = Culled – temperament
15 = Sold exposed – open
16 = Sold exposed – pregnant
Disposal codes: Mature cows and bulls
30 = Sold – certificate not transferred (if seedstock)
31 = Culled – teat and udder
32 = Culled – feet and legs
33 = Culled – reproduction
34 = Culled – productivity/progeny performance
35 = Culled – temperament
36 = Culled – age
37 = Died – age
38 = Alive but not active in herd inventory (bulls only)
Reason codes: Reason codes should be used to document why a cow did not raise a natural calf
50 = Open – missed calving opportunity
51 = ET program – donor dam
52 = ET program – recipient dam
53 = Moved to next calving season
54 = Aborted/premature

Source: Beef Improvement Federation.

Breeding Herd Inventory

A producer uses a breeding herd inventory to track animals currently in the herd and those that have been culled. Twice a year, the breed association sends a breeding herd inventory to producers for spring or fall calving herds. The producers are required to update their inventories for animals culled from the herd or animals added to the herd. The goal is to obtain a list of all animals for which the breeder will be recording performance data for the next 12 months. If data, a reason code or a disposal code is not reported for a female within the designated time frame, she typically will be inactivated. Typically, reactivation fees are structured to discourage allowing females to become inactive, so care should be taken that information on all females is reported correctly and on time.

Female Production Data

Traits associated with reproduction or fertility are some of the most economically important traits in beef cattle. Breeders are urged to record reproductive performance in both the female and male animals.

Breeders can use specific measures of reproductive performance in the female to monitor overall reproductive performance, identify genetic and environmental areas in which to concentrate improvement efforts and to make routine selection and culling decisions. Breed associations may vary slightly in the data they wish to collect, but typically, the following data should be recorded on females within seedstock herds:

Breeding dates – Record actual date of artificial insemination or observed natural service or record beginning and ending natural service exposure dates.

Pregnancy status – Between 50 days and 150 days following breeding, pregnancy status should be determined using rectal palpation or ultrasound. Culling of open cows after this determination is an excellent way to improve herd efficiency.

Calving date – Each calf's birth date should be recorded.

Calving difficulty/ease (dystocia) score – The following scoring system is recommended:

1 = No difficulty, no assistance.
2 = Minor difficulty, some assistance.
3 = Major difficulty, usually mechanical assistance.
4 = Caesarean section or other surgery.
5 = Abnormal presentation. These calves are not included when herd averages are calculated because abnormal presentations are not heritable, but should still be reported to the association.

Difficulty in calving (dystocia) influences herd economics in a variety of ways. Calf survival rate is decreased when calving difficulty is severe. Labor and

veterinary costs are increased if there is substantial calving difficulty. In addition, it has been shown rebreeding is less efficient for cows that experienced calving difficulty. Several breed associations include calving ease EPD (direct and maternal) in their genetic evaluations. Calving ease is an economically relevant trait; birth weight is not (however, it does serve as an indicator trait for calving ease because it is genetically correlated). Therefore, it is important to submit calving information. In addition, producers should continue to report corresponding birth weight information, which is used as an additional information source when calculating calving ease EPDs.

Gestation length – Calculate the number of days between the known breeding date and subsequent calving date. Cows with longer gestation periods have a shorter period of time after calving to get ready for rebreeding.

Calving interval – Calculate the yearling calving interval as the number of days between the second-to-last and last calving dates for a particular animal. Cows with consistently long calving intervals may eventually fail to rebreed with fixed breeding season management. Using a lifetime calving interval (the number of days between the first and last calving divided by the total number of calves) is a useful indicator of overall herd reproductive performance.

Cow weight – Record mature cow weight at least once a year. A practical time to record cow weights is at weaning, and it is important that all weights are taken consistently at the same time in the cow's stage of production. A producer can use cow weight information and other indicator traits, such as body condition to monitor individual or whole herd nutrient requirements.

Cow body condition score – Score the trait using a subjective visual evaluation system (chapter 20). The degree of condition reflects maintenance requirement, nutrient intake and past production. The scores reflect different degrees of fatness ranging from 1 (severely emaciated) to 9 (severely obese). For example, a cow that weighs 1,100 pounds moves up or down the scale one score with a 75- to 80-pound change in weight.

Udder suspension and teat size scores - Poor udder and teat confirmation is a major reason why cows are culled from the herd. Udder suspension and teat size scores reflect differences between animals regarding udder conformation. Udder suspension ranges from 9 (very tight) to 1 (very pendulous). Teat size scores reflect teat length and circumference from 9 (very small) to 1 (very large). These scores should be recorded within 24 hours of calving on the weakest quarter and preferably by the same person each time. Diagrams depicting each of these scores can be found in the BIF Guidelines.

Data recording requirements and practices differ widely between many seedstock and commercial producers. For commercial producers with labor constraints, data recording can be pared down significantly, while still allowing the producer to track herd productivity and make intelligent culling decisions. At a minimum, commercial producers should be recording calving ease scores, calf weaning weights and cow mature weights, plus tracking how often a cow has a calf (or culling immediately upon failure to breed) and monitoring body condition scores to make nutritional modifications as needed.

Male Reproduction Data

It is important to evaluate bulls (both yearlings and those returning to pasture for breeding) for reproductive soundness so bulls with fertility problems are culled before a large number of females show up open. The Society for Theriogenology establishes a standard set of guidelines and recommendations for breeding soundness exams. A qualified and trained veterinarian or professional should conduct the breeding soundness examination. The following procedures are recommended:

History and physical examination – A competent evaluator should examine each bull for any injury or abnormality. These defects include vision problems, foot and leg injuries and abnormalities that might prevent the mating process. This evaluation should include an evaluation of the scrotum and testes, rectal palpation of internal accessory glands and examination of the extended penis and prepuce.

Scrotal circumference – Scrotal circumference is measured at the widest part of the scrotum in centimeters and is generally accepted to influence the bull's capacity for sperm production and influence age at puberty in heifers. A yearling bull should measure at least 30 centimeters to be considered acceptable (Table 25.5). Some breed associations have more stringent requirements for scrotal circumference in yearling bulls, so the association's rule should be followed in that instance. The bull's scrotal measurement in centimeters, the bull's age and the appropriate adjustment factor (Table 25.6) are applied to the formula below to determine the 365-day scrotal circumference.

$$\text{Adj. 365 day yearling scrotal circumference} = \text{YSC} + [(365 - \text{age}) \times \text{Age adj. factor}]$$

Where YSC is yearling scrotal circumference.

Table 25.5. Minimum recommended scrotal circumference (SC).

Age (mo.)	*SC (cm)*
< 15	30
> 15 and < 18	31
> 18 and < 21	32
> 21 and < 24	33
> 24	34

Source: Society for Theriogenology.

Table 25.6. Age adjustment factors for scrotal circumference.

Breed	*Adjustment factor*
Angus	.0374
Red Angus	.0324
Brangus	.0708
Charolais	.0505
Gelbvieh	.0505
Hereford	.0425
Polled Hereford	.0305
Limousin	.0590
Salers	.0574
Simmental	.0543

Source: Geske.

Semen evaluation – A trained technician should collect semen samples using electro-ejaculation, an artificial vagina or rectal massage. The technician should evaluate the percent motility and morphology (Table 25.7). Morphology includes primary and secondary abnormalities, as well as the presence of other cells (i.e., white blood cells). If abnormal cellular material is present in the ejaculate, the technician should include this information in the report. Minimum recommended motility is 30% or a rating of fair and minimum recommended morphology is 70% normal cells. The technician also may evaluate progressive motility, which reflects not only motion in general, but the ability of sperm to move in a relatively straight line. This allows identification of progressively motile sperm from sperm that may move in a circular motion, but have no progressive motility. An absolute determination of the degree of fertility cannot be determined from a semen evaluation and it does not guarantee that an animal will be a good breeder, but does provide a reliable indicator of the animal's future performance.

Classification of bulls – A bull is categorized into one of three classes based on the results of their breeding soundness exam:

1. Satisfactory – meets or surpasses the minimum requirements for scrotal circumference, semen evaluation and physical exam.
2. Unsatisfactory – fails to meet the minimum requirements for scrotal circumference, semen evaluation and physical exam.
3. Deferred – does not fit into either the satisfactory or unsatisfactory categories. This bull requires additional maturity or a recovery period to address temporary problems.

It is important to note that sperm quality can be affected by environmental conditions, most notably heat stress. Sperm will show damage four weeks to six weeks after heat stress, rather than an immediate effect. As a result, fertility may be impaired for several weeks following severe heat conditions.

Breeding soundness report – The following items should be included in a complete breeding soundness exam:

1. Owner contact information – name, address and location.
2. Date of examination and identification of prior examinations and their results.
3. Animal identification (tattoo, eartag), breed and age.
4. Animal history, weight, condition and previous reproductive exam results.
5. Results of physical exam, scrotal circumference measurements, semen motility estimate and semen morphology.
6. Status of exam (satisfactory, unsatisfactory or deferred).
7. Signature and address of veterinarian conducting the examination.

Sire and Herd Reproductive Efficiency

Overall herd reproductive efficiency can be evaluated in a variety of ways. The following procedures are recommended to evaluate areas of improvement for both male and female reproductive efficiency:

Number of cows exposed – The number of cows exposed to either artificial or natural service in the present year's breeding season separated by bull and mating group.

Percent pregnant – This is a measure of the success of the breeding season. It is calculated as follows:

$$\%\ \text{pregnant} = \frac{\text{No. of cows diagnosed as pregnant}}{\text{No. of cows exposed at breeding}} \times 100$$

Live calving percent – this is a measure of the success of the cumulative results of the breeding and calving seasons. It is calculated as follows:

$$\text{Live calving}\ \% = \frac{\text{No. of live calves}}{\text{(No. of cows exposed - No. of cows sold or died + No. of cows purchased)}} \times 100$$

Percent Calf Crop Weaned – This measure also is frequently called weaning percent. It is recognized as

Table 25.7. Motility ratings.

Mass Activity (Gross)	*Rating*	*Individual*
Rapid swirling	Very good	> 70%
Slower swirling	Good	50-69%
Generalized oscillation	Fair	30-49%
Sporadic oscillation	Poor	< 30%

Source: Society for Theriogenology.

the most descriptive single measure of reproductive efficiency. It is calculated as follows:

$$\text{Weaning \%} = \frac{\text{(No. of calves weaned + No. calves sold preweaning)}}{\text{(No. of cows exposed - No. of cows sold or died + No. of pregnant cows purchased)}} \times 100$$

Evaluation of Growth Rate and Efficiency of Gain

Growth rate and efficiency of gain for beef cattle are of primary economic importance to the beef industry. Growth rate has a major impact on net return and is positively correlated with efficiency of gain, weight and value of retail product. Cost of production and net return are directly affected by efficiency of gain. The following procedures are recommended for the recording of growth and efficiency records:

Birth weight – Calf birth weight can be a useful indicator of calving difficulty. Birth weights should be recorded on all calves, alive and dead, within 24 hours of birth. Selection of breeding animals for smaller birth weight can be an effective criterion for improving direct calving ease, but should be used with caution. Single-trait selection for lower birth weights can have adverse effects on calf survivability and growth rate from birth to weaning. Thus, calving ease EPDs should be used instead of birth weight, when possible. Sex of calf, age of the dam and season of birth (calves are typically lighter for fall-calvers than spring-calvers) influence birth weight. Table 25.8 outlines the additive adjustment factors for birth weight that should be used in the following equation.

Adj. Birth Weight = Birth Wt. + Age of Dam Adj.

Birth weight can also be expressed as a ratio of the average of the birth weights of contemporary calves, which allows for comparison of calves across seasons within the same herd. The following formula is recommended:

$$\text{Adj. birth weight ratio} = \frac{\text{Individual adj. birth weight}}{\text{Average adj. birth weight of the group}} \times 100$$

Weaning weight – Calf weaning weight helps evaluate differences in mothering ability of cows and measures differences in growth potential of calves. It is recommended that weaning weight be standardized to 205 days and a mature dam equivalent. Weaning weight should be obtained when the group of calves' average age is close to 205 days and the age range to calculate the adjusted 205 days is 160 days to 250 days. If calves fall outside of this range, they should be given a separate management code and the weights should not be adjusted because the common adjustment factors are no long viable.

$$\text{205-day weight} = \frac{\text{WW - BW}}{\text{Age at Weaning}} \times 205 + \text{Birth Weight}$$

where WW= weaning weight and BW= birth weight

Adj 205-day wt. = 205-day wt. + WW adjustment factor

where WW= weaning weight

The first part of this formula is a calculation of average daily gain from birth to weaning by using the actual weaning weights less the animal's birth weight. This is multiplied by 205 to give the total expected gain from birth to 205 days. The actual birth weight is then added back and the weights are adjusted for the age of dam using the age of dam adjustment factors (Table 25.8). A ratio also can be calculated using the same procedure previously outlined, if desired, and can be useful to calculate a most probable producing abiltiy (MPPA) for weaning weight.

Most Probable Producing Ability (MPPA) – This value will commonly be included on produce-of-dam summaries. It is an estimate of the future productivity of that cow for any repeatable trait (weaning weight, as an example) using past production records. It takes into account her production levels relative to contemporaries, number of past records and the repeatability of the trait. The formula used to calculate a MPPA for weaning weight (assuming a repeatability of 0.4) is:

$$\text{MPPA} = 100 + \left[\frac{\text{N} \times 0.4}{1 + [(\text{N} - 1) \times 0.4]}\right] \times \left[\text{Avg. weaning wt. ratio} - 100\right]$$

where N=number of calves.

Yearling weight – Yearling weight is an important trait because of its relationship to efficiency of gain and pounds of trimmed retail boneless beef produced. Cattle on a high nutritional plane should be evaluated for yearling weight near 365 days. Cattle with

Table 25.8. Standard adjustment factors for birth and weaning weight.

		Weaning weight adjustment factors	
Age of dam	*Birth weight*	*Male calves*	*Female calves*
2	+8	+60	+54
3	+5	+40	+36
4	+2	+20	+18
5-10	0	0	0
≥11	+3	+20	+18

Source: Beef Improvement Federation.

moderate to low energy levels in their diets should have yearling weights adjusted to 452 days or 550 days (long yearling). Adjusted 365-day weight is computed as given below. Adjusted weights for 452 or 550 days are computed similarly, except 247 or 345 replaces 160 in the equation.

$$\text{Adj. 365-day wt.} = \frac{\text{Final wt.} - \text{WW}}{\text{N}} \times 160 + \text{Adj. 205-day wt.}$$

Where WW=Weaning Wt. and where N=Number of days between weights.

The final weight and weaning weight used are the actual weights taken at yearling (or long yearling) and weaning times. The number of days between weights represent the number of days between the dates yearling weight and weaning weight were obtained and this interval should be at least 70 days. The first part of the equation gives the average daily gain from weaning to yearling. This is multiplied times the number of days between 205 days and the target age (365, 452 or 550) being used for yearling weight. This total is added to the adjusted 205-day weight to get the adjusted yearling weight. The age of dam adjustment is already included with the adjusted 205-day weight, so no adjustment factor is added to the yearling weight. Because these weights are obtained on-farm within a single contemporary group where animals have likely been culled due to low weights at weaning, there is some bias in these values. BIF provides a formula to correct for this bias, which is located in the Guidelines for Uniform Beef Improvement Programs.

Post-weaning feed intake and efficiency – This trait is difficult to measure accurately, even in groups, and is expensive to evaluate in individual cattle. Recently, the larger availability of individual feed intake measuring systems has made collecting individual intakes more accessible for all producers. It is important to understand the various measures of feed efficiency (F:G, G:F, RFI and RADG), how they are derived and their limitations. More information on these traits and guidelines for obtaining postweaning feed intake and efficiency measures can be found in the BIF Guidelines for Uniform Beef Improvement Programs.

Carcass Evaluation

Tender, juicy, flavorful, healthful and safe beef products are the goal of all beef cattle improvement programs. Complete carcass evaluation includes measures of both quantity and quality of lean product. Emphasis on quality and yield will change as market conditions change, so it is important to continue to select for improvements in these traits. Some producers who sell at weaning will not have carcass trait selection as a primary goal in their breeding objective; however, wherever possible, selection for adequate carcass merit is desirable. Not all beef producers will have access to complete carcass information in the absence of retained ownership, however as much effort as possible should be made to obtain this data and share it not only within an operation, but also with relevant commercial producers and seedstock providers. Increasing the amount of data on large numbers of cattle can add to the time required as well as the cost of the performance program. When carcass data are desired, the following procedures are recommended:

Product quality – The visual appearance and palatability component of the carcass evaluation. The grades for young beef (A and B maturity) are Prime, Choice, Select and Standard.

An evaluator assigns the grades using visual evaluation. The criteria include physiological maturity, marbling, color, firmness and texture of lean meat, however marbling is the driving factor behind quality grades in young cattle.

Maturity – Maturity is an estimation of the physiological age of the carcass. It is determined by evaluating the size, shape and ossification of the bones and cartilages, and the color and texture of the lean meat. Maturity approximates the chronological age and is classified into these groups:

- Maturity A – 9 months to 30 months
- Maturity B – 30 months to 42 months
- Maturity C – 42 months to 72 months
- Maturity D – 72 months to 96 months
- Maturity E – more than 96 months

Marbling – Marbling is the flecks of fat in the lean meat. This is the primary factor determining quality grade after maturity is determined. It is evaluated visually in the ribeye muscle, between the 12th and 13th ribs. Marbling makes a small contribution to meat tenderness and is associated with juiciness and flavor. Nine degrees of marbling range from practically devoid to abundant. Intramuscular fat (known as marbling) percentages range from 2.76% for traces to 10.13% for slightly abundant. Marbling scores are typically expressed as a numerical score, such as those listed in the Table 25.9. They also may be listed as a larger value, which is a function of the numerical score (for example, a small 20 would be scored a 5.2 and also can be expressed as 5.2 x 100 = 520).

Color, firmness and texture – These are used to characterize the lean tissue. The scoring system is recommended in Table 25.10.

Table 25.9. Numerical Scores for marbling.

Quality	*Grade*	*Marbling Score*
Prime	Abundant	10.0 - 10.9
Prime	Moderately abundant	9.0 - 9.9
Prime	Slightly abundant	8.0 - 8.9
Choice	Moderate	7.0 - 7.9
Choice	Modest	6.0 - 6.9
Choice	Small	5.0 - 5.9
Select	Slight	4.0 - 4.9
Standard	Traces	3.0 - 3.9
Standard	Practically devoid	2.0 - 2.9

Table 25.10. Scores for lean tissues.

Score	*Color*	*Firmness*	*Texture*
7	Light cherry red	Very firm	Very Fine
6	Cherry red	Firm	Fine
5	Slightly dark red	Moderately firm	Moderately fine
4	Moderately dark red	Slightly soft	Slightly fine
3	Dark red	Soft	Slightly coarse
2	Very dark red	Very soft	Coarse
1	Black	Extremely soft	Very coarse

Source: Beef Improvement Federation

Yield grade – This is a method for evaluating the yield of saleable meat. The formula for yield grade is:

	2.50
+	(2.5 x adjusted fat thickness, in.)
+	(0.2 x kidney, pelvic, and heart fat, %)
+	(0.0038 x hot carcass weight, lbs.)
–	(0.32 x ribeye area, sq. in.)
=	USDA Yield Grade

Yield grades are often expressed in tenths of a grade to make more accurate comparisons, but when reported, generally the decimals are dropped and numbers are rounded down to the nearest integer (e.g., a 3.9 will be referred to as YG 3). A lower yield grade is more desirable.

Adjusted fat thickness – A measurement is taken at the 12th rib, perpendicular to the external fat, three-fourths of the distance of the ribeye from the backbone. An adjustment is allowed for unusual fat distribution.

Kidney, pelvic and heart fat percent – An estimate of fat located in the kidney knob, pelvic and heart regions. The estimate is recorded as a percentage of the carcass weight.

Ribeye area – Measured at the 12th rib and indicates the amount of muscling in the carcass. Higher ribeye areas generally lead to lower (more favorable) yield grades.

Hot carcass weight – The weight of the carcass as it leaves the harvest floor.

Warner-Bratzler shear force - These measurements are an objective way to gauge tenderness in research settings and is used in some genetic evaluation systems. It measures the force required to sever a core of muscle fibers from a steak; thus, lower numbers (less force) are desirable and indicative of a more tender carcass.

Percent retail product - Yield grade is one measure of saleable product, and percent retail product is the second. It reflects the percentage of closely trimmed, mostly boneless, retail cuts with a standardized fat content. The formula to calculate percent retail product trimmed to 0 inches of surface fat uses many of the same factors as yield grade and is calculated as follows:

% Total Retail Product = 65.59 – (9.93 x Adj. fat thickness, in.)
– (1.29 x Kidney knob, %)
+ (1.23 x Ribeye area, sq. in.)
– (0.013 x Hot carcass wt., lb.)

It can also be calculated using data from a meat packing facility that uses hot fat trimming as follows:

% Total Retail Product = 78.95 – (0.005 x Hot carcass wt., lb.)
– (1.56 x Hot fat trim, %)
+ (0.516 x Ribeye area, sq. in.)
– (1.14 x Marbling score: 4.0 to 4.9 = slight, etc.)

Ultrasound Measurements of Body Composition

During the past two decades, it has been well documented that real-time ultrasound scans of ribeye area, fat thickness and intramuscular fat measured in yearling bulls and heifers can be used for genetic improvement in carcass quality and cutability. Ultrasound measures, when collected and interpreted by a highly skilled technician, can serve as an indicator for actual carcass performance in genetic evaluation systems and contribute the bulk of records to many genetic evaluation systems due to their ease of collection. Actual carcass records are preferred for genetic evaluation; however, real-time ultrasound technology allows the beef industry to collect measurements of these traits in live breeding stock that can be used to obtain EPDs for carcass traits. This helps increase accuracy in breeding stock that otherwise would not have any carcass records until their progeny are harvested. These measures do have small amounts of bias, but are noninvasive and can be done on a much larger share of the population, at a lesser cost and a significantly faster rate than collecting carcass data through progeny testing.

The usefulness of ultrasound data is highly dependent on the abilities of highly trained and certified ultrasound technicians. Because of the reliance on scan records in National Cattle Evaluation (NCE), it is critical these data are collected, analyzed and interpreted correctly. Standards and guidelines have been established for collecting ultrasound measurements from breeding stock and many breed associations provide a list of certified technicians along with additional guidelines on timing and adjustment factors for scan data.

In the past, breeds have reported EPDs for carcass traits (ribeye, fat thickness and marbling) separate from EPDs for ultrasound traits. Most breeds currently report one set of EPDs for all carcass traits (encompassing scan data as an indicator trait contributing to the evaluation) and may include a variety of traits that vary from one association to another including ribeye area, fat thickness, yield grade, marbling and Warner-Bratzler shear force, based on measurements taken from both progeny carcass data and ultrasound scan data collected on live breeding stock.

Live Animal Evaluation

Evaluation of live animals considers any measured or subjective evaluations that help describe an animal. For example, breeding soundness evaluation involves physical examination of bulls, including examination of the penis, internal reproductive organs and scrotum. Some other common physical measurements and evaluations used in beef cattle operations include pelvic area, hip height, soundness and movement. Frame score calculated from linear hip height serves as an indicator of size at maturity and helps evaluate lean-to-fat ratio potential of an individual animal. No one frame size or mature size for an animal will be best for all feed resources, breeding systems and feed costs. The recommended procedures for live animal evaluation are as follows.

Frame score – This is a convenient way of describing the skeletal size of cattle. Animals should generally maintain the same frame score throughout their life, regardless of whether they are evaluated as young or mature animals. The recommended point for measuring hip height is a point directly over the hooks. This measurement can be adjusted to weaning (205 days) or yearling endpoints. Hip height is generally expressed in inches (Table 25.11). The frame score is calculated with the following formulas (actual heights and ages):

Frame score in bulls =
- 11.548
+ 0.4878 x hip height
– 0.0289 x days of age
+ 0.00001947 x days of age^2
+ 0.0000334 x hip height x days of age

Frame score in heifers =
- 11.7086
+ 0.4723 x hip height
– 0.0239 x days of age
+ 0.0000146 x days of age^2
+ 0.0000759 x hip height x days of age

Pelvic area – This is an indicator of calving difficulty (dystocia) in young heifers. In first-calf heifers, yearling pelvic area serves as a culling tool to remove heifers at risk for calving problems. The ideal time to take pelvic measurements is between 320 days and 410 days of age. A qualified technician or veterinarian should record the vertical and horizontal dimensions of the pelvis (Figure 25.5) to determine the area (multiplication of the vertical and horizontal dimensions) and it should be adjusted according to the following equations:

Bull adj. 365 day pelvic area = Actual pelvic area (cm^2) + (0.25 x 365 age in days)

Heifer adj. 365 day pelvic area = Actual pelvic area (cm^2) + (0.27 x 365 age in days).

Temperament – This trait is an assessment of an animal's response to handling and management. Animals that are easily agitated when subjected to routine handling are a safety, performance and welfare risk, not only to themselves, but to the handler and other animals within the herd. It typically is measured using a

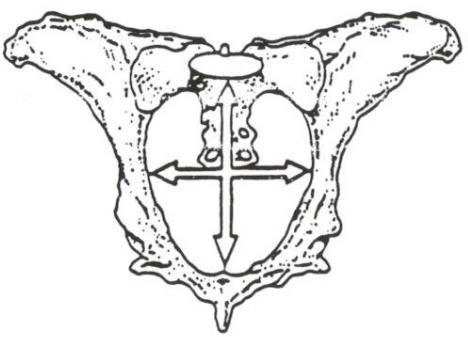


Figure 25.5. Vertical and horizontal dimensions to determine pelvic area. Source: Beef Improvement Federation.

Table 25.11. Hip heights (inches) and frame scores for 5- to 21-month-old heifers.

Age (months)	*Frame score*								
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
5	33.1	35.1	37.2	39.3	41.3	43.4	45.5	47.5	49.6
6	34.1	36.2	38.2	40.3	42.3	44.4	46.5	48.5	50.6
7	35.1	37.1	39.2	41.2	43.3	45.3	47.4	49.4	51.5
8	36.0	38.0	40.1	42.1	44.1	46.2	48.2	50.2	52.3
9	46.8	38.9	40.9	42.9	44.9	47.0	49.0	51.0	53.0
10	37.6	39.6	41.6	42.9	44.9	4.0	49.0	51.0	53.0
11	38.3	40.3	42.3	44.3	46.4	48.4	50.4	52.4	54.4
12	39.0	41.0	43.0	45.0	47.0	49.0	51.0	53.0	55.0
13	39.6	41.6	43.6	45.5	47.5	49.5	51.5	53.5	55.5
14	40.1	42.1	44.1	46.1	48.0	50.0	52.0	54.0	56.0
15	40.6	42.6	44.5	46.5	48.5	50.5	52.4	54.4	56.4
16	41.0	43.0	44.9	46.9	48.9	50.8	52.8	54.8	56.7
17	41.4	43.3	45.3	47.2	49.2	51.1	53.1	55.1	57.0
18	41.7	43.6	45.6	47.5	49.5	51.4	53.4	55.3	57.3
19	41.9	43.9	45.8	47.7	49.7	51.6	53.4	55.3	57.3
20	42.1	44.1	46.0	47.9	49.8	51.8	53.7	55.6	57.6
21	42.3	44.2	46.1	48.0	50.0	51.9	53.8	55.7	57.7

Source: Beef Improvement Federation.

Table 25.12. Disposition scoring system for beef cattle.

Score	*Description*
1-Docile	Gentle, undisturbed and exits chute calmly.
2-Restless	Quieter than average, attempts to back out of chute, exits chute promptly.
3-Nervous	Temperament is manageable, but animal is nervous. A moderate amount of struggling and exits the chute quickly.
4-Flighty	Jumpy and out of control. Exhibits froth at mouth and bellows. Runs fence line and tries to jump out of pen.
5-Aggressive	May be similar to a score of 4 with additional aggression. Exits chute quickly and may exhibit overly aggressive behavior.
6-Very Aggressive	Very aggressive behavior and exhibits a wild behavior when confined in a small place.

Source: Beef Improvement Federation.

subjective scoring system, such as the one listed in Table 25.12, and is based on evaluation of differences in disposition when animals are being worked in a squeeze chute. The trait is measured at weaning or yearling age to prevent any biases due to the animal's prior experiences, also called habituation. Several breed associations use these data to generate docility EPDs for genetic selection purposes. Each association may have a slightly different scoring system, so the breed association scoring system should supersede the information in Table 25.12 when data is being reported to the association.

References

American Angus Association. Angus Trait Heritabilities and Genetic Correlations. angus.org/Nce/Heritabilities.aspx. Accessed September 4, 2015.

American-International Charolais Association. Heritabilities and Genetic Correlations. charolaisusa.com/pdf/2015/09-08/Fall_2015_Heritability_and_Genetic_Correlations.pdf Accessed September 4, 2015.

Beef Improvement Federation. *Guidelines for Uniform Beef Improvement Programs* (9th Edition).

Kuehn L.A. and R.M. Thallman. (2015) Across-breed EPD tables for the year 2015 adjusted to breed differences for birth year of 2007. Proceedings: Beef Improvement Federation Research Symposium and Annual Meeting, Biloxi, MS. Pg 97-124.

National Beef Cattle Evaluation Consortium (2006). *Beef Sire Selection Manual* (2nd Edition) Retrieved from: nbcec.org/producers/sire.html. Accessed June 2015.

Society for Theriogenology/American College of Theriogenologists. Guidelines for The Bull Breeding Soundness Evaluation.

26 Expected Progeny Differences

Mark Johnson and Daniel Stein

Objectives

- **Examine the basic concepts of genetic prediction.**
- **Discuss appropriate use of EPDs and their accuracies.**
- **Identify useful tools in sire summaries.**
- **Describe the properties and proper use of economic selection indices.**

National Cattle Evaluation

The goal of National Cattle Evaluation (NCE) is to compare the genetic merit of beef cattle (males and females, parent and nonparent) from different herds within a breed, and to produce the best possible predictions of breeding values on all animals for traits of economic importance within the industry. Most beef breed associations conduct NCE programs, and the majority of the largest associations perform these evaluations at least twice yearly. The largest U.S. beef breed association performs weekly evaluations to provide the most comprehensive and up-to-date information for their producers. The trend of shortening the time between NCE evaluations will likely continue across most breed associations. Breed associations use progeny records, individual performance records, records on relatives, pedigree relationship and genomic results to estimate genetic merit. The goal of conducting NCE and producing estimates of genetic merit is to provide the very best genetic selection tools and information to enhance a producer's ability to make good selection decisions in both seedstock and commercial beef cattle operations.

NCE procedures benefit greatly from performance records that have ties across contemporary groups, herds and environments. Because of this, use of AI is beneficial in developing ties that allow accurate comparisons between herds. These reference sires create ties between herds so indirect comparisons can be made between bulls that do not have offspring in the same herd. An example is in Table 26.1.

These three herds all have calves sired by Bull A; therefore, he is the reference sire. Each herd also has calves sired by one bull unique to that herd. Comparisons of these herd sires are made through the reference sire. In Herd 1,

Table 26.1. Use of a reference sire to compare between herds.

	Herd 1	*Herd 2*	*Herd 3*
Reference sire	Bull A	Bull A	Bull A
Avg. calf weight	450	500	550
Herd sire	Bull B	Bull C	Bull D
Avg. calf weight	460	480	500

Source: Buchanan.

the calves of Bull B are 10 pounds heavier than those of Bull A. Assuming more growth is favorable, it is concluded that Bull B is superior to the reference sire. In Herd 2, the calves of Bull C are 20 pounds lighter than those of the reference sire. Therefore, Bull C should be somewhat inferior to the reference sire. In Herd 3, the calves of Bull D also are inferior to those of the reference sire, even though their actual weights are superior to that of Bull B in Herd 1. From this, it is concluded the relative genetic merit of the three herd sires rank B, C and D. This is despite the actual weaning weights of the three bulls rank in the opposite order. It is assumed there are large differences in management for the three herds because the weights of calves by the reference sire differed so widely between herds. It is also assumed the bulls were mated to randomly chosen groups of females in each herd (so the genetic merit of all of the mates is assumed to be the same) and that similar numbers of calves were produced by each bull in each herd.

The evaluation of breeding value in beef cattle is a rather complex problem for statistical analysis. However, at its base, these between- and within-herd comparisons are needed so cattle can be compared nationally and their breeding values can be estimated. Breeding value is the value of an individual animal as a parent, based on their additive genetic merit. The true breeding value of an individual is never known, but can be estimated from performance of the individual and its relatives.

Expected Progeny Difference (EPD)

Most beef breed associations express estimated breeding value as an Expected Progeny Difference (EPD). EPDs are influenced by the trait heritability, correlations with other

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

traits included in the genetic evaluation, number of records, relationships among the animals that have records and the distribution of information across herds included in the evaluation. EPDs are derived using performance records, pedigree information and, when available, genomic data. An EPD is the prediction of how future progeny of each animal are expected to perform relative to the progeny of other animals listed in the database. EPDs are typically expressed in units of measure for the trait. The exception would be EPDs for threshold traits (such as calving ease, maternal calving ease and heifer pregnancy), which are expressed in percentage units, where higher numbers predict a greater likelihood of the desired outcome. An EPD is simply one-half of the breeding value of an animal. They do NOT predict a level of performance expected to be achieved from an animal, but rather provide a tool that can be utilized to compare differences between genetic merit of animals. To illustrate this point, consider the example in Table 26.2.

The correct interpretation of the differences in the EPDs between these two sires is that one would expect the progeny of Sire 2 to be approximately 1.3 pounds heavier at birth, 5 pounds heavier at weaning, 2 pounds heavier at yearling and Sire 2's heifer progeny 3% less likely to calve unassisted than the progeny of Sire 1, if all calves are managed in a uniform manner and are produced from cows of similar genetic merit. As stated previously, the units of the EPDs for birth, weaning and yearling are estimated in pounds as these traits are typically measured in pounds. Calving Ease Maternal (CEM) is considered a threshold trait, as such the EPD is predicted in percentage units where higher numbers indicate a greater likelihood of achieving the desired outcome: calving without assistance.

EPDs also can be compared for animals across an entire breed, if desired. This is done using a percentile rank table. For example, if there is an Angus bull calf with a weaning weight (WW) EPD of 76, Table 26.3 shows the bull ranks in the best 5% of non-parent Angus bulls for that trait (shown in red).

The estimation of EPDs for purebred beef cattle and composites is performed by their respective breed associations during NCE, using systems called an animal model to generate EPD estimates. Animal models include information and predict EPDs for sires, dams and progeny utilizing all of the information available for the prediction. Older NCE systems, such as those from the 1970s, only provided EPD estimates for sires; however advancements in computing power have allowed the prediction of EPDs for all animals. The system of equations solved using an animal model is called Best Linear Unbiased Prediction (BLUP). EPDs are such a powerful tool because they allow for the correction of bias due to the genetic merit of the animal's mate, the environment in which the animal was raised and the culling of inferior animals at different stages of the production system.

EPDs make possible fair comparisons of animals between herds, independent of environmental conditions,

Table 26.2. Comparison of the EPDs from two sire prospects.

Trait	*Birth weight (lbs.)*	*Weaning weight (lbs.)*	*Yearling weight (lbs.)*	*Calving ease maternal (%)*
Sire 1 EPD	1.0	23	48	13
Sire 2 EPD	2.3	28	50	10
Difference	1.3	5	2	3

Table 26.3. Percentile Ranking of Non-parent Angus Bulls.

Top Pct.	*CED*	*BW*	*WW*	*YW*	*RADG*	*DMI*	*SC*	*DOC*	*HP*	*CEM*	*Milk*	*MW*	*CW*	*Marb*	*RE*	*$M*	*$B*	*$C*
1%	16	-3	84	148	0.34	-0.3	2.2	33	18	16	39	122	74	1.38	1.17	88	185	303
2%	15	-3	81	142	0.33	-0.2	2	32	17	15	37	114	70	1.27	1.09	85	178	294
3%	15	-2	79	138	0.32	-0.1	1.9	31	17	15	36	109	68	1.2	1.04	83	174	288
4%	14	-2	77	136	0.31	-0	1.8	30	16	14	35	105	66	1.15	1.01	82	171	283
5%	14	-2	76	133	0.31	0	1.8	29	16	14	34	102	64	1.11	0.98	80	168	280
10%	12	-1	71	126	0.29	0.2	1.5	27	15	13	32	92	59	0.97	0.88	76	159	267
15%	11	-1	68	121	0.28	0.4	1.4	25	14	12	31	85	56	0.88	0.82	73	153	258
20%	10	-0	66	117	0.28	0.5	1.3	24	14	12	29	79	53	0.81	0.76	71	148	252
25%	10	0.1	64	113	0.27	0.6	1.2	23	13	11	29	74	51	0.75	0.72	69	144	246
30%	9	0.4	62	110	0.26	0.6	1.1	21	13	11	28	69	49	0.69	0.68	67	140	241
35%	8	0.6	61	107	0.26	0.7	1	20	12	10	27	65	47	0.65	0.65	65	137	236
40%	8	0.9	59	105	0.25	0.8	0.9	19	12	10	26	61	45	0.6	0.62	63	134	232
45%	7	1.1	58	102	0.25	0.8	0.9	18	12	9	26	58	44	0.56	0.58	61	131	228
50%	7	1.3	56	100	0.24	0.9	0.8	17	11	9	25	54	42	0.52	0.55	60	128	224
55%	6	1.5	55	97	0.23	1	0.7	16	11	8	24	50	40	0.48	0.52	58	125	220
60%	5	1.7	53	94	0.23	1	0.6	15	10	8	24	46	38	0.45	0.49	56	122	216
65%	5	1.9	52	92	0.22	1.1	0.6	14	10	8	23	43	37	0.41	0.46	54	119	212
70%	4	2.1	50	89	0.22	1.2	0.5	13	10	7	22	38	35	0.37	0.43	53	116	207
75%	3	2.4	48	86	0.21	1.2	0.4	11	9	6	22	34	33	0.32	0.39	51	112	203
80%	3	2.7	46	82	0.2	1.3	0.3	10	9	6	21	29	30	0.28	0.35	48	109	197
85%	2	3	44	78	0.2	1.4	0.2	8	8	5	20	23	28	0.22	0.3	46	104	191
90%	0	3.4	40	72	0.18	1.6	0	5	7	4	19	15	24	0.16	0.25	42	99	183
95%	-2	4.1	35	63	0.17	1.7	-0.2	2	6	2	17	4	18	0.07	0.16	37	89	170
Avg	6	1.3	56	99	0.24	0.9	0.8	17	11	9	25	54	42	0.55	0.56	59	128	224

which is a huge advantage over phenotypic measures of performance. It is important to note that direct comparison of EPDs between animals must be strictly on a within-breed basis. Each breed has a different "base" that makes direct comparison of EPDs across breeds problematic. Across-breed EPD adjustment factors exist and are discussed later in this chapter.

To understand the use and application of EPDs, it helps to have an appreciation for what EPDs measure and how they are calculated. EPDs measure the additive genetic merit of an individual. Additive genetic merit is a measure of the value of the genes in an individual and how those genes affect the performance of their progeny. Think of the concept of additive genetic merit as an addition problem. The relative value of each of the animal's alleles (a function of its effect on a phenotype and the frequency at which it is observed in a population) can be summed to determine the animal's genetic merit. In practice, the value of each allele an animal possesses is not known, so instead an animal's total genetic merit is estimated and reported as an EPD.

The Use of Selection Indices

Even when properly following an effective breeding objective, determining the amount of emphasis to place on any single trait can be a daunting task. One simple solution to this issue exists in the form of selection indices. A number of different selection indices have been developed by various breed associations, allowing simultaneous selection for multiple traits. Most of these indices are economic selection indices and are expressed in dollars saved or earned rather than the customary units of measure for EPDs, such as pounds or inches. These selection indices are calculated using both a genetic and an economic component.

For many producers, it may provide a better understanding of the economic impact (in profit) their selection decision has in their breeding program. Just as EPDs are a tool that can be used to predict the differences, on average, in performance between the future offspring of individuals for a given trait; selection indices are a tool that can be used to predict differences, on average, in profit (dollars) between the offspring of individuals. As with EPDs, general selection indices only have meaning when compared to another animal of the same breed. Producers need to keep in mind these selection indices are not absolute, but responsive to the economic assumptions used in their calculation (for example, live-market weight and price; carcass weight and rail/grid price premiums and discounts; feed/feedlot costs; etc).

As with EPDs, selection indices must be used with caution and understanding to avoid undesired selection results. Selection indices offer great promise within the beef industry when used appropriately. Some breed associations allow the development of dynamic indices that can be tailored to the values within an individual herd. This means some indices can be tailored to specific markets.

An economic index is basically a subset of an animal's EPDs weighted by their corresponding economic values so the traits with greater impacts on production targets have a larger associated economic weight. It can be thought of as a breeding objective, since each index has clearly defined goals and marketing endpoints. The basic equation for an index of this type is:

$$\text{Index}=\text{EPD}_1(\text{Weight}_1)+\text{EPD}_2(\text{Weight}_2)+ \ldots + \text{EPD}_n(\text{Weight}_n)$$

The successful application of generalized selection indices relies on the logical implementation as outlined below (adapted from National Beef Cattle Consortium, 2006):

1. Identify the production and marketing system.
   a. When will the animals be marketed (at what age)?
   b. How will the animals be marketed?
   c. What is the current performance and genetic level of the herd?
2. Identify the index appropriate to the production system.
   a. What traits are included in the index?
   b. Do the economic assumptions align with the production system and breeding objectives?
3. Decide on the appropriate index for evaluation based on the priorities outlined in the first two steps.
4. Limit the use of additional EPDs.
   a. Do not place additional selection emphasis on any of the traits in the index, as it will over-emphasize that trait and limit the benefit gained from index selection.
   b. Additional selection emphasis can be placed on traits outside the index, but care must be taken to ensure that it aligns with the breeding objective and index.
   c. Use of additional EPDs can be beneficial when environment or management conditions necessitate upper limits on production potential for traits like milk production or mature size. For example, a producer may want to select for large values for Weaned Calf Value ($W), but place an upper limit (like breed average) on milk production potential or mature height, if keeping replacement heifers.

Following is an explanation taken from the Weaned Calf Value ($W) selection Index found in the Sire Summary of the American Angus Association. **$W** quantifies four primary economic impact areas:

Birth Weight - birth weight influences on calf death losses related to dystocia, weaned calf crop percentage and resulting revenue per cow,

Weaning Weight - direct growth impact on weaning weight revenue (pre-weaning growth and pounds of calf sold) and energy requirements and related costs to necessary to support pre-weaning calf growth.

Maternal Milk - revenue from calf pre-weaning growth and pounds of calf sold as influenced by varying cow milk levels and costs related to lactation energy requirements.

Mature Cow Size - expense adjustments are made for maintenance energy as related to differing mature cow size, including mathematical linkages between mature weight and yearling weight.

Table 26.4. How to read the report - American Angus Association Sire Summary.

Production EPDs

Calving Ease Direct (CED), is expressed as a difference in percentage of unassisted births, with a higher value indicating greater calving ease in first-calf heifers. It predicts the average difference in ease with which a sire's calves will be born when he is bred to first-calf heifers.

Birth Weight EPD (BW), expressed in pounds, is a predictor of a sire's ability to transmit birth weight to his progeny compared to that of other sires.

Weaning Weight EPD (WW), expressed in pounds; is a predictor of a sire's ability to transmit weaning growth to his progeny compared to that of other sires.

Yearling Weight EPD (YW), expressed in pounds; is a predictor of a sire's ability to transmit yearling growth to his progeny compared to that of other sires.

Residual Average Daily Gain (RADG), expressed in pounds per day; is a predictor of a sire's genetic ability for postweaning gain in future progeny compared to that of other sires, given a constant amount of feed consumed.

Dry Matter Intake (DMI), expressed in pounds per day; is a predictor of difference transmitting ability for feed intake during the postweaning phase, compared to that of other sires.

Yearling Height EPD (YH), expressed in inches; is a predictor of a sire's ability to transmit yearling height compared to that of other sires.

Scrotal Circumference EPD (SC), expressed in centimeters; is a predictor of the difference in transmitting ability for scrotal size compared to that of other sires.

Docility (Doc), is expressed as a difference in yearling cattle temperament, with a higher value indicating more favorable docility. It predicts the average difference of progeny from a sire in comparison with another sire's calves. In herds where temperament problems are not an issue, this expected difference would not be realized.

Claw Set EPD (Claw), is expressed in units of claw-set score; with a lower EPD being more favorable indicating a sire will produce progeny with more ideal claw set. For the ideal claw set, toes are symmetrical, even and appropriately spaced.

Foot Angle EPD (Angle), is expressed in units of foot-angle score, with a lower EPD being more favorable indicating a sire will produce progeny with more ideal foot angle. The ideal is a 45-degree angle at the pastern joint with appropriate toe length and heel depth.

Pulmonary arterial pressure EPD (PAP), is expressed in millimeters of Mercury (mmHg); with a lower EPD being more favorable indicating a sire should produce progeny with a lower PAP score. PAP score is an indicator of susceptibility to high-altitude disease commonly experienced at elevations greater than 5,500 feet. Selection for this trait aims to improve the genetic potential for a sire's progeny to have lower PAP scores ,thus a lower chance of contracting high-altitude disease, increasing the environmental adaptability of cattle living in mountain areas.

Maternal EPDs

Heifer Pregnancy (HP), is a selection tool to increase the probability or chance of a sire's daughters becoming pregnant as first-calf heifers during a normal breeding season. A higher EPD is the more favorable direction and the EPD is reported in percentage units.

Calving Ease Maternal (CEM), is expressed as a difference in percentage of unassisted births; with a higher value indicating greater calving ease in first-calf daughters. It predicts the average ease with which a sire's daughters will calve as first-calf heifers when compared to daughters of other sires.

Maternal Milk EPD (Milk), is a predictor of a sire's genetic merit for milk and mothering ability as expressed in his daughters compared to daughters of other sires. In other words, it is that part of a calf's weaning weight attributed to milk and mothering ability.

Herds (MkH) indicate the number of herds from which daughters are reported.

Daughters (MkD) reflects the number of daughters that have progeny weaning weight records included in the analysis.

Mature Weight EPD (MW), expressed in pounds, is a predictor of the difference in mature weight of daughters of a sire compared to the daughters of other sires.

Mature Height EPD (MH), expressed in inches; is a predictor of the difference in mature height of a sire's daughters compared to daughters of other sires.

Cow Energy Value ($EN), expressed in dollar savings per cow per year; assesses differences in cow energy requirements as an expected dollar savings difference in daughters of sires. A larger value is more favorable when comparing two animals (more dollars saved on feed energy expenses). Components for computing the cow $EN savings difference include lactation energy requirements and energy costs associated with differences in mature cow size.

Carcass EPDs

Carcass Weight EPD (CW), expressed in pounds; is a predictor of the differences in hot carcass weight of a sire's progeny compared to progeny of other sires.

Marbling EPD (Marb), expressed as a fraction of the difference in USDA marbling score of a sire's progeny compared to progeny of other sires.

Ribeye Area EPD (RE), expressed in square inches; is a predictor of the difference in ribeye area of a sire's progeny compared to progeny of other sires.

Fat Thickness EPD (Fat), expressed in inches; is a predictor of the differences in external fat thickness at the 12th rib (as measured between the 12th and 13th ribs) of a sire's progeny compared to progeny of other sires.

Group/progeny (C Grp/ Pg and U Grp/Pg), reflects the number of contemporary groups and the number of carcass and ultrasound progeny included in the analysis.

Hair Shed EPD

This EPD is expressed in units of hair shed score; with a lower EPD being more favorable indicating a sire should produce progeny who shed their winter coat earlier in the spring. Selection for this trait should improve the genetic potential for a sire's progeny to shed off earlier, increasing the environmental adaptability of cattle living in heat-stressed areas and producers grazing endophyte-infected (hot) fescue.

$Value Indexes

An economic selection index allows multiple change in several different traits at once pertaining to a specific breeding objective. The $Value is an estimate of how future progeny of each sire are expected to perform, on average, compared to progeny of other sires if the sires were randomly mated to cows and if calves were exposed to the same environment.

Table 26.4. How to read the report - American Angus Association Sire Summary. (cont'd)

Maternal Weaned Calf Value ($M), an index expressed in dollars per head; predicts profitability differences from conception to weaning with the underlying breeding objective assuming individuals retain their own replacement females within herd and sell the rest of the cull female and all male progeny as feeder calves. The model assumes commercial producers will replace 25% of their breeding females in the first generation and 20% of their breeding females in each subsequent generation. Traits included are as follows: calving ease direct, calving ease maternal, weaning weight, milk, heifer pregnancy, docility, mature cow weight, claw set and foot angle.

Weaned Calf Value ($W), an index expressed in dollars per head; to predict profitability differences in progeny due to genetics from birth to weaning. The underlying objective being producers will retain 20% of the female progeny as replacements and sell the rest of the cull females and their male counterparts as feeder calves. Traits included are as follows (in no particular order): birth weight, weaning weight, milk and mature cow weight.

Feedlot Value ($F), an index expressed in dollars per head; to predict profitability differences in progeny due to genetics for postweaning feedlot merit compared to the progeny of other sires. The underlying objective assumes producers will retain ownership of cattle through the feedlot phase and sell fed cattle on a carcass weight basis, but with no consideration of premiums or discounts for quality and yield grade. Traits contributing directly to the index are as follows: yearling weight (gain), carcass weight and dry-matter intake.

Grid Value ($G), an index expressed in dollars per carcass; to predict profitability differences in progeny due to genetics for carcass grid merit compared to progeny of other sires. The underlying objective assumes producers will market cattle on an above-industry-average carcass grid. Traits included in the index are as follows (in no particular order): carcass weight, marbling, ribeye area and fat.

Beef Value ($B), a terminal index expressed in dollars per carcass; to predict profitability differences in progeny due to genetics for postweaning and carcass traits. This terminal index assumes commercial producers wean all male and female progeny, retain ownership of these animals through the feedlot phase and market these animals on a carcass grid. Traits included in the index are as follows: yearling weight, dry-matter intake, marbling, carcass weight, ribeye area and fat.

**Combined Value ($C),** an index expressed in dollars per head; which includes all traits that make up both Maternal Weaned Calf Value ($M) and Beef Value ($B) with the objective that commercial producers will replace 20% of their breeding females per year with replacement heifers retained within their own herd. The remaining cull heifer and steer progeny are then assumed to be sent to the feedlot where the producers retain ownership of those cattle and sell them on a quality-based carcass merit grid. Expected progeny differences (EPDs) directly influencing a combined index: calving ease direct (CED) and maternal (CEM), weaning weight (WW), yearling weight (YW), maternal milk (Milk), heifer pregnancy (HP), docility (DOC), mature cow weight (MW), foot angle (Angle), claw set (Claw), dry matter intake (DMI), marbling (Marb), carcass weight (CW), ribeye area (RE) and fat thickness (Fat).

The resulting $W takes into account the revenue generated by heavier weaning weights as well as the expense of achieving those weights ultimately wrapping multiple EPDs into one dollar value.

Sire Summaries

The information and EPDs generated during NCE can be found in a breed association sire summary. Most breed associations no longer provide a print copy of these summaries, and instead post the information online for the public and their members. These summaries are an invaluable source of information and contain EPD records, information on genetic trends for the breed, percentile rankings (including breed average EPDs), possible change values and definitions of all the genetic prediction and other information found in a sire summary. If unsure of the units of measurement for a particular trait or how to interpret a specific EPD, the sire summary is the best source for this information. At least 27 beef breed associations currently conduct cattle evaluation programs. General selection indices aid in the selection for multiple traits at one time and are based on both production and economic information and often are expressed in dollar value.

Many of the summaries contain two listings of bulls that are separate from the general evaluation, which is available for all animals, usually through a general animal EPD search. The first is a listing of proven sires. These are older bulls that have a large number of calves with performance records. Therefore, the accuracies on the birth and weaning weight EPDs are generally at least 0.5. The second section is devoted to younger bulls that have lower accuracies (< 0.5 for most/all traits). Many associations also will list either focus dams, dam trait leaders or other similar designation. The criteria for these listings varies widely among the breeds. Following is an example of definitions for information found in the American Angus Sire Summary.

Contemporary Groups

Using proper data-recording practices is vital to obtaining the best results from NCE because not all variation in an animal's performance is due to genetics. Appropriate contemporary grouping strategies are paramount to this effort because they allow for adjustment of data to reflect the environmental conditions in which the animal was raised. There are no reliable mathematical adjustments for weather or differences in feed environment. Therefore, a contemporary group is formed to compare animals that experience similar environmental effects. The proper formation of large, multi-sire contemporary groups improves the quality and effectiveness of EPD as a selection tool.

Contemporary groups are groups of cattle that are the same sex, same breed composition, close in age, raised in the same environment and are subjected to the same management conditions. Differing nutritional planes (for example, creep feeding) or illness or infirmity may be reasons to split otherwise uniform contemporary groups. Forming groups correctly allows for unbiased comparisons of animals within a group and across herds, and this strategy is the basic premise behind EPD predictions. To illustrate this point, consider two animals from separate contemporary groups. The first calf weighed 425 pounds at weaning due to adverse environmental conditions. However, the mean performance of the contemporary group was 400 pounds. The second calf weighed 600 pounds at weaning because he had an ample supply of creep feed and favorable environmental

conditions. The mean performance of his contemporaries was 625 pounds. Comparing these animals directly does not account for the bias introduced by the environment. By comparing each animal to its contemporaries instead of each other, we can better account for environmental effects so the remaining differences in performance seen between animals more closely reflects heritable differences among them. When these records are submitted to NCE, both environmental conditions and the genetic merit of the other animals in the contemporary group are accounted for, and the genetic merit of these animals can be more fairly compared using their EPDs.

The key to effective contemporary grouping is to strike a balance between too many and too few groups. Assignments to contemporary groups should be as simple and inclusive as possible without neglecting major differences in management. For example, cattle chosen after weaning for show purposes could be in the same contemporary group as other animals similar in age, management and sex; however, they should be part of a separate contemporary group with those managed as show cattle for their yearling contemporary group. Contemporary groups never get larger as animals age, but they will likely decrease in size. As the cattle age, events such as sickness (or death), injury, culling and varied management can result in smaller contemporary groups.

Bias also can be introduced by not reporting progeny for all eligible animals within a herd. Some breeders may be tempted only to record the best-performing calves either to save money on registration and recording costs or to relieve anxiety that those poorer-performing calves will reflect unfavorably on their herd. In reality, the opposite effect is seen when producers selectively report calves and cull the poorest animals without reporting their data. For this reason, many associations have a low-cost way of recording performance data on cattle without registering them. Consider the following group of heifer calves, shown in Table 26.5.

Heifer 2 has above-average performance as compared to the mean of the contemporary group (600 pounds). However, if only the highest-performing progeny are recorded (progeny records for calves 4 and 5 are not reported, as in Scenario 2), the mean increases to 625 pounds. Now heifer 2 appears to only have average growth performance. Genetic evaluation systems use deviations from the mean for the contemporary group, rather than each calf's individual weight. Selective reporting does not give appropriate credit to the best animals in your herd. Reporting all progeny is both beneficial to NCE as well as to the producer and their customers who receive more accurate EPDs. Total Herd Reporting is a good data reporting practice and will ensure the most accurate data for both the producer reporting all of their calves as well as their customers.

Table 26.5. Weaning weight records from a small contemporary group.

Scenario 1		*Scenario 2*	
Calf	*Weight*	*Calf*	*Weight*
1	650	1	650
2	625	2	625
3	600	3	600
4	575	~~4~~	~~575~~
5	550	~~5~~	~~550~~

Examples of Contemporary Group Information from the BIF Guidelines:

Calving ease (direct and maternal) and birth weight

- Breeder/herd code.
- Year.
- Season (fall or spring).
- Sex of animal (bull or heifer).
- Breed composition.
- Birth management code.
- Service type (embryo transfer or normal).

Weaning weight

- Birth contemporary group.
- Management/pasture code.
- Date of weaning weight.
- Weaning sex (bull, heifers or steer) .
- Breed composition.
- Service type (embryo transfer or normal).

BIF has suggested guidelines for contemporary grouping including:

- Use group codes on registration forms to assign calves to contemporary groups according to management
- Place sick or injured calves into single-animal contemporary groups if their affliction caused changes in the calf's performance
- Take measurements on all calves on the same day (when all calves are within the recommended recording ages for the trait being measured. For example, weaning weight, when the average age of the animals in the contemporary group are 205 days and no members are older than 250 days of age or younger than 160 days of age). Include as many calves as legitimately possible Do not weigh calves individually as they reach 205 days of age. Weigh each calf individually when calves in the entire group are, on average, 205 days of age.
- Record performance on the entire group before separating them, especially before separating show calves and bulls designated as test station candidates.
- If the age spread is greater than allowed, choose two or more dates for recording of performance information, using as few as possible.
- The presence of progeny from two or more sires in each contemporary group is desirable, but not required.
- If carcass data are to be collected on culled animals, report weaning weights on all animals. These data allow selection of replacement females and bulls to be accounted for within the genetic evaluation and help prevent bias in the estimates.
- Do not include animals receiving any special treatment (show calves, animals at the bull test, animals specially managed for a sale) in the same contemporary group as animals not having an equal opportunity to perform.

Parent Average EPD

Every calf receives a random sample of half of the sire's genes and a random sample of half of the dam's genes to combine into the complete genetic makeup of the calf. This is called independent assortment, and this phenomenon is related to how parent average EPDs are calculated for animals when they are first born, up until the time the association receives their first individual record, progeny record or relative record. Parent-average EPDs have low accuracies, but are very easy to calculate. In the past, producers often calculated these EPDs, but with the newest genetic evaluation procedures, calculation will rarely be needed. However, it is useful to know that the first EPD published on an animal (usually denoted by a low numeric accuracy such as 0.05 or denoted with a letter such as P) is usually a parent average.

Procedure to Calculate Pedigree EPD

1. If both sire and dam of the young animal have EPDs, it is simply one-half the EPD of each parent or the average of the parent's EPDs.

   Pedigree EPD = 1/2 EPD of sire + 1/2 EPD of dam

2. If the EPD on the dam is missing (which happens rarely for animals where there have been no observations on a trait for a long period of time, such as carcass traits), EPDs on her relatives may be used.

   Pedigree EPD = 1/2 EPD of sire + 1/4 EPD of MGS

Note: If the EPD of the dam is known, the EPD information on the maternal grandsire (MGS) is not imperative and option 1 should be utilized.

Most breed associations have an interim EPD program based on pedigree information to provide EPDs on young animals that have not had an opportunity to have their individual performance included in the most recent national cattle evaluation for the breed.

Interim EPD

A majority of breed associations will generate their EPD either once, or more commonly, twice per year. Breed associations produce interim EPDs with existing parental EPDs combined with data collected during the time between NCE runs on the animal of interest (adjusted data on the trait of interest and maternal permanent environment effects). The advantage of this approach is to provide breeders a way to make earlier selection decisions prior to the next NCE, using the most up-to-date information possible.

During the next NCE, the animal's own performance and any additional information that contributes to the genetic evaluation will be added and used to calculate new EPDs. When new information is added to the evaluation, the accuracy of that EPD prediction will increase.

Accuracy

Each EPD value has an accuracy assigned to it. The true breeding value of an animal cannot be known with 100% certainty, which is why understanding EPD accuracy values is an essential part of sire and replacement heifer selection. The accuracy is a measure of confidence in the EPD. It is expressed as a value between zero and one (accuracies are sometimes expressed as the accuracy multiplied by 100; for example, an accuracy of 0.15 may be listed as 15). An accuracy of 0 would reflect no confidence in the estimate, whereas an accuracy of 1 would reflect complete confidence that the true breeding value was known. In practice, accuracy values do not appear with values that extreme (either no or complete confidence). A high accuracy (> 0.7) means there is a high confidence in the EPD and it is not expected to change much as further information is gathered. A low accuracy (< 0.4) means the EPD may change a great deal as additional information is gathered (Table 26.6).

When animals are born, they have a low-accuracy EPD formed from the average of the parent's EPD values (parent average EPDs above). In the process of forming a parent average EPD, it is assumed each animal received an average gamete from each parent. Because of this full-sibling flush, mates will all have the same parent average EPD for all traits when they are born. In reality, it is expected that any given gamete is average, but each gamete may have received a very favorable or very unfavorable sampling of genes or anything in between.

Very large numbers of genetically distinct full siblings are possible from the mating of a particular cow to a particular bull due to the size of the genome, so being able to more accurately describe the sampling of genes an animal did inherit, either through genomic approaches or through recording of data on the individual, its progeny or its relatives, is a huge asset and will be reflected in a higher (more desirable) value for the EPD accuracy (Table 26.7).

Table 26.6. Meaning and associated risk Levels of accuracy values.

Accuracy	*Meaning*	*Risk Llevel*
Less than .40	Very likely to change with more information	High
.40 to .60	Some change likely, records on few progeny	Moderate
.60 to .80	Small change possible, records on numerous progeny	Low
Greater than .80	Not likely to change much	Very Low

Source: Gelbvieh.org

Table 26.7. Possible change values for two bulls with the same birth weight EPD, but with different accuracy values.

Sire	*EPD*	*Accuracy*	*Possible change*	*68% Confidence range*	*95% Confidence range*
1 (unproven)	1.2	0.1	±2.7	-1.5 to 3.9	-4.2 to 6.6
2 (proven)	1.2	0.8	±0.6	0.6 to 1.8	0 to 2.4

Because higher accuracy correlates to more confidence in the prediction, it is useful to be cognizant of methods in which to build accuracy in young sires and replacement heifers. Accuracy is dependent on several different factors including trait heritability, number of phenotypic records on the individual and its relatives and number of records on any traits that are genetically correlated. Because the heritability cannot be influenced directly, recording the phenotypic performance of the individual in question and its progeny is the easiest way to build accuracy for an EPD on a particular trait (Table 26.8).

Because of the features inherent in genetic evaluation systems, phenotypic records on relatives also contribute towards accuracy. In the last few years, genomic information also has been included in the genetic evaluations for many breeds cattle. The addition of genomic information on an animal into genetic evaluation performed by the breed associations is another way to build accuracy in unproven animals. This will be discussed in greater detail in chapter 28.

In Table 26.8, the accuracy is specified two ways: the "true accuracy" and the BIF accuracy. In its strictest definition, accuracy is the correlation of the true breeding value with the predicted breeding value (keep in mind that an EPD is 1/2 of the breeding value). Accuracies for genetic evaluations can be denoted by many different names, including accuracy (r), reliability (r^2) or the BIF accuracy. Each value can be converted into the other, and the main difference between the numbers is how they are scaled. Accuracy (r) tends to be the highest value, whereas BIF accuracies are scaled down to smaller values (Table 26.8).

Practical use of EPD Accuracies

A practical way to think about EPD accuracies is the possible change in an EPD given a specific accuracy. Many breed associations publish possible change tables as part of their sire summaries, and they often are found in the same section as the EPD percentile rankings tables. They represent a 68% confidence interval around the reported EPD. To illustrate this concept, consider two bulls that both have a birth weight EPD of 1.2 (Table 26.7). The unproven sire's EPD has a much larger possible change value than the proven bull. This means he may sire progeny with considerably lower birth weights than previously thought, or his EPD may trend towards siring progeny with a higher birth weight. The proven bull's EPD will be much more stable with time as greater numbers of progeny are born, as there is a high confidence in the estimate listed.

Table 26.8. Approximate number of progeny records needed to obtain a specified accuracy level.

"True" Accuracy (r)[1]	BIF Accuracy[2]	Heritability (h^2)		
		Low (0.1)	Moderate (0.3)	High (0.5)
0.1	0.01	1	1	1
0.2	0.02	2	1	1
0.3	0.05	4	2	1
0.4	0.08	8	3	2
0.5	0.13	13	5	3
0.6	0.20	22	7	4
0.7	0.29	38	12	7
0.8	0.40	70	22	13
0.9	0.56	167	53	30
0.999	0.99	3,800	1,225	700

1 r calculated as: $\sqrt{\frac{nh^2}{4+(n-1)h^2}}$ where n is the number of progeny recorded.

2 BIF accuracy calculated as: $1-\sqrt{1-r^2}$

Accuracy and possible change values share a relationship. As more information is accumulated, accuracy increases and possible change decreases. Approximately two-thirds of animals are expected to have true progeny differences inside the 68% confidence range. The possible change value can be doubled and used to calculate a 95% confidence range. For example, the probability the true progeny difference for birth weight on Sire 1 is between -1.5 and 3.9 is 68%. These true differences have a much greater chance of falling toward the center of the range defined by the possible change value than falling close to the extremes. However, the EPD changes with time as performance information is recorded to more closely reflect the true breeding value and the accuracy increases (and possible change decreases) with this added information.

Knowing the amount an EPD can change with time, as accuracy increases, is a very useful tool for risk management. Using a bull that may not have EPDs as impressive as a new yearling bull, but has high accuracies is a reasonable choice to limit risk. Use of an artificial insemination program is one of the most effective ways to incorporate genetics from proven bulls into the herd. For those producers less adverse to risk, the younger, unproven sire offers the opportunity to find a bull with the newest genetics and more extreme EPD values, while simultaneously absorbing the risk that the EPDs for that sire may change and he may not be as impressive as initially estimated. A good strategy for herds large enough to breed to several sires throughout the breeding season is to balance their genetic risk. They can do this by using several proven herd sires, coupled with some younger herd sires to help balance the risk of their breeding decisions within their herds.

Understanding both EPDs and their associated accuracies is an important step towards making appropriate breeding decisions within the herd, while simultaneously managing risk within the production operation.

Across Breed EPDs

EPDs were developed because of the need to directly compare animals within a breed across multiple herds and environments. Thus, the direct comparison of animals using EPDs is feasible within breed, even across different herds within that breed. However, it is not appropriate to directly compare the EPDs of animals across breeds (for example, comparing the EPDs of an Angus with a Hereford) because each breed has a different EPD base value. These base values can be thought of as scaling factors. For example, if two EPDs are generated in the same evaluation that have a difference of 5 (a weaning weight EPD of 5 vs. 10 for example), they are directly comparable (a 5-pound difference). If two

numbers are scaled differently (add three to the EPD of five, and two to the EPD of 10), they are no longer directly comparable (the difference is now 4 pounds). This is why EPDs from animals of different breeds should not be directly compared. The only exception to this rule is if two or more breeds perform a joint evaluation and present their EPDs on the same scale.

It is possible to compare some EPDs across breeds after they have been adjusted to account for differences in scale between breeds. The U.S. Meat Animal Research Center (USMARC) in Clay Center, Neb., conducts research to estimate the appropriate breed specific adjustment factors, which can be used to calculate across breed EPDs (AB-EPDs). The updates for the AB-EPD adjustment factors are completed each summer and provided at the BIF annual meeting (Table 26.9).

AB-EPDs can be used to improve crossbreeding program design and avoid problems generated by mismatching animals with inappropriate EPDs for certain traits. The example in Table 26.10 illustrates the use of AB-EPDs. In this example, a producer uses two breeds, Angus and Hereford, in a rotational crossbreeding system. If a producer is interested in uniformity of sires for multiple traits, the AB-EPD can assist the comparison of sires by adjusting the breed specific EPD to a common AB-EPD. The AB-EPD adjustment factors are useful for other breeding program designs such as a terminal crossbreeding system.

How accurate are the AB-EPDs? The accuracy of any EPD is not perfect for animals within a breed and the level of accuracy depends on factors, such as type and amount of data and the heritability of the trait. BIF Guidelines state the accuracy of the AB-EPD will be determined from the accuracy values within breed and accuracy of breed differences. It is recommended to use the lowest within-breed accuracy levels for the AB-EPD accuracy levels.

Table 26.10. Example of using across-breed adjustment factors from Table 26.9 to convert noncomparable within-breed EPDs to comparable across-breed EPDs.

Breed		*BW*	*WW*	*YW*	*Milk*
Angus	AB -- Adj. Factors [1]	0	0	0	0
Bull #1A	EPD[2]	2.8	56	83	20
	AB-EPD[3]	2.8	56	83	20
Hereford	AB -- Adj. Factors [1]	1.0	-16.1	-44.0	-10.4
Bull #2B	EPD[2]	1.8	68	101	22
	AB-EPD[3]	2.8	51.9	57	11.6

1 AB adj. factors are the across-breed adjustment factors from Table 26.9.
2 EPDs are the within-breed EPD values from the breed's genetic evaluation for the bull of interest.
3 Across-breed EPDs after adjustment factors are applied to within-breed EPDs.

Contribution of Data to EPD predictions

Most breed associations use animal model (AM) procedures to compute EPDs. The use of an animal model has a variety of benefits including:

- Each individual's own performance and the performance of its progeny, siblings, parents, grandparents, etc., is utilized to evaluate genetic merit.
- Because the performance of the animal itself—as well as all available information on relatives—is included in the EPD estimate, EPDs are available on both parent and nonparent animals.
- Preferential mating of certain individuals does not bias the results; therefore, an expensive bull can be used only on genetically superior cows and his EPD will not be inflated because the EPD accounts for the genetic merit of the animal's mate.
- Use of an animal model makes appropriate adjustments for genetic trend.

Table 26.9. Adjustment Factors to Estimate Across-Breed EPDs.

Breed	*Birth weight*	*Weaning weight*	*Yearling weight*	*Milk*	*Marbling score*	*Ribeye area*	*Fat thickness*	Carcass weight
Angus	0.0	0.0	0.0	0.0	0.00	0.00	0.000	0.0
Hereford	1.0	- 16.1	- 44.0	- 10.4	- 0.32	0.06	- 0.075	- 67.3
Red Angus	2.5	- 19.5	- 29.8	2.7	- 0.13	0.24	- 0.049	- 14.4
Shorthorn	4.2	- 32.5	- 44.0	2.9	- 0.05	0.55	- 0.025	7.2
South Devon	2.3	- 27.0	- 68.1	4.4	- 0.38	0.40	- 0.181	- 72.5
Beefmaster	4.0	21.3	- 3.8	9.5				
Brahman	9.7	49.8	10.8	18.8		0.01	- 0.164	- 36.6
Brangus	2.7	14.2	0.5	15.8				
Santa Gertrudis	4.9	37.5	34.9	20.8	- 0.46	0.14	- 0.091	- 10.8
Braunvieh	1.9	- 19.4	- 42.4	4.8	- 0.65	1.05	- 0.107	- 51.7
Charolais	6.2	29.6	24.7	8.7	- 0.31	0.82	- 0.200	8.8
Chiangus	2.5	- 21.0	- 36.0	4.2	- 0.47	0.57	- 0.140	- 17.8
Gelbvieh	3.3	- 11.6	- 19.6	12.4	- 0.52	0.92	- 0.102	- 5.3
Limousin	2.2	- 17.2	- 48.6	- 2.1	0.01	0.65	- 0.021	- 3.1
Maine Anjou	1.6	- 30.0	- 63.1	- 4.3	- 0.46	1.02	- 0.184	- 32.9
Salers	0.6	- 9.9	- 41.8	7.1	0.09	1.16	- 0.179	- 43.0
Simmental	2.5	- 13.0	- 18.7	1.7	- 0.08	0.48	- 0.049	- 5.4
Tarentaise	2.5	19.1	- 15.8	22.4				

Source: Kuehn and Thallman, 2019.

- An animal model can account for both direct and maternal contributions to a trait, such as direct and maternal components of weaning weight.
- EPDs can utilize information collected for both the trait of interest and genetically correlated indicator traits.
- EPDs account for culling bias due to poor performance.

Many associations now include information from genomic tests into EPD calculations, resulting in increased accuracy for younger, non-parent animals.

New EPDs are constantly being developed at breed associations for novel economically important traits. Some of these EPDs provide selection tools containing traits, which are notoriously difficult to select for (such as heifer pregnancy), but which have a tremendous effect on profitability or offer management benefits (such as docility).

Use of EPDs for Selection

All producers, and especially purebred seedstock producers, are encouraged to consider EPDs in their breeding programs because they allow for increased targeted selection rather than selecting animals raised in favorable environments. Any good breeding program begins with a breeding objective. A breeding objective is a mission statement outlining selection goals. It defines the traits most important for individual programs, while taking into account marketing endpoints, environmental concerns, available labor, type of breeding program (terminal or raising replacements) and genetic resources. There are too many EPDs to select for excellent genetic merit in every possible trait, so the breeding objective is essential in determining traits that should receive the most focus.

It is important to remember that both favorable and unfavorable genetic correlations exist between economically important traits, so single-trait selection should never be practiced. By knowing which traits are important in the breeding objective, selection can be practiced and genetic merit can be managed to avoid any unfavorable effects of those selection decisions.

A more balanced selection program focused on reasonable breeding objectives is desirable and uses EPDs to effectively reduce risks based on selection decisions. Many important traits are not included in sire summaries. Careful monitoring of reproductive performance, calf mortality, libido in bulls and regularity of calving is still critically important. All bulls should pass a breeding soundness examination prior to being purchased and/or turned out with cows, and all cows should be pregnancy detected to ensure reproductive failures of either cows or bulls are rectified in a timely manner. However, cattle producers should consider EPDs at every opportunity possible. For commercial producers, this may apply only for herd bull purchasing decisions; however, other opportunities should be utilized if they are available. When making selection decisions with EPDs, it is vitally important to remember that even low-accuracy EPDs incorporate all available information on an animal and reflect the best estimate of their value as a parent. Because of this and the fact that EPDs separate out effects of environment, EPDs are more effective for selection decisions than using phenotypes or performance data alone.

Ideally, purebred producers use EPDs for their selection decisions for any traits in the breeding objective where they are available, and are encouraged to report performance data back to their corresponding breed association. Producers are strongly encouraged to provide complete, accurate records on all calves born each year. Complete, accurate recordkeeping is one of the best tools to ensure the best possible EPD estimates and fairly represent genetic differences to customers, and is in both the association's and the producer's best interests.

EPDs for the Commercial Producer

Many breed associations have a mechanism in place where individual purebred producers can obtain EPDs on every individual within a herd, which includes not only bulls and cows, but also replacement females and calves. Commercial producers may not have EPDs available on every animal in their herd unless they are large enough to perform their own within-herd genetic evaluation or participate in a breed association's reporting program, but they can use EPDs to practice effective genetic selection through their herd bulls. Commercial producers should demand such information from their sources of breeding stock, whether they are purebred or hybrids.

A commercial producer's first task is choosing the appropriate breed or breeds for their individual program. Once breeds are chosen, the breeding objective forms the backbone of the selection program. Each of the selection decisions should reflect the priorities set within the breeding objective, which takes into account available labor, end points, marketing and environmental concerns. For example, dry environments where available forage and water may be limiting, will likely necessitate avoidance of high EPDs for mature size or maintenance requirements (or yearling weight if no other EPDs are available) and milk.

References

Angus Sire Evaluation Report. angus.org. Accessed July 2020

Bourdon, R.M. (2000) *Understanding Animal Breeding* (2nd Edition). Prentice-Hall Inc., Upper Saddle River, NJ.

Buchanan, D.S. et al. (1993) Animal Breeding: Principles and Applications (4th Edition). Animal Science Department, Oklahoma State University.

eBEEF. eBEEF fact sheets and videos. Accessed June 2015.

Gregory, K.E., L.V. Cundiff and R.M. Koch (1999) Composite Breeds to Use Heterosis and Breed Differences to Improve Efficiency of Beef Production. Roman L. Hruska U.S. Meat Animal Research Center Agriculture Research Service, USDA in Cooperation with the Institute of Agriculture and Natural Resources, University of Nebraska, Lincoln.

National Beef Cattle Evaluation Consortium (2006). *Beef Sire Selection Manual* (2nd Edition)

Oklahoma State University Breeds of Livestock. Retrieved from ansi.okstate.edu/breeds.

Rolf, M. (2014) Understanding EPD accuracies. OSU Cooperative Extension Fact Sheet AFS-3169.

Rolf, M and T. Smith. (2014) Ten tips for utilizing a cattle sale catalog. OSU Cooperative Extension Fact Sheet AFS-3289.

Weaber, R.L. (2005) Introduction to Indices. Proceedings: Beef Improvement Federation Research Symposium and Annual Meeting, Billings, MT. July 6-9, 2005. Pg. 78-81.

27 Management of Effective Mating and Crossbreeding Systems

Mark Johnson and Daniel Stein

Objectives

- **Identify key genetic principles relevant to crossbreeding.**
- **Review the advantages and disadvantages of effective mating systems.**
- **Discuss the advantages of crossbred beef cattle.**

Introduction

It is important to remember that in the course of forming any breed, animals with preferred characteristics are subtly inbred. At one point in history, all animals were running free and interbred randomly. However, when humans decided to form breeds, they selected those animals with desired characteristics, then closed the herdbook. For example, when the Angus breed was formed, animals that were black and polled were chosen and those characteristics were propagated within that breed. When a breed is first formed and the herdbook closed, populations are necessarily small, which results in small amounts of inbreeding accumulation within breeds. Also, when closing a herdbook, the only available genetic variation that can be subsequently selected is that variation which is present in the original animals. With time, new mutations can introduce new genetic variation into a breed, but this is a very slow process. We are effectively limited to the variation present within a single breed for selection. This section will discuss the implications of crossbreeding and outline strategies for effective implementation of mating systems into breeding programs.

Inbreeding

Inbreeding is defined as the mating of closely related individuals. Basically, inbreeding occurs when animals with common ancestors in their pedigree are mated together. The primary genetic effect of inbreeding is to increase the number of homozygous gene pairs and decrease the number of heterozygous gene pairs. With the increase in homozygosity, inbreeding results in discovery of undesirable recessive genes (it does not create them, but rather allows them to be seen) and tends to bring about a decline in average phenotypic performance. This decline in performance is labeled inbreeding depression, and it is well documented in the scientific literature. Table 27.1 shows inbreeding depression has the largest effect on traits with low heritabilities, such as fertility and longevity.

The method used to determine the level of inbreeding is the inbreeding coefficient. The inbreeding coefficient measures the percent increase in homozygous gene pairs in an individual relative to the average of the population from which the individual came. If a bull has an inbreeding coefficient of 0.25, he is expected to have 25% more homozygous gene pairs than a non-inbred individual from the same population. The range of inbreeding coefficient values is 0 to 1.0, where a 0 is an animal with no inbreeding, and 1 is an animal that is completely inbred. In practice, animals with these extreme values are rarely seen. Most animals will have a small, but non-zero, inbreeding coefficient. Inbreeding is utilized primarily in herds with high genetic merit, which are devoted to production of breeding stock. Inbreeding practices have both beneficial and detrimental effects; therefore, inbreeding should be carefully considered before implementation. Much like EPD accuracy, deciding what level of inbreeding that can be tolerated in the herd is a matter or deciding a tolerance for risk. The higher the average inbreeding coefficient, the more risk is accepted for expression of recessive genetic abnormalities; inbreeding depression in performance traits; and decreasing performance in reproductive

Table 27.1. Class of trait and inbreeding depression.

Classes of trait	*Heritability*	*Inbreeding depression*
Reproduction	Low	High
Growth	Moderate	Moderate
Carcass	High	Low

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

traits like fertility, longevity and lifetime production.

Inbreeding can be used to yield a net positive effect by concentrating the use of a genetically superior individual (linebreeding). Historically, producers used inbreeding to develop lines of inbred cattle, such as the Line 1 Herefords. The principle is analogous to the inbred lines in the crop and poultry industries. This can be valuable if crossbreeding is planned, because two individuals that are highly inbred, but of different genetic lines, can be crossed to generate a highly outbred individual. In the past, inbreeding would be used to critically evaluate an individual before forming a breeding program around that individual (for example, progeny testing for undesirable recessive genes). Through the study of genomics, it is known that every animal likely carries many recessive lethal mutations, so the industry has begun moving towards using genetic testing to identify these problems. However, this approach has limitations because it only discovers known abnormalities.

Crossbreeding

Crossbreeding, which is the mating of individuals with different breed makeup, is widely used in commercial beef production. It should be used by all commercial producers because improvement in efficiency, especially for lowly heritable traits, can be dramatic if appropriate breeds are used in a planned mating system. Crossbreeding does not eliminate the need for outstanding purebred livestock, but instead provides another avenue for the use of these genetics for management of genetic potential and performance. The benefits of crossbreeding are twofold: heterosis and breed complementarity.

Heterosis

Heterosis is the average superiority of a crossbred individual over the average of breeds involved in the cross. Heterosis arises from combining genes from different breeds, so inferior recessive genes are concealed. It is important to remember heterosis is superiority over the AVERAGE of the parental breeds. Sometimes an animal will exhibit greater performance than both parental lines, particularly if the parental lines are similar in performance, but this is not always the case. For example, if crossing a Holstein and a Jersey, do not expect the crossbred progeny to have the best the milk production of a Holstein. Instead, it is expected to perform better than the average of those two breeds. One common confusion regarding heterosis rests with its effects on birth weight. Heterosis would be expected to add approximately 2.4% (NBCEC, 2010) to the average of the parental birth weights if both parent breeds are of *Bos taurus* descent (British or Continental cattle). If a very large increase of the expected performance in birth weight is observed, it is likely due to an inaccuracy in the estimate for one or both of the parental breeds or other factors outside the scope of heterosis. Heterosis may be calculated as:

$$\% \text{ Heterosis} = \frac{\text{Crossbred Avg. - Straightbred Avg.}}{\text{Straightbred Avg.}} \times 100$$

Breed A: Average WW = 500 pounds
Breed B: Average WW = 520 pounds
A x B Crossbred Calf: Expected Avg WW=510,
Actual performance = 540 pounds

$$\% \text{ Heterosis} = \frac{540 - 510}{510} \times 100 = 5.8\%$$

Heterosis can be observed in three different ways: individual, maternal and paternal heterosis. Individual heterosis is the advantage of the crossbred individual relative to purebred individuals. Maternal heterosis is the advantage of the crossbred mother over the average of purebred mothers. For example, a Hereford x Angus cow would be expected to have greater fertility, more lifetime production and more reproductive success than the average of purebred Herefords and Angus. Maternal heterosis is one of the most powerful tools available to manage reproductive performance in beef cattle. If heterosis only can be utilized in one of these areas, it should be exploited for maternal heterosis. Paternal heterosis is the advantage of a crossbred male over the average of purebred males. Paternal heterosis generally only has an effect on testis characteristics and conception rate. Unlike the beef female, the male does not have any direct effect on growth or survival, so the benefits of heterosis are more limited. However, particularly if young males are being used, the benefit in added conception rate can be important.

Generally, heterosis levels can be grouped into three major classes. Reproductive traits typically show fairly high levels of heterosis. Growth traits generally have moderate levels of heterosis, while carcass traits show very little heterosis. It should be noted that this is exactly the reverse of the general levels of heritability for these classes of traits (Table 27.1). The most important message on heterosis is that it cannot overcome poor-quality genetic inputs. The quality of the offspring produced is directly dependent on the parental stock. Likewise, choice of incredibly high-quality breeding stock does not offset the positive aspects of an effective crossbreeding system, particularly as related to maternal heterosis. Selection of quality parental animals is complementary to crossbreeding systems and should be used together to create an optimal mating system for a commercial herd.

Breed Complementarity

Breed complementarity is the advantage gained from using an optimum combination of breeds. The goal of using breed complementarity is to combine the most positive characteristics and strengths of several breeds into one individual crossbred animal (Table 27.2). When producing replacement heifers, breeds should be chosen that have complementary maternal characteristics and are a logical fit for the production environment. When producing market calves, the optimal blend of growth and carcass characteristics should be the overall goal. When beginning a crossbreeding system, choosing the most appropriate

Table 27.2. Breeds grouped into biological types for seven criteria[a].

Breed	*Growth rate and mature size*	*Lean to fat ratio*	*Marbling*	*Tenderness*	*Age at puberty*	*Milk production*	*Tropical adaptation*
Jersey	X	X	XXXX	XXX	X	XXXXX	XX
Longhorn	X	XXX	XX	XX	XXX	XX	XX
Wagyu	X	XXX	XXXX	XXX	XX	XX	XX
Angus	XXXXX	XX	XXXXX	XXX	XX	XXXX	X
Red Angus	XXXX	XX	XXXX	XXX	XX	XXX	X
Hereford	XXXX	XX	XXX	XXX	XXX	XX	X
Red Poll	XX	XX	XXX	XXX	XX	XXXX	X
Devon	XX	XX	XXX	XXX	XXX	XX	X
Shorthorn	XXXX	XX	XXXX	XXX	XX	XXXx	X
Galloway	XX	XXX	XXX	XXX	XXX	XX	X
Braunvieh	XXX	XXXX	XX	XX	XXXX	XX	XX
Gelbvieh	XXXX	XXXXX	X	XX	XX	XXXX	X
Holstein	XXXXX	XXXX	XXX	XX	XX	XXXXX	X
Maine Anjou	XXXX	XXXX	XX	XX	XXX	XXX	X
Salers	XXXX	XXXX	XXXX	XX	XXX	XXXx	X
Norwegian Red	XXXX	XXXX	XXX	XX	XX	XXXX	X
Swedish Red & White	XXXX	XXXX	XXX	XX	XX	XXXX	X
Simmental	XXXXX	XXXX	XX	XX	XXX	XXXX	X
Limousin	XXXX	XXXXX	X	XX	XXXX	X	X
Charolais	XXXXX	XXXXX	XX	XX	XXXX	XX	X
Piedmontese	XX	XXXXXXX	X	XXX	XX	XX	XX
Belgian Blue	XXX	XXXXXXX	X	XXX	XX	XX	X
Romosinuano	X	XXX	XX	XX	XXX	XXX	XXX
Tuli	XX	XXX	XXX	XX	XXX	XXX	XXX
Brangus	XXXX	XXX	XXX	XX	XXX	XXX	XXX
Beefmaster	XXXX	XXX	XX	XX	XXX	XXX	XXX
Santa Gertrudis	XXXX	XXX	XX	XXX	XXX	XXX	XXX
Bonsmara	XXX	XXX	XX	XX	XXX	XXX	XXX
Brahman	XXXX	XXXX	XX	X	XXXXX	XXXX	XXXX
Nellore	XXXX	XXXX	XX	X	XXXX	XX	XXXX
Boran	XXX	XXX	XX	X	XXX	XXX	XXXX
Sahiwal	XX	XXX	XX	X	XXXX	XXXX	XXXX

a Increasing numbers of X's indicate higher values.
Source: Cundiff, 2014.

breed combinations is the most important first step in implementing the mating system. The goals outlined in the breeding objective will help with this process.

Crossbreeding Systems

Crossbreeding systems fall into two general categories: terminal systems and rotational systems. Both systems have advantages and disadvantages for different types of producers. Larger producers also can combine characteristics of each to capitalize on the advantages of both systems. A general summary, including minimum herd size, number of breeds required and retained heterosis can be found in Table 27.3.

Sometimes, commercial cattle producers are frustrated by textbook rotational crossbreeding systems. The source of frustration originates from the added investment in fencing, labor, time and facilities. If crossbreeding systems are well planned, both production and profitability increase favorably. Unfortunately, poorly planned systems will be frustrating and costs may outweigh the gains in production efficiency. Choose a mating system that will be feasible with the amount of time and labor available for management. It is better to choose a simpler, more manageable crossbreeding system that makes some sacrifices in retained heterosis than to choose a system that cannot be managed properly. Thus, it devolves into random mating, incorrect mating decisions within the system or an ever-increasing diversity and number of breeds being utilized. Fortunately, the diversity of crossbreeding systems and the availability of composites can make the management of these systems accessible and feasible for producers of any size and level of resources.

Terminal Crossbreeding Systems

Terminal crossbreeding systems are defined by their lack of emphasis on maternal traits and strong emphasis on output traits, such as weight and carcass traits. Because

Table 27.3. Summary of crossbreeding systems by amount of advantage and other factors[a].

Type of system		*Cow herd*	*% of Marketed calves*	*Advantage (%)[b]*	*Retained heterosis (%)[c]*	*Minimum no. of breeding pastures*	*Minimum herd size*	*Number of breeds*
2-Breed rotation	A*B Rotation	100	100	16	67	2	50	2
3-Breed rotation	A*B*C Rotation	100	100	20	86	3	75	3
2-Breed rotational Terminal sire	A*B Rotation	50	33			2		
	T x (A*B)	50	67			1		
	Overall	100	100	21	90	3	100	3
Terminal cross with straightbred females[d]	T x (A)	100	100	8.5	0[e]	1	Any	2
Terminal cross with purchased F_1 females	T x (A*B)	100	100	24	100	1	Any	3
Rotate Bull every four years	A*B Rotation	100	100	12 - 16	50 to 67[f]	1	Any	2
	A*B*C Rotation	100	100	16 - 20	67 to 83[f]	1	Any	3
Composite breeds	2-breed	100	100	12	5	1	Any	2
	3-breed	100	100	15	67	1	Any	3
	4-breed	100	100	17	75	1	Any	4
Rotating unrelated F_1 Bulls	A*B x A*B	100	100	12	50	1	Any	2
	A*B x A*C	100	100	16	67	1	Any	3
	A*B x C*D	100	100	19	83	2	Any	4

a Adapted from Ritchie et al., 1999.
b Measured in percentage increase in pounds of calf weaned per cow exposed.
c Relative to F_1 with 100% heterosis.
d Gregory and Cundiff, 1980.
e Straightbred cows are used in this system, which by definition, have 0% maternal heterosis; calves produced in this system exhibit heterosis, which is responsible for the expected improvement in weaning weight per cow exposed.
f Estimates of the range of retained heterosis. The lower limit assumes that for a two-breed system with stabilized breed fractions of 50% for each breed, three-breed rotation assumes animals stabilize at a composition of 1/3 of each breed. Breed fractions of cows and level of maternal heterosis will vary depending on sequence of production.
Source: NBCEC *Sire Selection Manual*, 2nd Edition.

of this, replacement heifers should NEVER be retained in this type of system. All progeny should be marketed within a terminal crossbreeding system. Enhanced opportunity to utilize breed complementarity is the main advantage of terminal systems since male and female breeds can be chosen for specific roles and progeny do not need to fill two roles: production of replacement females and production of high-quality beef products. Any terminal cross should have a breed(s) of males excelling in growth and carcass merit, depending on planned marketing endpoint(s) of resulting offspring. Females should be selected from breeds that are appropriate for the production environment and of adequate mothering ability.

This type of system requires at least two other breeders to supply animals to the terminal system. One of those breeders is the source of replacement females. This breeder should place major emphasis on maternal traits, such as reproductive fitness, milking ability and longevity. The second breeder serves as a bull source for the terminal system and would emphasize growth rate and efficiency. Terminal crossbreeding systems have the potential to generate 100% of the possible individual heterosis provided there are no breeds in common between the sires and dams. This also provides an opportunity to take maximum advantage of breed complementarity.

A variation to the system could be that one producer, rather than the three breeders, carry out the steps. However, the size of the operation would need to be large enough to produce both replacement females and sires for the terminal cross system within separate pastures and management systems.

Aside from maximum use of heterosis and breed complementarity, terminal systems are easy to implement because maternal trait performance can be ignored. Accordingly, selection decisions are easier as selection pressure is applied to fewer traits. Additionally, terminal systems also are implemented easily due to the use of only one breed of male at a time. As a result, only one breeding pen or pasture is needed. Any size operation can use a terminal system as long as the replacements can be purchased. This ease, however, also leads to the big disadvantage of terminal systems. Replacements must be purchased unless a segment of the herd is set aside to generate replacements. Introducing animals from outside the herd can lead to increased incidence of disease and it eliminates control over selection practices. It is important to have a source of replacement breeding stock which is high in quality and has been managed to reduce the possibility of disease transmission (proper

vaccinations and health programs). Johnes, brucellosis, tuberculosis and bovine viral diarrhea (BVD) all are diseases of which to be aware when purchasing animals. On the positive side, the purchase of animals outside the herd can be advantageous. For example, replacements may not need to be purchased every year to take advantage of periods of lower pricing or more abundant supplies. Sometimes it is cheaper to purchase heifers developed by a professional heifer development center or purchase bred heifers already mated to calving ease bulls, so the purchase of an additional "heifer bull" is not necessary.

Two-breed Terminal Sire – This type of crossbreeding system (Figure 27.1) uses purebred cows of one breed (A) and a sire of a different breed (B). Like all terminal crossbreeding systems, no replacement heifers are kept, so they must be purchased. Charolais or Limousin sires used on Angus cows is a common example of this type of breeding system. The main drawback of this mating system is the complete lack of utilization of maternal heterosis, which is very important for fertility and reproductive performance. It does, however, take advantage of 100% individual heterosis in the calves, and a slight improvement in pounds of calf weaned per cow exposed will likely be observed.

Terminal Cross with Purchased F_1 Females – This terminal cross system is very similar to that previously described, with the exception that it allows capitalization on maternal heterosis (Figure 27.2). It produces maximum (100%) heterosis in both the calves and the cows, but does not exploit paternal heterosis. This crossbreeding system is one of the easiest to implement, and all calves will have identical breed composition, which enhances uniformity and marketing opportunities. Additionally, it works for herds of any size, provided they can source high-quality replacement females from a herd with a good health program that satisfies the requirements in the breeding objective and only requires one breeding pasture. When compared to the parent breeds, a 24% increase in pounds of calf weaned per cow exposed is expected.

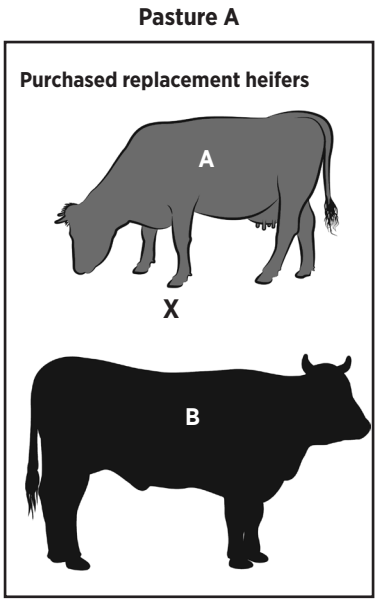


Figure 27.1. Terminal cross with purebred females.

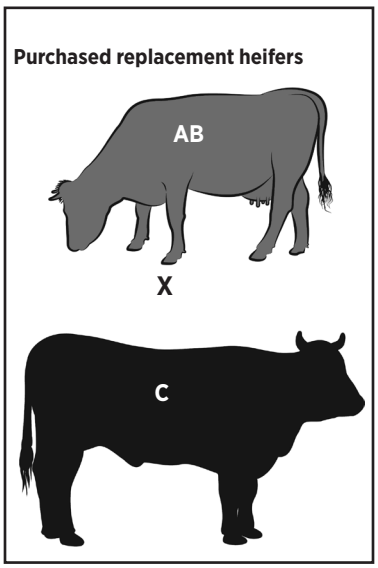


Figure 27.2. Terminal Cross with Purchased F_1 Females.

Rotational Crossbreeding Systems

Rotational crossbreeding systems are defined by their ability to generate replacement females from within the herd. Each cycle or pasture uses a different breed of male, and some female offspring are kept from each cycle as replacements. Keeping replacements from within the herd minimizes risks related to disease transmission, but some amount of heterosis is sacrificed in this process. Generally speaking, the more breeds involved in the rotational system, the less heterosis lost. However, care must be taken that the system chosen is appropriate for the management available and overall size of the production operation, rather than just maximization of retained heterosis. Rotational systems also sacrifice some benefits of breed complementarity, and all breeds used in the rotation must possess superior genetic merit for both maternal and output characteristics without sacrificing cowherd efficiency and fit to the environment. In any given year, more than one breed of males needs to be maintained and multiple breeding pastures must be available.

For any type of crossbreeding system, the choice of breeds is vitally important. Large differences between breeds for many traits of economic relevance make it important to remember inferior breeding stock or stock used unwisely will cancel out benefits of heterosis. Each producer should carefully consider the breeds readily available, design a system that can be used effectively with those breeds and be careful not to deviate from this plan. Setting up an effective rotational crossbreeding system takes time and dedication to establish uniformity in the calf crop. Therefore, to realize success and taking into account management availability, it is vitally important an effective system is chosen and maintained through time.

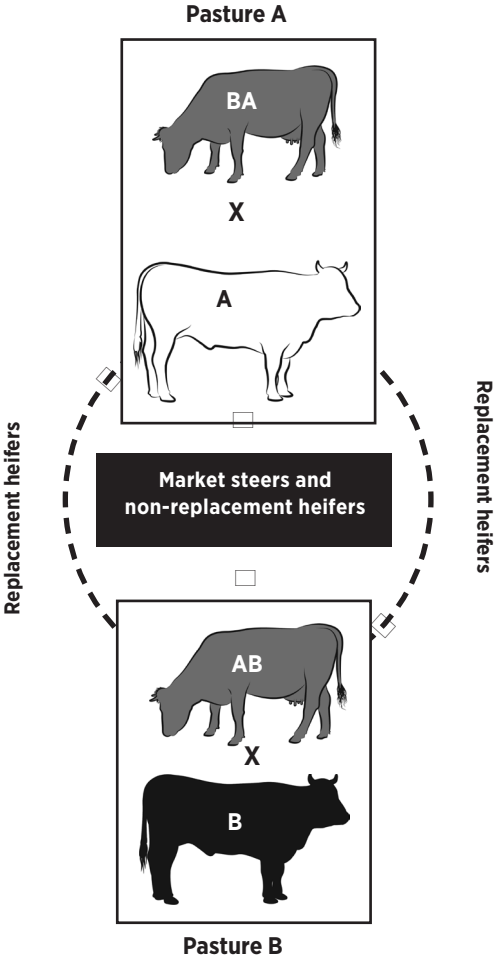


Figure 27.3. Schematic of a two-breed rotational crossbreeding system. Females labeled AB are sired by bulls of breed A and females labeled BA are sired by bulls of breed B.

Two-Breed Rotational Crossbreeding System – The most common example of a rotational crossbreeding system is a two-breed rotation (Figure 27.3) and is the simplest to implement, because it requires the fewest resources. It only requires two breeds of sires, two breeding pastures and a minimum herd size of approximately 50 cows to implement. In this system, females sired by males of one breed are mated to males of the opposite breed. After this system is fully established, approximately 67% of the maximum possible heterosis is retained for both the calf and the cow. Based on this increase in retained heterosis, expect a 16% increase in the pounds of calf weaning weight per cow exposed as compared to the average of the parental breeds. One simple way to manage the breeding pastures and mating needs is to tag calves with colored tags denoting the breed of their sire. Heifers retained in this system would be moved to breeding pastures with cows having the same colored ear tags and bred to the bull of the opposite breed. Breeds should be chosen that minimize color variation and pattern, if possible, to facilitate marketing of calves not retained.

Some breeders will prefer to utilize a three-breed rotational crossbreeding system, which also is set up so females produced in one pasture are rotated to another where they can be bred to the breed of bull sharing the lowest breed composition. The primary advantage of adding an extra breed is an increase in retained heterosis (up to 86% versus 67% in the two-breed rotation), but the disadvantage is the increased complication in management and requirement for an additional breeding pasture.

Combination Systems

Large producers can capitalize on some of the advantages of both terminal and rotational systems by producing replacement females in a rotation of breeds with outstanding maternal performance, and mating older females to a male from a breed with good growth and carcass merit. This allows capitalization on increased genetic change within the rotational system, producing replacement heifers by decreasing the generation interval and emphasizing replacement female selection towards maternal traits. The terminal portion allows for greater productivity of older cows by breeding to high-performance terminal bulls (without worrying about calving ease or maternal traits) to maximize salable weight and/or carcass merit for those retaining ownership. In other words, the cows can be matched to the production environment and the terminal sires can be matched to the marketplace. Figure 27.4 illustrates a combination two-breed rotation and terminal crossbreeding systems, which often are called roto-terminal systems. For example, Hereford and Angus bulls could be mated to all females under the age of five to sire replacement females in a commercial herd within a standard two-breed rotational system. Cows more than five years of age could then be mated to Charolais or Limousin bulls with all offspring from the terminal crosses being sold.

This type of system requires more breeding pastures (at least three) and a herd size of approximately 100 (50 in the rotational portion and 50 in the terminal portion) to be operated efficiently, particularly in regards to purchasing herd bulls of three different breeds. However, this system utilizes breed complementarity within the terminal cross in addition to receiving performance benefits due to maternal heterosis. In a two-breed rotation with a terminal sire, there would be 100% individual heterosis in the terminal portion of the herd, 67% individual heterosis in the rotation part of the herd and 67% maternal heterosis in the entire herd. The cows also would be older before using a performance-oriented bull, so calving difficulties should be minimized.

Composites

Composites and the mating systems associated with them are one alternative to the many crossbreeding systems available to producers. Composites are basically hybrids between two or more breeds of cattle. Popular examples include SimAngus, Lim-Flex, Balancer, etc. A producer should carefully consider the characteristics of composite cattle before choosing to use them. The advantage of utilizing composites is that they can be managed like a purebred herd within a single pasture and encompass as many or as few animals as desired, while still maintaining some heterosis (approximately 50% or greater), depending on the number of breeds used to from the composite and the proportion of each of those breeds within each animal (Table 27.2). Surprisingly, composite cattle retain a high level of hybrid

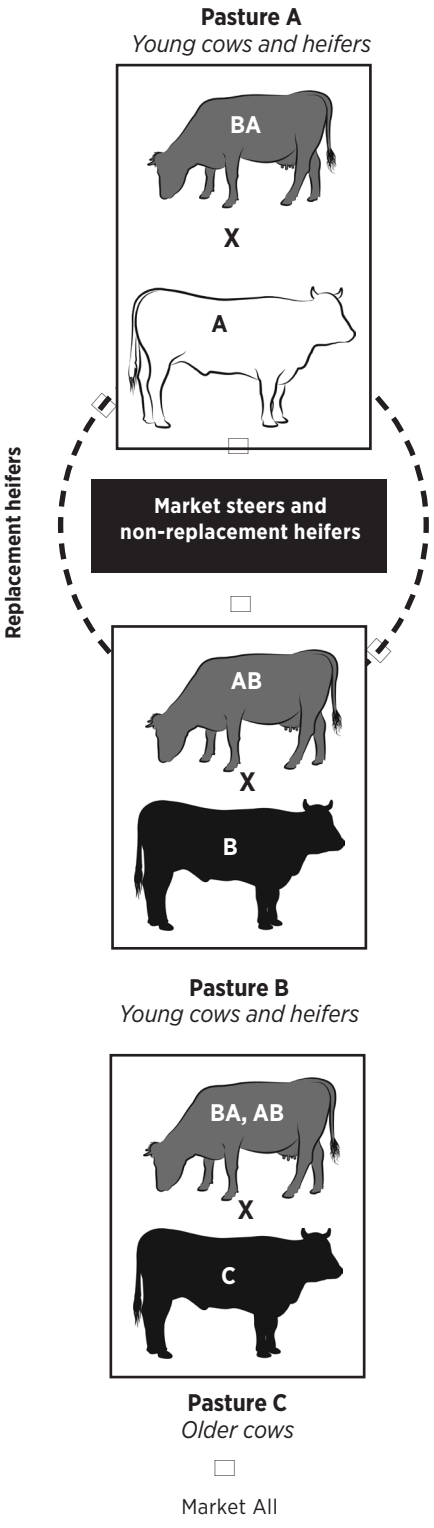


Figure 27.4. Schematic of a two-breed rotational/terminal sire. Females labeled AB are sired by bulls of breed A and females labeled BA are sired by bulls of breed B.

vigor; however, the levels are less than observed in F_1 cross cattle.

Keys to Crossbreeding Success

It is better to choose a simpler, more manageable crossbreeding system that makes some sacrifices in retained heterosis than to choose a system that cannot be managed properly and devolves into random mating, incorrect mating decisions within the system or an ever-increasing diversity and number of breeds being utilized.

The biggest key to success in any crossbreeding system is to choose a viable, manageable system and stick with it. Establishment of a sustainable level of retained heterosis takes several generations of animals, and these systems cannot be set up and reach equilibrium overnight. Therefore, discipline in applying the system's principles through time will ensure the most uniform calf crop and the establishment of a viable system that will provide all the advantages of crossbreeding and function effectively for years to come.

Conclusion

A good breeding program starts with an end goal in mind and designs an effective mating system around those goals and challenges. This is facilitated by consistently and effectively applying selection on the traits economically important in your herd through time and periodically re-evaluating progress towards these goals. Production records must be maintained and utilized to evaluate where changes need to be made to continue progressing towards a sustainable, efficient and profitable beef cattle enterprise.

References

Cundiff, L. (2014). A historic view of the germplasm evaluation program's influence on the US beef industry. 2014 Beef Improvement Federation Research Symposium and Annual Meeting. June 18-21, 2014. Lincoln, NE. bifconference.com/bif2014/documents/PowerPoints/01-BIF2014-USMARC-Cundiff.pdf.

eBEEF. eBEEF fact sheets and videos. eBEEF.org. Accessed June 2015.

Gregory, K. E. and L. V. Cundiff. 1980. Crossbreeding in beef cattle: evaluation of systems. *Journal of Animal Science*. 51:1224-1242.

National Beef Cattle Evaluation Consortium (2006). *Beef Sire Selection Manual* (2nd Edition) Retrieved from: nbcec.org/producers/sire.html. Accessed June 2015.

Oklahoma State University Breeds of Livestock. Retrieved from ansi.okstate.edu/breeds.

Ritchie, H., D. Banks, D. Buskirk and J. Cowley. 1999. Crossbreeding systems for beef cattle. Michigan State University Extension Bulletin E-2701.

Rolf, M. (2015) OSU Extension fact sheet AFS-3174 *Color Patterns in Crossbreed Beef Cattle*.

28 Genetics in the Genomics Era

Mark Johnson and Daniel Stein

Objectives

- **Define important genomics concepts and terms.**
- **Discuss the proper use of genomic information for genetic selection.**
- **Discuss the implementation of genomics in National Cattle Evaluation.**
- **Identify genomic technologies impacting the future of beef cattle selection.**

Terminology

Bases - The building blocks of deoxyribonucleic acid (DNA) sequence. Can be either A, T, G or C. Because mammalian genomes are diploid (two copies of each chromosome, one from each parent), bases are typically talked about in terms of base pairs.

Chromosome - A linear (in mammals) structure comprised of packaged DNA. Bovines have 29 pairs of autosomal chromosomes plus the sex chromosomes.

DNA Markers - Mutations at a specific place in the genome, which can be utilized for genomic analyses.

Genome - The sum total of all genetic material in an animal ,including DNA found in the nucleus of a cell. Also may include DNA from the mitochondria (mitochondrial genome).

Heterozygous - The organism possesses two different alleles at the same locus (for example, CT or AB). Heterozygous animals can be referred to as carriers because they "carry" two different forms of the allele.

Homozygous - The organism possesses the same allele (two copies of the same allele) on each chromosome at a locus (for example, CC or TT, AA or BB).

Microsatellite - Repeats of certain pieces of the DNA sequence that can be used as genetic markers. Genotypes are typically expressed as the number of repeats (for example, 123/126). These markers are sometimes used in parentage panels, but their use is declining due to expense and assay difficulty.

Scored - Refers to the act of recording a genotype on an animal.

SNP - Stands for Single Nucleotide Polymorphism. Pronounced "snip." A single base mutation in the DNA sequence that can be used as a genetic marker. For example, one chromosome exhibits an A and another a G at the same position (which would be called an A/G SNP). These types of markers are gaining in popularity due to their ease and decreasing expense to genotype.

SNP chip - Panel of SNP markers used to obtain genotypes on an animal. Common SNP chips used in the beef industry include the 50K, 80K and 150K. Lower density chips also are used by some breed associations.

What is DNA?

Use of genomic technologies in the beef industry is ever-increasing. To understand the value and use of DNA markers, it helps to begin with basics about the genome and DNA. DNA provides the code needed to perform processes within an organism's body both to keep it alive and to perform in an expected way. DNA is simply a sequence of nitrogen bases (coded A, C, T and G) bound together in long strings that are packaged into chromosomes within each cell. All of these chromosomes make up an organism's genome.

There are enough bases (letters) within the cattle genome to fill up approximately 2,000 New York City phone books. Given that, think of the genome as a giant stack of large phone books. Each book is like a chromosome and the entire stack of books is the genome. Inside each of the books, the names and numbers represent the DNA sequence.

Cattle have 29 pairs of autosomal (non-sex determining) chromosomes and one pair of sex chromosomes (either XX for females or XY for males). Cattle inherit one chromosome from each of their parents, so for every place in the genome, there are two different alleles (alternative forms of a gene). This is why genotypes (genetic make-up of an individual) are recorded in pairs (for example, AA, BB or AB). Some regions of the genome are the same in all animals of a species. Regions of the genome that vary between animals

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

are mutations, and these mutations can be used as DNA markers. If an animal has two copies of the same mutation (PP or pp), they are homozygous (think homozygous polled or horned). If an animal has two different copies of the mutation (Pp), they are heterozygous (think heterozygous polled).

What are DNA Markers?

There are several different types of DNA markers used in the beef industry today. The oldest type are called microsatellites, and these are small pieces of DNA (a few bases) that are repeated over and over again. These markers would be scored and the genotype recorded as the number of repeats. For example, a heterozygous animal might have a genotype of 123/142, meaning one chromosome has 123 repeats, and the other had 142 repeats. Microsatellite markers often are used in parentage testing, although their use has declined in recent years. Because microsatellites are numbers of repeats, there often are more than two possible alleles at any given location. This makes microsatellites a very powerful tool, but also harder and more expensive to assay. A newer type of marker, SNPs, have increased in popularity because they are simpler and less expensive to genotype than microsatellites. SNPs are a single base change in the DNA sequence and typically only have two possible alleles at any given location. A SNP genotype would look like A/C, or G/T if calling the bases directly, or AA, AB or BB using genetic coding.

Returning to the phone book analogy, think of microsatellites as common last names in the phone book. If examining a phone book, likely the last name Smith or Jones is repeated many times, just as combinations of DNA bases repeated in a microsatellite. SNP markers are similar to finding small typos in the phone books. Only one letter has changed, but it can be identified and tracked within the phone book. When performing a genetic marker test, it is similar to testing each phone book for the errors or repeated names at known positions. Unlike receiving the entire phone book, only some of the "errors" are received. Not every typo or repeat is surveyed, but given those that have been obtained, tests can be performed for characteristics of important regions of the genome.

DNA markers are used in genomic applications just like one would use a marker on the side of a road while taking a long trip. Consider planning a trip across the U.S. from Boston, MA to San Diego, CA, which is about 3,000 miles (Figure 28.1). Since the bovine genome is about 3 billion base pairs, it makes an easy comparison. If there are only 300 road markers (300 SNP markers) for your road trip, There is a marker every 10 miles (10 million bases). If you have 50,000 road markers (like a 50K SNP chip), there is a marker every 316.8 feet (60,000 bases). If given the task of finding an interesting landmark to visit on the trip, it would be much easier to find one with markers every 316.8 feet rather than every 10 miles. SNP markers within the genome work similarly: the more markers you have, generally the easier it is to locate interesting regions of the genome that affect economically important traits in livestock.

Figure 28.1. Map depicting a trip from Boston, MA to San Diego, CA.

As genotyping prices continue to decrease, these types of tests will become even more affordable and have greater industry acceptance.

Uses of DNA Technologies

There are a variety of options for utilization of genetic testing, including parentage testing; management of genetic abnormalities; testing for simply inherited traits, such as coat color; and panels dedicated to production traits.

Parentage Testing

Parentage testing involves using DNA markers to establish the most probable sire (or dam) for a particular calf. Parentage testing is typically used to exclude potential sires, as dams are typically assumed known. In the past, parentage testing was performed exclusively with a small number of micro-satellite markers. Most organizations are now, or have already transitioned to a larger number of SNP markers for parentage testing because they are abundant, can be automated, have low error rates for genotyping and are easy to standardize between different testing laboratories and organizations.

To more closely examine how parentage testing works, consider this example using SNP genotypes at one locus being used to identify the most likely parent of the calf:

Sire 1	Sire 2	Dam	Calf
A1 A2 A G	A1 A2 G G	A1 A2 G G	A1 A2 G A

Because one allele is inherited from each parent, one can start by examining the dam genotypes. She is homozygous for G, so it is known she passed on a G to the calf. Upon examination of the calf's genotype, it can be seen that the G must have come from the dam, which means the A was inherited from the sire. Sire 1 could have passed on an A allele, but sire 2 could not have, because he is homozygous G. In this case, where dam genotypes are known, and there are a small number of potential sires,

sire 2 can be excluded by using only one locus. However, if the dam genotypes were unknown, exclusion of either sire is not possible. While parents can be excluded using this process, results from parentage testing cannot be used to conclusively prove parentage. Additionally, paternity testing is complicated when close genetic relationships exist between bulls, because they are more likely to share the same marker alleles. Because of this limitation, it is very helpful to avoid using related sires in multi-sire pastures and obtain dam genotypes whenever it is cost effective to do so. Additionally, because this approach only excludes sires, it is vital all potential sires are submitted for testing to avoid an incorrect result. To make this process easier, it may be helpful to collect DNA samples from all sires before turning them out at the beginning of the breeding season.

Parentage testing often is utilized to verify the sires and dams of embryo transfer calves and used frequently to discern between an artificial insemination sire and a herd sire when the calf's birth date is somewhat ambiguous. It also can be utilized in multi-sire pastures to evaluate the efficacy of a sire and manage genetic potential within the herd. A bull's worth in a commercial cattle operation is relative to his ability to sire calves with additional value captured when he sires calves with superior performance. The second objective can be evaluated and selected for using EPDs. However, in multi-sire pastures, the bull's ability to sire calves can be hard to pinpoint without additional information. Genetic testing to establish parentage in multi-sire pastures can be a valuable tool. Knowledge of which bulls are making money, and which are a drain on limited resources is an effective, if not essential, risk management tool.

Genetic Abnormality Testing

In recent years an abundance of genetic defects in a variety of breeds have resulted in substantial associated economic losses. In this section, how genetic defects are inherited, how to determine the probability of producing an affected calf and strategies to decrease issues related to genetic defects in the herd will be discussed.

Inheritance

The cattle genome is made up of 29 pairs of autosomal chromosomes plus the sex chromosomes. Genetic defects are a result of mutations resulting in alleles that cause a lethal condition or severely handicap the performance of an individual. Simply speaking, at any location in the genome where there is a mutation, there are two alleles, which can be thought of as alternate forms of a gene. One allele comes from the sire and the other from the dam. Many mutations within the genome cause no known effects. Alleles of interest are either those which cause small effects on phenotype (the animals' performance or how it looks), typically for performance traits, those which cause large detrimental effects on phenotype, or those that are lethal. Most genetic defects in beef cattle are a result of autosomal recessive mutations. The term autosomal recessive reflects the mode of inheritance for these defects, meaning the mutation is on one of the 29 autosomal chromosomes (not a sex chromosome). These conditions are not expressed as a phenotype unless the animal receives two copies of the damaged allele (one on each of the two chromosomes inherited from its parents). The inheritance of these genetic defects works exactly like the inheritance of horns or red coat color, which also are autosomal recessive conditions and require two copies of the red (or horned) allele before a difference is seen in phenotype. Because these traits are recessive, possessing only one copy of each of these alleles (a defect, red color or horns) is not enough to change phenotype, because it is masked by a dominant allele (normal condition, black color or polled). These animals often are called carriers, because they carry a recessive condition, but do not express it.

In any mammalian genome (the size of most mammalian genomes is 3 billion base pairs), it is almost assured there will be multiple recessive lethal genetic defects present within the DNA sequence. However, because they often are recessive, there must be two copies in the genome (one from each parent) to see affected progeny. In practice, the pairing of two disease alleles rarely occurs when animals are not inbred, because each animal likely carries mutations that cause different conditions. One of the best strategies to avoid incidence of genetic defects is to avoid mating animals to their relatives, or to employ a planned crossbreeding system (but keeping carrier status in mind when mating animals having a common breed composition).

Determination of Risk

When the mode of inheritance is known, the probability of producing an affected calf can be calculated by knowing the carrier status of the parents. Because the normal allele is dominant, there is no way to visually determine which animals are carriers and which are not. The only way to make that determination is through genetic testing or through known parentage of an affected calf.

If the animal tests as normal for a particular genetic defect, it has two normal alleles (represented by NN) and if the animal is tested and determined a carrier, it has one normal allele and one disease allele (represented by Nn). If an animal has ever produced an affected progeny (where the defect can be observed in the phenotype, represented by nn), they can automatically be determined a carrier (Nn) and do not need to undergo genetic testing. If an inherited disease/defect is lethal, all adult animals are either normal or carriers (NN or Nn). They cannot have two copies of the disease allele (nn) and live.

When the carrier status of the parents is known, the probability of producing normal, carrier or affected progeny can be calculated using what is called a Punnett square. It is simply a square with four quadrants and works like a multiplication table. The alleles for each possible parental gamete (sperm and egg) are placed around the outside. The letters are matched on the interior squares and the percentages are multiplied together to determine the probabilities of each status in the progeny. To illustrate this point, consider the following examples:

Example 1: Punnett square for the mating of two normal (NN) animals.

		Male	
	Potential Gametes	*N* 50%	*N* 50%
Female	N 50%	NN 25%	NN 25%
	N 50%	NN 25%	NN 25%

In the example shown above, the two parents tested as normal, and do not carry any disease alleles. Because each gamete will contain one of the two parental gametes, each one will be seen approximately 50% of the time (outside column and row). Both parents are normal, so there are N gametes 100% of the time and all progeny (inside the bolded square) will have all normal alleles. This result illustrates why animals can be declared "clean" through pedigree. If the sire and dam have both been tested and determined carrier-free, any progeny of the mating will be free of disease alleles and do not need to undergo genetic testing.

Example 2: Punnett square for the mating of one normal (NN) and one carrier animal (Nn).

		Male	
	Potential Gametes	N 50%	n 50%
Female	N 50%	NN 25%	Nn 25%
	N 50%	NN 25%	Nn 25%

In Example 2, the mating of a carrier bull to a normal female. The female's gametes will assort the same as in Example 1, and she will always contribute N (normal) alleles to her progeny. The sire, however, can contribute either a normal (N) or disease (n) allele to his progeny. Each allele will occur in approximately 50% of his gametes, meaning one half will be normal and one half will contain the disease allele. When the possible gamete combinations (seen inside the bolded square) are matched, = half of the calves (50%) will have two normal alleles (left side of the bolded box) while the other half of calves will be carriers (Nn - right side of the bolded box). In this scenario, affected calves are not seen, but they do have the potential to transmit the disease alleles to progeny in the next generation.

The only time affected calves are generated is when two carrier animals are mated together, such as illustrated in Example 3. Each sire and dam produces 50% gametes with normal alleles and 50% with disease alleles. When combined together in the progeny (bolded black box) all three genotypic classes can be present. This can be interpreted in terms of each progeny or in terms of a group of progeny produced from a group of carrier sires and dams. In the former, each progeny from the mating would have a 25% chance of having two normal alleles, a 50% chance of being a carrier and a 25% chance of being affected (yellow box). In a group scenario (for example, a large number of full-sib flushmates), 25% of progeny is expected to have two normal alleles, 50% to be carriers and 25% to be affected. Knowing the carrier status of the herd through genetic testing makes effective risk management possible.

Example 3: Punnett square for the mating of two carrier animals (Nn).

		Male	
	Potential Gametes	N 50%	n 50%
Female	N 50%	NN 25%	Nn 25%
	n 50%	Nn 25%	nn 25%

Strategies to Manage Risk of Genetic Defects

Whether or not there is a genetic test for the defect of interest, the incidence of genetic defects will dictate how it can be managed. If there is a test available for the genetic defect, it is advantageous to test those animals which have never had an affected calf, placing special emphasis on testing individuals which have carrier animals in their pedigrees. There is no need to test an animal that has produced an affected progeny, since they are known carriers or one out of two animals that are tested "clean." If an animal is genetically superior in many other ways, but is a carrier of a genetic defect, they do not need to be culled immediately. As observed in the Punnett square examples above, as long as a carrier is always mated to an animal that has two normal alleles (homozygous normal), they will never have affected progeny. However, those progeny will then need to be tested to determine if they are carriers. It is a good risk management practice to test any animals to be retained, such as replacement females, if there is a chance they may be carriers. Alternatively, females do not need to be tested if only non-carrier bulls are utilized. As a general rule, animals scheduled for culling do not need to be tested.

Seedstock producers are encouraged to be cognizant of any breed registry requirements relevant to an animal's carrier status. Some breed associations do not allow carrier animals to be registered, and many will require testing to determine carrier status if there are carriers in the animal's pedigree, provided that a genetic test exists. Often, progeny of animals that are carriers can be registered if the genetic test shows the animal itself is not a carrier. It is much more effective to know these requirements before making decisions regarding replacement females or culling, rather than suffering the consequences later. Breed associations do a very good job of identifying and clearly displaying the

status of carrier animals on the breed association webpages. If there are questions about whether a carrier animal can be registered, contact the breed association for more information.

Commercial cattlemen may find it easier to manage the genetic defect, rather than indiscriminately cull animals. For example, if a known normal (NN) bull is purchased, the carrier status of females may not matter because there will be 100% normal calves with an autosomal recessive inheritance. Alternatively, if using a bull in one breed on cows of another breed in a crossbreeding program, the likelihood of encountering the same defect in two different breeds is extremely low. Because of this, crossbreeding can be an effective risk management strategy for genetic defects. However, it should be noted that care must be taken when keeping replacement females if utilizing bulls of the same breed in subsequent years so no affected calves are produced.

Testing Procedure and Availability

If ordering DNA tests for genetic defects in beef cattle, there are several providers. Contact your provider to obtain information on pricing, sample submission procedures and preferred sample types. If test results are desired to be utilized by a breed association, make sure to follow the association's procedures for sample submission. Often, the sample should be submitted to the breed association office first, rather than submitting samples to the company directly.

Knowing how genetic defects are inherited can assist in making good management decisions, both to preserve genetic progress and reduce or eliminate economic losses associated with genetic defects. In addition, awareness of genetic defect testing and how to calculate the risk of producing affected progeny will help analyze risk and manage the incidence of genetic defects and their associated economic losses in the herd.

DNA Testing for Qualitative Traits

Qualitative traits, also called simply-inherited or Mendelian traits, are those controlled by one or a few genes in the genome. Knowing the genotype of an animal at these loci will often provide the information needed to determine the phenotype. Examples of these types of traits include coat color or horned/polled status. These types of traits are excellent candidates for marker assisted selection. The Punnett squares outlined before will help determine the odds of obtaining a desired phenotype in the same way they can be utilized for risk management of genetic abnormalities. For example, breeding two heterozygous polled animals will yield a 25% chance for either horned or homozygous polled offspring and a 50% chance for producing a heterozygous polled offspring.

DNA Testing for Quantitative Traits

Availability and adoption of genomic technologies has been expanding rapidly in the last few years. A variety of products are now available for many different types of cattle. Modern genomic profiles result from a panel of DNA markers. This genomic information, in tandem with phenotypic performance data collected from within contemporary groups and pedigree information provides values that can be used in the calculation of genomic-enhanced EPDs. Most major U.S. breed associations are utilizing these technologies in their National Cattle Evaluation programs. The Beef Improvement Federation has outlined the position that the value of genomic testing can only be realized when the results are incorporated into National Cattle Evaluation and provided to producers in the form of an EPD and its associated accuracy. These are most commonly called genomic-enhanced EPDs. When both a genomic-enhanced EPD and separate, individual results from a genomic test both exist, selection should ALWAYS be practiced on the genomic-enhanced EPD alone, as it already incorporates performance data, pedigree data and the genomic test. The result of all of this information being incorporated into the genomic-enhanced EPD is an increased accuracy of the EPD, which means increased in confidence in the EPD estimate. These accuracy increases often are expressed in terms of progeny equivalents, which can range widely (some estimates have included anywhere from two to 20 progeny equivalents, although they vary from breed to breed and from one test to another), depending on the heritability of the trait and the amount of genetic variation the test explains. This expression equates the information gained from the genomic test to a specified number of progeny out of the sire or dam which would provide an equal increase in accuracy. To find out the current progeny equivalents for a particular test, consult the specific breed association. It is important to invest in this technology only if a robust test exists for your breed of cattle.

One of the main advantages of genomic testing is the increase in accuracy observed on young animals, which receive genomic-enhanced EPDs. In effect, this shortens the generation interval because more accurate culling decisions can be made earlier in the animal's life. Depending on the trait, genomic-enhanced EPDs on unproven bulls have the same amount of accuracy as if they had already sired 10 to 36 calves, depending on the trait. Examples are shown in Table 28.1.

Best Use of DNA Technology for Production Traits

Potential benefits from genomic selection, which is using high-density genomic testing data for selection decisions (like using genomic-enhanced EPDs), are greatest for traits that:

1. Are lowly heritable (such as fertility and longevity).
2. Are difficult or expensive to measure (such as feed efficiency or disease resistance).
3. Are measured late in life (longevity or stayability).
4. Are not typically measured in breeding animals (carcass traits).
5. Are sex-limited and cannot be measured on that sex of animal (for example, milk production in bulls).

It is important to remember these tips for success:

1. Only use a test designed for the breed of cattle owned (for example, do not use a test designed for Angus cattle on Hereford animals).

Table 28.1. Progeny equivalents (PE) - Carcass trait PE equate to actual carcass harvest data not ultrasound scan equivalents.

Trait	*PE*
Calving ease direct	26
Birth weight	23
Weaning weight	27
Yearling weight	23
Scrotal circumference	15
Dry matter intake	12
Docility	12
Claw angle	10
Foot angle	10
Calving ease maternal	20
Heifer pregnancy	17
Milk	36
Mature weight	15
Carcass weight	15
Carcass marbling	11
Carcass ribeye	17
Carcass fat	14

Source: angus.org Sire Evaluation Report. *Genomics*, 2020

2. Verify the test being considered explains a sufficient portion of genetic variation to provide useful information (check with the breed association to get current information on progeny equivalents to better evaluate potential return on investment).
3. Reward producers who provide the additional information (whether it is genomic data, ultrasound data or whatever data deemed most important) needed to make appropriate selection decisions.
4. Keep in mind the expected additional value from being able to buy animals with increased accuracy at a young age.
5. Whenever confronted with two types of information (for example, genomic enhanced EPDs vs a genomic test result), always choose to select on the metric providing the most comprehensive data on an animal's genetic merit (in the previous examples, the genomic-enhanced EPD should be the primary selection tool.)
6. Carefully consider return on investment in this technology and invest in those products that provide ample return on investment, and pass on using those that do not.

Conclusion

Genomic-enhanced EPDs are the best estimate of an animal's genetic value as a parent, combining all sources of information. Genomics permit higher prediction accuracies for younger animals and characterizes genetics for traits where it is difficult to measure the phenotype.

References

Angus Sire Evaluation Report. Genomics. angus.org. Accessed July 2020

eBEEF. eBEEF fact sheets and videos. eBEEF.org. Accessed June 2015.

National Beef Cattle Evaluation Consortium (2006). *Beef Sire Selection Manual* (2nd Edition).

NBCEC Brown-Bagger Presentations. nbcec.org/professionals/brownbag.html. Accessed February 2015.

Oklahoma State University Breeds of Livestock. Retrieved from ansi.okstate.edu/breeds.

Rolf, M. (2012) Using Genomics Part I: What are DNA Markers? OSU Cooperative Extension Fact Sheet. AFS-3167.

Rolf, M. (2013) Using Genomics Part II: Risk Management of Genetic Defects. Oklahoma Cooperative Extension Fact Sheet. AFS-3170.

Rolf, M. (2015) OSU Extension fact sheet. AFS-3167, *Collecting a DNA Sample*.

Rolf, M. (2012) Using Genomics Part I: What are DNA Markers? Oklahoma Cooperative Extension Fact Sheet. AFS-3174.

29 Development of Replacement Beef Heifers

Daniel Stein and David Lalman

Objectives

- **Discuss heifer development program goals.**
- **Explore heifer development nutritional strategies.**
- **Discuss various management decisions related to replacement heifers.**

When it comes to obtaining females to replace culled heifers or cows to maintain herd size or obtaining females to increase the herd numbers to expand the herd size, cow-calf producers have a choice of either retaining heifers raised within their own herd or purchasing open or pregnant heifers or cows. There are advantages and disadvantages with each of these approaches. Producers must take into account several factors such as market prices, production costs and tax implications when determining the optimal herd replacement strategy that will fit their breeding program (Clark et al., 2005; Shulz and Gunn, 2014). Many cow/calf operations will have the knowledge, expertise and resources conducive to a replacement heifer enterprise and will choose to retain, develop and breed heifers from their own herd for the purpose of replacing culled breeding females; while others operations may be better suited to purchase either open or bred replacement heifers or cows. The current-year replacement heifer selection will impact the genetic make-up and production traits of the beef herd for the next seven to 10 years. The implementation of proper selection criteria, growth and developmental strategies, health and nutritional programs and breeding strategies of replacement heifers are essential to meet both short-term and long-term objectives of the operation (Bridges, 2013).

Importance of Early Calving at 2 Years of Age

The time period required for replacement heifers to pay for their development and maintenance is referred to as the payback period (Moorey and Biase, 2020). This payback period will fluctuate between different operations. Typically, six calves are necessary for the female to pay for her development and maintenance expenses. That is, a 7-year-old female producing her sixth calf is the break-even point. If the female does not produce a calf one year, the payback period is nine calves (Moorey and Biase, 2020). Research shows heifers becoming pregnant early in their first breeding season, whether through natural service or artificial insemination, remain in the herd longer and produce more cumulative calf weaning weight (Lesmeister et al., 1973; French et al., 2013). More specifically, Cushman et al., (2013) reported heifers that calved the first 21-day period of the calving season had increased herd retention compared with heifers that calved in the second 21-day period or later. Similarly, Funston et al. (2012) found heifers born in the first calving period had a higher first conception rate, a higher percentage calving in first 21 days, a greater first calf weaning weight and a higher second conception rate than heifers born in the second or third calving period. In a Canadian study, Damiran et al, (2018) reported an increased longevity in heifers that had their first calf during the first 21-day period of the calving season (7.2 years ± 0.3) compared with heifers that calved in the second (6.5 ± 0.4 years) and third 21-day periods (6.2 ± 0.4 year) with no differences in longevity between the group two and group three period heifers. Bridges (2013) suggested if a heifer conceives late during the breeding season compared to her herd mates and calves late during the calving season compared to her herd mates, that heifer is more likely not to be cycling at the beginning of the upcoming breeding season and will, more than likely, conceive late during the second breeding season. This recurring cycle of events is likely to carry on until eventually the female will turn up

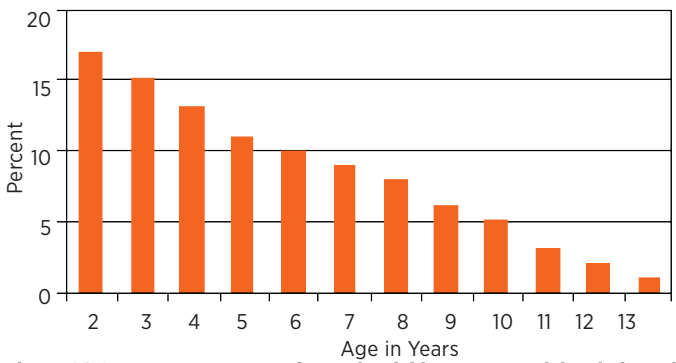


Figure 29.1. Mean percentage of cows in Dickinson research herd plotted by age of cow. Source: Ringwall.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

open during the breeding season and will probably be culled. Therefore, the replacement heifer program, whether raised or purchased, should strive to achieve a high percentage of heifers calving early during the first calving season to maintain lifetime reproductive efficiency. This can be accomplished by retaining and exposing more heifers than needed to a short breeding season (30 days to 45 days) and retaining only the heifers that become pregnant during that time. Pregnancy status should be determined as soon as possible after the breeding season ends (approximately 30 days) and open heifers can be marketed as feeder heifers.

Heifer Development from Birth to Weaning

In most beef cow-calf operations retaining heifers raised within their own herd, the early development of replacement heifers is entrusted entirely to the heifers' mothers. However, some producers use creep feeds to boost calf gains while the calves are still nursing. Occasionally, some purebred operations raising embryo transfer calves will utilize dairy cows as surrogate mothers and these calves are exposed to large quantities of milk while growing. Even though the cost effectiveness of these practices often is debated, there is little doubt they will increase calf gain.

A hidden expense, which might occur in a few instances, comes as a result of increased body condition in young heifer calves while still nursing their mothers. High-energy creep feeds or very heavy milking mothers that cause heifers to become extremely fat can unfavorably influence replacement heifer performance by depressing future milk production and lifetime productivity (Holloway and Totusek,1973; Martin et al., 198; Sexten, et al., 2004). Mammary development is in a critical stage from two months to three months of age until about nine months or just before puberty. If a calf is storing considerable amounts of extra fat during that time, excessive fat can be deposited in the mammary gland and inhibit its development. On the other hand, a certain minimum amount of fat is necessary for the gland to grow, so underfeeding can inhibit development as well.

The use of creep-feeding should be evaluated by the producer to determine if it will provide production and economic benefits to the operation. Nursing pressure on the cow has rarely been shown to be reduced with creep feeding as research indicates milk intake by creep and non-creep fed calves is similar. Faulkner et al., (1994) showed forage DM intake decreased linearly with increasing levels of creep feed, whereas milk DM intake was not affected by level of creep feed. Lusby (1989) reported calves prefer milk first, highly palatable creep second and forage third and suggested when milk and forage are available, creep feed may become a substitute for forage. Thus, creep feed may be advantageous only when forage supplies need to be extended. However, conflicting data can be found in the literature regarding the effect of creep feeding on forage intake as Loy et al., (2002) reported no difference in forage consumption by calves fed creep feed.

Beef producers need to observe heifer body condition if they are using high-energy creep feeds or dairy-based recipient cows. Because of the differences in birth weight and frame size, it is impossible to recommend a common average daily gain appropriate for all young heifers. Therefore, monitoring the body condition (fatness) of the heifer calf through visual appraisal may be the most practical way to evaluate the potential likelihood of excess fatness (chapter 15). Creep-feeding calves with a self-limited amount of high protein feed, such as soybean meal, can allow most heifer calves to grow adequately without concern for extreme fatness. One such creep-feeding program has been described by OSU beef nutritionists as the Oklahoma Silver program (chapters 21 and 22).

Implant or No Implant

Research has clearly shown the timing of implanting and the number of implants given can impact fertility in heifers. However, there is little, if any, detrimental effects on reproductive performance of heifers that will potentially be retained as replacement animals when administered growth-promoting implants at the time of branding (2 months to 4 months of age) or at the time of weaning. In fact, in research trials where one implant was administered to heifer calves between 30 days of age and weaning, calving difficulty was not influenced and fertility was only slightly reduced; a 1% to 3% reduction in pregnancy rate (Selk, 1997). In two recent studies (Rosasco et al., 2018; 2019) implants administered at branding time (3 months of age) or at weaning did not influence subsequent reproductive performance of retained females. On the other hand, weight gain is consistently improved when heifers are implanted at branding or at weaning (Selk, 1997; Rosasco et al., 2018; 2019).

Heifers implanted at birth and close to puberty, generally around 9 months to 14 months of age, had substantially reduced fertility that ranged from a 7% to 39% reduction in pregnancy rate compared to nonimplanted heifers (Selk, 1997). Similarly, heifers implanted more than once had substantially reduced fertility. Therefore, heifers potentially be kept as replacement females should either not be implanted at all, or they should be implanted only one time between 30 days of age and weaning age. Replacement heifers should not be implanted prior to 30 days of age or after about 7 months of age, and they should never be implanted more than once.

Immunizations from Birth through Weaning

Early immunization for blackleg and malignant edema at approximately 2 months of age will be appropriate in most areas for all calves including those becoming replacements. If heifers are to be vaccinated for brucellosis, be certain to do this between 4 months and 10 months of age in Oklahoma. It is advisable to vaccinate heifers nearer the younger age if

possible. Other immunizations should be done three weeks to four weeks prior to weaning. Booster injections can be given at weaning time (Caldwell, 2019).

Visit with a local veterinarian about the need to vaccinate replacement heifers for:

- Infectious Bovine Rhinotracheitis (IBR).
- Bovine Virus Diarrhea (BVD 1 and 2).
- Parainfluenza–3 (PI3).
- Clostridial vaccines also known as 7–way or 8–way blackleg vaccines.
- Hemophilus.
- Leptospirosis.
- Camplyobacter (sometimes called Vibriosis).
- Pinkeye vaccines in relationship to the high-risk period of disease such as late spring and early summer.
- Internal and external parasite control (chapters 38 and 39).

Fortunately, many of the above immunizations are now included in combination vaccinations. Use the one most appropriate for the herd health history and local disease situation.

Weaning stress can result in serious health problems, especially respiratory disease. Heifers affected with respiratory disease and pneumonia often have significant lung damage, do not grow and develop properly and must be culled prior to breeding.

Influence of Modified Live Vaccines on Reproductive Performance

Infectious reproductive diseases are a continual threat to the beef herd as reproductive performance can be negatively affected throughout the reproductive cycle of the female. Bovine Viral Diarrhea and Infectious Bovine Rhinotracheitis (bovine herpesvirus) are two diseases often vaccinated for in the beef herd. Affected reproductive performances from infectious reproductive diseases that have been reported in the literature include decreased ovulation rates, fertilization rates, embryonic survival rates and fetal survival rates (Chiang et al., 1990; Perry et al., 2013). Commercial vaccines are a readily available and beneficial tool in the prevention of these diseases; however, vaccination does not always mean immunization, as each individual animal's response to the vaccine will vary (Perry et al., 2017; Caldwell, 2019).

Veterinarians regularly recommend female beef cattle be vaccinated with either a modified-live virus (MLV) or inactivated virus vaccine (IVV) to reduce the risk of reproductive failure. However, there is evidence MLV versions of some vaccines can have negative effects on reproductive performance in well-managed herds (Perry et al., 2018). MLV vaccines can possess an unacceptable risk of causing undue harm if administered to previously unvaccinated pregnant heifers or cows, or if administered as the initial dose of MLV vaccine to heifers or cows within a minimum of 30 days of breeding (Givens and Newcomer, 2017). The choice of the type of pre-breeding vaccine to use and the timing of its administration is a choice the producer needs to carefully consider. The producer should always strive to determine the best balance between appropriate disease protection and minimal harmful effects from the vaccines themselves. This balance will be different for each cattle operation across the country, making it imperative that cattle producers consult their local veterinarian to discuss the most current information on all products available when making decisions about pre-breeding vaccinations in their herds (Daly, 2016; Perry et al., 2017). This balance to achieve appropriate disease protection also includes other management practices besides vaccinations. As the gestating fetus is the most susceptible individual within a cow–calf operation (Caldwell, 2019), the producer should always be cognizant of the fact the purchase of a pregnant cow, where the disease status of the fetus is unknown, is considered by many to be the number one method of bringing BVD into the herd (Walz, 2020).

Development from Weaning through First Breeding Season

Target Weight for First Breeding Season

A major decision related to the post-weaning development strategy revolves around the idea of a targeted weight for heifers to reach by the beginning of the first breeding season. This target weight is generally defined as body weight expressed as a percent of expected mature weight. Thus, to be able to define and execute a target weight goal, one must first have an accurate estimate of average mature cow weight. Mature cow weight should be determined using cows that range from 4 years to 7 years old, weights recorded at or around the time of weaning and adjusted to a body condition score of 5 (see chapter 20). Sale weights of culled mature cows can be used if collecting weight data from cows in the current inventory is not practical.

Target weight strategies in the heifer development program basically fall into two categories:

a) Approximately 55% of expected mature weight achieved by the beginning of the first breeding season. This strategy is sometimes characterized as lower input or a more extensive heifer development system.
b) Approximately 65% of expected mature weight achieved by the beginning of the first breeding season. This strategy is sometimes characterized as higher input or more intensive because more nutritional inputs are required.

Factors affecting the timing of puberty and early pregnancy at 14 months to 15 months of age include genetics, photoperiod, level of nutrition and growth rate (Wiltbank et al., 1966; Schillo et al., 1992; Martin et al., 1992; Hall, 2013). In general, it has been well documented that an inverse relationship exists between post-weaning level of nutrition

and age at puberty (Short and Bellows, 1971; Beverly and Spitzer, 1979). Similarly, early pregnancy is related to the number of heifers achieving puberty and first estrous cycle prior to or soon after the beginning of the first breeding season (Short and Bellows, 1971; Byerley et al., 1987). This early research provided the foundation for the guideline to develop heifers to a target weight of 65% of expected mature weight by the beginning of the first breeding season.

The 65% rule of thumb has been effective over a wide range of environments and breed types (Patterson et al., 1992). While this guideline is still sound and effective, more recent work has questioned the economic feasibility of this level of nutritional input (Hall, 2017).

Recent studies have investigated reproductive performance and subsequent productivity of heifers developed with lower nutritional inputs (and lower cost) to achieve around 50% to 55% of expected mature weight by the beginning of the first breeding season. Critical in the lower-input strategy is the concept of timing the beginning of the breeding season with availability of high-quality forage in order to take advantage of compensatory weight gain during the breeding season. Continued nutritional restriction through breeding and gestation results in reduced pregnancy, lower body condition at first calving and lower rebreeding success for the second calf.

In three studies (Funston, 2004; Roberts et al., 2009; Larson et al., 2009), the lower input system resulted in no reduction in the percentage of heifers becoming pregnant during the first 21 days of the breeding season. However, other work reported reduced early pregnancy percent (15%; Eborn et al., 2013) or early calving percent (11%; Martin et al., 2008) when heifers were developed to lighter weights. Hall (2017) summarized overall pregnancy rates in eight studies and reported only a slight numerical advantage (2%) for the 65% target-weight system (Table 29.1).

The lower-target weight system did result in lower development costs per heifer and per pregnancy. In one experiment, heifers developed to 55% of expected mature weight had more calving difficulty (Patterson et al., 1992). Hall (2017) cautioned that conception to synchronization and timed AI systems may be lower in the lower-input development system.

Table 29.1. Impact of target weight on overall pregnancy rates in replacement beef heifers[1].

Study	No. of heifers	Target weight[2] (% of mature weight) 55	65
Patterson et al., 1992 (*Bos Taurus*)	137	84 %	89 %
Funston and Deutscher, 2004	240	92 %	88 %
Martin et al., 2008[3]	261	87 %	90 %
Roberts et al., 2009	397	87 %	92 %
Eborn et al., 2013	360	77 %	83 %
Mulliniks et al., 2013	191	91 %	84 %
Lardner et al., 2014	176	86 %	88 %
Bailey et al., 2014	203	74 %	77 %

1 Adapted from Hall, 2017
2 65% - Range 58% to 65%; 55% - Range 48% to 56%
3 In this study, 55 = 50% and 65 = 56%

Table 29.2. Puberty weight of heifers and mature weights by breed through time.

Breed	Puberty weight Year 1975	Puberty weight Year 2000	Mature weight 1975	Mature weight 2000
Angus	585	753	1,103	1,410
Hereford	588	768	1,073	1,409
Simmental	631	742	1,190	1,404
Gelbvieh	600	700	1,121	1,323
Limousin	643	779	1,201	1,391
Charolais	667	728	1,246	1,371
Brahman	731	754	1,272	1,322

Source: MARC GPE Progress Reports

Breed effects play a major role on age at puberty and therefore the number of heifers cycling and becoming pregnant in a controlled breeding season. In general, breeds with *bos indicus* influence reach puberty later and breeds with greater genetic potential for milk production reach puberty earlier (Table 27.2). Therefore, the lower target weight system is not recommended for cattle with significant *bos indicus* influence (Patterson et al., 1992). Additionally, Hall (2017) cautions that most studies comparing the 65% and 55% target weight systems have been conducted using *bos taurus* breed types with either crossbred or composite cattle. Composite and crossbred cattle are expected to achieve puberty at an earlier age, compared to purebred cattle because of heterosis. Therefore, the lower target-weight system may not work as well for purebred heifers.

Number of Heifers to Retain

The sustainability and profitability of a cow-calf operation is dependent on the longevity of each breeding female and the production of a live calf every year (Mousel et al., 2014). Cow culling rates can vary greatly from year to year due to pregnancy status, health issues or drought. The 2007-08 National Animal Health Monitoring System (NAHMS) reported approximately one-third of the cows culled are removed because they do not become pregnant during the breeding season. Furthermore, 15.6% of all culled cows leave the herd before 5 years of age and an additional 31.8% leave the herd between 5 and 9 years of age (NAHMS).

Culling rates can vary substantially between operations based on the amount of selection pressure placed on one or more specific traits. Some operations may choose to market excess bred heifers or bred mature cows at a younger age. These scenarios contribute to the number of heifers needed to be retained each year. According to a survey of U.S. cow/calf operations (NAHMS, 2017), on average, 16.3% of calves weaned or expected to be weaned were classified as replacement females. Culling and replacement data collected from 1990-2012 from the North Dakota State University Cow Herd Appraisal Performance Software (CHAPS) showed the typical culling rate was 14.1%, while the typical replacement rate was 17.8%. The production benchmark values from the CHAPS program is 14.9% for

replacement rate and a 13.2% cull rate. This data provides a starting point in choosing how many heifers to retain as replacements each year. Even in the very best scenarios, some heifers will be difficult or impossible to breed, some bred heifers will lose their pregnancy and some will lose their calves at or shortly after calving. For these reasons, most Extension specialists and researchers recommend exposing at least 10% more heifers than needed.

As mentioned previously, an alternative is to treat the heifer development enterprise essentially as a stocker enterprise, retaining a much greater percentage (if not all) of the heifer calves. In this program, generally, the 55% target weight would be employed for the purpose of keeping nutritional costs down through the first part of the breeding season. Subsequently, the cattle are turned out on high-quality forage to ensure compensatory, rapid growth during the breeding season and exposing the heifers to fertile bulls for a short breeding season (usually 30 days). The heifers that become pregnant are retained and the opens are marketed as feeder heifers. In this system, adequate nutrition/development through first calving is critical so the heifers have had time to achieve body condition score of 6 and 85% to 90% of their expected mature weight by the time they calve.

Use of Reproductive Tract Soring

Reproductive Tract Scoring (RTS) is a subjective measurement which involves the rectal palpation of the heifer reproductive tract (uterine horns and ovarian structures) and the subsequent assignment of a reproductive tract score, ranging from 1 to 5 (1 = immature; 5 = presence of a corpus luteum), to assist the producer in making replacement heifer decisions. Since age at puberty is difficult to measure directly, RTS can estimate pubertal status and, if performed before the onset of the breeding season, can be a predictor of heifer reproductive performance allowing for heifers with a poor breeding potential to be removed from the breeding group before any further costs are incurred. The RTS system has been shown to a repeatable measure between and within practitioners and to be moderately heritable (.32 + 0.17).

A RTS of 1 is refers to a prepubertal heifer, a RTS of 2 or 3 is refers to a peripubertal heifer (transitional stage), and a RTS of 4 or 5 is refers to a pubertal (cycling) heifer. The reproductive performance of heifers with an RTS of 1 or 2 is less than that of heifers with an RTS of 3 or greater. Heifers with a RTS of 1 or 2 are less likely to be cycling at the beginning of the breeding season and therefore are less likely to become pregnant. If they do become pregnant, they do so later in the breeding season, suggesting heifers with a RTS of 1 should possibly be eliminated from the breeding group. It is worth mentioning that some heifers do not exactly fit a particular RTS score and it is up to the producer and/or practitioner to decide on which of the measures are to be given the most emphasis.

RTS should be done about one month or less prior to breeding if the score is to be used as a culling tool as an indicator of a heifer's ability to conceive early during the first breeding season. If RTS is to be used as a selection tool to place pressure on age at puberty, the best time to evaluate the heifers is when approximately 50% of the heifers are thought to be cycling based on age, weight and occasional observations for estrus.

Another possible application of the RTS system is to assess the nutritional program being utilized by the producer. If RTS is taken within a sufficient time before the start of the breeding season (approximately 30 days to 60 days); based on the results of the tract scores, the producer can adjust the ration to help the heifers reach developmental goals prior to the beginning of the breeding season or the beginning of the breeding season can be adjusted.

The uterine and ovarian dimensions for each of the reproductive tract scores are described in Table 29.3. The reproductive tract score is based on the degree of uterine horn development and ovarian status (size of dominant follicle and presence or absence of a CL).

Timing of Weight Gain from Weaning to Breeding

In the 65% target weight system, a major objective is to achieve a high percentage of heifers experiencing their first estrous cycle before the beginning of the breeding season. Until recently, very little was known regarding the importance of the timing of this weight gain. Would it be desirable to have the heifers gain at an even pace at

Table 29.3. Description of uterine and ovarian measurements for different Reproductive Tract Scores (RTS).

Reproductive Tract Score	*Uterine horns (diameter, mm)*	*Ovarian length (mm)*	*Ovarian height (mm)*	*Ovarian width (mm)*	*Ovarian structures*
1	Immature, < 20 mm, no tone	15	10	8	No palpable follicles
2	20-25 mm, no tone	18	12	10	8 mm follicles
3	20-25 mm, slight tone	22	15	10	8-10 mm follicles
4	30 mm, good tone	30	16	12	> 10 mm follicles, CL possible
5	> 30 mm	>32	20	15	CL present

approximately 1.33 pounds per day? Or, could growing the heifers slowly through most of the winter, then putting them on a very high plane of nutrition for the last two months prior to breeding gain some biological and economical efficiency?

Kansas State University and OSU researchers (Smith et al., 1995; Lynch et al. 1996; Marston et al., 1992) have independently studied the timing of gain. KSU workers noted that heifers gaining at 0.55 pounds per day until the last two months and then grown at 2.5 pounds per day were equal in reproductive performance to heifers grown at 1.31 pounds per day from November to May. The heifers that were pushed in the last two months were more efficient, consuming 12% less DM than the conventionally grown heifers. At OSU, heifers that were wintered to achieve 0.6 pound per day gain, then fed in a dry lot, gained 1.92 pounds per day and reached puberty 20 days to 30 days younger than their counterparts fed to gain at more uniform rates. This indicated that growing programs allowing heifers low to moderate rates of gain during most of the growing phase and then accelerate their growth leading into the breeding season may be cost effective and result in more heifers cycling early. This could be critical to the success of an AI and estrous synchronization program.

Cost Comparisons with Different Feed Cost Scenarios

To help make decisions about heifer growing strategies, Table 29.4 contains total cost comparisons of feed for heifers from weaning on Nov. 1 to start of breeding season on May 1. The SLOW-FAST program is designed to rough heifers through the winter as inexpensively as possible. The assumed SLOW diet is 2 pounds per head per day of a high- protein supplement such as soybean meal. The remainder of the diet is prairie hay (5.8% crude protein) fed free choice. Average daily gain on this diet for medium-framed 500-pound heifers is only 0.35 pound per head per day (1996 NRC). The FAST gain portion is a self-fed ration programmed to achieve the required 3.16 pounds per day gain and reach the 65% of mature weight target the last 60 days.

This ration is as follows:

10%	cottonseed hulls
5%	alfalfa pellets
49.5%	corn
30%	corn distillers grain
4.5%	molasses
1%	vitamin A, Rumensin® 80, limestone, salt, zinc sulfate

Table 29.4. Price comparisons of EVEN GAIN and SLOW-FAST growing programs with different feed price situations.

Corn	$3/bu	$4.50/bu	$5.00/bu
CSM	$250/ton	$300/ton	$400/ton
Hay	$80/ton	$85/ton	$90/ton
EVEN GAIN	$155.71	$193.10	$223.13
SLOW-FAST GAIN	$155.64	$176.83	$194.19

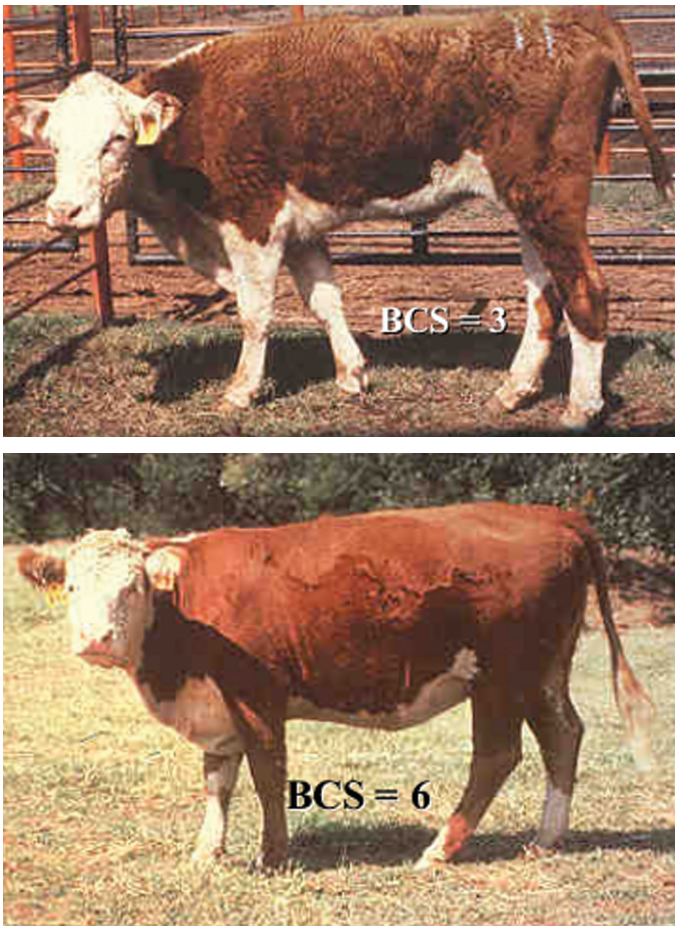


Figure 29.2. A very thin heifer BCS 3 (top) and a correctly developed heifer BCS 6 (bottom).

During this FAST growing phase, the heifers will average 620 pounds and consume 20.4 pounds per day on an as-fed basis.

The diet formulated to achieve the EVEN GAIN from November to May was chosen to achieve 1.33 pounds gain per day. Average weight of the heifers during this growing program would be 595 pounds and they would need to consume 15.4 pounds of the following ration daily to reach the desired target weight:

47%	prairie hay
35%	corn
14%	cottonseed meal
3%	molasses
1%	vitamin A, salt, Rumensin® 80, zinc oxide

A second alternative, if alfalfa hay is available, would be:

66%	alfalfa hay (18%)
33%	corn
1%	vitamin A, salt, Rumensin® 80, zinc oxide

The total feed ingredient costs for these heifer-growing programs were compared with four different corn price scenarios (Table 29.4). Because most other feeds are affected by the corn price, it was used as the basic feedstuff. Hay prices and cottonseed meal prices are listed as estimates of what they might be as the corn price changed.

With lower grain price situations, the SLOW-FAST gain approach appears to be slightly less expensive. As feed prices change, the comparisons should be re-evaluated. The added advantage of more heifers cycling earlier could make these growing programs the method of choice on ranches that synchronize and breed artificially.

Using Wheat Pasture

Years of research and experience with stocker cattle wintered on small grain pasture prove SLOW-FAST is a good choice for a heifer growing ration. Heifers weaned in October are old enough to make good use of wheat pasture that becomes available in late November. In years when good wheat pasture is available, grazing the heifers on wheat will allow 1.5 pounds per day gain throughout the winter growing period. Heifers wintered on good wheat pasture will be heavy enough to enter the breeding season in April or early May in excellent body condition and at the target weight. Some caution must be taken to avoid severe weight and condition loss if heifers are wintered on wheat pasture, removed from wheat, then placed on lower-quality pasture such as native or Bermudagrass until the breeding season begins. Setting aside a few acres of small grain pasture for graze-out allows the replacement heifers to graze high-quality pasture well into May. Some producers have reported disappointing conception rates on heifers grazing lush wheat pasture. Other producers indicated they have excellent results from using wheat pasture for replacement heifer growing programs. No definitive research data is available to directly address this unanswered question. When comparing the price of renting wheat pasture with those programs listed above, it should be noted the price per pound of gain of the least expensive scenario in Table 29.2 is $0.41. The most expensive program costs $0.81 per pound of gain. Wheat pasture, if available, will compete well with those costs.

Using Ionophores in Replacement Heifer Diets

In an effort to ensure more replacement heifers are bred to calve early in their first calving season, producers should consider using a supplement containing an ionophore in the growing diet of the heifers. Ionophore is the generalized name for the feed additives monensin (Rumensin®) and lasalocid (Bovatec®). Both are presently approved for use with growing programs for replacement heifers. Research has shown growing heifers fed 200 milligram monensin per head per day reached puberty at an earlier age than did similar heifers fed similar diets containing no monensin (Moseley et al., 1977, 1982; McCartor etal.1979; Sprott, 1981). Similar data is available for lasalocid. Most stocker cattle research indicates the addition of 100 milligrams to 200 milligrams of an ionophore increases average daily gain by 0.1 pound to 0.2 pound per day. During a 150-day growing period of a replacement heifer, this means an additional 15 pounds to 30 pounds in average weight improvement of the heifers by breeding time.

Yearling Immunizations (four to six weeks prior to breeding)

Replacement heifers should be given booster immunizations at one year of age. Often, this will include a modified live form of the respiratory disease vaccinations (BVD 1 and 2, BRSV, IBR, PI3) and the clostridial vaccines also known as 7–way or 8–way blackleg vaccines. The modified live vaccines must be given at least 30 days prior to the start of the breeding season. The annual vaccinations for the bacterial reproductive vaccines including 5-way Leptospira and Campylobacter (Vibrio) fetus could be given at this time as well. See a veterinarian for additional information.

After the First Breeding Season

Many Oklahoma ranchers breed the replacement heifers about a month ahead of the mature cows in the herd. In addition, they use a shortened 45- to 60-day breeding season for the replacement heifers. The next logical step is to determine which of these heifers failed to conceive in their first breeding season.

As the bulls are removed from the replacement heifers, arrange with a local veterinarian to have those heifers evaluated for pregnancy in about 60 days. In two months, experienced palpation technicians should have no difficulty identifying which heifers are pregnant and which are not pregnant (open). Heifers that are open after this breeding season should be strong candidates for culling. Culling these heifers immediately after pregnancy checking serves three very useful purposes:

1. Identifying and culling open heifers early will remove subfertile females from the herd. Lifetime cow studies from Montana indicated properly developed heifers exposed to fertile bulls that did not become pregnant were often subfertile compared to the heifers and did conceive (Bellows). In fact, when the heifers that failed to breed in the first breeding season were followed throughout their lifetimes, they averaged a 55% yearly calf crop. Despite the fact that reproduction is not a highly heritable trait, it makes sense to remove this genetic material from the herd so as to not proliferate females that are difficult to get bred.
2. Culling open heifers early will reduce winter costs. If the rancher waits until the next calving season to find out which heifers do not calve, the winter feed expense will be lost and there will be no calf to help pay the bills. Money can be better spent in properly feeding pregnant cows, which will be producing a saleable product the following fall.
3. Identifying the open heifers shortly after the breeding season (60 days) will allow for marketing the heifers while still young enough to go to a feedlot and be fed for the choice beef market. The grading change of several years ago has a great impact on the merchandising of culled replacement heifers. B maturity carcasses, those estimated to be 30 months of age or older, are no longer allowed to be graded choice, and may be discounted because of new Bovine Spongiform Encephalopathy

export rules. Therefore, it is imperative to send heifers to the feedlot while young enough to be fed for four to five months and not be near the B maturity age group. Auction barn order buyers will be especially leery of heifers that may be near 18 months to 20 months of age because B maturity beef receives a considerable discount when harvested at the packing plant.

The percentage of open heifers will vary from ranch to ranch. Do not be concerned if after a good heifer development program and adequate breeding season it is found that 10% of the heifers still are not bred. These are the very heifers to identify early and remove from the herd. It makes good business sense to identify and cull nonpregnant replacement heifers as soon as possible.

Growing Bred Replacement Heifers

Bred replacement heifers that will calve in several months need to continue to grow and maintain body condition. Ideally, 2-year-old heifers should be a BCS 6 (Figure 29.2) at the time their first calf is born. This allows them the best opportunity to provide adequate colostrum to their calf, repair their reproductive tract, return to heat cycles, rebreed on time for next year and continue normal body growth. From breeding until calving time, heifers need to gain 1 pound to 1.5 pounds per head per day, assuming they are in good body condition after the breeding season. Heifers will need supplemental protein if the major source of forage in the diet is Bermudagrass, native pasture or grass hay. If the forage source is adequate in quantity and average in quality (6% to 9% CP), heifers will need about 2 pounds of a high-protein (38% to 44% CP) supplement each day. This will probably need to be increased using higher-quality hay such as alfalfa or additional energy feed (20% range cubes) as winter weather adds additional nutrient requirements. Soybean hulls or wheat middlings also may be used to ensure adequate energy intake of pregnant heifers.

Wheat Pasture for Bred Heifers

Although wheat pasture can be used more efficiently to add gain on stocker cattle or weaned replacement heifers, wheat pasture, if adequate rainfall produces growth, also can be used as a supplement for pregnant replacement heifers. Using wheat pasture judiciously makes sense for pregnant heifers for two reasons. Pregnant heifers consuming full feed of wheat pasture will gain about 3 pounds per head per day. If they are on the wheat too long, the heifers can become very fat and possibly cause dystocia (calving difficulty). If wheat pasture is used for bred heifers, use it as a protein supplement by allowing the heifers access to the wheat pasture on at least alternate days. Some producers report that one day on wheat pasture and two days on native or Bermudagrass works better. This encourages heifers to rustle in the warm season pasture for the second day, rather than just stand by the gate waiting to be turned back into the wheat. Whatever method is used to grow the pregnant replacement heifers, plan to have them in good body condition by calving so they will grow into fully-developed, productive cows.

Body Condition Score at Calving is Critical

One of the major constraints in the improvement of reproductive efficiency of beef cows is the duration of the post-calving anestrous period. If cows are to maintain a calving interval of one year, they must conceive within 80 days to 85 days after calving. Body condition at calving time determines to a great extent the rebreeding performance of beef cows in the subsequent breeding season. Based on research of mature and young cows from several studies, cows that maintained body weight and ample energy reserves before parturition, exhibited estrus sooner than cows that lost considerable body weight and, consequently, had poor energy reserves.

Body weight change during pregnancy is confounded with embryo and placenta growth. Therefore, the estimation of body fat by use of body condition scores is more useful in quantifying the energy status of beef cows. The numeric system of body condition scoring is an excellent estimator of percentage body fat in beef cows. BCS accounted for 85% to 91% of the variation in stored body energy in cows. Examples of different body condition scores are shown in Figure 29.2.

The processes of fetal development, delivering a calf, milk production and repair of the reproductive tract are all physiological stresses. These stresses require the availability and utilization of large quantities of energy to enable cows to be rebred in the required 85 days. Add to these physiological stresses the environmental stresses of cold, wet weather on spring calving cows, and often energy intake of range beef cows, is below body maintenance needs. As the intake falls short of the energy utilized, then the cow compensates by mobilizing stored energy or adipose tissue and during a period of several weeks, a noticeable change in the outward appearance of the cow takes place. This is a change in the body condition and can be monitored by assigning body condition scores to cows and quantifying the degree of change. Cows in a thin body condition at calving slowly return to estrus. Postpartum increases in energy intake can modify the length of the postpartum interval. However, increases in the quality and quantity of feed to increase postpartum body condition can be very expensive. The producer must ask - does the improvement in reproductive performance achieved by expensive postpartum feeding to thin cows be in adequate body condition justify the cost of the additional nutrients?

Heifers Thin at Calving

Oklahoma researchers used 81 Hereford and Angus x Hereford heifers to study the effects of BCS at calving and post-calving nutrition on rebreeding rates at 90 days and 120 days after calving (Bell et al.). Heifers were divided into two groups in November and allowed to lose body condition or maintain body condition until calving in February and March. Each of those two groups was then redivided to either gain weight and body condition postpartum or to maintain body condition postpartum. Figure 29.3 illustrates the change in body weight of heifers that calved in a BCS 5 or greater or those that calved with a BCS less than or equal to 4.9. The same pattern that has been illustrated in the other

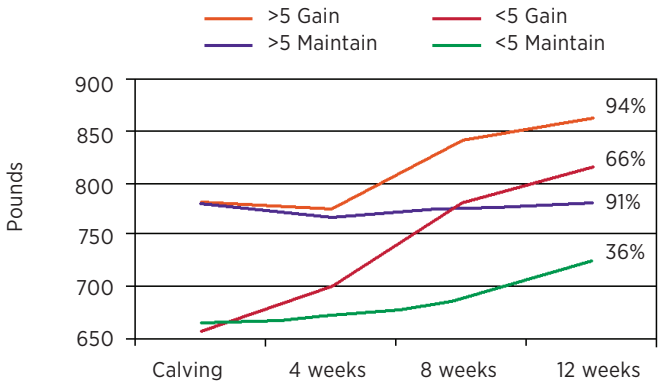


Figure 29.3. Postpartum body weight of heifers with body condition greater than 5 or less than 5 at calving and fed to gain or maintain weight. Pregnancy rates are indicated on the right side of the graph. Source: Bell et al.

experiments is manifest clearly with these heifers.

Thin heifers that were given ample opportunity to regain weight and body condition after calving actually weighed more with a greater body condition by eight weeks than heifers that had good body condition at calving and maintained their weight through the breeding season. However, the rebreeding performance (on the right side of the legend of the graph) was significantly lower for those that were thin (66 percent) at parturition compared to heifers that were in adequate body condition at calving and maintained condition through the breeding season (91 percent).

Post-calving increases in energy and, therefore, weight and body condition gave a modest improvement in rebreeding performance, but the increased expense was not adequately rewarded. The groups that were fed to maintain postpartum condition and weight received 4 pounds of cottonseed meal supplement (41% CP; $0.13 per pound) per day. The supplement cost for the 69-day-feeding period was approximately $36 per cow. The cows in the gain groups were fed 28 pounds of a grain mix (12% CP; $0.073 per pound) at a total supplement cost of $141 per cow. Both groups had free choice access to grass hay (Wettemann). The improvement in reproductive performance (66% pregnant vs. 36% pregnant) of the thin 2-year-old heifers was not enough to offset the large investment in feed costs.

Other data sets have shown conclusively cows that calve in thin body condition, but regain weight and condition going into the breeding season, rebreed at a slower rate than those that calve in good condition and maintain that condition into the breeding season. Table 29.3 from Missouri researchers illustrates the number of days between calving to the return to heat cycles, depending on body condition at calving and body condition change after calving.

This data clearly shows young cows that calve in thin body condition (BCS 3 or BCS 4) cannot gain enough body condition after calving to achieve the same rebreeding performance as cows that calve in moderate body condition (BCS 5.5) and maintain or lose only a slight amount of condition. Cows must rebreed 85 days after calving to calve again at the same time next year. Notice that none of the averages for cows that calved in thin body condition were recycling in time to maintain a 12-month calving interval. The body condition score target for 2-year-old heifers at calving should be 6. This condition score will give the heifer the best opportunity to calve with no additional threat of dystocia and the very best opportunity to rebreed in 85 days.

Table 29.5. Predicted number of days from calving to first heat as affected by body condition score (BCS scale 1 = emaciated; 9 = obese).

BCS at calving	*Condition score change after calving to day 90*						
	-1	*-0.5*	*0*	*0.5*	*1*	*1.5*	*2*
3	189	173	160	150	143	139	139
4	161	145	131	121	115	111	111
5	133	116	103	93	86	83	82
5.5	118	102	89	79	72	69	66

Source: Lalman et al.

Sort Young Cows from Mature Cows

First-calf heifers have historically been the most difficult females on the ranch to get rebred. They are being asked to continue to grow, produce milk, repair the reproductive tract and have enough stored body energy (fat) to return to heat cycles in a short time frame following parturition. Two-year-old cows must fill all of these energy demands at a time when their mouth is going through the transition from baby teeth to adult teeth. If these young cows are pastured with the larger, older cows in the herd, they very likely will be pushed aside when the supplements are being fed in the bunk or on the ground. The result of these adverse conditions for young cows very often is a lack of feed intake and lowered body condition. Of course, lowered body condition results in delayed return to heat cycles and a later and smaller calf crop the following year.

North Dakota State University data of commercial cow herds recorded during a 21-year period illustrates the differences in size of very young cows and the very mature (11 years and older) cows (Figure 29.4). Very young cows and very old cows cannot compete with middle age cows weighing 200 pounds to 250 pounds more.

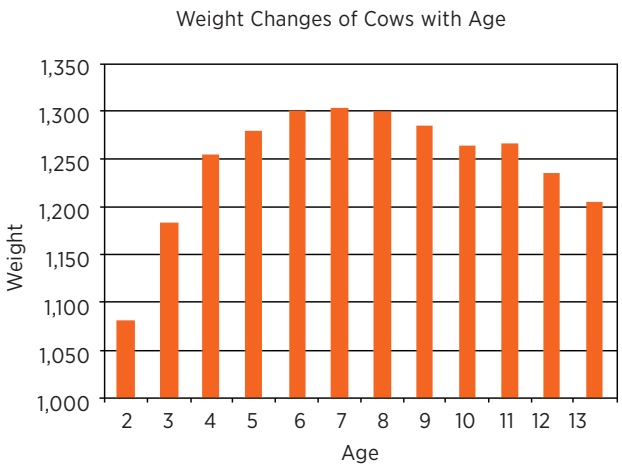


Figure 29.4. The average weight of commercial beef cows in North Dakota SPA data by age. Source: Ringwall.

Cost of Replacement Heifer Development

Shulz and Gunn (2014) provide further details and a convenient enterprise analysis spreadsheet related to raising heifers versus buying heifers for beef cow replacement. This publication and decision tool enables producers to address the question of buying versus raising replacement heifers from an economic perspective. It does not address biosecurity risk related to potentially introducing diseased cattle into the herd when replacements are purchased with unknown background.

Conclusion

Properly immunize heifers at two months, weaning and at one year of age according to a veterinarian's recommendation. Depending on the ranches long- and short-term goals and available resources, development systems from weaning through breeding targeting 55% to 65% of expected mature weight can be successful. The most economical growing program for replacement heifers utilizes standing or harvested forages as a major portion of the diet. Heifers may be grown slowly then given higher energy feed or grazed forage to accelerate the rate of gain to achieve acceptable target weight by the start of the breeding season.

Utilize the highest-quality hays and/or the best pastures because young cattle cannot utilize low-quality roughage as well as mature cows. Use an ionophore to improve feed utilization and hasten the onset of puberty.

Breed replacement heifers three weeks to four weeks ahead of the adult cows. Cull all open heifers after the first breeding season. Grow bred heifers adequately so they have a BCS 6 at calving time. Sort young cows, 2- and 3-year-olds, from older, larger cows to ensure adequate feed intake for young, growing, but smaller cows.

References

Anderson, K. J., D. G. LeFever, J. S. Brinks, and K. G. Odde. 1991. The use of reproductive tract scoring in beef heifers. *Agri-Practice* 12:19–26.

Bell, D. et al. Effects of Body Condition Score at Calving and Postpartum Nutrition on Performance of Two-Year-Old Heifers. OSU Animal Science Research Report MP-129.

Bellows, R.A. (1966) Increasing Pounds of Calf Weaned Per Cow Bred. Proceedings: 17th Montana Nutrition Conference. Bozeman, MT. Pg. 56-65.

Beverly, J.R. and J.C. Spitzer. (1979) Management of Replacement Heifers for a High Reproductive and Calving Rate. Texas A&M University. B-1213. College Station, TX.

Bridges, G. A. 2013. Replacement female strategies. 2013. In: Proceedings of the Driftless Region Beef Conference, Jan. 31 - Feb. 1, Grand River Center, Dubuque, Iowa; p. 19–26. http://www.iowabeefcenter.org/proceedings/DriftlessConference2013.pdf

Boyer CN, AP Griffith and KL DeLong. Reproductive failure and long-term profitability of spring- and fall-calving beef cows. *Journal of Agricultural and Resource Economics*. 2020;45:78–91.

Brinks, J. S. 1994. Genetic influences on reproductive performance of two-year-old beef females. Pages 45–53 in Factors Affecting Calf Crop. M. J. Fields and R. J. Sand, ed. CRC Press, Boca Raton, FL.

Caldwell, M. 2019. Beef Cattle Reproductive Herd Health. Proceedings, Applied Reproductive Strategies in Beef Cattle; August 20-21, 2019; Knoxville, TN

Chiang, B. C., P. C. Smith, K. E. Nusbaum and D. A. Stringfellow. 1990. The effect of infectious bovine rhinotracheitis vaccine on reproductive efficiency in cattle vaccinated during estrus. *Theriogenology* 33: 1113-1120

Clark, R. T., K. W. Creighton, H. H. Patterson and T. N. Barrett. 2005. Economic and Tax Implications for Managing Beef Replacement Heifers. *Professional Animal Scientist* 21:164–173. doi: 10.15232/S1080-7446 (15) 31198-0.

Cushman R.A., L.K Kill, R.N. Funston, E.M. Mousel and G.A. Perry 2013. Heifer calving date positively influences calf weaning weights through six parturitions. *Journal of Animal Science* 91(9):4486–91. doi: 10.2527/jas.2013-6465

Daly R. 2016. Unintended consequences: Could MLV vaccines be harming reproduction? Applied Reproductive Strategies in Beef Cattle – Des Moines, Iowa, Sept. 7-8.

Damiran, D., K. A. Larson,, L. T. Pearce, N .E. Erickson and B. H. A. Lardner 2018. Effect of calving period on beef cow longevity and lifetime productivity in western Canada. *Translational Animal Science* 2:S61–S6. doi: 10.1093/tas/txy020

Faulkner, D. B., D. F. Hummel, D. D. Buskirk, L. L. Berger, D. F. Parrett, and G. F. Cmarik. 1994. Performance and nutrient metabolism by nursing calves supplemented with limited or unlimited corn or soyhulls. *Journal of Animal Science* 72(2):470-477.

Funston R.N., Musgrave J.A., Meyer T.L., Larson D.M. 2012. Effect of calving distribution on beef cattle progeny performance. *Journal of Animal Science* 90(13):5118–21. doi: 10.2527/jas.2012-5263. Epub 2012 Aug 7.

Funston, R.N., J.A. Musgrave, T.L. Meyer and D.M. Larson. 2012. Effect of calving distribution on beef cattle progeny performance. *Journal of Animal Science*. 90:5118-5121.

Funston, R. N., and G. H. Deutscher. 2004. Comparison of target breeding weight and breeding date for replacement beef heifers and effects on subsequent reproduction and calf performance.*Journal of Animal Science*. 82:3094–3099.

Funston, R. N., J. A. Musgrave, T. L. Meyer and D. M. Larson. 2011. Effect of calving period on ADG, reproduction, and first calf characteristics of heifer progeny. Proc. West. Sect. American Society of Animal Science. 62:231–233.

French, J. T., J. K. Ahola, J. C. Whittier, W. M. Frasier, R. M. Enns, and R. K. Peel. 2013. Differences in lifetime productivity of beef heifers that conceived to first-service artificial insemination (AI) or a clean-up bull via natural service (NS) as a yearling and among females that were offspring of an AI or NS mating. Prof. Animal Scienc. 29:57-63.

Givens D. and B.W. Newcomer. 2017. Does modified-live viral vaccine administration to heifers or cows lack substantial risk? Beef Session, Moderators: Randall Spare, Dave Sjeklocha, Eric Behlke. The AABP Proceedings, Vol. 50. pg. 43-48.

Hall, J.B. and J.B. Glaze Jr. 2017. Heifer Nutritional Development Strategies. Proceedings, Applied Reproductive Strategies in Beef Cattle. August 29-30, Manhattan, KS

Holloway, J.W. and R. Totusek. 1973. Relationship between preweaning nutritional management and the growth and development of Angus and Hereford females. *Journal of Animal Science* 37:807

Holm, D. E., P. N. Thompson, and P. C. Irons. 2009. The value of reproductive tract scoring as a predictor of fertility and production outcomes in beef heifers. *Journal of Animal Science*. 87:1934-1940.

Lalman, D.L., D. H. Keisler, J. E. Williams, E. J. Scholljegerdes and D. M. Mallett. 1997. Influence of Weight and Body Condition Change on Duration of Anestrus by Undernourished Suckled Beef Heifers. Journal of Animal Science 75, 2003.

Lardner, H.A., D. Damiran, S. Hendrick, K. Larson and R. Funston. 2014. Effect of development system on growth and reproductive performance of beef heifers. *Journal of Animal Science* published 28 April 2014, 10.2527/jas.201

Lesmeister, J.L., P.J. Burfening and R.L. Blackwell. 1973. Date of first calving in beef cows and subsequent calf production. *Journal of Animal Science* 36:1-6.

Lusby, K.S. and D.R. Gill. Creep Feeding, Beef Cattle Handbook, BCH-5476

Lusby, K.S Creep Feeding Beef Calves. 1994. Circular E-848 Oklahoma Cooperative Extension Serviced Division of Agricultural Sciences and Natural Resources, Oklahoma State University

Lusby, K.S. 1989. Limit Fed Creep Feeds for Nursing Calves. The Bovine Proceedings-No. 21 Pg. 92-95.

Lynch, J.M. et al. (1996) Timing of Gain Does Not Alter Puberty and Reproductive Performance of Beef Heifers Fed a High-Roughage Diet. Kansas State University Cattleman's Day. Report of Progress 756. Pg. 29-31.

Marston, T.T. et al. (1992) Heifer Development on Dormant Native Range with Fiber-Based Supplements or Limited Drylot Feeding. Oklahoma State University Animal Science Research Report. MP-136. Pg. 172-178.

Martin, T. G., R. P. Lemenager, G. Srinivasan, and R. Alenda. 1981. Creep Feed as a Factor Influencing Performance of Cows and Calves. *Journal of Animal Science*, Volume 53:1. Pg. 33–39. doi.org/10.2527/jas1981.53133x

McCartor, M.M,, R.D. Randel and L.H. Carroll. 1979. Dietary alteration of ruminal fermentation on efficiency of growth and onset of puberty in Brangus heifers. *Journal of Animal Science* 48:488.

Moorey, S.E. and F.H Biase. 2020. Beef heifer fertility: importance of management practices and technological advancements. *Journal of Animal Science and Biotechnology* 11:97. doi.org/10.1186/s40104-020-00503-9

Moseley, W.M. et al. (1977) Effects of Monensin on Growth and Reproductive Performance of Beef Heifers. *Journal of Animal Science* 45:961.

Moseley, T.G. et al. (1982) Relationship of Growth and Puberty in Beef Heifers Fed Monensin. *Journal of Animal Science* 55:357.

Mousel, E.M., R.A. Cushman, G.A. Perry and L.K. Kill. 2014. Effect of heifer calving date on longevity and lifetime productivity. Driftless Region Beef Conference, Jan. 30-31, Dubuque, Iowa

National Research Council. (1996) Nutrient Requirements of Beef Cattle. 7th Revised Edition. National Academy Press. Washington, D.C.

Perry, G.A., A.D. Zimmerman, R.F. Daly, R.E. Buterbaugh, J. Rhoades, D. Scholz and C.C. Chase. 2013. The effects of vaccination on serum hormone concentrations and conception rates in synchronized naive beef heifers. *Theriogenology*, 79, 200-205.

Perry, G.A., E.L. Larimore, M.R. Crosswhite, B.W. Neville, V. Cortese, R.F. Daly and C.R. Dahlen. 2016. Influence of Vaccination with an Inactivated or Modified Live Viral Reproductive Vaccine on Reproductive Parameters in Beef Cows. *Journal of Animal Science,* 94(suppl. 2), 152.

Perry G.A., T.W. Geary, J.A. Walker, J. J.J. Rich, E.J. Northrop, S.D. Perkins, C.L. Mogck, M.L. Van Emon, A.L. Zezeski, and Russell F. Daly. 2018. Influence of vaccination with a combined chemically altered/inactivated BHV-1/BVD vaccine or a modified-live BHV-1/BVD vaccine on reproductive performance in beef cows and heifers. *The Bovine Practitioner* Vol. 52 (1), 53-58.

Perry,G.A., R.F. Daly and C.C. Chase. 2017. Influence of Modified Live Vaccines on Reproductive Performance in Beef Cattle. Range Beef Symposium XXV Nov. 28-30, Cheyenne WY.

Randle, R. 2002. Heifer development and reproductive tract scoring for a successful heifer program: the show-me-select replacement heifer program: a coordinated management concept. Proceedings, The Applied Reproductive Strategies in Beef Cattle Workshop, Sept. 5-6, 2002, Manhattan, KS.

Ringwall, K. 2012). BeefTalk: Understanding Culling and Replacement Rates Critical. ag.ndsu.edu/news/columns/beeftalk/beeftalk-understanding-culling-and-replacement-rates-critical/

Rosasco, S.L., L.H. Schmitz, S.H. Cox, R.C. Dunlap, D.M. Hallford, A.F. Summers and E.J. Scholljegerdes. 2018. Effects of growth-promoting implants administered during the suckling phase on growth, conception rates, and longevity in replacement beef heifers grazing native range. *Translational Animal Science*. 2:S180-184

Rosasco S.L, C. J. Kassetas, S.H. Cox, R.L. Dunlap, J.A. Hernandez Gifford, E.J. Scholljegerdes and A.F. Summers. 2019. Effects of growth-promoting implants administered during the suckling phase or at weaning on growth and reproduction in replacement beef heifers grazing native range. *Translational Animal Science*. 3:S1 774-S1778

Smith, M.F. and G. A. Perry. 2013. My Herd is a Reproductive Wreck: What Can I Do? Proceedings, Cattleman's College, National Cattlemen's Beef Association's Convention, Feb. 5-6, Tampa, FL.

Selk, G. 1997. Implants for suckling steer and heifer calves and potential replacement heifers. In Symposium: Impact of implants on performance and carcass value of beef cattle (pp. 40–50). Stillwater: Oklahoma Agricultural Experiment Station.

Sexten, W.J., D.B. Faulkner and F.A. Ireland. 2004. Influence of Creep Feeding and Protein Level on Growth and Maternal Performance of Replacement Beef Heifers. *Professional Animal Scientist* 20:3. Agricultural & Environmental Science Collection. Pg. 211-217.

Shulz and Gunn (2014). Raising Versus Buying Heifers for Beef Cow Replacement. Iowa State University, File B1-73.

Smith, J.M. et al. (1995) Influence of Timing and Rate of Gain on Puberty and Reproductive Performance of Beef Heifers. Kansas State University Cattleman's Day. Report of Progress 727. Pg. 101-103.

Walz. P. 2020. Vaccination to protect against reproductive disease. Virtual 2020 Applied Reproductive Strategies in Beef Cattle (ARSBC) Webinar Series. beefrepro.org/arsbc/

Wettemann, R.P. (2004) Personal Communication.

30 Management Considerations for Bulls

Daniel Stein and David Lalman

Objectives

- **Discuss the impacts of nutrition on development and fertility in young bulls.**
- **Present nutritional considerations and recommendations for bull development.**
- **Discuss how bulls should be used for breeding at different stages of their lives.**

Bull Development Nutritional Considerations

For a yearling bull to be used successfully in a breeding program, he should have reached puberty three months to four months before breeding time. The age of a bull at puberty depends on several interrelated factors. Among these factors, size or weight, age and breed contribute the most to age at puberty. The production of semen by a young bull largely depends on his overall growth as well as the development of his testicles and other reproductive organs. The size of testicles and volume of semen produced are positively correlated. Consequently, a well-managed bull development program will provide adequate nutrition to achieve puberty and allow the bulls in a contemporary group to express differences in growth and carcass characteristics.

However, young bulls can be, and frequently are, overfed to the point they become excessively fat. Research indicates overconditioning has a negative impact on fertility of young bulls. In fact, numerous experiments have documented feeding diets higher in energy concentration, compared to diets with moderate energy concentration leads to reduced epididymal sperm reserves, reduced sperm motility and increased abnormal sperm cells (Coulter, 1994). The exact mechanism by which feeding high-energy diets for long periods of time reduces fertility in young bulls is not known, although it is clear that overconditioning plays an important role. Increased fat deposition in the testes and in the neck of the scrotum have been implicated in reduced fertility. In one experiment, young bulls fed a high-energy diet had 34% greater total scrotal lipid (13.7%) than bulls fed a moderate energy diet (10.2%; Coulter, 1994). In these studies, the correlation between total scrotal lipid and epididymal sperm reserves was -0.26 and the correlation between back fat thickness and epididymal sperm reserves was -0.38. These articles suggest the insulative properties of fat deposited over the testes and in the neck of the scrotum leads to reduced thermoregulation capacity, increased scrotal temperature and ultimately, reduced bull fertility (Coulter, 1994).

Diets high in fermentable carbohydrates and lacking in effective fiber also can lead to acute and (or) subclinical acidosis as well as laminitis or subclinical laminitis (Nocek, 1996). These conditions are more commonly found in high-energy diets containing a greater proportion of concentrate feed. In general, high-energy diets that create (either sporadically or consistently) a ruminal environment with a pH of 5.5 or lower cause acute or subclinical acidosis and laminitis. Therefore, feeding management and diet formulation should be designed to minimize the occurrence of this condition. Feed formulation guidelines to achieve optimal ruminal health when higher energy diets are fed include a minimum of 20% dietary effective NDF (see chapter 17 for more information), and a minimum of 30% dietary NDF with at least 75% coming from forage. Remember that many coproduct feeds, such as distiller's grains, corn gluten feed, wheat middlings and soybean hulls are high in NDF. However, the NDF in these feeds is rapidly fermented, highly digestible and therefore contributes very little to the effective fiber (eNDF) value of the diet.

A rule of thumb to achieve optimal rate of growth and body composition is to provide adequate nutrition to reach approximately 60% to 65% of their expected mature weight by the beginning of the breeding season. Cattle with larger skeletal size or frame will generally be heavier at maturity compared to cattle with a smaller skeletal size and therefore, will need to be grown or developed to a greater extent by the time they are one year old. The frame scoring system shown in Table 30.1 is a common method used to estimate mature size and weight of bulls. Obviously, weight at a given age and hip height (frame score) will vary considerably depending on muscularity, chest width or overall thickness, depth of rib or heart girth and fatness.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 30.1. Cattle frame scores for males based on hip height in inches[a].

Age (months)	Frame score[3] 3.0	4.0	5.0	6.0	7.0	8.0
5	37.5	39.5	41.6	43.6	45.6	47.7
6	38.8	40.8	42.9	44.9	46.9	48.9
7	40.0	42.1	44.1	46.1	48.1	50.1
8	41.2	43.2	45.2	47.2	49.3	51.3
9	42.3	44.3	46.3	48.3	50.3	52.3
10	43.3	45.3	47.3	49.3	51.3	53.3
11	44.2	46.2	48.2	50.2	52.2	54.2
12	45.0	47.0	49.0	51.0	53.0	55.0
13	45.8	47.8	49.8	51.8	53.8	55.8
14	46.5	48.5	50.4	52.4	54.4	56.4
15	47.1	49.1	51.1	53.0	55.0	57.0
16	47.6	49.6	51.6	53.6	55.6	57.5
17	48.1	50.1	52.0	54.0	56.0	58.0
18	48.5	50.5	52.4	54.4	56.4	58.4
19	48.8	50.8	52.7	54.7	56.7	58.7
20	49.1	51.0	53.0	55.0	56.9	58.9
21	49.2	51.2	53.2	55.1	57.1	59.1
Mature	52.3	54.1	55.9	58.0	60.0	62.0

Frame score (5 to 21 months) = 0.4878 (ht)[b]
- 0.0289 (days of age) + .00001947 (days of age)[c]
+ 0.0000334 (ht) (days of age) - 11.548

Steer slaughter weight[d]	1,000	1,100	1,200	1,300	1,400	1,500
Mature bull weight[e]	1,570	1,730	1,890	2,050	2,200	2,360

a Approved by the Beef Improvement Federation.
b USDA Medium Frame Size is a Frame Score of approximately 4.0 to 5.5.
c Steers continue growth longer than bulls, being about 1/2 inch to 1 inch taller at 18 to 21 months.
d At 0.5 inch fat cover.
e At 12 months, bulls weigh 50% to 60% of this mature weight, under most development programs.
Source: Ag Life Extension, E-192

Another good barometer for appropriate growth, development and body condition of young bulls is to simply use the body condition scoring system described in chapter 20. The system uses 1 for emaciated animals and 9 for very obese animals. A good target for body condition score in young bulls is 6 at the beginning of their first breeding season. Perhaps the best way to verbally describe the ideal condition is bloomy but not fat.

BIF Guidelines for On-Farm and Central Bull Test Stations

Most bulls undergo some form of performance testing after weaning, either on the farm or at a central bull test station. The Beef Improvement Federation (BIF) provides guidelines for uniform beef improvement programs emphasizing the use and interpretation of performance data and quality management programs in improving the efficiency, profitability and sustainability of beef production (Cassady, 2010). Most breed associations participate in the BIF organization and encourage use of their guidelines for bull development. Guidelines are provided for on-farm testing as well as for central bull test stations. The guidelines are useful in designing an optimal nutrition program to ensure bulls are adequately grown and developed, while not becoming overconditioned prior to being put into service.

Weaning Weight and Yearling Weight

Guidelines for yearling and weaning data include recommended average age at weaning of around 205 days within a contemporary group. Recommended average contemporary group ages for yearling weight data collection are based on the development program chosen and determined primarily by the energy content of the test period diet. For example, recommended average contemporary group age is 365 days for bulls receiving a high-energy diet, 452 days for bulls receiving moderate-energy diets and 550 days for bulls receiving low-energy diets. Specific criteria for high-, moderate- or low-energy concentrations are not provided, although the assumption is that moderate-energy programs will be based on high-quality forage and possibly some concentrate supplementation, while low-energy diets will be based on year-round grazing and/or harvested forage with little concentrate feeding and will include some moderate- to low-quality forage.

For on-farm testing programs, BIF recommends a minimum of 70 days from weaning to data collection for yearling weight. However, for central bull test stations feeding concentrate-based diets (high energy as described above), the BIF guidelines include a minimum of 21 days for an adaptation period and a minimum of a 112-day test period using diets containing 60% to 70% TDN on a DM basis. This is equivalent to approximately 1 to 1.15 mega calories of metabolizable energy per pound of feed and similar to the recommended energy concentration suggested for feed intake and feed efficiency data collection.

Feed Intake and Feed Efficiency

Specialized equipment is necessary to evaluate post-weaning feed intake and feed efficiency as animals must be housed in contemporary groups, although feed intake data must be collected on an individual animal basis. These specialized feeding facilities are gradually becoming more abundant around the country and include commercial facilities designed by American Calan®, GrowSafe Systems Ltd.® and Insentec BV®. Recommended guidelines for feed intake and efficiency traits include a minimum of a 21-day adaptation period, a minimum of 70 days on test and a minimum energy concentration in the diet of 1.1 mega calories of metabolizable energy per pound of feed. For perspective, good-quality corn silage contains about 1.2 mega calories per pound, fresh Bermudagrass forage and high-quality alfalfa hay contains about 1.0 mega calories per pound, while cracked or dry rolled corn and corn dried distiller's grains contains about 1.5 mega calories of metabolizable energy per pound.

Consequently, bull development diets can be formulated to contain around 1.1 mega calories of metabolizable energy

and easily meet the minimum effective fiber criteria mentioned above. Diets fed free choice at or close to this energy level are recommended. These formulation criteria would be considered a moderate energy level and should achieve optimal growth and development of young bulls to ensure early, as well as long term reproductive health and soundness. Note that this criteria is not designed to maximize post-weaning growth rate.

Cow-to-Bull Ratios for Commercial Herds

The three major goals of any breeding season should be to:

1. Get cows settled as early in the breeding season as possible.
2. Cows need to be bred to the bulls with the highest possible genetic worth.
3. Achieve both as economically as possible by getting the cows bred with the fewest possible bulls.

Defining the optimum female-to-bull ratio is important to a successful breeding season. However, no one ratio is optimal for all ranches or small herd operations. The number of bulls required to adequately cover the breeding females is related to many factors influencing the female-to-bull ratio including:

- distribution of the breeding females,
- terrain,
- water availability,
- carrying capacity and feed intensity,
- pasture adaptation and
- pasture size.

Bull variation is caused by:

- age,
- condition,
- mating ability,
- libido,
- fertility,
- sperm reserve,
- social behavior and
- injury.

Management decisions include:

- length of breeding season,
- reproductive diseases,
- breeding intensity and
- amount of observation.

Most of these factors must be considered in defining the optimum female to bull ratio. Figure 30.1 illustrates how difficult it is for producers to know the optimum cow-bull ratio. This study, conducted in Colorado, shows the percentage of synchronized females that bulls impregnated when given the opportunity to breed three to 51 synchronized females. Notice that some bulls had a poor percentage

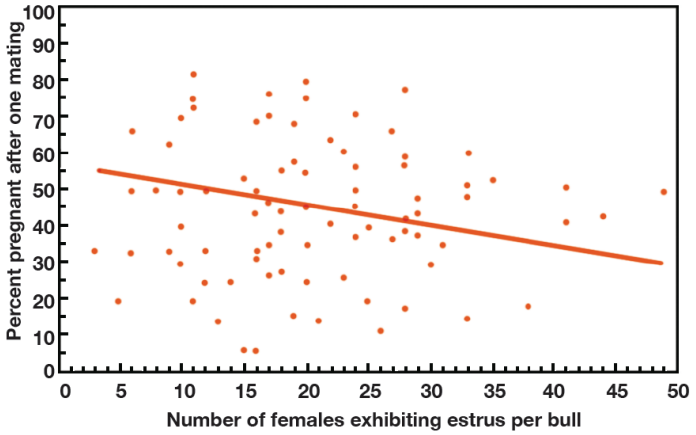


Figure 30.1. Effect of number of females exhibiting estrus on the percentage pregnant by each bull in single-sire mating of estrous synchronized females. Source: Pexton et al.

pregnancy rate, even when exposed to small numbers of females and some bulls had a high rate, even though they were running with 30 or more synchronized females. The vertical axis depicts the percentage pregnant after one opportunity to mate with the group of synchronized females.

Proper management during the breeding season should result in each female being bred by a single fertile bull each time she is in estrus. Bull overlap (more than one bull breeding a cow in heat) is not desirable, primarily because it does not enhance pregnancy rates. Disadvantages of bull overlap are increased risk of bull injury through competition for estrous females, additional pressure from social dominance and the extra costs incurred by purchasing and maintaining more bulls.

Research at an Eastern Colorado research station, where the average carrying capacity is 25 acres per animal-unit-year, showed similar conception rates for bull-to-female ratios of 1:25 and 1:50 (Healy, et al.). This research was conducted with multi-sire breeding pastures. All of the bulls were experienced bulls and had previously passed a breeding soundness examination.

Bull overlap can be decreased by eliminating bull congregation within breeding pastures. This can be achieved by dividing the breeding herd into separate pastures or by using pastures with natural barriers to reduce mixing of breeding groups. In addition, riders can be used to keep bulls well distributed among breeding groups.

Large cow-to-bull ratios can reduce bull costs on very large ranches with minimal risk. On a small 50- to 100-cow operation, using just one bull that happens to undergo an injury or disease could spell disaster for an entire calf crop.

Recommendations for smaller herds that will utilize only one bull per pasture may need to be more conservative. A time-honored rule of thumb is to place about the same number of cows or heifers with a young bull as his age is in months. For instance, a bull that is 14 months old going into his first breeding season should be expected to breed 14 cows or 15 cows, while a 2-year-old bull may be placed with 20 cows to 25 cows. Mature bulls that have passed a

veterinarian's breeding soundness exam normally give good results when placed with 25 cows to 35 cows.

Bull Pastures

Maintaining a 60- to 75-day breeding and calving season can be one of the most important management tools for cow-calf producers. A uniform, heavier and more valuable calf crop is one key reason for keeping the breeding season short. Plus, more efficient cow supplementation and cow herd health programs are a product of a short breeding season.

Many small producers lose all of these money-making advantages because they do not have a pen or trap that will hold the bull away from cows and heifers for nine months to 10 months of the year. It is a good idea to have a bull pasture that is somewhat isolated. Bulls kept away from cows will remain quieter and will fight less. A pasture with adequate area also will encourage exercise and reduce confrontations between bulls.

Several sources of information about cattle fencing on the internet include Dr. John Spitzer, a Clemson University beef cattle specialist, who uses a minimum of two acres per bull for the bull pasture. Well-fertilized introduced pastures, such as Bermudagrass in eastern Oklahoma (with adequate rainfall) can stand this stocking density. However, native grass situations will require more acreage per bull unless the producer wants to feed a great deal of hay and supplement during much of the year.

Clemson uses a five-strand, high-tensile fence with the strands spaced 10 inches apart. High-tensile wire is a heavy gauge, smooth wire that can be made as a permanent system with in-line wire stretchers. The first strand is 10 inches above the ground. The end result is a fence 50 inches tall.

The fence, of course, must be electrically charged. A good high-voltage, low-amperage fence energizer or charger provides the energy source. The Clemson design uses the second, third and fifth wire as charged wires, with the first and the fourth wire attached to grounds. The grounds will be most effective if they are set deep into the soil. This will allow for good grounding even when summer droughts cause top soil to become quite dry. Different designs may fit different situations. For example, some designs electrify the first wire (from the bottom) and make the second wire a ground (Figure 30.2). Talking to a commercial representative from a reputable fencing supply company can be very helpful. Being able to keep the bull away from the cows for nine months to 10 months of the year is a critical step to a more efficiently managed, profitable cow-calf enterprise.

Bull Management After the Breeding Season

After the breeding season, bulls become a necessary evil or an unwelcome visitor. Many producers might like to forget about them for the balance of the year and some almost do. While it is true that bulls during the post-breeding season do not require much management, adequate planning and care

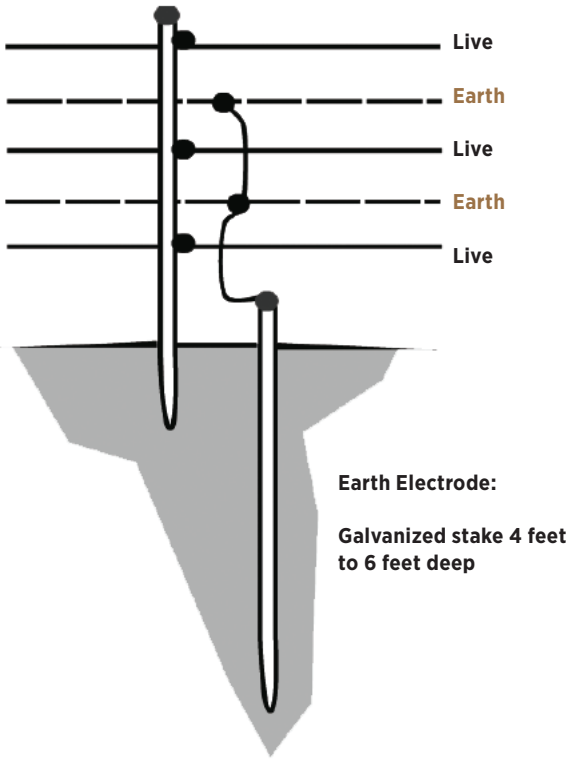


Figure 30.2. Example of fence design. Source: Adapted from Spitzer.

ensures bull costs will be reasonable and ready to go again when needed. In most spring-calving herds, the breeding season begins in the spring or early summer and extends for two months to three months. With a 60-day prebreeding conditioning period, the post-breeding season is about seven months, usually in the fall and winter. Goals for this period are basically as follows:

- keep feed costs at a practical minimum,
- keep the bulls in moderate condition,
- minimize chance of injuries and
- allow growth of young bulls.

Post-Breeding Appraisal

As bulls come out of the breeding pasture, one of the first steps should be to appraise the bull battery and sort them three ways. The largest group should be the mature bulls in good condition that will not require any special care. Perhaps the most important group is the young bulls that are still growing and need higher-quality feed (Figure 30.3). Bulls that are extremely thin or need special care for other reasons can be placed in this group as well. The last group is for old or crippled bulls that have completed their productive life and are to be marketed.

All bulls should have access at all times to a high-quality vitamin and mineral mix. Vitamin and mineral requirements for breeding bulls do not differ substantially from the cow herd and therefore, a well-designed mineral program that complements the ranch's base forage resources should work well for the bulls (see chapter 19 for more information).

Mature bulls in good condition can exist very well on an essentially all-roughage diet. While the amount will vary

Figure 30.3. Young bull in performance testing program.

some with the size of the cattle, a good rule to remember is about 2% of their body weight in dry feed per day is required. Protein needs will parallel closely those of a dry pregnant mature cow in the middle third of gestation. Bulls weigh 1.5 times as much as cows, so the protein supplement should be fed accordingly. Bulls may only actually be working 60 days to 90 days out of the year. If they cannot gain body condition while they are not working and consume average to high-quality forage or hay, their female progeny may not be able to either.

Yearlings

Yearlings should be left with the cow herd for 60 days or less. Beyond that time, their body condition may decline to such a degree that it may have long-range effects on their growth. After removal from the cow herd, yearlings should be kept separate from the older bulls at least through their second winter.

After the breeding season, yearling bulls should have access to higher-quality pasture, hay or silage. Protein supplementation may be required if forage contains 8% protein (DM basis) or less. These cattle are still growing rapidly, and may need to replace some condition lost during the breeding season. Feeding low-quality hay or grazing extremely low-quality pasture without supplementation is not advisable for these young bulls that are still growing.

Salvage Bulls

Often, bulls that have completed their productive life because of age or injury can be marketed to advantage after a brief period on a high-energy feed program. Bulls will vary greatly in condition at the end of the breeding season depending upon the number of cows per bull, the length of the breeding season and the quality of the feed available.

However, most bulls will gain very rapidly and efficiently after the breeding season if they are provided with the necessary nutrition. These bulls should be placed on excellent pasture or free-choice hay of high quality, then fed a concentrate feed that provides the most economical energy source, usually a cereal grain. Concentrates can be fed at the rate of 20 pounds to 25 pounds per head per day, although when fed at this level, it should be split into two equal feedings. Grain supplements should be started slowly and gradually increased to avoid digestive disturbances. At this nutritional level, bulls can be expected to gain between 3 pounds to 5 pounds per day for at least 60 days. Mature cattle also make excellent use of silage, if available.

Conclusion

A careful balance in terms of development nutrition level is necessary to achieve optimal reproductive capacity and longevity in young bulls without overfeeding or overconditioning. Moderate levels of dietary energy and moderate body condition are recommended for bull development. Once bulls have matured, access to abundant, clean water, a high-quality mineral mix and a good-quality roughage source should provide adequate nutrition to accomplish moderate body composition for optimal fertility. Overconditioning is never a good practice for bulls, no matter the age or stage of development. Also consider that bulls not capable of maintaining moderate body condition, while consuming moderate- to high-quality forage, may have high maintenance requirements (and therefore would produce cows with high maintenance requirements) or a medical problem that needs to be addressed.

References

Corah, L.R., H. Ritchie and G. Selk. The Nutritional and Reproductive Management of Beef Bulls. National Beef Cattle Handbook BCH-2030.

Coulter, G.H. 1994. Beef Bull Fertility: Factors Affecting Seminal Quality. Factors Affecting Calf Crop. Fields and Sand, CRC Press.

Healy, V.M. et al. 1991. Lowering Production Costs: Investigating the Optimal Use of Bull Power. 1991 Beef Program Report. Colorado State University, Ft. Collins, CO. Pg. 23-28.

Nocek, J.E. The Link Between Nutrition, Acidosis, Laminitis and Environment. Western Canada Dairy Seminar Proceedings. Available at: wcds.ualberta.ca/wcds/wp-content/uploads/sites/57/wcds_archive/Archive/1996/wcd96049.htm

Pexton, J.E., P.W. Farin, R.A. Gerlach, J.L. Sullins, M.C. Shoop, P. J. Chenoweth. 1989. Efficiency of Single-Sire Mating Programs with Beef Bulls Mated to Estrus Synchronized Females. *Theriogenology* 32:705.

Pruitt, R.J. and L.R. Corah. 1985. Effects of Energy Intake After Weaning on the Sexual Development of Beef Bulls 1. Semen Characteristics and Serving Capacity. *Journal of Animal Science* 60:1186.

Selk, G. 1994. Management of Beef Bulls. OSU Extension Fact Sheet ANSI-3254, Cooperative Extension Service, Oklahoma State University.

Spitzer, J.C. 2003. Personal Communication. Clemson University.

31 Synchronizing Heats in Beef Cows and Heifers

Daniel Stein, Brian Freking and Barry Whitworth, DVM

Overview

- **Provide a summary of some of the most popular estrous synchronization methods.**
- **Discuss answers to key producer questions.**

Introduction

Estrus synchronization is a reproductive management tool that facilitates artificial insemination (AI) to occur, so producers can capitalize on the superior genetics available through the use of commercially processed semen. There are three basic types of synchronization protocols: 1) estrus detection only, 2) estrus detection and clean-up fixed-time insemination and 3) fixed-time insemination. Estrus synchronization should never be a substitute for nutrition, herd health or herd management. When managed properly, estrus synchronization effectively can be used to facilitate not only AI, but natural service as well. For some producers, natural service may be the easiest method of breeding cattle and estrus synchronization may be as potentially beneficial to producers using natural mating as AI. USDA data shows approximately 8% of cow-calf producers in the U.S. incorporate estrus synchronization into their breeding program. For an estrus synchronization program to be implemented successfully, it must be well thought-out and well planned. The benefits of incorporating estrus synchronization into a breeding program, whether using natural service or AI include:

- Improving management by more easily defining the breeding season and the calving period.
- A labor-saving tool if monitoring parturition; females can be grouped by expected date of parturition.
- Increasing the time needed for postpartum recovery in cows and first-calf heifers.
- Allowing for greater use of superior sires through artificial insemination (AI) or by natural service.
- Increasing calf performance and weaning weights due to earlier birthdates in the calving period.
- A more uniform calf crop in size and age, which can be a potential advantage at marketing time.
- Improving nutritional status of females; females can be grouped according to stage of gestation and fed accordingly.

Estrus detection can be a very time- and labor-intensive activity, which makes AI programs impractical for some producers. However, with some synchronization protocols, estrus detection can be eliminated because animals can be inseminated at a pre-determined time, known as fixed-time AI. Synchronization protocols that incorporate fixed-time AI not only synchronize the estrous cycle, but induce ovulation at a pre-determined time to facilitate insemination. The first step in deciding upon a synchronization protocol is for the producer to decide how much time, if any, is available for estrus detection or if estrus detection is even feasible. For synchronization protocols recommended by the Beef Reproduction Task Force; it is suggested that mature cows be in a BCS 5 or greater and at least 50 days or more postpartum at the time of insemination. For young, thin and late-calving cows that are less likely to have resumed their estrous cycle, protocols including a progestin (progesterone) should be considered. An intravaginal insert containing progesterone (Eazi-Breed™ CIDR® Cattle Insert—see section on Products used to Synchronize Estrus in Beef Cows and Heifers*)* can induce some non-cycling cows to cycle and improve their chance of conceiving. However, these protocols may not be cost effective for cows that are too thin or have recently calved. Age and weight influence the onset of puberty in heifers; they should attain 60% of their mature weight prior to breeding. When 50% of the heifers have a **Reproductive Tract Score** of three or greater at 50 days to 60 days prior to breeding, estrus synchronization protocols tend to be more successful. Also, synchronization protocols that include a progestin (progesterone) may induce some prepubertal heifers to cycle.

Beef Reproduction Task Force Recommendations and Available Tools

The Beef Reproduction Task Force is a multi-state Extension group, whose objective is to provide timely

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

information regarding applied reproductive strategies in beef cattle. Choosing an estrus synchronization protocol that can be used with AI or with natural service can be difficult, as a number of synchronization protocols are available. To assist cattle producers in determining an effective estrus synchronization protocol, the Beef Reproduction Task Force provides recommendations for estrus synchronization protocols to be used in either cows or heifers. These protocol recommendations are updated annually by the Task Force. The current protocol recommendations are found at the Applied Reproductive Strategies in Beef Cattle website at appliedreprostrategies.com.

The Beef Reproduction Task Force also provides a free Excel-based *estrus synchronization planner* developed by Iowa State University. This synchronization planner is a useful tool to aid in planning protocols to fit the producer's desired outcomes. The Original planner outlines protocols for one group of females and the Multigroup planner outlines up to 12 different groups of females scheduled during a 12-month period. These planners will guide users to appropriate protocols, and based on user inputs, translate selections into dates and times on a printable calendar.

Products Used to Synchronize Estrus in Beef Cows and Heifers

The mode of action of the commercial products used for synchronization in beef cows and heifers is the same mode of action as hormones produced endogenously and released during the course of the estrous cycle in the animal. Traditional estrus synchronization protocols only synchronize estrus, not ovulation. Current protocols that incorporate fixed-time AI are designed to synchronize not only estrus; but also ovulation in animals often in various stages of the estrous cycle when implemented. The fundamental principle of synchronization is to first control the timing of the onset of estrus (standing heat) by controlling the length of the estrous cycle. There are only a few approaches to controlling the length of the estrous cycle. The first is to regress or "kill" the corpus luteum (CL), a structure of the ovary that produces progesterone. Intentional regression of the CL before the time of natural regression, termed luteolysis, will allow the female to come into estrus, thereby shortening the estrous cycle. This intentional regression of the CL is accomplished by the exogenous administration of prostaglandin F2α (PG), which is endogenously released from the uterus endometrium of the animal during the estrous cycle. The second is to administer exogenous progestins to delay the time of estrus following natural or induced luteolysis and can extend the length of the estrous cycle. Following ovulation, the female will form a CL-producing progesterone. In cycling cows and heifers, progestins will not affect luteolysis. Once CL regression has occurred, progestin administration can prevent a cow or heifer from showing signs of estrus and ovulating. Additionally, gonadotropin-releasing hormone (GnRH) will initiate a cascade of hormonal responses that will cause follicles greater than 8 millimeters to 10 millimeters in size to ovulate. The primary functions of an exogenous administration of GnRH, which is endogenously produced by the animal during the course of the estrous cycle, are to initiate follicle turnover at the start of a synchronization protocol and to synchronize ovulation with the delivery of semen during a fixed-time AI protocol.

Three primary groups of products are used to synchronize estrus or ovulation in beef cattle: prostaglandin F2α (PG), progestins (progesterone) and gonadorelins (gonadotropin-releasing hormone; GnRH). The prostaglandin products each contain ProstaglandinF2α or an analogue of Prostaglandin$F_2\alpha$. The prostaglandin products currently available for estrus synchronization are: Lutalyse® HiCon (dinoprost tromethamine), ProstaMate™ (dinoprost tromethamine), In-Synch (dinoprost tromethamine), Estrumate® (cloprostenol sodium), Synchsure® (cloprostenol sodium) and estroPLAN® (cloprostenol sodium). The progestin products include: Eazi-Breed™ CIDR® (controlled internal drug release), an intravaginal insert and MGA® (melengestrol acetate), a feed-additive. The gonadorelin products currently approved by the FDA include:

Cystorelin®, which is approved for use in combination with SYNCHSURE to synchronize estrous cycles to allow for fixed-time artificial insemination (FTAI) in lactating dairy cows and beef cows;

GONAbreed®, which is approved for use in combination with cloprostenol sodium to synchronize estrus cycles to allow for fixed-time artificial insemination in lactating dairy cows and beef cows;

Factrel®, which is approved for use with Estrumate (cloprostenol injection) to synchronize estrous cycles to allow for fixed time artificial insemination (FTAI) in lactating dairy cows and for use with cloprostenol sodium to synchronize estrous cycles to allow for FTAI in beef cows; and

OvaCyst™, which is approved for indications in support of reproduction management as prescribed by veterinarians.

Producers should visit with a veterinarian about the products used for synchronization as a current veterinary-client-patient-relationship (VCPR) will be necessary before some of these products can be purchased. In all cases, be sure to use the correct synchronization product at the recommended time and follow Beef Quality Assurance practices when administering the products.

Protocols for Heifers: Estrus Detection Required

An inexpensive method of synchronization (Figure 31.1) is the one-shot prostaglandin protocol. However, this method involves several days of monitoring the animals for estrus. This method is based on the physiology of the CL, the structure on the ovary that produces progesterone. Though prostaglandin regresses or "kills" the CL; approximately

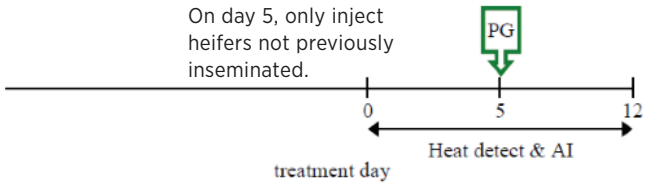


Figure 31.1 One-shot prostaglandin protocol.

five days prior to estrus and five days following estrus, prostaglandin has no effect on the CL. Following ovulation, it takes approximately five days for the CL to be fully functional and responsive to prostaglandin. Approximately five days prior to estrus, if not pregnant, the animal will release endogenous prostaglandin from the uterus endometrium to regress the CL naturally. By observing the animals for estrus for five days prior to the administration of prostaglandin; 1) those animals in the stage of the estrus cycles where their CL is regressing will be coming into estrus and 2) those animals that have just ovulated will take five days to form the CL and will respond to the prostaglandin injection.

Another low-cost system for estrus synchronization (Figure 31.2) uses melengestrol acetate (MGA®) and prostaglandin. MGA® is a progesterone-like feed additive, approved to suppress estrus in feedlot heifers and is not approved to synchronize estrus. In 1997, MGA® was approved for feeding 0.5 milligram MGA® daily for up to 24 days to suppress estrus in heifers intended for breeding. As heifers often are confined in a dry-lot during development and breeding—especially if artificial insemination is used—MGA® can be used in this protocol. MGA® should be fed at 0.5 milligrams per head per day for 14 days in 2 pounds to 5 pounds of a highly palatable carrier (feed). It is highly recommended to feed the carrier alone for several days before administering the MGA® so the cattle become accustomed to coming to the feed bunk to eat. Females will exhibit estrus two days to five days after withdrawal of the MGA®, but the standing estrus exhibited immediately after MGA® withdrawal is subfertile and females should not be bred on this estrus. A single injection of PG is administered 19 days after the MGA® has been removed from the feeding program. Most females will exhibit estrus 48 hours to 72 hours after the PG injection. The females will need to be monitored for signs of estrus at least twice per day and females should be inseminated 12 hours after the first observation of standing estrus.

The seven-day CIDR® protocol (Figure 31.3) involves the use of an Eazi-Breed™ CIDR® Cattle Insert, an

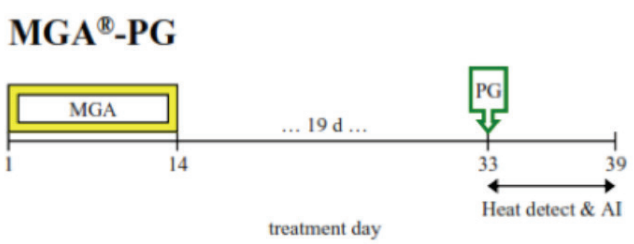


Figure 31.2 Estrous synchronization using Melengestrol Acetate (MGA®) and PGF. MGA®

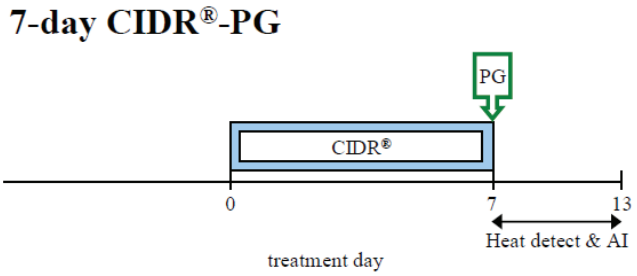


Figure 31.3. The seven-day CIDR® protocol involves the use of an Eazi-Breed™ CIDR® Cattle Insert.

intravaginal insert which contains progesterone. The CIDR® consists of a "T" shaped nylon backbone that is coated with a silicone layer containing about 10% progesterone by weight. The CIDR® is inserted into the vagina using a lubricated applicator following cleaning and disinfection of the applicator and vulva area. The CIDR® is easily removed by pulling an attached nylon cord. A small amount of vaginitis is a common observation at CIDR® removal; however, fertility is not compromised. In the absence of a CL, a CIDR® functions as an artificial CL by releasing progesterone, thereby suppressing estrus and ovulation. The CIDR® is left in the animal for seven days with PG administered at the time of CIDR® removal. Those animals that did not have a CL at the time of CIDR® removal and PG administration, will be in estrus approximately 24 hours before those animals that had a CL, as it takes approximately 24 hours for the CL to regress.

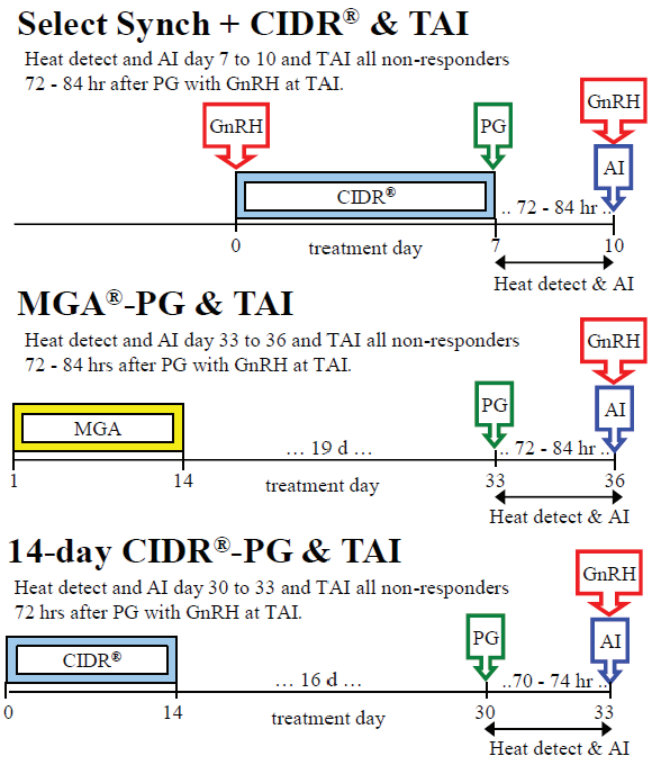


Figure 31.4. Fixed-time AI protocols for heifers with limited estrus detection.

Fixed-Time AI for Heifers: Limited Estrus Detection

The following protocols (Figure 31.4) are similar to the Heat Detection Protocols (Figures 31.2 and 31.3) except the animals are observed for signs of estrus for a limited period of time (72 hours to 84 hours or 70 hours to 74 hours following the PG injection, respectively). At that time, all heifers that have not shown signs of estrus are to be bred and given an injection of GnRH at the time of insemination. With the Select Synch + CIDR® protocol, GnRH is recommended, as heifers responding with a new follicular wave are more likely to conceive at the clean-up fixed time insemination. The 14-Day CIDR® protocol is similar to the MGA®-PG protocol except for the interval between CIDR® removal and the administration of PG, which is reduced to 16 days in the 14-Day CIDR® protocol as the progesterone in the CIDR® treated animals is cleared from the body much faster than MGA®-treated animals.

**Fixed-Time AI for Heifers: No Estrus Detection

Labor required to detect estrus has limited the use of AI for some producers. Estrus synchronization protocols are currently available, eliminating the need to detect estrus, allowing AI to be performed at predetermined fixed times without reducing AI pregnancy rates (Figure 31.5). The CO-Synch protocol uses GnRH and PG to synchronize estrus and ovulation prior to fixed-time AI. The seven-day CO-Synch + CIDR® protocol for heifers is the same protocol as the seven-day CO-Synch + CIDR® protocol for cows except heifers are inseminated between 52 hours and 56 hours after CIDR® removal and cows are inseminated between 60 hours and 66 hours CIDR® removal.

The five-day and seven-day CO-Synch + CIDR® protocols are similar, except for differences in the interval from GnRH to PG administration and the length of CIDR® treatment (five days versus seven days, respectively). Also, there are two injections of PG required with the five-day protocol. These two injections of PG are required with the five-day protocol to effectively regress accessory CL's that form as a result of GnRH-induced ovulations at the beginning of the protocol. The five-day and seven-day CO-Synch + CIDR® protocols have been shown to perform comparably on the basis of pregnancy rates resulting from fixed-time AI. The five-day protocol provides an effective alternative to the seven-day protocol for use in facilitating fixed-time AI; however, the producer must take into consideration the increased labor and treatment costs associated with the five-day CO-Synch + CIDR® protocol.

Synchronization Protocols for Cows: Estrus Detection Required

An inexpensive method for synchronizing estrus in mature beef cows is referred to is the Select Synch protocol (Figure 31.6). This protocol consists of a GnRH injection followed seven days later by an injection of PG. Females are observed for signs of estrus 36 hours before and up to six days following the PG injection. Cows are inseminated 12 hours after standing estrus is first observed. Most cows will exhibit estrus by day four after the PG injection, although some may exhibit estrus up to six days after PG. **Note:** there is a possibility of 5% to 20% of the cows showing signs of estrus 1.5 days to 2 days prior to the administration of the PG.

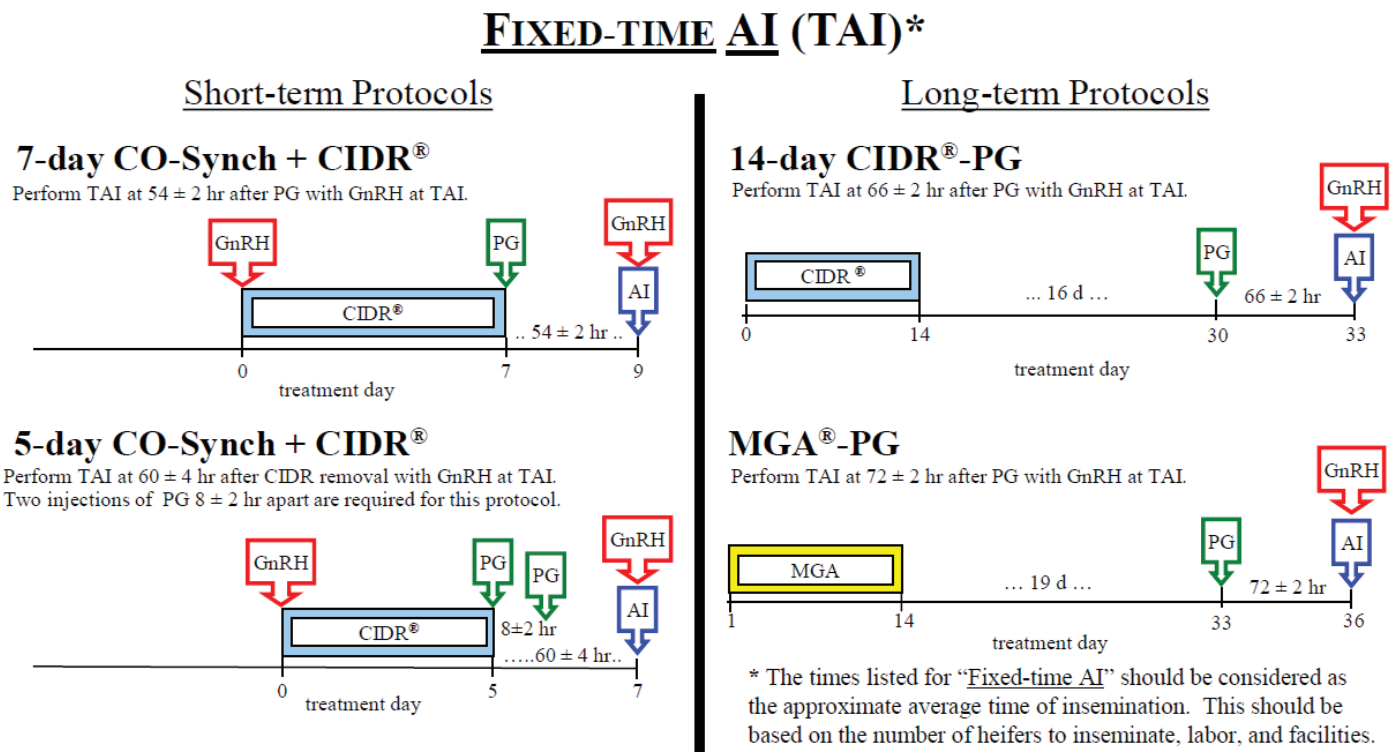


Figure 31.5. Fixed-time AI protocols for heifers with no estrus detection.

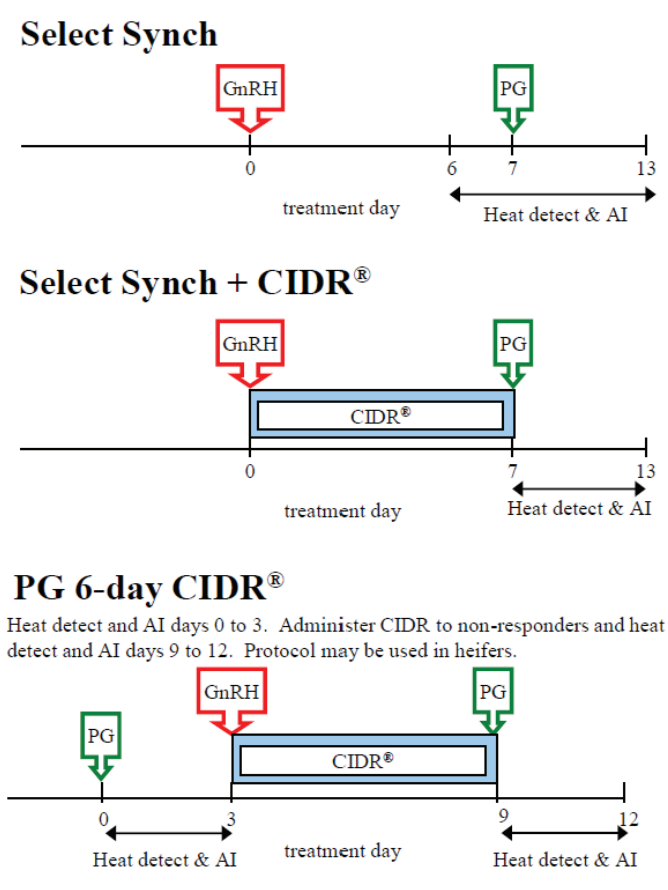


Figure 31.6. Protocols for cows with estrus detection.

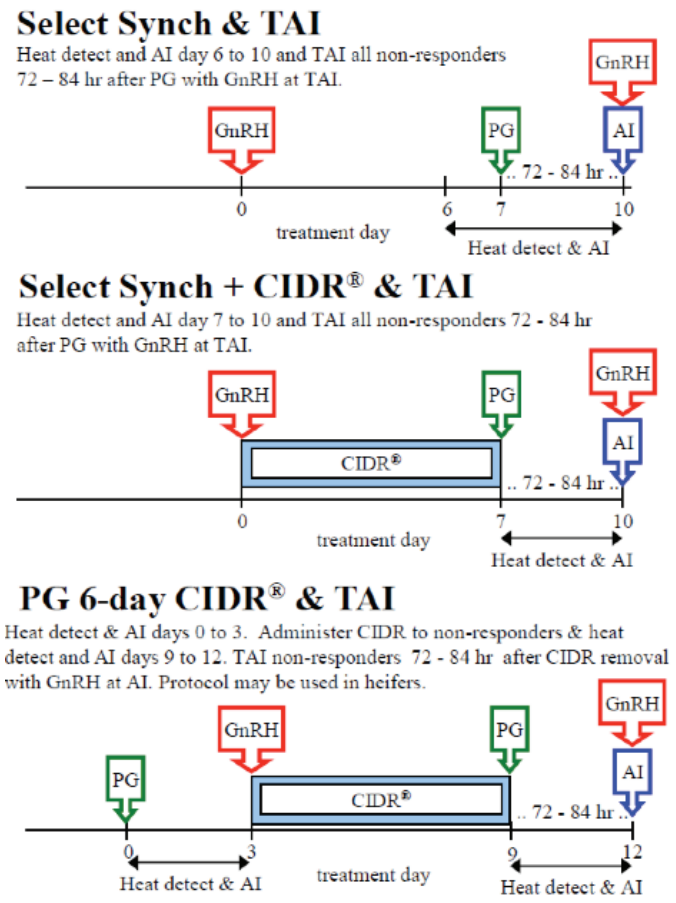


Figure 31.7. Protocols for cows with limited estrus detection.

Cows observed standing before the PG injection should be inseminated 12 hours after standing estrus is first observed. To eliminate the possibility of cows coming into estrus prior to the PG, a CIDR® may be used to suppress estrus until PG is administered on day seven of the protocol (Select Synch + CIDR® protocol). The PG six-day CIDR® protocol reduces the synchronization costs for any cows inseminated after the first injection of PG. More days of estrus detection are required than with the Select Synch or Select Synch + CIDR® protocol.

Fixed-time AI for Cows: Limited Estrus Detection

The following protocols (Figure 31.7) are similar to the Heat Detection Protocols (Figure 31.6) except the cows are observed for signs of estrus for a limited period of time (72 hours to 84 hours after PG). At that time, all cows not showing signs of estrus are to be inseminated and administered an injection of GnRH at the time of insemination to synchronize ovulation.

**Fixed-Time AI for Cows: No Estrus Detection

The five-day CO-Synch + CIDR® and the seven-day CO-Synch + CIDR® protocols (Figure 31.8) are both effective protocols for fixed-time AI. A slight increase in fertility (3% to 5%) has been reported with the five-day protocol versus

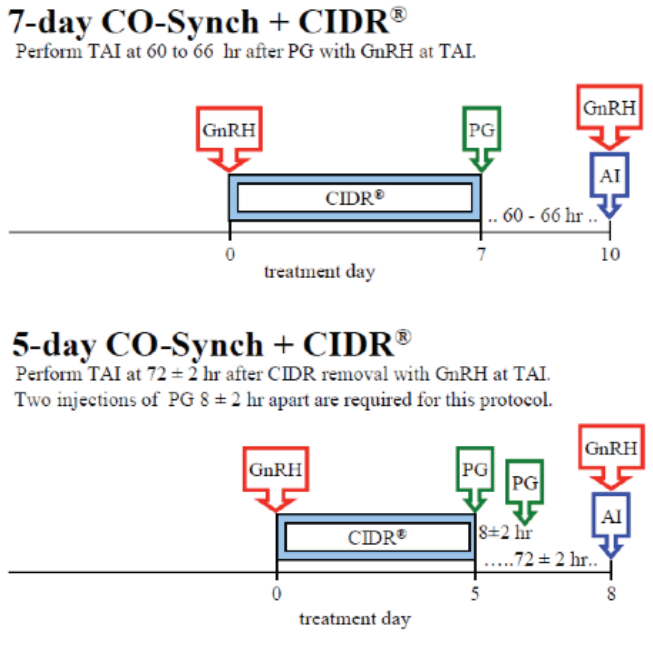


Figure 31.8. Fixed-time AI protocols for cows with no estrus detection.

the seven-day protocol. The two injections of PG required with the five-day protocol CO-Synch + CIDR® means the animals are put back through the working facility an extra time compared to the seven-day CO-Synch + CIDR® protocol.

**Fixed-Time AI for *Bos indicus* Cows: No Estrus Detection

Synchronization systems used in *Bos taurus* do not yield consistently similar results in *Bos indicus* type cattle. The modified five-day PG + CIDR® (Figure 31.9) has been shown to be more effective in *Bos indicus*-based breeds of cows. The modified five-day PG + CIDR® calls for an injection of prostaglandin at the start of the five-day synchronization protocol.

Synchronization and Natural Service

Although AI may not be desirable in all breeding programs, advantages from synchronization are desirable so the producer can more closely time the calving of a group of females, better utilizing labor at calving time and producing a more uniform group of calves to market. A low-cost synchronization protocol not producing a tight synchrony of standing estrus should be utilized, preferably a protocol recommended for use with estrus detection. An extremely close synchrony of a large group of females may overextend the bull power to breed the herd, as typical bull-to-cow ratios will not be adequate when using natural service with synchronization since a greater portion of the herd will be cycling at the same time. The impact of a failure to identify a sub-fertile bull or a disease problem prior to turnout is magnified with a synchronized estrus. Research from Healy et al. (1993) showed that when heifers were synchronized and bred with natural service sires, no differences in the overall pregnancy rates were observed when the bull-heifer ratio was 1-to-16 or 1-to-25 in a 28-day breeding season (Table 31.1). However, the estimated days to conception was less in heifer stocked at 1-to-16 (eight days into breeding season), compared with heifers stocked at 1-to-25 (11 days into breeding season).

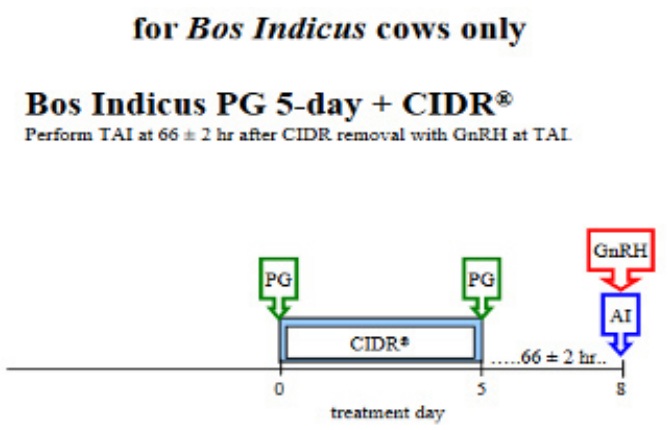


Figure 31.9. Fixed-time AI protocols for *Bos indicus* cows.
**** The time listed for fixed time AI should be considered as the approximate average time of insemination. This should be based on the number of cows to inseminate, labor and facilities.**

Guidelines for Using Bulls With Synchronization

(adapted from Johnson and Chenoweth)

1. Use a synchronization protocol recommended for use with heat detection. If the estrus synchronization protocol is one injection of PG, turn bulls out when the PG injection is given or turn bulls out and give PG five days later. For the Select Synch protocol, turn bulls out three days before PG. The tightness of synchrony achieved with a fixed-time AI protocol is not desirable in this case.
2. Use a small pasture or lot to reduce the physical energy the bull uses to travel.
3. Have a complete breeding soundness exam performed on bulls prior to use.
4. Use bulls two years to four years of age that are agile, active and known breeders. Bulls used in a multi-sire group should have their pecking order established well before turnout.
5. Use a bull-to-female ratio of 1-to-15 to 1-to-25.
6. Single sires eliminate bull fights, however, there is some data to indicate fertility was increased when two bulls were used.
7. Monitor activity closely during the two days to five days of most intense activity.
8. After the intense period of activity, it is best to rest the bull for two weeks or more prior to turning the bull back out. This may not be possible in small herds with only one or two bulls.

Table 31.1. Effect of bull-to-heifer ratio on pregnancy status and date of conception.

	Bull:Heifer Ratio[a]			
	1:50	*1:15*	*1:25*	*1:16*
	Non-synchronized		*Synchronized*	
Number of bulls in pasture	2	2	4	6
Day six pregnancy rate, %	40	38	41	53
Day 28 pregnancy rate, %	82	77[a]	83	84[b]
Estimated day of conception after turnout	10[b]	10[b]	11[b]	8[b]

a Each pasture had 100 heifers with different number of bulls present to reach each respective stocking rate.
b Means within row lacking common superscript differ ($P<0.05$. Adapted from Healy et al., 1993)

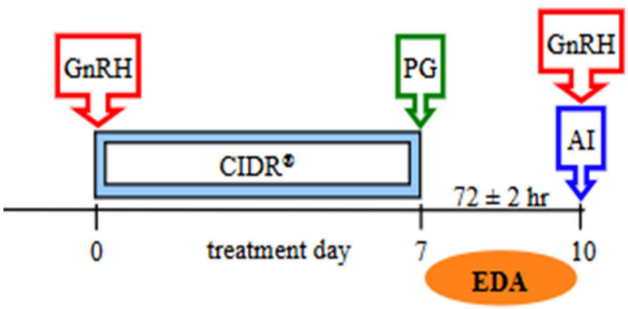
Sexed Semen Protocols

Use of sexed semen can result in conception rates that are decreased compared to conventional semen used in the same situation. Sexed semen can be used on any female observed in estrus (standing heat) and synchronized with any heat detection protocols on the original Protocol Sheet for conventional semen. Use estrus detection aids (EDA) for detecting females. For best results perform AI 16 to 22 hours after detecting female in estrus

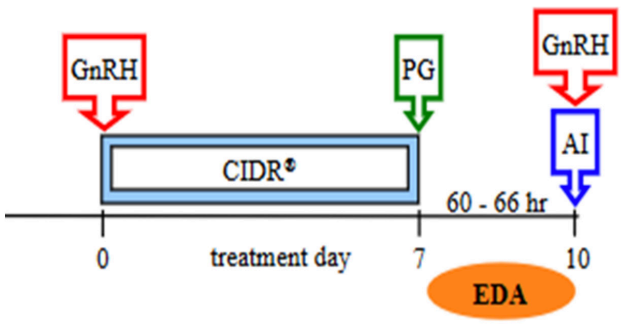
Fixed Time AI (FTAI) using Sexed Semen

It is recommended to use sexed semen on females that have exhibited estrus (standing heat) before FTAI and conventional semen on females that have not exhibited estrus (standing heat).

7-day CO-Synch + CIDR® (Heifers only)
Perform TAI at 72 hours after PG with GnRH at TA

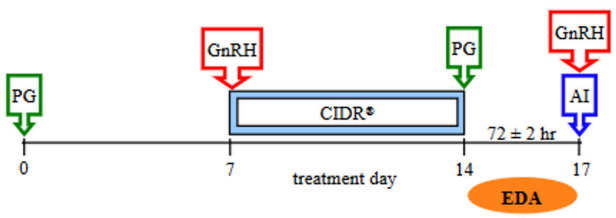


7-day CO-Synch + CIDR® (Cows only)
Perform TAI +60 to 66 hours after PG with GnRH at TA



The time listed for "Fixed-time AI" should be considered as the approximate average time of insemination. This should be based on the number of females to inseminate, labor, and facilities.

PG-7 7-day CO-Synch + CIDR® (Heifers only)

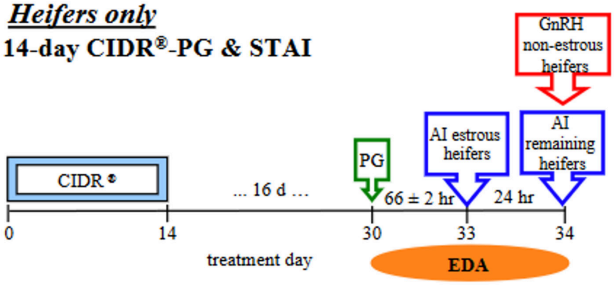


Perform TAI 72 ± 2 hours after second PG with GnRH at TAI. Heifers in estrus (standing heat) receive sexed semen, heifers not in estrus (standing heat) by TAI receive conventional semen.

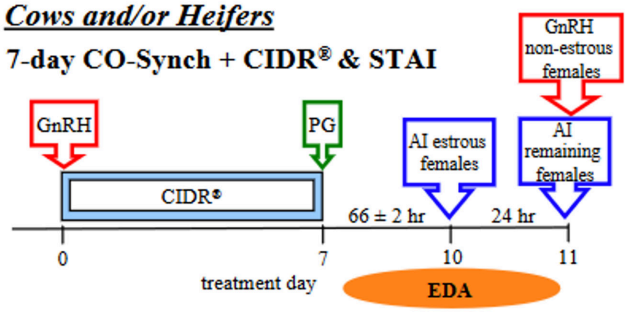
Split-Time AI (STAI)

Perform first TAI 66 ± 2 hours after PG in estrous females. GnRH administered at second TAI only in non-estrous females. Females detected in estrus by first or second AI receive sexed semen. Females that do not come into estrus receive conventional semen at second AI.

Heifers only
14-day CIDR®-PG & STAI



Cows and/or Heifers
7-day CO-Synch + CIDR® & STAI



Management at Calving

There seems to be a concern from producers that if the females are inseminated on the same day, they will calve on the same day. Bader et al. (2005) showed that cows conceived on the same day gave birth to calves during a 16- to 21-day period, dependent upon the respective sire. These distributions indicate successful use of fixed-time AI will not result in an overwhelming number of cows calving on the same day(s) (Figure 31.10).

A Word of Caution:

When handling all synchronization hormones, wear latex or non-latex protective gloves regardless of gender (e.g., prostaglandin is a vasoconstrictor and smooth muscle contractor, women of childbearing age, asthmatics and persons with bronchial and other respiratory problems should exercise extreme caution when handling this product). These hormones function in the human body like it does in a heifer or a cow therefore, caution should be taken when handling all synchronization hormones.

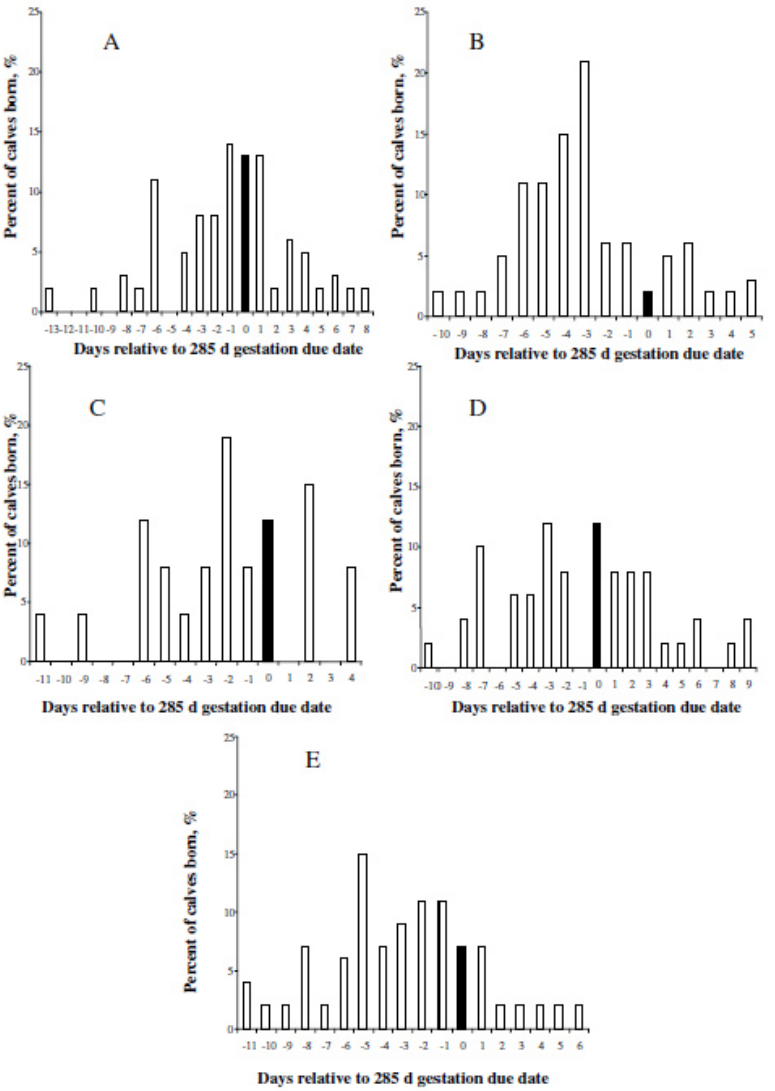


Figure 31.10. Calving distributions patterns at the respective locations for cows that conceived to fixed-time AI calving dates among cows that conceived on the same day to the respective sires (A, B, C, D and E) were 21, 16, 16, 20 and 18 days. Sire B at location 1 and sire E at location three were the same sire. The shaded bar in each graph represents an anticipated 285-day gestation due date. From Bader et al. (2005)

References

Bader, J.F., F. N. Kojima, D. J. Schafer, J. E. Stegner, M. R. Ellersieck, M. F. Smith and D. J. Patterson. 2005. A comparison of progestin-based protocols to synchronize ovulation and facilitate fixed-time artificial insemination in postpartum beef cows. *Journal of Animal Science* 83: 136-143.

Beef Reproductive Task Force; Applied Strategies in Beef Cattle. 2021. beefrepro.org/about/history/

Dahlen, C.R. 2012. Control of estrus with natural service. Proceedings, Applied Reproductive Strategies in Beef Cattle. December 3-4, Sioux Falls, SD

Ellis, R. W. 2008. Natural Service Mating with Bulls: Management Guidelines. Proceedings, Applied Reproductive Strategies in Beef Cattle. December 2-3, Fort Collins, CO.

Healy, V.M., G.W. Body, P.H. Gutierrez, R.G. Mortimer and J.P. Piotrowski. 1993. Investigating optimal bull:heifer ratios required for estrus-synchronized heifers. *Journal of Animal Science* 71:291-297.

Johnson, S.K., R.N. Funston, J.B. Hall, G.C. Lamb, J.W. Lauderdale, D.J. Patterson and G.A. Perry. 2013. Protocols for Synchronization of Estrus and Ovulation. Beef Reproduction Task Force.

Johnson, S. and P. Chenoweth. Use of Natural Service Sires with Synchronized Estrus. beefrepro.unl.edu/pdfs/naturalservice.pdf

Lamb, G.C. 2013. Control of Estrus in Cows. Applied Reproductive Strategies in Beef Cattle. October 15-16, Staunton, VA

Lauderdale, J. W. 2009. ASAS Centennial Paper: Contributions in the *Journal of Animal Science* to the development of protocols for breeding management of cattle through synchronization of estrus and ovulation. *Journal of Animal Science* 87:801–812.

Nogueira, M.F.G., P. Fernandes, R.L. Ereno, R.A.L. Simões, J. Buratini Junior and C.M. Barros. 2010. Luteinizing Hormone Receptor (LHR): basic concepts in cattle and other mammals. A review. *Animal Reproduction*. 7:51-64.

Patterson, D.J., D.A. Mallory, J.M. Nash, N.T. Martin and M.F. Smith. 2011. Strategies to Optimize Use of AI in Cow/Calf Production Systems: Focus on Fixed-Time AI Protocols for Cows. Applied Reproductive Strategies in Beef Cattle-Northwest. September 30 – October 1, Boise, ID.

Perry, G. 2004. Detection of standing estrus in cattle. FS921B. South Dakota State University Cooperative Extension Service, Brookings. South Dakota

Pruitt, R.J., L.R. Corah, D.D. Simms and M.F. Spire. 1982. Natural mating of Estrus-synchronized Heifers and Indicators of Bull Fertility. Cattlemen's Day, Kansas State University Agricultural Experiment Station. Kansas State University, Manhattan, KS. hdl.handle.net/2097/7128

Yelich, J. V. and G. A. Bridges. 2012. Synchronization response: *Bos taurus* vs. *Bos indicus* cattle. Beef Improvement Federation Research Symposium and Meeting. April 18-21. Houston TX.

32 Artificial Insemination

Daniel Stein, Brian Freking and Glenn Selk

Objectives

- **Discuss the importance of artificial insemination training.**
- **Discuss heat detection and its aids.**
- **Discuss methods of artificial insemination.**
- **Introduce methods of semen handling.**

Various technologies are available to both the purebred and commercial beef cow-calf producers to enhance the efficiency, productivity and profitability of their operation. Artificial insemination (AI) is one of those reproductive technologies that can be profitably incorporated into the breeding program and used in both heifers and cows. Although AI has been commercially available since 1938, when the first AI organization in the U.S. was established, it is underutilized in the U.S. beef herds. According to the most recent USDA data, approximately 8% of cow-calf producers in the U.S. incorporate AI into their breeding program. Common reasons beef cattle producers give as to why they have not implemented AI into their breeding program is the labor, time required and/or cost. The advantages of incorporating an AI program into the beef herd breeding program are numerous. One of the main reasons a cow-calf producer might implement an AI program into their breeding program is to take advantage of the commercially available semen from proven, genetically-superior sires normally too expensive to acquire as a resident herd sire. Other advantages include:

- The ability to breed more females at one time to a given sire.
- A reduced investment in resident herd bulls due to the reduced number of bulls needed in the herd.
- The enhanced genetic value in the replacement heifers retained in the herd.
- An increase in bio-security by controlling disease transmission.
- The selection of gender by using sexed semen; the early identification of reproductive problems (freemartins, non-cycling cows, etc.) and when combined with estrous synchronization, a shorter calving season can be achieved, resulting in a more consistent, uniform calf crop.

A successful AI program requires attention to detail in all areas of herd management. Many managerial decisions relative to feeding, facilities, fences, corrals, equipment and sire selection will be necessary. Sound health and nutrition programs (cows in good body condition) are requirements of any successful breeding program, but are absolutely essential for a successful AI program. Additional areas in which management expertise must be exerted for a successful AI program include estrus (standing heat) detection, artificial insemination technique, proper semen handling and semen tank management.

Estrus (Standing Heat) Detection

The most limiting factor in AI programs is the proper detection of cows or heifers in estrus or standing heat. Estrus, or standing heat, is the period of time occurring during the estrous cycle (every 18 days to 24 days) in sexually mature, non-pregnant heifers or cows when they are receptive to mounting activity by the bull or other animals in the herd. Estrus behavior (cows standing to be mounted by other herd mates) is the only external sign when ovulation may be occurring and cows should be artificially inseminated. As sperm are usually fertile for 24 hours to 30 hours after insemination and the ova (egg) have a fertile life of eight hours to 10 hours, proper timing of insemination depends largely on effective heat detection and is critical for achieving high pregnancy rates. Table 32.1 illustrates the effect of estrus detection rate on pregnancy rate.

For a successful AI program, the producer needs to achieve a high percentage of pregnancy, requiring good estrus detection.

Heat Detection Requires Observation

The unquestionable sign of estrus or standing heat is that the cow or heifer in estrus permits other herd mates to mount her while she remains standing. An animal moving

Table 32.1. Effect of estrus detection rate on pregnancy rate.

Estrus detection rate	55%	60%	65%	70%	75%	80%	85%	90%	95%
Conception rate	70%	70%	70%	70%	70%	70%	70%	70%	70%
Pregnancy rate	38.5%	42%	45.5%	49%	53.2%	56%	59.5%	63%	66.5%

Adapted from George Perry, fact sheet 921B.

away in response to an attempted mount by another animal is either just coming in to or going out of standing heat and further observations are needed to confirm the correct interpretation. Usually, the animal in estrus is restless and often will mount and ride other animals in the herd. However, individuals that mount or ride other animals may not necessarily be in estrus; only those remaining standing for mounting are in estrus.

The most productive means of determining which cows or heifers are in estrus is to conduct visual observations for standing heat at a minimum of two times a day for a minimum of 30 minutes at early morning and late evening. Preferably, these times need to be 12 hours apart and for consistency, performed by someone designated to be in charge of heat-detection and records information including animal identification, time of observation and location of all mounting activity. More frequent observation also may be beneficial, if practical (for example, noon and midnight). The detection of standing heat in cattle while sitting in the feed truck, or while cattle are eating at the feed bunk or hayrack is difficult because hungry cattle often are more interested in feed than each other. Table 32.2 describes the percentage of cows showing signs of standing heat at different times of the day.

The largest percentage of cows exhibit signs of standing heat at the least convenient time for accurate heat detection (6 p.m. to midnight and midnight to 6 a.m.). This is a major cause of heat detection inefficiency. Many of the cows that experience a standing heat from midnight to 6 a.m. can be observed as having secondary signs of heat at the time of normal heat detection on the previous evening.

Table 32.2. Time of day when cows exhibit estrus.

Time of day	*Cows exhibiting estrus (%)*
6 a.m. to noon	26.0
Noon to 6 p.m.	18.1
6 p.m. to midnight	26.9
Midnight to 6 a.m.	29.0

George Perry, Fact Sheet 921B

Estrous synchronization will aid in the accurate detection of standing heat and shorten the number of days that heat detection must be performed (learn more about estrous synchronization in chapter 31).

Secondary Signs of Estrus

Secondary signs of standing heat that a producer may observe include:

1. A willingness to mount other cows, even though neither cow may be willing to stand for the mount.
2. A roughened tail-head where the hair on her tail-head could be standing up or completely missing, which is evidence that the cow has been ridden by other animals or other animals have tried to mount.
3. Dirty streaks or marks on lower hips, sides or shoulders as the forefeet of rider animals may leave traces of mud or dirt on the sides and hips of cows or heifers in standing heat. Both sides of the animal must show signs of being ridden, since an animal cannot be ridden and marked on only one side.
4. Restlessness, nervousness, standing head to tail, circling, head butting, pacing, sniffing and licking other animals and resting their chins on the back or hip of other animals all may be indicative of a cow about to exhibit estrus.
5. The grouping together of animals. Animals coming into estrus usually will congregate into small sexually active groups. Whenever a small group of animals gather together, it should be watched closely for animals in standing heat.
6. A clear mucus discharge can be observed hanging from the vulva or smeared on the pin-bones or rump by the tail of an animal in estrus.
7. A bloody discharge often appears two days to three days after the end of estrus, which usually indicates a missed heat and should be recorded to observe this animal for a return to estrus in 18 days to 24 days.

None of these secondary signs alone is a positive determination of estrus. Standing to be mounted by a bull or another cow/heifer is the only conclusive sign that an animal is in estrus and ready to be inseminated (Table 32.3).

Table 32.3. Secondary signs of standing heat.

Six to 19 hours before standing heat	*During standing heat (can last from 6 to 24 hours)*	*After standing heat (up to 10 hours)*
Will not stand to be ridden	Stand to be ridden	Will not stand to be ridden
May be vocal and smells other cows	Nervous and restless	Clear mucous discharge
Nervous and restless	Congregates and rides other cows	
Attempts to ride other cows	Vulva is moist, red and slightly swollen	
Vulva is moist, red and slightly swollen		

Estrus Detection Aids

Several different types of aids for the detection of standing heat are available for producers implementing AI programs. Estrus-detection aids (and estrous synchronization protocols) can greatly increase the likelihood of detecting cows or heifers in standing heat; however, these are just aids and are not substitutes for visual observation.

These types of aids include chin-ball markers placed on a marker animal such as an androgenized cow or a deviated and vasectomized teaser (gomer) bull. The chin-ball marker consists of a bowl-type reservoir filled with paint with a spring-loaded ball valve, similar to a ballpoint pen. The marker is strapped underneath the chin of the marker animal. When the marker animal mounts and rides another animal, the chin-ball marker is activated (the ball valve is depressed) and paint markings are left on the animal's back or rump area (different colors of paint are available). The producer must learn to interpret these paint markings, since paint markings also can be left when the marker animal rests its chin on another animal's back or rump area.

Several types of commercial mounting-activity detectors are available to the producer to aid in the detection of standing heat. These devices are glued (or contain an adhesive) to the rump area, just forward of the tail-head of the cow or heifer suspected to be in estrus in the near future. These detectors rub off, causing a visual color change to the pad due to a dye capsule releasing dye through a pressure valve and lighting up when a switch is compressed, or sending a signal to a computer when pressure is exerted on a transponder button. A prolonged pressure (usually three seconds) from the brisket/chest area of the mounting animal will "activate" these detectors. Detectors will be more effective in areas with little or no low-hanging tree limbs, brush or back-rubbing devices, since false readings can occur. These different types of detectors will vary in price and the producer must learn to interpret the results of the type of detector utilized.

Tail-head chalking is an economical estrus detection method used by many dairies in the U.S. An oil-based paint stick is available at most farm and ranch supply stores and in a variety of colors. The paint stick is rubbed on the tail-head from anywhere between the hook or hip bones back to and including the corner where the tail begins its vertical decent. The oil-based paint stick is relatively rain resistant and is unlikely to be rubbed off in low-hanging tree limbs or brush. After a week to 10 days, it will likely take on a flaky, crusted appearance as it dries. When the cow or heifer is in standing heat and being ridden repeatedly, the chalk will be mostly rubbed off. When a cow or heifer is coming into standing heat and is trying to be mounted by other animals and is not standing completely, the tail paint (chalk) will be slightly smeared with the hair and chalk being ruffled forward with a feathered appearance. When those conditions are observed, the cow or heifer needs to be monitored closely. Reading the chalk strip is not hard, but does require close observation and practice for proper interpretation. Used mainly in dairies, electronic activity monitoring systems are available to detect estrus.

The pedometer, which measures steps taken by the animal, is used along with a computer to monitor the cow's behavior pattern, activity, rest time and restlessness. Animals in estrus usually are restless and often increase their physical activity and may walk long distances. Pedometers establish a base-line of normal activity and using that base-line, a formula calculates an increase or a decrease in activity. The most recent electronic system marketed for monitoring physical activity associated with estrous behavior contains a microprocessor and a three-dimensional accelerometer. Accelerometers measure motion in three dimensions: side to side, up and down and front to back.

The producer needs to remember that no estrus detection system is fail-safe. They should be aware of the advantages and disadvantages of the system of estrus detection incorporated into the breeding program being considered.

The Timing of Artificial Insemination

The average interval from the onset of estrus or standing heat to ovulation in the cow or heifer has been shown to be approximately 32.0 hours (± 4.7 hours), with the average interval from the end of estrus to ovulation being approximately 20.6 hours (± 6.4 hours). The interval from the onset of estrus to ovulation is not related to the duration of standing heat. Maximum fertility for artificial insemination occurs when cows or heifers are inseminated during the last half of standing heat; more so, nearer the end of standing heat. The deposition of semen 10 hours to 12 hours before ovulation allows the sperm cells to go through a process known as capacitation — which is the physiological changes the sperm cells must undergo to have the ability to fertilize the egg. Once ovulation takes place, the egg travels very rapidly to the site of fertilization in the oviduct. The fertile life of the egg is shorter than that of the sperm (Figure 32.1). Fertility decreases slightly when cows are bred a few hours on either side of this target time period and marked decreases in fertility are seen when breeding occurs more

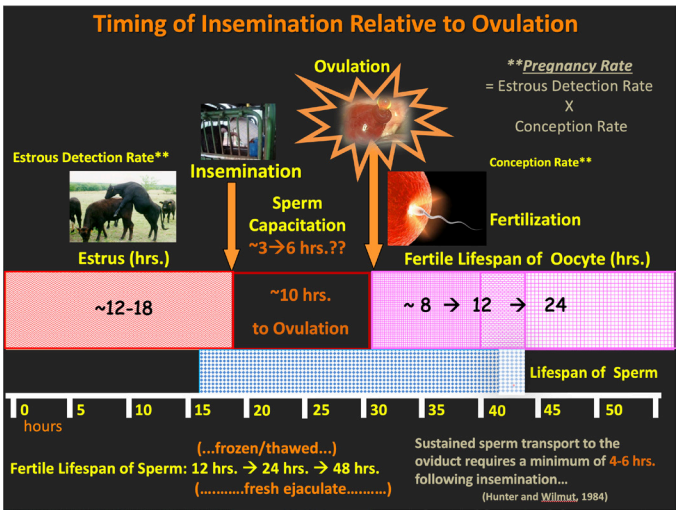


Figure 32.1. Illustration of the relationship among duration of estrus (standing heat, duration of the sperm lifespan, length of capacitation, duration of fertile lifespan of sperm and time of ovulation and duration of oocyte lifespan).

than 12 hours away from the end of estrus.

A guideline proven to work well for the timing of AI is often referred to as the a.m./p.m. rule (Table 32.4). At the end of the morning estrus detection period, animals detected in estrus the prior evening are bred. At the end of the evening estrus detection period, those observed in estrus that morning are bred. Acceptable pregnancy rates are found following the practice of inseminating cattle approximately 12 hours after the first observed standing heat. However, it is essential to remember the presence of fertile sperm in the oviduct must coincide with the time when the oocyte (egg) is viable (8- to 12-hour period following ovulation). Insemination too soon following detection of estrus, can decrease the probability that viable sperm are present at ovulation. However, insemination too late, relative to detection of estrus, may result in the oocyte dying before the sperm complete capacitation. When the onset of estrus is accurately determined by 24-hour electronic heat detection, insemination of heifers at 16 hours to 20 hours after the onset of estrus may optimize pregnancy rate (Wetteman et al.).

Semen Handling

Table 32.4. Using the a.m./p.m. rule for cow's first observed estrus.

First observed estrus	*Insemination time*	*Too late for optimum results*
Morning	Same evening	Next morning
Evening	Next morning	After 3:00 p.m. the next day

The quality of frozen semen when it arrives at the farm or ranch is determined by the bull and organization that processed it. Once it arrives, producers must take proper steps to ensure its viability. It is imperative to keep the canister, cane and unused semen straws as low as possible in the neck of the tank. A best management practice is to not expose semen to what has been identified as the danger zone, which is -112 F to -148 F (-80 C to -100 C). The critical temperature is approximately -112 F. Semen that is exposed to temperatures warmer than -112 F, even for a short period of time may be damaged. The extent of the damage depends on how long the semen is exposed to the elevated temperatures. Although it is easy to maintain frozen semen at a safe temperature, it is also easy to destroy it in a few moments of carelessness.

Shipper Tank

When shipping frozen semen, it is in a shipper tank referred to as a "vapor" tank, as liquid nitrogen itself is considered a hazardous material and cannot be in the tank during transport. When preparing a vapor tank for shipping, liquid nitrogen is actually poured into the tank, then absorbed into a special absorbent material lining in the tank. After a period of time, the liquid nitrogen not absorbed is poured back out of the tank leaving only vapor in the tank.

The temperature of a properly charged dry shipper should be approximately -301 F (-185 C) or colder. The "vapor" tanks keep the semen at a safe storage temperature during transport until the semen is either transferred back into another liquid nitrogen storage tank or thawed and used for insemination. Usually, a vapor tank will store semen safely for six days to eight days if unopened and the tank is shipped in an upright position. However, the holding time may be decreased for a tank shipped on its side or upside down. Frequent opening of the tank will result in a shorter holding time.

Tank Management

The semen storage tank consists of a tank within a tank, with an extremely efficient insulation system under vacuum between the inner and outer tanks. Because of the vacuum container construction, the temperature can remain at -320 F (-196 C), the temperature of liquid nitrogen, as long as at least 2 inches of liquid nitrogen is present in the tank. Technical advances in design and construction have produced storage tanks with a liquid nitrogen holding time of six months to nine months. Although semen storage tanks are well constructed, they still are susceptible to damage from mishandling. Semen tanks should be kept in clean, dry and well-ventilated areas. Avoid excessive movement of the tank. The inner chamber containing liquid nitrogen is suspended from the outer shell by the neck tube. Any abnormal stress on the neck tube, caused by sudden jarring or an excessive swinging motion, can crack the tube, resulting in vacuum loss from the outer chamber.

To increase holding time, keep the tank in a cool location away from direct sunlight. Avoid drafts from furnaces and outside air to help prevent excessive nitrogen evaporation. Make sure there is sufficient ventilation in the room to prevent possible suffocation of those nearby, which is caused by excessive nitrogen gas in the air.

Use boards or pallets to protect the tank from corrosion by keeping it elevated above concrete or wet floors. Corrosion of the outer shell will shorten the functional life of the tank and possibly cause failure. Pick a location safe from children and vandals, but do not hide the tank; it must be placed where it can be seen daily and monitored routinely for nitrogen level.

Finally, the liquid nitrogen level in the tank should be monitored regularly so it never goes dry. Always be watchful for a lid that has been left off and frost or sweat on the tank. Give particular attention to the neck and vacuum fitting. Frost indicates the vacuum insulation has been lost and liquid nitrogen has been or is evaporating rapidly. If you suspect this has happened, use a wooden yardstick to measure the amount of liquid in the tank. If the tank contains liquid nitrogen, the semen must be transferred to a good tank immediately. Should the tank be empty of liquid nitrogen, it is doubtful that the semen is viable and should be evaluated before it is used.

Retrieving Semen

Although the temperature of liquid nitrogen is -320 F (-196 C), there is a temperature gradient in the neck

Table 32.5. Temperatures found in the neck tube of a typical semen tank.

Location in necktube	*Range in temperature (F)*
Top	+36 to +54
1 inch from top	+5 to -8
2 inches from top	-41 to -51
3 inches from top	-103 to -116
4 inches from top	-148 to -184
5 inches from top	-220 t -256
6 inches from top	-292 to -313

of the semen storage tank (Table 32.5). The temperature in the neck of the tank is important because sperm injury occurs at temperatures as low as -112 F. This sperm injury is permanent and cannot be corrected by returning the semen to the liquid nitrogen. A rule of thumb many producers follow is to work below the frost line observed in the neck of the tank (Figure 32.2); however, the frost line has been shown to vary from -40 F to -184 F (-40 C to -120 C) between tanks. It is thought climatic conditions affect the "frost line" of the tank. The temperature in the neck of the tank also will become warmer as the liquid nitrogen level in the tank decreases. Sexed semen for commercial use is packaged in 0.25-milliliter straws instead of 0.5-milliliter straws. Furthermore, the concentration of sperm cells per straw of sexed semen is significantly lower than conventional semen. Although 0.25-milliliter straws containing sexed semen may be handled similarly to 0.5-milliliter straws, the smaller diameter makes them more sensitive to semen handling errors.

Best management practices to minimize thermal damage:

- Identify canister containing the desired semen. A semen inventory, keeping track of the location of each bull prevents unnecessary searching.
- Remove the canister from its storage position to the middle of the tank. Raise the canister just high enough in the neck region to grasp the desired cane of semen. **Keep the canister tops at a minimum, no higher than the frost line.**
- Grasp the desired cane and immediately lower the canister to the tank floor. Keep the cane as low in the tank as possible while removing the unit of semen. Use tweezers to remove the straw. If the straw is located in the upper goblet, bend back the top tab of the cane to a 45-degree angle. This will keep the straw from bending or breaking. **The straw should be removed within eight seconds from the time the canister is raised into position.**
- Immediately after the unit of semen is immersed in water, return the cane to the canister by raising the canister over the cane. Return the canister to its storage position.
- Any time it takes more than **eight seconds** to locate a particular cane, the canister should be lowered back into the tank to cool completely. **Never return a unit of semen to the tank once it has been removed from the cane.**

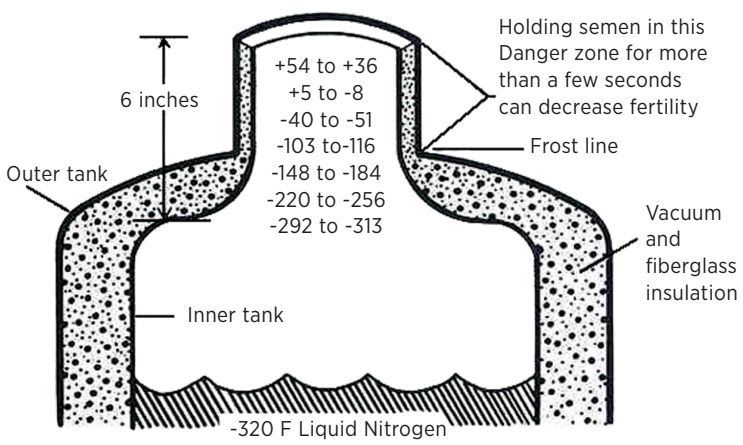


Figure 32.2. Cross-section diagram of liquid nitrogen tank.
(Adapted from American Breeder Service)

Semen Transfer Between Tanks

- Transfer of semen between tanks must be coordinated and rapid. Two people should be involved and tanks should be arranged side by side.
- Fill the tanks with liquid nitrogen before transfer, if possible.
- Have the appropriate canister in each semen tank in the center position.
- Transfer the canes quickly (within three seconds to five seconds). Never touch the units of semen with bare fingers.

Thawing Procedures

The correct thawing recommendation for semen in straws is not the same for all AI organizations. However, almost all organizations now recommend warm-water thawing of straws for 10 seconds to 60 seconds. For optimum results, follow the specific recommendations of the semen processor. Breeders may use semen from various AI organizations, but practice only one thawing procedure. The National Association of Animal Breeders (NAAB) has recommended that, when in doubt, 90 F to 95 F for a minimum of 40 seconds should be used as a universal thawing recommendation. Do not "pocket thaw" straws of semen unless recommended by the company packaging the semen. The pocket thaw should not be used for semen packaged in straws from other companies.

A major concern with warm-water thaw is the danger of cold shock when the straw is mishandled after thawing. Cold shock is the permanent injury to sperm caused by a sudden decrease in semen temperature after thawing. It occurs when semen is thawed, then subjected to cold environmental temperatures before reaching the cow. The severity of damage depends on rate and span of temperature drop. If precautions are taken to prevent cold shock, the advantage of warm thaw will be realized. Following are some thawing tips:

- Always keep insemination equipment clean, dry and warm.
- Use a thermometer to check the temperature of the warm-water thaw; do not guess at the temperature. Check the thermometer for accuracy at least every six months with a reference thermometer.
- Use an insulated water bath designed for thawing semen or a one-pint wide-mouth thermos deep enough to immerse the entire straw. Electronic thawing devices, which maintain water temperature accurately between 90 F and 95 F, are now available. These are convenient to use when breeding many cows at one time. Do not rely on the thermostat of the device to be correct. Always use a thermometer to double-check the temperature of water bath.
- Never thaw more than one unit of semen at a time. Breed cows individually, so thaw units of semen individually. Although research has shown that multiple straws can be thawed simultaneously, bulk thawing of semen should only be considered when a large group of synchronized cattle are to be inseminated. A general recommendation as to the number of straws that may be thawed simultaneously detracts from the overall importance of proper semen handling for successful AI. Straws thawed in bulk should be agitated slightly to keep them from sticking together.
- Gently shake the straw as it is taken from the tank to remove any liquid nitrogen that may be retained in the cotton plug end of the straw.
- Time the thaw with a watch to avoid guessing.
- When possible, use thawing recommendations of the AI organization from which the semen was processed. Otherwise, use NAAB's recommendation for 90 F to 95 F for a minimum of 40 seconds.

It is essential frozen semen is handled and thawed carefully and properly to obtain optimum results. It also is important to deal only with reputable, well-established AI organizations because their semen has been processed under standard, controlled conditions routinely evaluated.

During Insemination

One of the most frequent chances for semen damage is during transport to the cow. After thawing, the semen temperature must be maintained as close to 95 F as possible. Handling thawed semen and preparing the insemination rod should be done in a sheltered, preferably heated, area. Proper steps for handling semen include:

- While the semen is thawing, warm the insemination rod by rubbing it briskly with a paper towel. In cold weather, place the warm rod within clothing so it will be close to the body and maintain warmth.
- After the semen is thawed for the required time, dry it thoroughly with a paper towel to protect it from rapid cooling.
- Adjust the air space in the straw to ensure no semen is lost when the end of the straw is cut off. This can be done by slightly flicking the wrist while holding the straw at the crimp-sealed end.
- Transfer the straw to the rod and cut the tip of the crimp-sealed end of the straw squarely and through the air space. Only sharp scissors or a specially designed straw cutter should be used. Make sure to cut the straw "square" to achieve a good seal with the sheath.
- Wrap the assembled insemination rod in a clean, dry paper towel and tuck it within your clothing for transportation to the cow. Do not place the rod in your mouth or carry it uncovered in your hand.
- Inseminate the cow within minutes after thawing. The period of time between removing the semen from the tank and depositing the semen in the cow should not exceed 15 minutes.

Insemination Process

The recto-vaginal insemination process is used. Although not part of the female genital tract, the rectum (terminal portion of the large intestine) is an important organ to become familiar with, because your arm inside the cow will be working through this thin-walled tube. The rectum is 10 inches to 12 inches long and very stretchable. This is important to understand because it is through the rectum that manipulation of the cervix occurs during the insemination process. The anus serves as a valve between the rectum and the outside. A muscular ring (anal sphincter) keeps the anus closed. The gloved hand is inserted by forming the thumb and fingers into a cone tip and with a slight rotary motion, forcing it into the rectum. The anus is stretchable; hence, your hand and arm can easily slip into the rectum. Waves of peristaltic contractions will be encountered from the rectal wall. These often feel like rings. When strong, these contractions may block your hand from moving forward and make it difficult to manipulate the genital organs through the rectal wall. Judgment must be developed as to how much resistance to exert with the hand against these contractions so the animal will not be injured.

Sanitary Technique

Wash your hands. Inseminating cows is an invasion into the delicate uterine environment that is very conducive to growing bacteria. Bacteria on your hands could be transferred to your inseminating gun during the loading procedure. Likewise, thoroughly clean the inside edges of the lips of the vulva with a paper towel before inserting the insemination rod. If contaminants are carried into the uterus during insemination, these organisms could thrive and grow rapidly, resulting in metritis and infertility.

Semen Placement

The insemination process is a straight-forward process. However, since relatively few sperm cells will be used compared to a natural service by the bull, placement is critical. Semen should be deposited in the body of the uterus just in front of the cervix (Figure 32.3). One can recognize the proper site by the change in tissue consistency – from firm and hard in the cervix to soft and spongy in the uterus. To achieve the highest possible fertility rate, semen should be deposited at the very front end of the cervix. The internal (or

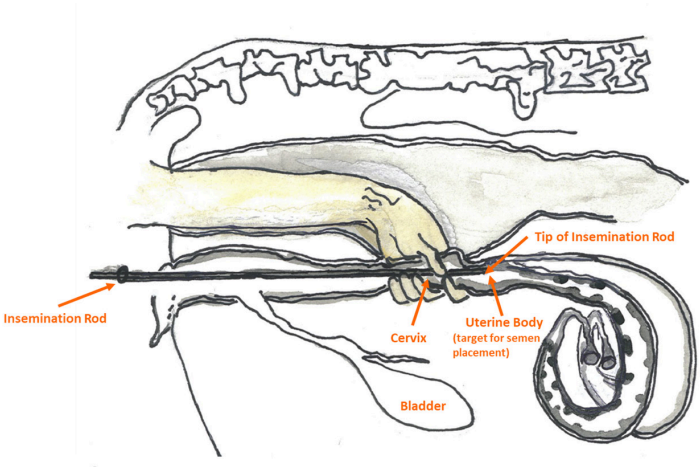


Figure 32.3. Placement for semen.

front) end of the cervix is often called the anterior cervical opening (os). Depositing semen at this location requires the use of a special device called a Cassou pipette, or AI gun. Steps of the process include:

1. Put on a clean plastic palpation sleeve and lubricate the glove and sleeve with a clean, nontoxic lubricant.
2. First gently clean rectum of manure, then gently insert arm into rectum by forming a cone with your fingers.
3. Thoroughly clean exterior of the vulva and surrounding area with clean paper towels.
4. Dilate the lips of the vulva by exerting slight downward pressure of the forearm in the rectum and backward pressure with the fingers just inside the rectum.
5. Insert AI gun as far as possible into the vestibule and vagina without touching the internal surface of vulva (point tip of A.I. gun upward while keeping track of gun with the gloved hand)
6. Pass the AI gun along the roof of the vagina until it reaches the cervix (avoid the suburethral diverticulum, a blind pocket just beneath the opening to the urethra).
7. Grasp the cervix through the rectal wall and guide the AI gun into the opening of the cervix with the aid of the thumb and little finger. The opening into the cervix protrudes back into the vagina. This forms a 360-degree blind pocket completely around the cervical opening. This pocket is referred to as the fornix vagina.
8. Apply gentle pressure and manipulate the cervix over the AI gun with a rotary movement of the wrist and movements of the fingers until penetration of the cervix (moving the cervix forward and backward to pass the annular rings may be needed).
9. Determine the length of the cervix and place the index finger at the uterine end of the cervix.
10. Move the AI gun forward through the cervix until feeling the tip bump the index finger. Make sure the location is not in the fornix vagina or caught between the cervical rings.
11. Slowly depress the plunger of the AI gun and deposit the semen in the uterine body.
12. Avoid pulling the A.I. gun backwards when depositing the semen because it may be deposited in the cervix and/or vagina.

In adequately restrained cattle and practice, this will take 30 seconds to two minutes. Passing an insemination syringe might not always be easy, because encountering natural obstructions may occur before semen deposition.

Reminder of Obstacles

The front end of the vagina forms a circular blind pouch where it joins the backward projecting cervix. This blind pouch is referred to as the fornix vagina and is usually from half-inch to 1 inch deep, surrounding the entire dome-shaped back end of the cervix. There will be other obstacles once inside the cervical canal. Firm, finger-like projections arranged in three to four circular rings extend into the canal. These cause the passageway to be crooked and contain blind pockets or dead ends. The circular blind pouch of the vagina and the winding cervical canal with its dead ends are the two major stumbling blocks for anyone learning how to artificially inseminate.

Next to estrous detection, semen placement error (by the technician) is most likely to affect fertility. Correct semen placement is very difficult to confirm in the field. It is impossible to check for correct pipette placement. The pipette position changes too easily. Post mortem tracts or examining culled cows inseminated with dye can be used to check semen placement after slaughter. Studies using dye deposition followed by slaughter have shown that up to 70% of the cows are inseminated incorrectly. The dye was placed in the vagina, posterior cervix, uterine horn or bladder. The target for semen deposition is the anterior cervical os, a difficult site to find. Inexperienced inseminators often do not pass the pipette far enough, or they pass it too far into the uterine horns. Since the body of the uterus is only half-inch to 0.75-inch in length, pipette passage 1 inch into the uterus results in most of the semen entering only one horn, effectively reducing conception. Semen deposition is often made too rapidly and semen takes the avenue of least resistance. If one horn is not as open as the other, it does not receive enough semen.

Take time while breeding a cow and depositing the semen. It only takes a few extra seconds to make sure semen is deposited correctly. The plunger should be slowly depressed during a five-second period, allowing the semen to flow slowly and evenly, divided between horns. In non-pregnant cows, walls of the uterus are soft and spongy. Insemination guns should never go beyond the front end of the cervix, because it is too easy to poke into or through the uterine wall. This could cause infection and perhaps even fatal peritonitis.

Experienced Technicians

Professional technicians are more successful at insemination than inexperienced owners or managers. Inseminators should periodically attend AI courses to improve or correct techniques. Selection of a qualified inseminator is an important element in the success of the AI program. While the insemination process is simple to

understand, it does require considerable manipulative skill. Companies selling semen often conduct three- or four-day training programs that provide individuals with sufficient skill to begin inseminating cows and heifers. However, newly trained individuals generally experience lower conception rates until they have inseminated a number of animals. Regular practice at inseminating is required to maintain high conception rates. In many localities, AI studs have trained inseminators who provide insemination service for a reasonable fee. Cattle operations where artificial insemination is routinely used often have a well-trained individual who may be available as a technician. Before producers make a decision whether to hire a trained technician or to train a member of the farm team, they should weigh the considerable cost of a reduced conception rate during the learning process against the fees paid for a trained technician.

References

A.I. Management Manual (2nd edition) American Breeders Service, DeForest, WI.

Dalton, J.C. 2014. Insemination Related Factors Affecting Fertilization In Estrous-Synchronized Cattle. Proceedings Applied Reproductive Strategies in Beef Cattle Symposium. October 8-9. Stillwater, OK.

DeJarnette, M. and Ray Nebel. A.I. Technique in Cattle. Select Reproduction Solutions™. selectsires.com/resources/fertilitydocs/ai_technique_cattle.pdf

DeJarnette, M. and Ray Nebel. Reproductive Anatomy and Physiology of Cattle. Select Reproduction Solutions™. selectsires.com/resources/fertilitydocs/reproductive_anatomy.pdf

Eller, A. Jr. and W.D. Whittier. 1988. Estrous Synchronization and Artificial Insemination in Beef Herds. Virginia Cooperative Extension Service, Publication 400-34. Blacksburg, VA. Accession:015734942.

Hoffman, David. 2014. The Value of Artificial Insemination in Beef Cattle. The West Central Missouri Region Agriculture Newsletter.

Hurnik, J.F., GJ King and H.A. Robertson. 1975. Estrous and Related Behavior in Postpartum Holstein Cows. *Applied Ethology* 2:55.

Kaproth, M. 2006. Forensics for the Bull Stud and Semen Processing Lab: Interpreting Tank, Straw and Semen Quality Clues. Proceedings of the 21st Technical Conference on Artificial Insemination & Reproduction, National Association of Animal Breeders. September 14-15, Milwaukee, WI.

Elliott, L. M. , J. L. Parcell, D. J. Patterson, M. F. Smith and S. E. Poock. 2013. Factors Influencing Beef Reproductive Technology Adoption. *Journal of the American Society of Farm Managers and Rural Appraisers*. Page 100-119.

Parish, J. Reproductive Management of Beef Cattle Herds, Extension Fact Sheet, No. 2615, (Extension Service, Mississippi State University, 2010). http://msucares.com/pubs/publications/p2615. pdf.

Parish, J and J. E. Larson. 2010. Artificial Insemination Programs for Cattle, Extension Fact Sheet, No. 2628. (Extension Service, Mississippi State University). http://msucares.com/pubs/publications/p2628.pdf.

Perry, G. Detection of Standing Estrus in Cattle.2004. Fact Sheet 921B. South Dakota State University.

Small-scale U.S. Cow-calf Operations. 2011. USDA:APHIS:VS:CEAH

Smith, M.F. 1, K.G. Pohler, G. A. Perry and D. Patterson. 2012. Physiological Factors that Affect Pregnancy Rate to Artificial Insemination in Beef Cattle. Proceedings Applied Reproductive Strategies in Beef Cattle Symposium. December 3-4, Sioux Falls, SD.

Stroud, B. 2012. Consequences of Mishandling Frozen Semen and Embryos. Proceedings Applied Reproductive Strategies in Beef Cattle Symposium. December 3-4, Sioux Falls, SD.

USDA. 2011. Small-scale U.S. Cow-calf Operations. USDA:APHIS:VS:CEAH

Wettemann, R.P., M.L. Looper, M.L. Warner, T. Prado and G.L. Morgan. 1998. Estrous Behavior and Time of Ovulation in Beef Cows during the Summer. Oklahoma State University Animal Science Research Report. Pages 227-231.

Wettmann, R.P. I. Rubio, F.J. White, D.W. Kastner and D.L. Lalman. 2004. Influence of Time of Insemination after the Onset of Estrus on Pregnancy Rate of Beef Heifers. Oklahoma State University Animal Science Research Report.

33 Available Options for Embryo Production in Cattle

Daniel Stein, Joao G. N. Moraes and Jazmin Markey

Objectives

- **Learn about the available options for embryo production in cattle.**
- **Discuss the history of embryo transfer.**
- **Learn about oocyte development.**
- **Discuss the selection of the donor cow.**
- **Discuss the benefits and drawbacks of utilizing MOET and IVF followed by embryo transfer.**
- **Learn about the evaluation, cryopreservation, labeling and transfer of embryos.**
- **Discuss the selection and preparation of the recipient females.**
- **Discuss the importance of a certificate of the procedure(s) performed.**

Available Options for Embryo Production

Embryo transfer is an assisted reproductive technology (ART) used by livestock producers to assist with the transfer of genetics to the next generation. In the beef and dairy cattle industries, there are currently two methods of producing embryos utilized in an Embryo Transfer (ET) program. Embryos can be either in vivo-derived (IVD) or in vitro-produced (IVP).

In vivo-derived embryos are generally produced using multiple ovulation embryo transfer (MOET) techniques. MOET is based on ovarian stimulation of donor cows or heifers with exogenous follicle-stimulating hormone (FSH) to promote multiple ovulations. Following estrus expression, multiple artificial inseminations (two to four) are performed to ensure the majority of the ovulated oocytes are fertilized. Approximately seven days post-insemination, trans-cervical uterine flush is conducted to recover the embryos from the uterine horns.

In vitro embryo production involves recovery of the oocytes directly from the follicle using ultrasound guided trans-vaginal follicular aspiration. The recovered oocytes are then matured, fertilized and cultured in vitro. In vivo-derived or in vitro-produced embryos may be transferred fresh into synchronous recipients, or are cryopreserved (frozen) for transfer at a later time. Embryo transfer of both IVD and IVP embryos have gained a considerable level of popularity in the cattle industry. In this chapter, IVP embryos are referred to as IVF embryos.

A Brief History

Most of the current MOET technology was developed in the 1970s and 1980s; however, its history goes back much further. The first successful embryo transfer demonstrating that embryos of one breed could be transferred and develop in the uterus of another breed was first performed in rabbits by Walter Heape in 1890. Heape transferred two Angora rabbit embryos into an inseminated Belgian doe. The Belgian doe went on to produce a mixed litter of four Belgian and two Angora kits. In 1950, the first successful embryo transfer in the U.S. producing a live calf was reported by Elwyn Willett. Initially, embryos were recovered from donors and transferred into recipient animals using surgical procedures. The first report of a calf born from non-surgical embryo transfer was in 1964. It was not until the mid 1970s that non-surgical (transcervical) method for both the recovery and transfer of embryos eventually replaced the surgical methods completely and the utilization of MOET grew in popularity.

The first human birth utilizing IVF was in 1978. The first IVF calf was produced in 1981 by Dr. Benjamin Brackett at the University of Pennsylvania School of Veterinary Medicine. The procedure leading to the birth of the first IVF offspring in humans and cattle involved the recovery of oocytes obtained using laparotomy, a surgical incision into the abdominal cavity. In 1984, the first pregnancies in humans using the ultrasound to observe the ovary while aspirating the oocyte from the follicle termed transvaginal ultrasonography were reported. In 1988, a technique was described for the repeated collection of bovine oocytes using transvaginal ultrasound guided aspiration. Today, the ultrasound-guided transvaginal aspiration procedure has been adopted as a standard reproductive technology in humans and many farm animal species. Transvaginal ultrasound oocyte recovery is currently being performed in beef cattle, dairy cattle, goats, mares, pigs, as well as

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

other exotic species. There are currently many names for Ultrasound-guided Transvaginal Aspiration, and they all refer to the same procedure: Transvaginal Oocyte Recovery (TVOR), Transvaginal Aspiration (TVA), Follicular Aspiration (FA), Ovum Pick Up (OPU) and Ex Vivo Puncture (EP).

Oocyte Development in Bovine

The reproductive potential of every normal newborn calf, whether a male or female, is enormous. There are an estimated 150,000 potential eggs (ova) in the female and billions of sperm produced by each male. Through natural breeding, only a fraction of the reproductive potential of an outstanding individual, male or female, can be realized. The average herd bull sires 15 calves to 50 calves per year and the average cow will have one calf per year. With artificial insemination, it is possible to utilize the vast numbers of sperm produced by a genetically superior bull; however, the reproductive potential of the female has been largely under-utilized. On average, the female will produce an average of eight calves to 10 calves in her lifetime with normal management programs. What artificial insemination has done for the genetically important bull in the transfer of genetics, the potential exists for MOET and IVF to do for the genetically important cow, which is to greatly increase the number of offspring she can produce in her lifetime than what is possible by natural service or artificial insemination.

The female is born with the number of oocytes she will ever have during her reproductive life. Oocytes (immature eggs or ova) in cattle are formed during embryogenesis and develop within individual follicles within each ovary. In cattle, there is an estimated 50,000 to 100,000 oocytes per ovary in the female at birth, each contained in their respective follicle. Within each female, the number of follicles in one ovary is comparable to the number of follicles in the other ovary; however, there can be substantial differences between females in the total number of follicles present in both ovaries. The follicles in the ovary are held in a state of dormancy until they are selected to grow and develop at regular intervals during the late fetal developmental stage and continuing throughout the reproductive life of the female. Once active, the follicles and oocytes either grow to maturity and ovulate or degenerate and die, ultimately depleting the ovary's pool of oocytes. This ovarian reserve of dormant follicles represents the entire supply of oocytes (or eggs) available to female throughout her reproductive life.

In follicles recruited to grow and develop, the follicles growth can be monitored by ultrasonography. Active follicles grow in cohorts, or groups, in what is referred to as a follicular wave. In bovine there can be two, three or four follicular waves which occur in each 21-day estrous cycle. Follicles, containing the oocytes, in a cohort either grow to maturation and ovulation or undergo atresia, or death. It takes approximately 100 days for a follicle and its oocyte to reach the mature ovulatory stage. The number of follicles detected in a follicular wave is related to the number of follicles populating the ovary. The number of follicles in a follicular wave is highly repeatable and the estimated heritability of the number of follicles is approximately 0.35 in heifers.

Selection of the Donor Cow: MOET and IVF

Beef producers differ in their opinions as to the criteria for selecting a genetically outstanding or superior cow. Whether the criteria are performance records, show-ring appeal or both, consideration must be given to the potential dollar value of her calves as considerable expense can be incurred to achieve a successfully transferred pregnancy. Therefore, the sale value of the newborn calf should be high enough to warrant the expense of the MOET or IVF procedure. MOET or IVF is not a cure-all. The procedures do not make average cattle good or good cattle better. These procedures are suitable for a limited number of seedstock producers with cattle that can serve as breed or species improvers for one or more economically important traits.

Outside of genetics, nutrition is probably the greatest single factor that influences the response of a donor to stimulation by follicle stimulating hormone. This means the MOET or IVF donor should be maintained at the level of nutrition appropriate for her size and level of milk production. Both the very obese cow and the thin cow will have reduced fertility, so it is important the donor cow be in an appropriate body condition score (BCS 5 to BCS 6) at the time of embryo transfer. The potential MOET donor should be reproductively sound to produce maximal results. The MOET donor also should have a normal reproductive tract on rectal palpation and have a normal postpartum history, especially with regard to cycle lengths of 18 days to 24 days. Prospective donor cows in multiple ovulation embryo transfer (MOET) should be selected on the following criteria:

- Regular heat cycles commencing at a young age.
- A history of no more than two (2) breedings per conception.
- Previous calves born at approximately 365-day intervals.
- No parturition difficulties or reproductive irregularities.
- No conformational or detectable genetic defects.

Benefits and Drawbacks of Utilizing MOET vs IVF in an Embryo Transfer Program

MOET

There are benefits and drawbacks with the use of both MOET and IVF. The following is an abbreviated and somewhat simple explanation of a complex process to explain and discuss those benefits and drawbacks.

MOET donors are subject to a stimulatory protocol (superovulation) to increase the number of follicles that

are ovulated each estrous cycle. Factors that contribute to the success of the superovulation protocol are breed, age, parity, management practices, ovarian follicular reserve and superovulation history of the donor. FSH injections in a superovulation program are initiated at the onset of a follicular waive, before follicle dominance has occurred. An example (Figure 33.1) of a stimulatory protocol for *Bos taurus* cattle consists of the insertion of a CIDR (progesterone) on day "0" of the protocol followed by an injection of gonadotropin releasing hormone (GnRH) on day 2 followed by an FSH regime commencing on day 4 consisting of two injections per day during a 4-day period. The FSH regime consists of twice-daily injections (AM/PM) of decreasing doses of FSH. Individual animals might respond differently to the FSH treatment, so doses are normally adjusted as an animal re-enters a superovulation program. The purpose for the administration of FSH is to overcome the decrease in endogenous FSH that occurs during the estrous cycle as to either; A. stimulate follicular growth or B. inhibit follicular atresia (death) in order to initiate multiple ovulations from the available pool of follicles in the ovary. On day 7 the donor receives two injections of Prostaglandin $F_2\alpha$($PGF_{2\alpha}$) 12 hours apart (am/pm), with the CIDR being removed at the time of the second $PGF_2\alpha$ injection. The administration of $PGF_{2\alpha}$ causes the corpus luteum to regress and allow the animal to come into estrus or standing heat for insemination.

Because of the release of multiple ova from the multiple follicles on the ovary, there is a greater than normal need to be certain that viable sperm reach the oviducts of the superovulated female. Therefore, the donor is inseminated more than one time. Donors are usually inseminated with one unit of semen at the onset of standing estrus, 2 units of semen 12 hrs. after the onset of standing estrus, and 1 unit of semen 24 hrs. after the onset of estrus. Using high quality semen with a high percentage of normal, motile cells is a critical step in any embryo transfer program. The correct site for semen placement is in the uterine body.

Embryos are flushed approximately seven days after insemination. MOET of the donor is usually performed on a 60-day schedule, but there are some reports where MOET has been performed on a 35-day schedule for a short period of time. At times, there can be a lack of reliability or individual variation in the response when inducing superovulation in MOET donor females with FSH. *Bos indicus* females have been shown to have a greater variability in the ovarian follicular response to FSH with studies indicating that *Bos indicus* donors may require less FSH than *Bos taurus* donors to achieve optimal responses therefore, lower doses of FSH are recommended for *Bos indicus* enrolled in a MOET program.

Embryo flushing and embryo transfer both are done after an epidural anesthetic has been given to block contractions of the rectum and aid in the ease of manipulation of the cervix and the uterine horns. To collect the embryos nonsurgically, a foley catheter is inserted through the cervix of the donor cow, and a special flush media is allowed to flow into and out of the uterus to flush, or collect, the embryos seven days after estrus (Figure 33.2). This collection procedure is relatively simple without harm to the cow. A pre-sterilized stylet is placed in the lumen of the foley catheter to offer rigidity for passage through the cervix into the body of the uterus. When the tip of the catheter is in the body of the uterus, the cuff is slowly inflated with air or flushing media. The catheter is then gently pulled so the cuff is seated into the internal os of the cervix. Additional air/flushing media is then added to the cuff to completely seal the internal os of the cervix. A Y-tubing with inflow and outflow tubes is attached to the

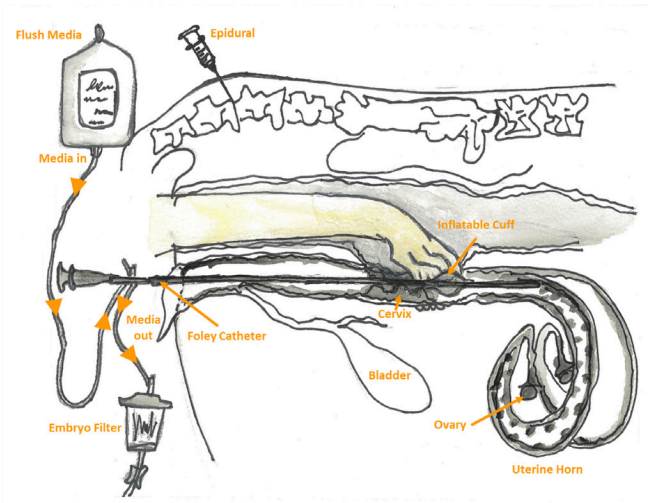


Figure 33.2. Placement of epidural anesthetic injection to block rectal contractions and placement of the foley catheter to flush and collect embryos.

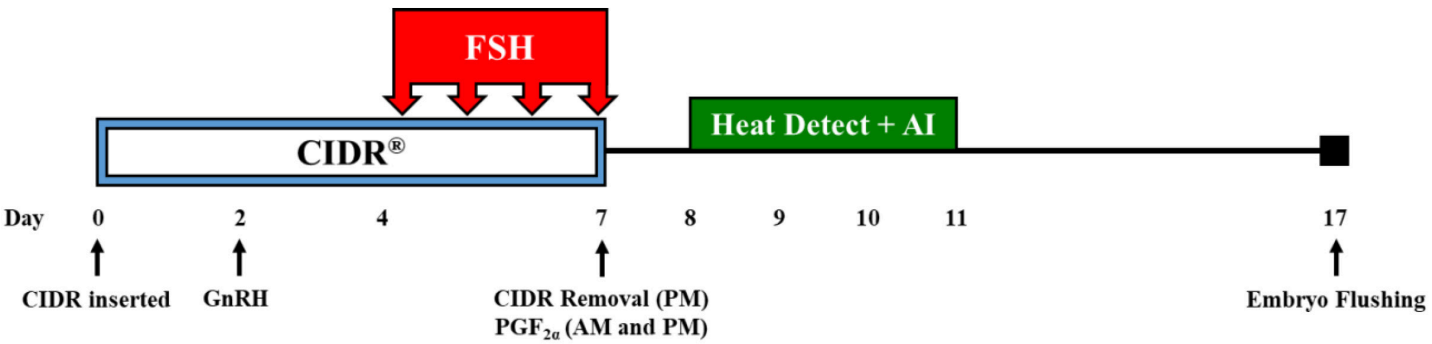


Figure 33.1. Protocol (or could use the term "timeline") for superovulation of *Bos taurus* cattle.

catheter. A flow control valve on each inflow and outflow tube assists with the regulation in the flow of the flush media into and out of the uterus. The uterus is filled with the flush media to approximately the size of a 40-day pregnancy and the flush media in the uterus is agitated rectally, especially in the upper one-third of the uterine horn. The flush media is sequentially added and removed by gravity flow. Some technicians may choose to use a smaller volume and flush one uterine horn at a time using a syringe. Each uterine horn is filled and emptied with the flush media. The embryos are flushed out with this fluid into a filter designed to catch the embryos. The filter may include a search dish and is washed to recover the contents of the filter that can be transferred to a petri dish to search for the embryos under a stereomicroscope. Of the 31,803 MOET collections performed in the beef and dairy industry reported in the 2019 AETA survey (2018 data), there was an average of 11.5 ova collected per procedure resulting in an average of 6.5 viable embryos. Of these, 28% were transferred fresh with 72% being frozen.

IVF

In IVF donors, the predominant oocyte collection technique is ultrasound-guided transvaginal aspiration where unfertilized oocytes are harvested directly from the ovaries. IVF can often be used in donors that have been unable to achieve success in a traditional MOET program. Follicle aspiration in the literature has been reported as both a non-invasive and an invasive procedure that can cause injury to the reproductive tract if not performed by an experienced technician. Ultrasound-guided transvaginal aspiration may be performed two to three times during a cow's estrous cycle for a period as long as six months; however, there are reports of no long-term detrimental effects on the donor's fertility after two times per week aspirations for over a year when performed by an experienced technician. Usually, a greater number of transferrable embryos per donor can be generated through IVF than through MOET; thus, with the improvements in the in vitro-production systems, IVF seems to be gaining popularity over conventional MOET techniques because of this potential to produce more calves per year. Since ultrasound-guided transvaginal aspiration does not involve flushing the uterus as in MOET, pregnant donors can be collected through the first trimester of pregnancy (approximately to day 100 to day 120 of gestation). Heifers as young as 10 months of age also can enter an IVF program. In the case of the unexpected death or the slaughter of a valuable female, oocytes can be recovered from the ovaries at the time of death.

There are two major IVF protocols which includes a non-stimulation and pre-stimulation procedure. The difference between the protocols is whether the donor will be stimulated with FSH prior to aspiration. As *Bos indicus* cattle have high antral follicle population, large numbers of oocytes can be obtained by ultrasound-guided transvaginal aspiration without superstimulation. However, synchronization of follicular wave emergence and superstimulation is usually used in *Bos taurus* donors. The use of FSH generally increases embryo development rates but does add an additional cost to the overall procedure. Of the 119,409 ultrasound-guided transvaginal aspirations performed in the beef and dairy industry reported in the 2019 AETA survey (2018 data), 49.7% were performed without FSH in the protocol while 50.3% did utilize FSH in the protocol. The average number of oocytes recovered per aspiration procedure with no FSH was 15.7, resulting in the average of 12.4 fertilized oocytes and a final number of 2.4 viable embryos. The average number of oocytes recovered per aspiration procedure with FSH was 18.7, resulting in the average of 17.7 fertilized oocytes and a final number of 6.1 viable embryos. Of the viable embryos (with FSH and witheout FSH), 55% were transferred fresh, with 45% being frozen.

The superovulation process begins by screening the donor and removing the dominant follicles on the ovary. This is done to synchronize a population, or a wave, of follicles to be stimulated by the administration of FSH if desired. The FSH regime commencing on day 4 consisting of two injections per day can occur over a two-day to a three-day period. Coasting, the time between the last FSH injection and the aspiration of the follicles using ultrasound-guided transvaginal aspiration can range from 20 hours to 40 hours or more. Follicles 7 mm to 10 mm seem to yield oocytes that are the most competent and have a higher chance of becoming an embryo.

The ultrasound-guided transvaginal aspiration system consists of an ultrasound with a transvaginal transducer probe to visualize the ovaries and a needle guide system through which a needle/tubing apparatus is guided to pierce the follicle and collect the oocyte complex along with follicular fluid (Figure 33.3) An aspiration pump, or syringe, is required to create suction, which causes the follicular fluid and oocytes to flow through the tubing and into a collection vial. Numerous heating apparatuses including a test tube warmer, filter warmer, warming table and stage warmer are necessary to keep the oocytes at a consistent temperature, between 95 F (35 C) and 98.6 F (37 C). Keeping the oocytes warm throughout the entire process is critical. The head of the ultrasound transducer is positioned to the left or right of the cervix, depending on which ovary is to be collected. The ovary is positioned against the transducer so the ovary

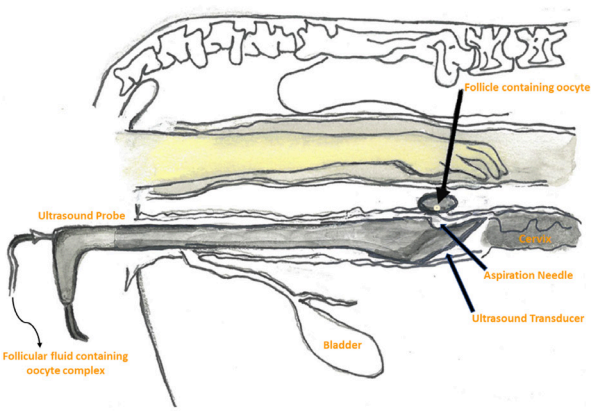


Figure 33.3. Ultrasound-guided transvaginal oocyte aspiration process for in vitro fertilization.

(follicles) can be visualized on the ultrasound screen. A "target line" programmed into the ultrasound's software is displayed on the screen and indicates where the follicle needs to be positioned for successful aspiration. The needle is slowly advanced forward until the vaginal wall is pierced and the needle is visualized entering the ultrasound field. By monitoring the needle's position and simultaneously manipulating the ovary per rectum, the needle can be directed into the follicle. Once the needle enters the follicle, the syringe or aspiration pump is activated and the follicular fluid and oocyte are collected into the embryo filter that contains some oocyte collection media. The filter contents are washed and transferred to a petri dish and the oocytes are evaluated using a stereomicroscope.

The aspirated oocytes are graded based on layers of cumulus cells and cytoplasm appearance (Figure 33.4). Oocytes with multiple layers of cumulus cells and a regular cytoplasm (grades 1 and 2) have a better chance of producing a viable embryo. The oocytes then go through an in vitro maturation (IVM) process for 18 hours to 24 hours to become ready for fertilization. The oocytes are fertilized with semen, then cultured in an incubator for seven days. The embryos are counted and graded, then frozen or transferred fresh into recipients.

Since the oocytes are matured and fertilized in the laboratory, one straw of semen can be used to fertilize the aspirated oocytes from several donors, allowing producers to more effectively and efficiently utilize scarce or expensive semen. The utilization of sexed semen is also more feasible using IVF. Additionally, multiple sires can be used on a donor's oocytes collected during a single aspiration.

Evaluation of the Embryos

Using a stereomicroscope, the individual embryos are evaluated for their quality and classified numerically for the potential likelihood of success if transferred to a recipient female. Embryos are graded on their conformity to several physical characteristics including shape, color/density of cytoplasm, number and compactness of cells, area of perivitelline space, number of extruded or degenerate cells, frequency and size of cytoplasmic vesicles and stage of development relative to age. In vitro-produced embryos have morphologies that differ from in vivo-derived embryos. The best environment to develop bovine embryos is within the uterus of the cow, not in the laboratory. Embryo quality is of the utmost importance in the survival of the stress of freezing and thawing. Grade 1 embryos are generally considered the only ones to freeze. Grade 2 embryos can be frozen and thawed, yet pregnancy rates are typically reduced.

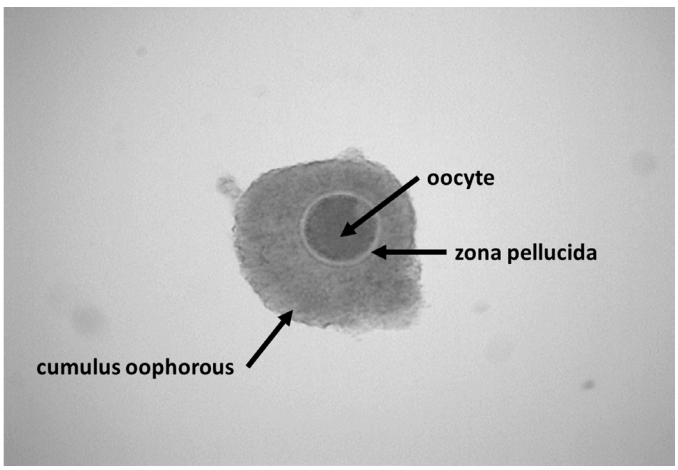


Figure 33.4. Aspirated Oocyte.

Embryos are classified as:
Grade 1: Excellent or good
Grade 2: Fair
Grade 3: Poor
Grade 4: Dead or degenerating

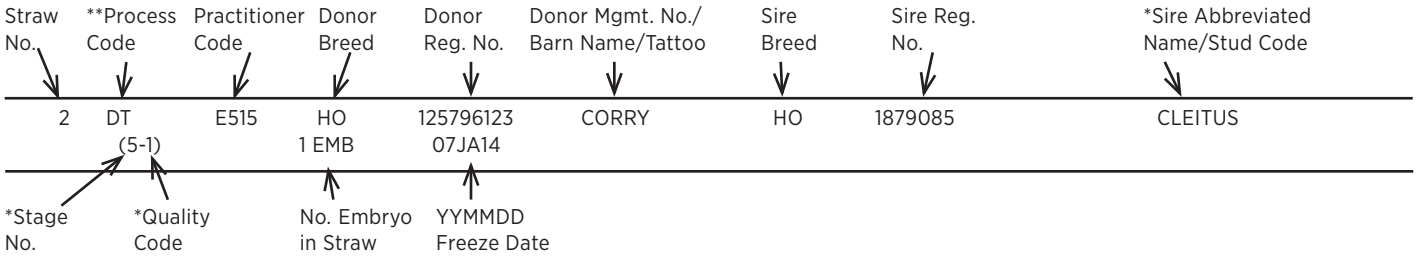
Embryos also are evaluated for their stage of development without regard to quality. These stages are numbered:
Stage 1: Unfertilized
Stage 2: Two-cell to 12-cell
Stage 3: Early Morula
Stage 4: Morula
Stage 5: Early Blastocyst
Stage 6: Blastocyst
Stage 7: Expanded Blastocyst
Stage 8: Hatched Blastocyst
Stage 9: Expanding Hatched Blastocyst

Cryopreservation of Embryos

The utilization of embryo cryopreservation has become a fundamental part of the technique of embryo transfer, particularly the commercial application in the bovine embryo transfer industry. There are generally two types of techniques used in the cryopreservation of bovine embryos; the conventional slow rate cryopreservation and vitrification. The most common slow-freeze cryoprotectants are glycerol and ethylene glycol. Vitrification is an ultra-rapid cryopreservation method where high concentrations of cryoprotectants are used in combination with a rapid cooling rate to avoid ice formation during freezing. Cryopreservation without the formation of damaging ice crystals is the primary advantage of vitrification over conventional slow rate freezing. Regardless of the method used, the selection of embryos to be cryopreserved is a key factor influencing the success of the procedure. It is important to realize that many of the differences in morphological characteristics that constitute the embryo grading criteria are magnified by the freeze–thaw process.

Embryo Labeling

- IETS stage and grade codes are not required but are strongly recommended to be printed on the label.
- Loading one embryo per straw is strongly recommended, regardless of cryoprotectant. However, it is allowable to



**Use Appropriate Processing Code

DT	Direct Transfer in vivo
DT-IVF	Direct Transfer IVF
DTX	Direct Transfer Sexed Semen - Female
DTY	Direct Transfer Sexed Semen - Male
DTX-IVF	Direct Transfer Sexed Semen - Female-IVF
DTY-IVF	Direct Transfer Sexed Semen - Male-IVF
DTF-IVF	Direct Transfer Embryo Biopsied - Female-IVF
DTM-IVF	Direct Transfer Embryo Biopsied - Male-IVF
DTB	Direct Transfer Biopsied

freeze/vitrify more than one embryo per straw when they are not for direct transfer (DT).

The head of the cane or cane tab, top and bottom goblets and straw extension or plug should be the following colors as required in the IETS Manual.

- Yellow – Direct transfer (DT) embryos
- White – NON-direct transfer embryos
- Light Blue – Vitrified embryos (the use of this color indicates the method of cryopreservation, and thus, supersedes the use of Yellow, even if the embryo is vitrified for DT, but should be labeled "DT-VIT").

Transfer of the Embryos

Recipient cows should be at least 60 days postpartum before ET. Just prior to transferring the embryo into a recipient animal, the ovaries of the recipient are palpated rectally to determine which ovary has ovulated. The use of an ultrasound machine to evaluate the corpus luteum (CL) is highly recommended. If a recipient does not have a CL at the time of transfer, she should not be used. The embryo will be transferred into the uterine horn on the side in which ovulation took place. This is determined by the presence of the CL on the ovary. The embryo is gently expelled in the forward tip of the uterine horn (Figure 33.5). Great care should be taken to prevent damage to the lining of the uterus. Because MOET embryos develop and grow in the ideal environment (the reproductive tract of the cow) they have greater viability than IVF embryos. Pregnancy rates are approximately 10% higher in MOET-derived embryos compared to IVF-derived embryos, and pregnancy losses throughout gestation are normally greater in IVF-derived embryos compared to MOET-derived embryos. Pregnancy rates depend on the quality of the embryos before freezing, the ability of the person freezing the embryos, the storage practices, the quality and preparation of the recipients and the skill of the person performing the transfers. So, if unacceptable pregnancy rates are experienced, don't forget

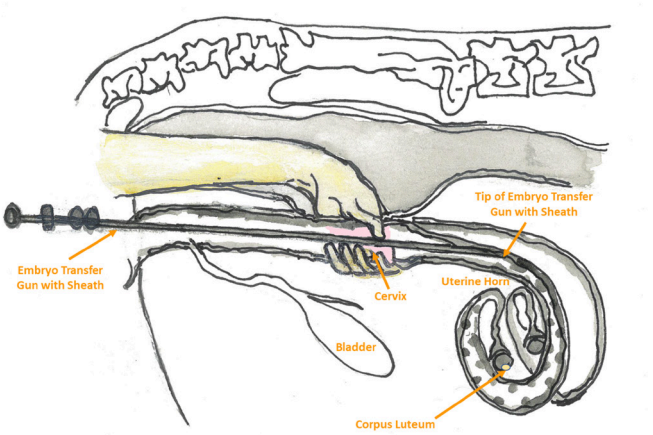


Figure 33.5. Drawing showing embryo transfer to a recipient cow.

it may not be the fault of the practitioner transferring the embryos (who usually receives the blame).

Selection and Preparation of Recipient Females

Proper recipient herd management is very critical to the success of a MOET or IVF program. Cows that are productively sound, exhibit calving ease, good temperament and good milking and mothering ability are good recipient prospects. They must be on a proper plane of nutrition (BCS 6 for beef cow recipients and BCS 3 to BCS 4 for dairy breed recipients) and on a sound herd health program. A recipient female can receive an embryo seven days after she is detected in standing estrus, or a group of recipients can be synchronized and multiple embryos transferred at one time. To maximize embryo survival in the recipient female following transfer, conditions in the recipient reproductive tract should closely resemble those of the donor. It is imperative the donor and the recipient have a very similar uterine environment when the transfer takes place. This requires synchronization of the estrus cycles between the donor and the recipients, optimally within 12 to 24 hours of each other. This is to ensure synchrony between the stage

of embryonic development in the donor cow with the stage of diestrus in the recipient cow. Embryo-uterine synchrony is very important to achieve good pregnancy rates. Many different estrous synchronization protocols are available that can be used to synchronize recipients for ET. Remember, synchronizing drugs are effective only on recipient females already cycling. Anestrus, or noncycling, cows that are too thin or too short in postpartum days will not make useful recipients.

Certificate of Procedure Performed

Following any of the aforementioned MOET or IVF procedures are performed; embryo recovery, oocyte recovery, IVF and transfers that are preformed, a "Certificate" of the procedure should accompany each embryo. These documents signed by the technician, practitioner or team leader performing the procedure, provide pertinent information including the mating (sire and dam) for each embryo, the number of embryos in each straw, the stage and grade of each embryo, how the embryos were washed and handled, the time interval from collection until freezing and the cryoprotectant used to freeze the embryos. The freezing method and cryoprotectant used are of particular importance as to ensure the correct thawing technique is utilized to achieve optimal transfer rates.

References

AETA Education Committee. 2017. Labeling Guidelines for Embryo. aeta.org/docs/teaching-modules/aeta_module_labeling_2017_ed.pdf

Barfield, J. 2016. Evaluation of in vitro-produced bovine embryos. Semantic Scholar corpus ID 51996065. api.semanticscholar.org/CorpusID:51996065

Betteridge, K. J., Editor. 1977. Embryo Transfer in Farm Animals: a review of techniques and applications. Canada Department of Agriculture.

Britt, Jack H. 2008. Oocyte development in cattle: physiological and genetic aspects. Revista Brasileira de Zootecnia, 37(spe), 110-115. doi.org/10.1590/S1516-35982008001300013

Demetrio, D., E. Benedetti, D. Marsh, P. Comyn and A. Weakley. 2017. Bovine In Vitro Embryo Production. Teaching Modules. AETA. aeta.org/edu-teaching-modules.asp

Hasler, J.J. 2017. A Recent History of Superovulation and Pregnancy Data in North America. Vetoquinol USA, Inc. Repro360. repro360.com.au/sites/default/files/A%20recent%20history%20of%20superovulation.pdf.

Hobbs, D., C. Holcomb and J. Gibbons. 2020. Short term incubation of frozen/thawed bovine embryos. Evidence-Based ET research and Publications. American Embryo Transfer Association.

IETS Manual, 5th Edition

Gabriel A., A. Cedeño and R. J. Mapletoft. 2019. Strategies to increment in vivo and in vitro embryo production and transfer in cattle. Animal Reproduction. Vol. 16 No. 3. doi.org/10.21451/1984-3143-ar2019-0042

Lamb, G. C., P. L. P. Fontes and Nicky Oosthuizen. 2019. In vitro fertilization (IVF) versus multiple ovulation embryo transfer (MOET): making the decision to use one or both. Proceedings, Applied Reproductive Strategies in Beef Cattle p. 233-249. August 20-21, 2019; Knoxville, TN

Moore, S.G. and J.F. Hasler. 2017. A 100-Year Review: Reproductive technologies in dairy science. *Journal of Dairy Science* Vol. 100:12:10314-10331.

Qi M, Yao Y, Ma H, Wang J, Zhao X, et al. 2013. Transvaginal Ultrasoundguided Ovum Pick-up (OPU) in Cattle. *J Biomim Biomater Tissue Eng* 18:118. doi:10.4172/1662-100X.1000118

Selk, G. 2002. Embryo Transfer in Cattle, OSU Extension Fact Sheet AFS-3158, Oklahoma Cooperative Extension Service, Oklahoma State University. extension.okstate.edu

Seidel, G.E., Jr. and S.M. Seidel. (1991) Training Manual for Embryo Transfer in Cattle. FAO Animal Production and Health Paper 77. Retrieved from fao.org/DOCREP/004/T0117E/T0117E00.HTM

Sirard, M. 2018. 40 years of bovine IVF in the new genomic selection context. *Reproduction* Vol. 156: Issue 1. DOI: doi.org/10.1530/REP-18-0008 p. R1-R7.

Stadheim, J. A. 2015. TEST TUBE TECHNOLOGY: Using IVF on cows has numerous pros, cons. Retrieved June 22, 2020, from tsln.com/news/test-tube-technology-using-ivf-on-cows-has-numerous-pros-cons/

Wright, Jr RW, Ellington J. 1995. Morphological and physiological differences between in vivo- and in vitro-produced preimplantation embryos from livestock species. *Theriogenology* 44:1167-1189.

34 Choosing a Calving Season

David Lalman, Mark Johnson, Daniel Stein and Glenn Selk

Objectives

- **Discuss the pros and cons of using fall, spring and both fall and spring calving seasons.**
- **Review the calving season choices available to producers.**
- **Suggest areas producers should consult for future research findings.**

Tradition

Traditional calving seasons in the Great Plains have been closely aligned with Mother Nature's attempt to preserve the species *Bos taurus*. With few exceptions, large mammals in the wild would deliver their offspring in springtime and the lactation and attempts to rebreed, therefore, would coincide with the growing of warm season plants for food. Similarly, cow-calf management schemes have centered on the traditional spring calving season. With a 285-day gestation, early summer breeding seasons are necessary to produce another spring calf the following year. As beef cow operations became more efficient, producers learned the advantages in labor management, feed utilization and market position gained by creating a shorter, more distinct calving season. In the southwest, producers have been able to get the jump on northern plains neighbors by starting the breeding season earlier (April or May) to produce February and March calves. Early spring calves can be weaned earlier in the fall ahead of the glut of northern calves or weigh more at weaning time because they are older. The SouthernPlains and southeastern cattle operations also have the additional option of utilizing cool-season pastures with cows producing fall calves ready to market in spring or summer.

Why Consider Change

Traditional methods of cow-calf management are sometimes severely challenged by the squeeze of very high input prices and low prices for weaned calves. Producers and land-grant university researchers are looking at many nontraditional alternatives. Efforts are being made to reduce input costs and increase the product's value as it leaves the cow-calf operation. In Oklahoma, costs per cow each year are very near the national average reported in Standardized Performance Analysis (SPA) data. SPA reports summarizing Texas, Oklahoma and New Mexico data indicate an average break-even cost of $1.67 per pound of weaned calf ($1.70 per pound when the average was weighted using number of breeding cows). On average, more than one-third of total production costs could be attributed to grazing costs and home-raised feed or purchased feed costs. This cost has given the best opportunity for reduction. During the mid 1990s, calves often sold for much less than the break-even cost. Therefore, examining nontraditional calving and breeding seasons in an effort to discover a much less expensive program for maintaining cows and producing calves was inevitable.

Cow-calf managers determine when the breeding season begins and ends, thus determining when the calving season begins and ends because gestation length is relatively constant. The manager also determines when the calves are weaned and marketed. Breeding, calving, weaning and marketing dates are not strictly the product of Mother Nature, but are managerial decisions that do not have to conform to tradition. It is interesting to note that beef is the only major meat animal species currently allowed to rear its offspring. Is this due to necessity or tradition? Pork and poultry both have lower costs of production.

Lots of Choices

Southern Plains producers have many alternatives for calving seasons. Lengths of seasons vary from 45 days to 365 days. Spring and fall have become the seasons of choice for calving, but tremendous differences exist as to what months within each of those seasons are the primary months for calving. Deciding on the use of one or two calving seasons is a big first step. Many fall calving seasons have arisen from elongated spring seasons. Two calving seasons fit best for herds with more than 80 cows. To take full advantage of the

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

economies of scale, a ranch needs to produce at least 20 steer calves in a season to realize the price advantage associated with increased lot size. Therefore, having a minimum of 40 cows in each season is desirable.

Using two seasons instead of one can reduce bull costs a great deal. Properly developed and maintained bulls can be used in both the fall and the spring, therefore reducing the bulls needed by half.

Another small advantage to having two calving seasons is the capability of taking fall-born heifers and keeping them nonpregnant another few months to be bred in the spring season and vice versa. Thus, replacement heifers are 2.5 years old at first calving instead of 2 years old. These heifers should be more likely to breed early in the breeding season and have slightly less calving difficulty. Research has shown these differences to be small, so the cost of six months additional feed must be minimal to make this strategy pay.

Many producers like the dual calving seasons because of the spread of the marketing risk. Having half of the calf crop sold at two different times allows for some smoothing of the cattle cycle.

Two calving seasons require more time spent watching cows and heifers during calving. More pasture management and fencing may be needed to successfully have both a fall and spring calving season. The fall and spring herds must be maintained separately for most of the year because they are in different stages of production and have different nutritional requirements. In addition, breeding seasons will require fall calving cows be separate from spring calving cows during their respective breeding seasons.

Spring Calving Decisions

Producers who prefer spring calving systems still have choices. Early spring calving (February and March) has been utilized to a great extent in Oklahoma and north Texas. This time frame often puts calving during a wet, cold weather pattern. Weather stresses to baby calves can cause some direct weather-related death loss or scours that can be difficult to manage. Lactating cows require considerable energy and protein in February, March and April before spring grass is growing enough to supply all of the nutrients needed. The breeding season is initiated in April or May and continues through June. This comes at a time when weather stresses are minimal with the exception of the first blast of heat that occurs nearly every June.

Early spring calves are old enough to utilize forage by mid summer and weaning is in mid- to late October. During years with adequate summer pastures, calves should reach their genetic potential for weaning weight.

Some producers may consider moving their spring calving season to later in the spring or early summer. Research conducted in Nebraska has been studying the use of June as a target calving month (Sprott, Selk and Adams). They have been attempting to greatly reduce cow costs by making this change. Calving is carried out at a pleasant time of year, so weather stresses on the calves are reduced. Breeding is initiated in August and early September. Cows are wintered on sand hills range with very little added supplemental feed. Additional hay is given only in times of severe winter weather. The sub-irrigated meadows available in the sand hills are used for early spring grazing. The hope is that cows will regain enough body condition in spring to calve in adequate body condition by May. For cows to have adequate body condition going into the winter, the calves will be weaned in the fall at the usual dates, even though they are considerably younger. Results from this multi-year study suggest the program may be successful. Similar calving season changes are being tried by a few Kansas cow-calf operations. Some of these herds have been written about in the popular press. Consequently, Oklahoma and Texas producers are asking about the feasibility of changing to late spring and summer calving.

Hot Weather and Breeding Seasons

The first real concern to address with this potential change is the breeding season in late summer. Heat stress is rarely a problem for cows pastured in Nebraska. Although daytime temperatures can occasionally reach the century mark, nighttime temperatures often fall into the 60s F. Contrast those temperatures with typical summer weather in Oklahoma and Texas where temperatures can exceed 95 F with nighttime lows only dropping to near 80 F many days in a row. Many hours of the day can be quite hot and cause the slightest rise in body temperature of cattle. Research conducted at OSU illustrated the possible impact of heat stress of beef cows on their reproductive capability. In this experiment, the cows were bred naturally after synchronization, then exposed to mild or severe heat stress. The cows were stressed on day eight through day 16 after breeding (Table 34.1).

All of the cows were slaughtered on day 17 and the uterine contents were studied for the presence of an embryo. Note that only half of the cows undergoing severe heat stress had an embryo present and the conceptus, which is the embryo plus fluids and membranes, weighed half as much as did those from control cows. Severe heat stress shortly after breeding certainly had an adverse affect on embryo survivability and therefore, pregnancy rates.

Table 34.1. Effects of imposed heat stress on reproduction in beef cows.

	Control	*Mild stress*	*Severe stress*
Daytime temp (F)	71	97	98
Nighttime temp (F)	71	91	91
Relative hum. (%)	25	27	40
Rectal temp. (C)	38.9	39.3	39.8
Rectal temp. (F)	102.0	102.7	103.6
Pregnancy (%)	83	64	50
Conceptus[1] wt (g)	0.158	0.111	0.073

1 Embryo plus fluids and membranes.
Source: Biggers.

The Impact of Hot Weather on Bull Fertility

Several research trials have been conducted through the years on the effect of high temperatures on bull fertility. In 1963, researchers exposed bulls to temperatures of 104 F and 54% humidity for an eight-hour period and then allowed the temperature to drop to 82 F with 72% humidity for the remainder of the 24-hour period (Johnston, Naelapaa and Frye). This temperature regimen was continued for seven days and was designed to resemble natural conditions in the subtropics. They found the high temperatures resulted in detrimental effects on initial sperm motility, sperm concentration and total number of sperm per ejaculate.

More recently, Oklahoma scientists placed bulls in controlled environments of 95 F for eight hours and 87 F for the remaining 16 hours while similar bulls were placed in environments of constantly 73 F (Meyerhoeffer et al.). These treatments were applied to the bulls for eight weeks, then all bulls were exposed to the 73 F environment for another eight weeks. During the treatment, the heat-stressed bulls had rectal temperatures of 0.9 degrees higher than nonstressed bulls. The percentage of motile sperm cells decreased significantly in the bulls stressed by two weeks of heat stress (Figure 34.1).

Sperm motility did NOT return to normal values until eight weeks after the end of the heat stress. This explains some of the reduction in fertility often associated with summer and early fall breedings. The conclusion is that high ambient temperatures can result in detrimental effects on fertility on both the cow and the bull.

In 2001, Dr. L. R. Sprott of Texas A&M reviewed data from experiment stations in northern, mid-western and southern states. In the Montana and South Dakota (northern) data, spring and late-summer breeding seasons were similar in reproductive performance. In Kansas (mid-western), there was a substantial drop-off of first service conception rates for artificially bred cows from May to June and a further reduction in July. Illinois (mid-western) data showed a 14% greater pregnancy percentage for cows exposed to bulls in May and June, compared to cows exposed in July and August. The data for the southern states (Louisiana, Texas and New Mexico) produced the expected responses. Cattle exposed to breeding seasons in the high desert of New Mexico had excellent reproductive performance throughout the spring and summer months. Low nighttime temperatures and low humidities in the higher altitudes of New Mexico provide comfortable environments for reproducing cattle. However, spring and especially summer-month breeding seasons in Louisiana and Texas, where both heat and humidity are a problem, produced very low pregnancy rates especially July through September. In Oklahoma, late-spring and summer calving seasons that require breeding to start in late July and August will be impacted by heat and humidity and fertility can be expected to be reduced.

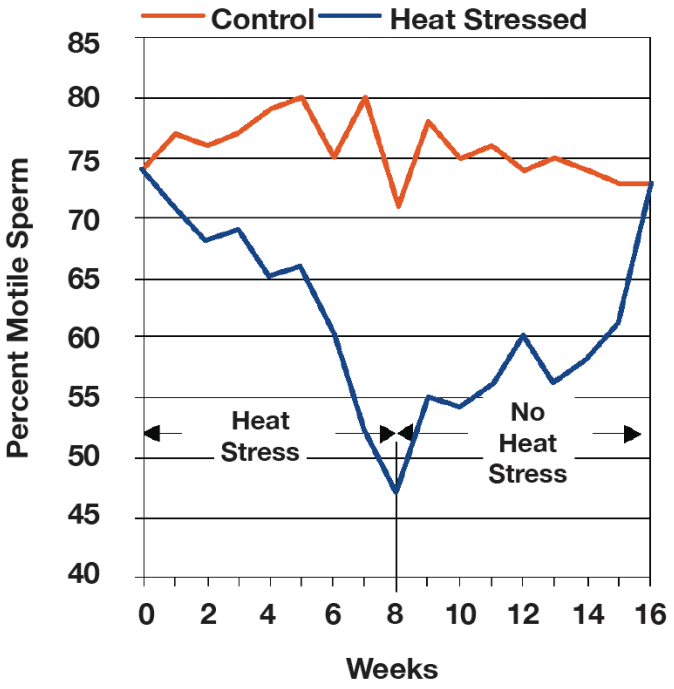


Figure 34.1. Percent motile sperm from bulls during and after heat stress. Source: Meyerhoeffer.

What to Do with Late Spring and Summer Calves

The next point of concern with late spring and summer calving is what to do with the calves. Leaving them to nurse the cow until they are seven months old is self-defeating, as the cows would become extremely thin or need considerably more feed to nurse in the dead of winter. Therefore, calves should be weaned in this scheme in early fall, at about 120 days of age. The Nebraska program has calves winter on alfalfa hay, supplemental grain and subirrigated meadows, then be available for sale as summer pastures are beginning to grow. Also, they are examining retained ownership options through summer grazing and/or the feedlot. The expense to feed the calves in the winter will offset some of the advantage gained in reduced feed for the cows. Small grain pastures may provide a source of feed for these lightweight calves in Oklahoma and northern Texas. This is a program that will be examined more closely in the fall calving section.

Another key issue is the body condition of the cows at calving time if they have been roughed through the winter and growth of spring grasses is late in spring (chapter 20). Thin cows at calving time provide less and poorer colostrum for early health of the calves, but more importantly, these cows return to heat very slowly, may be calving later in subsequent years, or may be open at pregnancy checking time.

The Nebraska Sandhill research merits consideration in those regions where expected climatic conditions during breeding will not be detrimental to reproductive performance. The issue of heat stress in July, August and early September suggests that caution should be taken before changing the calving season to late spring or early summer in other regions.

Fall Calving

The advantages and disadvantages of fall calving have been discussed in Oklahoma since the introduction of perennial cool season grasses such as fescue. Many producers who live in central or western parts of the state have only warm-season pastures, which include native and Bermudagrass, available to them. It often is thought that fall calving is only for those who live close to Arkansas or Missouri. Ranchers with only warm-season grasses might be surprised at the comparative advantages of fall calving. Fall calving programs are now being tried to a very limited extent in Wyoming, Nebraska and the Dakotas. Producers in those states are becoming aware of the strengths of a fall-calving program.

Producing a weaned calf ready to go onto lush spring and early summer grass has its appeal. Examining the 10-year average percentage change in beef cattle prices shows the fall-born calf can be in strong demand in the spring and early summer. Figure 34.2 illustrates the average percentage change in prices for 400- to 500-pound steer calves and 700- to 800-pound feeder steers in Oklahoma City. The slaughter cattle price changes represent the averages for Oklahoma-Texas Panhandle feedlots. The midpoint of the graph (100) represents the yearly average. Therefore, you can predict that 400- to 500-pound steer calves will bring 3% to 4% more than the yearly average in March and April. Likewise, producers can expect calves to be 2% to 4% less than the yearly average if marketed in the fall (October and November). It is no mystery that the price dips at the normal weaning time for the glut of calves sold in the October to November time frame.

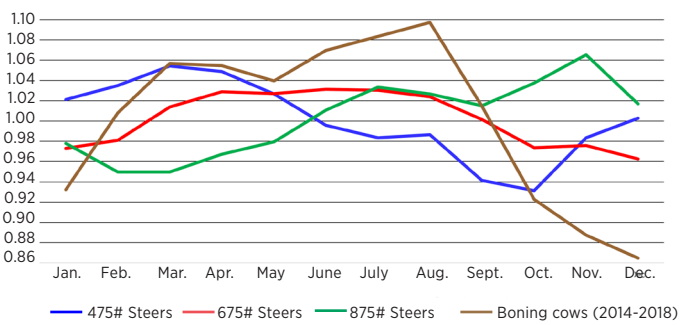


Figure 34.2. Ten-year average price percentage change in steers. Source: Jones.

Operations that calve in September and October enjoy excellent reproductive performance from the cows. The body condition of cows after summer pastures should be excellent. These cattle return to heat more quickly than do the thinner spring-calving cows and the breeding season in late November and December is usually completed in moderate weather. Often, the producers who dislike fall calving have tried to calve in October and November (often after wheat planting is complete). This puts the breeding season well into the harsher winter months and can cause some decrease in the pregnancy percentage. An added bonus to fall calving is that fall-born calves are lighter in average birth weight than are genetically similar spring-born calves. A lower incidence of dystocia also aids in the return to estrus and partially helps explain the routinely high reproductive rates of fall-calving cows.

Producers who winter cows on native range often believe it is too costly to have fall calvers because of feeding a lactating cow all winter. However, the Upper Midwest producers are finding fall calving does not have to be more expensive. The trick is to reduce expensive feed inputs after the breeding season is done. This will get the pregnant fall-calving cow through the winter healthy enough to regain body condition during the summer months after the calf has been weaned. Table 34.2 is a comparison of a typical range supplementation program for spring and fall cows. The amounts of supplement shown are the daily per head feed supplied during each respective month. The dollar figure is the number of days in the month multiplied by the amount fed and the price of supplement fed each day. These cows are considered to be moderate in frame size and milk production. The price used for cottonseed meal (CSM) is $343 per ton and for 20% range cubes is $250 per ton.

The supplementation program for fall-calving cows requires adequate forage to be available. Standing forage in the fall and early winter will be adequate to maintain body condition with the supplemental protein. In late winter and

Table 34.2. Common supplementation strategies for cows grazing native warm-season forage[a] during winter.

Month	*Spring calving cows*		*Fall calving cows*	
	Good cow condition and/or moderate weather	*Marginal cow condition and/or severe weather*	*Good to moderate cow condition and/or moderate weather*	*Thin cow condition and/or severe weather*
October	None	1 lb HP	2 lb HP	3 lb HP
November	1 lb HP[b]	2 lb HP	3 lb HP	4 lb HP
December	2 lb HP	3 lb HP	4 lb HP	6 lb MHP[d]
January	3 lb HP	4 lb MP	6 lb MHP[d]	7 lb HP
February	3 lb HP	5 lb MP[c]	6 lb MHP[d]	7 lb HP
March	3 lb HP	6 lb MP	5 lb MHP[d]	6 lb HP
April	2 lb HP	4 lb MP	3 lb MHP[d]	3 lb HP

a Forage protein declines to a low of around 3% to 4% during mid winter.
b HP = high protein supplement, containing 35% to 40% protein, as fed basis.
c MP = moderate protein supplement, containing 20% protein, as fed basis.
d MHP = moderate-high protein supplement, containing 25% protein, as fed basis.

very early spring, the energy requirements of lactating spring calving cows are increased to the point that protein alone may not get the job done and 20% range cubes are necessary. They are not needed for fall-calving cows because fall-calving cows are in excellent body condition at calving time. They return to heat early in the fall breeding season. Most mature fall calvers will be rebred by the first of the year. These cows can stand some loss in body condition between the end of the breeding season and spring grass. Therefore, protein supplementation and hay in addition to standing forage will suffice. It should be expected fall-calving cows would consume 20% more forage than spring calvers.

Using the OSU Enterprise Budgets (Sahs and Doye, 2015), annual pasture, hay, protein supplement and mineral costs were recently estimated to be about $272 for a spring-calving system and $313 for a fall-calving system. While the forage and feed costs for the fall-calving system are expected to be greater, calves from mature cows are frequently weaned at 8 months to 9 months of age around the middle of July. This results in rapid calf gain during the early summer and an additional 100 pounds to 200 pounds of weaning weight. Calves from first-calf heifers and older cows should be weaned at 7 months of age or earlier because of the longer lactating period.

Calving Season Length

Research using 394 ranch observations from the Texas, Oklahoma and New Mexico SPA data set provides insight into the age-old argument about leaving the bull out or having a defined breeding season (Parker et al). A positive relationship was found between number of days of the breeding season and the cost per cwt. of calf weaned. Also they reported a negative relationship between number of days of the breeding season and pounds of calf weaned per cow per year. The data suggested that for each day the breeding season was lengthened, the annual cost of producing 100 pounds of weaned calf increased by 4.7 cents and pounds of calf weaned per cow per year decreased by 0.158 pound. The range of breeding seasons in the data set was 11 days to 365 days. The producer who leaves the bull out year-round (365 days) had $13.63 greater costs per cwt. of weaned calf than the producer who used a 75-day breeding season. That same producer sold 45.82 fewer pounds of calf per cow per year on the average than producers with a 75-day breeding season.

How to Start a Controlled Calving Season

In most herds on a year-round calving season, a natural calving concentration already exists. Nutrition is the major factor responsible for cows cycling and conceiving. Since pastures usually are at their peak of quality in spring and early summer, a natural concentration of calving may occur in late winter and spring. No system of getting on a controlled breeding program can completely eliminate the delaying of some cows from their current calving schedule. However, by taking advantage of the natural concentration in a herd, the problem can be minimized.

A simple way to convert a herd from year-round calving to a two-season system is to split the cow herd into two calving seasons. Cows that calve late for one season would be moved into the alternative season as "early calvers." Consequently, breeding for these early calving cows will be delayed so they should calve in sync with the rest of that group the following year.

For example, assuming a 60-day spring calving season (March and April) and a 60-day fall calving season (September and October) are desired, all cows calving from May 1 through October 31 would be moved to the fall-calving group. These cows would be exposed to bulls from about November 23 to about January 23. Cows calving from November 1 through April 30 would be moved to a spring-calving group and exposed to bulls from about May 23 to about July 22.

Controlled calving seasons require planning to ensure a pasture and/or dry lot area is available to maintain bulls away from cows and heifers.

Other Considerations

Producers are encouraged to evaluate and deploy their time, money and other resources in the most economically feasible fashion. For all the information presented in this chapter about planning your calving season, don't overlook the obvious: what time of year best fits your schedule? Cow-calf operations are often part of a larger farm and ranch enterprise; or in many cases, a secondary farm enterprise. With this in mind, consider if there is a "best" time of year, based on your schedule permitting more opportunity to check cows and young calves possibly needing assistance or treatment. In many operations, saving one or two calves makes the difference between a profitable cow-calf enterprise versus one that will not break even. This can be a challenge if calving when other parts of a farm and ranch operation are busy or other responsibilities occur when cows are calving.

Conclusion

No one calving and breeding season fits every operation. Larger herds in the southern plains should consider two calving seasons. The cost of savings on reduced bull inputs and older replacement heifers plus two marketing windows offers economic advantages. Additional labor during two calving seasons and timing of labor needed must be considered.

Producers with traditional spring-calving programs may consider switching to or adding fall calving. It need not be more costly. Fall calving can benefit from current higher seasonal market trends. Moving the spring-calving season to May and June should be studied closely in Oklahoma because of the potential rebreeding problems in very hot weather.

Before any change in breeding, calving and weaning seasons are made, consider the marketing plan first. Is there a willingness and ability to retain ownership to market

the product to its best advantage? Study Figure 34.2 on the seasonality of cattle prices before making a significant change.

References

Biggers, B.G. et al. (1987) Effect of Heat Stress on Early Embryonic Development in the Beef Cow. *Journal of Animal Science* 64: 1512.

Johnston, J.E., H. Naelapaa and J.B. Frye, Jr. (1963) Physiological Responses of Holstein, Brown Swiss and Red Sindhi Crossbred Bulls Exposed to High Temperatures and Humidity. *Journal of Animal Science* 22:432.

Jones, S. (2004) Livestock Marketing Information Center. Personal Communication.

Meyerhoffer, D.C. et al (1985) Reproductive Criteria of Beef Bulls During and After Exposure to Increased Ambient Temperature. *Journal of Animal Science* 60:352.

Parker, R. et al. (2005) "Cow-Calf Cost of Production." *Journal of Agricultural and Applied Economics*. 37 (August).

Selk, G. (2004) Length (of breeding season) Does Matter. Cow-Calf Corner. Sunup. Retrieved on March 12, 2004 from ansi.okstate.edu/exten/cc-corner/lengthmattersofbreedingseason.htm

Sprott, L.R., G. E. Selk and D. C Adams. (2001) Review: Factors Affecting Decisions on When to Calve Beef Females. *Professional Animal Scientist* 17:238-246.

35 Calving Time Management for Beef Cows and Heifers

Daniel Stein, Joao G. N. Moraes and Glenn Selk

Objectives

- **Understand a normal delivery.**
- **Assess the need for assistance.**
- **Know how to apply proper assistance when needed.**

Calf losses at calving time are often a result of dystocia (difficult calving) problems. Many of these losses occur to calves born to first calf heifers and can be prevented if the heifers and cows are watched closely and the dystocia problems detected and corrected early. A veterinarian should handle serious and complicated calving problems. Ranchers must use good judgment in their decisions as to which problems will require professional help, and the earlier help is sought, the greater the survival rate of both cow and calf.

Recognize Normal Calving

If the calf is in normal presentation, position, and posture (Figure 35.1) and the pelvic area is large enough, the vast majority of animals will give birth without assistance. Recognizing a normal calving is just as important as knowing when a calving is abnormal, so calving help will not be given unless needed.

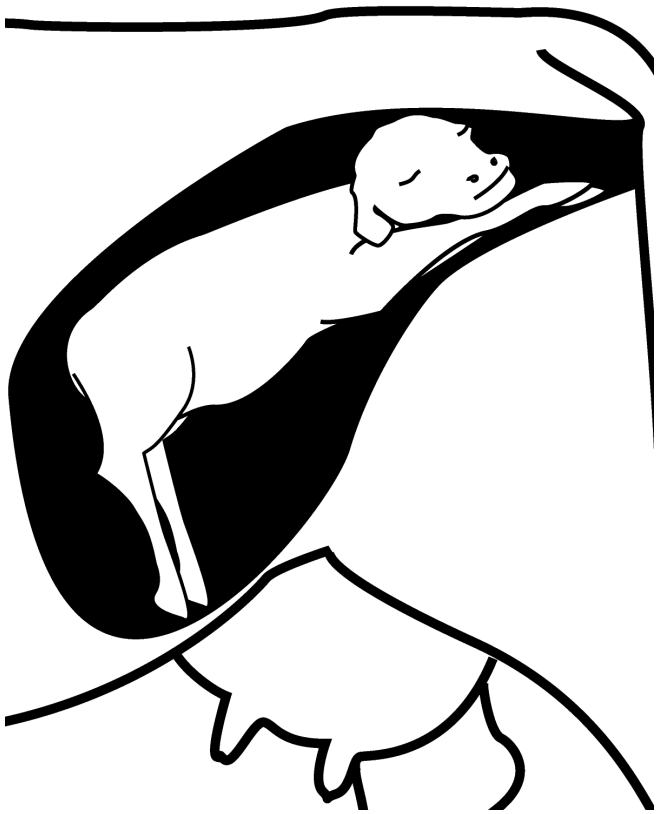


Figure 35.1. A correct anterior presentation.

The Three Stages of Parturition

Stage 1

The first stage of parturition is characterized dilation of the cervix and mild contractions of the uterus. At the beginning of stage one, the contractile forces primarily influence the relaxation of the cervix, but uterine muscular activity is still rather quiet. The normal cervix is tightly closed right up until the cervical plug is completely dissolved. In stage 1, cervical dilation begins around four hours to 24 hours before the actual birth. During this time, the progesterone block is no longer present and the uterine muscles are becoming more sensitive to all factors that will increase the rate and strength of contractions. Stage 1 is likely to go completely unnoticed, but there may be some behavioral differences such as isolation or discomfort or signs of nervousness, such as repeatedly lying down and getting up. Near the end of stage 1, producers may observe elevation of the tail, switching of the tail and increased mucous discharge.

Stage 2

The second stage of parturition is defined as the delivery of the newborn. It begins with the entrance of the membranes and fetus into the pelvic canal and ends with the completed birth of the calf. The second stage is characterized by intense uterine contractions and noticeable straining. Clinically the

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

onset of stage 2 is marked by the appearance of membranes or water bag at the vulva. The traditional texts, fact sheets, magazines and other publications state that stage 2 lasts from two hours to four hours. Data from Oklahoma State University and the USDA experiment station at Miles City, Montana, would indicate stage 2 is much shorter being approximately one hour for heifers and one-half hour for adult cows. See Examining the Cow later in this chapter. In heifers, not only is the pelvic opening smaller, but also the soft tissue has never been expanded. Older cows have had deliveries before and birth should go quite rapidly unless there is some abnormality such as a very large calf, backwards calf, leg back or twins.

Stage 3

The third stage of parturition is the expulsion of the placenta or fetal membranes. In cattle this normally occurs in less than eight hours to 12 hours. The placental membranes are often considered retained if after 24 hours they have not been expelled. The attachment sites where the placenta interfaces with the uterine lining are referred to as a placentome. This is where the caruncles in the uterus attach to the cotyledons of the placenta. At one time, it was considered necessary to remove the membranes by manually "unbuttoning" the attachments. Research has shown that manual removal is detrimental to uterine health and future conception rates. A bovine has a set number of caruncles and if any of those are torn off, they do not regenerate. A certain number of attachment sites are required to support a pregnancy, so it's not a good idea to manually try to remove the placenta and risk damage to the caruncles. Cows with retained placenta are at high risk of developing metritis, an inflammation of the uterus caused by the overgrowth of pathogenic bacteria. Metritis is normally diagnosed between three days to 14 days postpartum and is characterized by a watery, foul-smelling, reddish-brownish uterine discharge. Antibiotic therapy is recommended for cows that develop metritis. Contact your veterinarian for the proper management of retained placenta and metritis.

Dystocia

What is dystocia? In principle, dystocia is a delayed or difficult birth or an abnormal or difficult labor. Traditionally, it is any birth needing assistance. Dystocia is the number one cause of calf mortality in the first 96 hours of life. Calving-ease scores (CES) should be used as a method of recording dystocia. Here is an example of CES: 1) unassisted calving; 2) slight difficulty, assisted calving (e.g., correction of calf presentation, position, or posture); 3) difficult calving (e.g., correction of calf presentation, position or posture, with significant traction applied); and 4) extremely difficult calving (e.g., fetotomy, cesarean section). Cows with CES of 2 to 4 are considered to have dystocia. Calving ease scores are a great tool for identifying problem bulls or bulls that excel in calving ease.

Causes of Dystocia

What are the causes of dystocia? The causes of dystocia can be multifaceted and include not only the fetus and the dam, but also the management practices of the producer. Most common is fetal-maternal size mismatch which could be explained as a calf too big, pelvis too small or both. As for calving difficulty, prevention is worth a pound of cure. Proper sire selection is a key to preventing calving difficulty. Review chapter 27 Management of Effective Mating and Crossbreeding Systems to learn more of sire selection to reduce calving difficulty. Also, consult chapter 29, Development of Replacement Beef Heifers. Underdeveloped heifers and heifers bred to bulls with large birth weights are both factors causing increased incidence of difficult births. The second most prevalent cause is the abnormal presentation, position, or posture of the calf. Presentation refers to whether the calf is coming forward (anterior) with both front legs and head extended into the birth canal; backwards (posterior) with both hind legs extended into the birth canal (soles of the hooves up and toes pointed down); or transverse with either all four legs in the birth canal or the back of the calf entering the birth canal. Position refers to how the calf is positioned in relation to the cow. If the calf's back is up towards the cows back (spine) it is considered right-side up (dorsal). This is the only position that is considered normal. If the calf's back is down on the bottom of the pelvis it is upside down (ventral). Posture refers to the relationship of the calf's limbs and head with its own body. The normal presentation in cattle is anterior presentation or head first, the normal position would be right side up (dorsal), and normal posture is the head located in-between the fore limbs and extended into the pelvic canal. Any position that involves the calf's head turned back or one of the legs turned back is abnormal. Remember, a normal delivery cannot be achieved unless the head and both front limbs are presented into the pelvic canal and on through the vulva. Having normal presentation, position and posture is very important to stimulate cervical dilation for successful calving. A third cause of dystocia would be lack of uterine contractions or uterine fatigue. The causes of this are complex and not completely understood. Sometimes hormonal imbalances may result in the cervix not being completely dilated or uterine contractions not occurring frequently or strongly enough. Low calcium levels such as seen with milk fever or grass tetany may be responsible. In any case, those problems usually require the assistance of a veterinarian to correct. Other causes of dystocia are twins or genetic mistakes (fetal monsters).

Effects of Dystocia on the Calf

What are the effects of dystocia or difficult birth on the calf? Obvious to everyone is a dead calf at birth or a calf killed while assisting with the delivery process. Additional effects include trauma such as leg fractures, ruptured diaphragm and nerve damage due to excessive pulling, improper placement of chains or the development of a hiplock. A third and greatly overlooked effect is a weak calf, sometimes called weak calf syndrome, which may be brought on by a prolonged stage 2. This is due to increased time

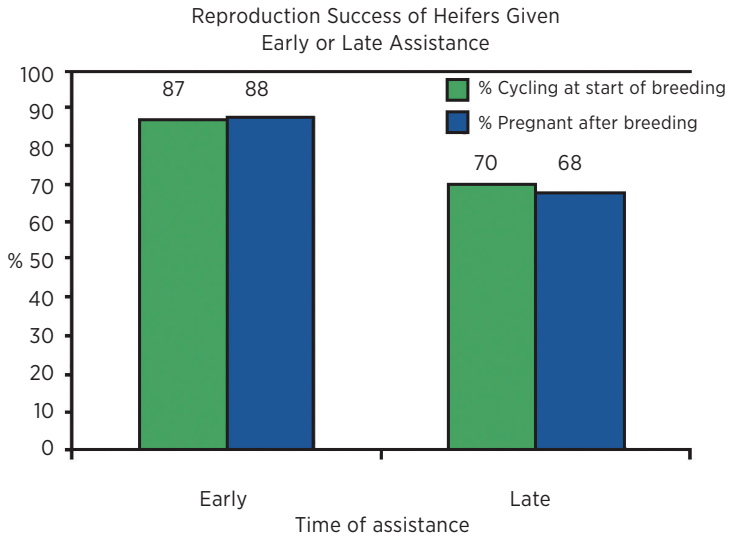


Figure 35.2 – Impact of early or late assistance in subsequent rebreeding performance of first calf heifers. Source: Doornbos et al., 1984.

exposed to increased pressure associated with increased uterine contractions and straining of the dam. Many things can cause calves to be weak at birth, but dystocia is the single most common cause of compromised calves.

A prolonged stage 2 with no progress in delivery of the calf results in hypoxia or decreased oxygen and increased carbon dioxide to the fetus. Such calves do not have normal respiratory efforts. They do not have strong gasping and panting efforts. They do not have rapid respiration or heart rates necessary to distribute oxygen to the tissues and carbon dioxide back to the lungs. Lactic acid and carbon dioxide levels remain quite high. These calves are depressed, they do not sit up well, they do not shake their heads and ears, and if weather is cold they do not shiver to warm themselves. Shivering increases metabolism, which increases heat. These calves have poor metabolism to begin with and their body temperature consequently drops. Even those that first appeared to breathe and sit up normally soon become depressed, are slow to rise and are slow to nurse. Many do not nurse without assistance and die within 12 hours to 24 hours. Even those that do nurse, may nurse too late for good antibody absorption. All calves born without assistance experience hypoxia, acidosis and, commonly, hypothermia. Dystocia calves experience the same changes but to a greater degree (Mee, 2008; Gary et al., 2015). Calves born dead or that die within 24 hours of birth, after a gestation length of at least 260 days, are considered stillbirths. In summary, the effect of dystocia is not just dead calves and injured heifers or cows, but also weak and sick calves.

Effects of Dystocia on Post-calving Fertility

In addition to being the greatest cause of baby calf mortality, calving difficulty markedly reduces reproductive performance during the next breeding season. The reason why dystocia reduces reproductive outcomes is because dystocia is a major risk factor for the development of uterine diseases. The economic impact of postpartum uterine diseases for dairy and beef enterprises include infertility, increased culling for failure to conceive, reduced milk production, and cost of treatment (Sheldon et al., 2009).

Results from a Montana study (Doornbos et al., 1984) showed that heifers receiving assistance in early stage 2 of parturition returned to heat earlier in the post-calving period and had higher pregnancy rates than heifers receiving traditionally accepted obstetric assistance (Figure 35.2). In this study, heifers were either assisted when the fetal membranes (water bag) appeared early or were allowed to progress normally and assisted only if calving was not completed within two hours of the appearance of the water bag (late).

Heifers that were allowed to endure a prolonged labor had a 20% lower rate of cycling at the start of the next breeding season. In addition, the rebreeding percentage was 17% lower than the counterparts that were given assistance in the first hour of labor.

Prolonged deliveries of baby calves (in excess of one hour to one and a half hours) often result in weakened calves and reduced rebreeding performance in young cows.

Prepare Before Helping

- **Equipment:** Before calving season starts, do a walk-through of pens, chutes and calving stalls. Make sure all are clean, dry, strong, safe and functioning correctly. This is a lot easier to do on a sunny afternoon than on a cold dark night when you need them.
- **Protocol:** Before calving season starts, develop a plan of what to do, when to do it, who to call for help (along with phone numbers) and how to know when you need help. Make sure all family members or helpers are familiar with the plan. It may help to write it out and post copies in convenient places. Talk to the local veterinarian about the protocol and incorporate their suggestions. A veterinarian will be a lot more helpful when you have an emergency during the kids' school program if you have talked a few times during regular hours.
- **Lubrication:** Lubrication is extremely important during dystocia intervention. Many lubricants have been used and one of the best lubricants is probably the simplest – nondetergent soap and warm water. Polyethylene polymer-based lubricant are an excellent option. However, it is very toxic if leaked into the abdominal cavity. Thus, proper examination for uterine lacerations is critical, and polyethylene polymer-based lubricants should not be used if C-section is being considered.
- **Supplies:** The medicine chest should be stocked with disposable obstetrical sleeves, nonirritant antiseptic, lubricant, obstetrical chains (60-inch and/or two 30-inch chains), two obstetrical handles, mechanical calf pullers and injectable antibiotics. Do not forget the simple things such as a good flashlight with extra batteries and some old towels or a roll of paper towels. It may be helpful to have all these things and other items packed into a 5-gallon bucket for easy access.

Signs of Impending Calving in Cows or Heifers

As the calving season approaches, the cows will show typical signs that will indicate parturition is imminent. Changes gradually seen are udder development or making bag and the relaxation and swelling of the vulva or springing. These indicate the cow is due to calve in the near future. There is much difference between individuals in the development of these signs and certainly age is a factor. The first-calf heifer, particularly in the milking breeds, develops udder for a very long time, sometimes for two months or three months before parturition. The springing can be highly variable too. Most people notice that Brahman influence cattle seem to spring much more than a Holstein.

Typically, two weeks preceding calving, springing becomes more evident, the udder is filling and the loss of the cervical plug might be observed. This is a very thick tenacious, mucous material hanging from the vulva. It may be seen pooling behind the cow when she is lying down. Some people mistakenly think this happens immediately before calving, but can be seen weeks before parturition. Therefore, it is only another sign the calving season is here.

The immediate signs usually occurring within 24 hours of calving are relaxation of the pelvic ligaments (e.g. tailhead becomes more evident) and strutting of the teats. These can be fairly dependable for the owner who watches the cows several times a day during the calving season. The casual observer or even the veterinarian who is knowledgeable of the signs but sees the herd infrequently cannot accurately predict calving time from these signs. The relaxation of the pelvic ligaments really cannot be observed in fat cows (BCS 7 or greater). However, relaxations of the ligaments can be seen very clearly in thin or moderate body condition cows and can be a sign of impending parturition within the next 12 hours to 24 hours. These changes are signs the manager can use to more closely pinpoint calving time. Strutting of the teats is not really very dependable. Some heavy milking cows will have strutting of the teats as much as two or three days before calving and on the other hand, a thin poor milking cow may calve without strutting of the teats.

Another thing that might be seen in the immediate 12 hours before calving would be variable behavior such as a cow that does not come up to eat or a cow that isolates herself into a particular corner of the pasture. However, most of them have few behavioral changes until the parturition process starts.

Examining the Cow

It is important to know with complete confidence exactly when and how long to leave the cow and when to seek help. An issue facing the rancher at calving time is the amount of time heifers or cows are allowed to be in labor before assistance is given. Traditional textbooks, fact sheets and magazine articles state that stage 2 of labor lasted from two hours to four hours. Stage 2 is defined as that portion of the birthing process from the first appearance of the water bag until the baby calf is delivered. Data from Oklahoma State University and the USDA experiment station at Miles City, Mont., clearly show that stage 2 is much shorter, lasting approximately 60 minutes in first calf heifers and 30 minutes in mature cows (Table 35.1).

Table 35.1. Research results for length of stage 2 parturition.

Study	*No. of Animals*	*Length of Stage 2*
USDA (Montana)*	31 mature cows	22.5 min.
USDA (Montana)*	29 first calf heifers	54.1 min.
Oklahoma State University**	35 first calf heifers	55.0 min.

*Doornbos et al., 1984. JAS: 59:1
**Putnam et al., 1985. Therio: 24:385

In these studies, heifers in stage 2 that labor much longer than one hour or cows in stage 2 much longer than 30 minutes definitely needed assistance. Research information also shows that calves from prolonged deliveries are weaker and more disease prone, if born alive. In addition, cows or heifers with prolonged deliveries return to heat later and are less likely to be bred for the next calf crop. If the heifer is not making significant progress one hour after the water bag or feet appear, examine the heifer to see if assistance should be provided. Mature cows should be watched for only 30 minutes before a rectal exam is conducted. If safe delivery of the calf on the farm does not occur, call a veterinarian immediately.

Most ranches develop heifers fully and use calving ease bulls to prevent calving difficulties. However, a few difficult births are going to occur each calving season. Use the concept of evening feeding to get more heifers calving in daylight. Giving assistance early will save a few more calves. This results in healthier more productive two-year cows to rebreed next year.

Once state 2 of parturition begins, if after 30 minutes no progression is observed, cows and heifers should be examined to determine if intervention is needed. To examine an animal, wash the vulva, anus and the area in between using soap and warm water. Using a disposable sleeve (shoulder length) and a good lubricant (usually available from your veterinarian), insert your hand slowly and do not rupture the waterbag. If the calf's presentation is not an anterior (Figure 35.1) or posterior position (Figure 35.3) or if the calf is very large or the heifer small, seek professional help.

Proper Placement of Obstetrical Chains

To properly use obstetrical chains when assisting with a difficult birth, follow the example in Figure 35.4. To attach the chain, loop it around the thin part of the leg above the fetlock. Then, make a half hitch and tighten it below the joint

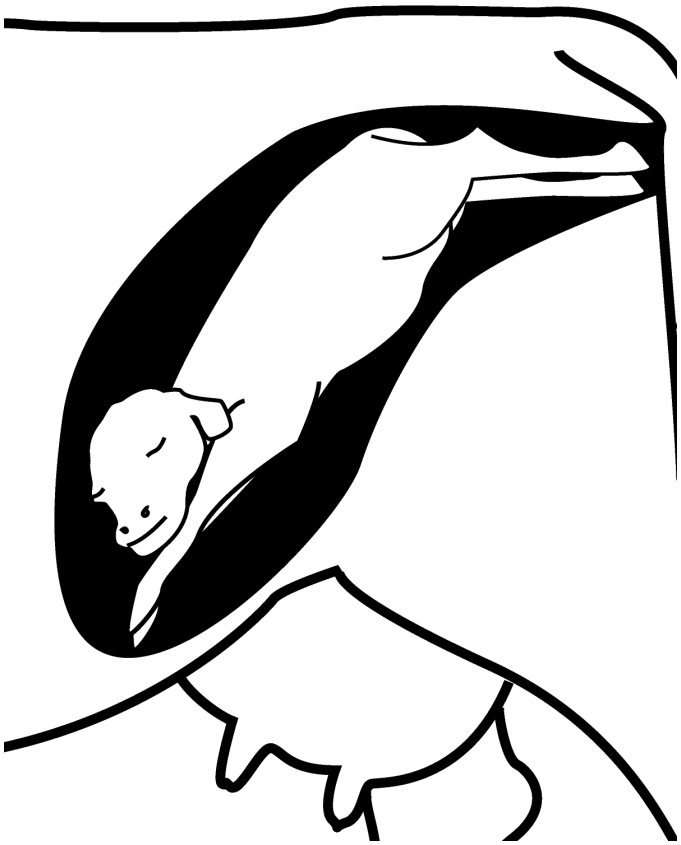


Figure 35.3. A posterior presentation.

Place loop above and halfhitch below fetlock joint. Connecting chain should be on the top of the leg

Figure 35.4. Proper placement of obstetrical chains.

and above the foot. Make certain the chain is positioned in such a manner that it goes over the top of the toes. In this way, the pressure is applied so sharp points of the calf's hooves are pulled away from the soft tissue of the vaginal wall.

Forced Extraction of a Calf

It is very important at all times to exert pressure only when the animal strains and to relax completely when the cow relaxes. The old idea of maintaining a steady pressure during assistance is wrong, unless the cow has already given up and no assistance is coming from her.

Excessive or improper pressure often causes injuries to the dam such as vaginal tears, uterine rupture, paralysis or uterine prolapse. All usually can be prevented, but when they occur, immediate attention of a veterinarian is needed.

Vaginal tears generally heal with proper antibiotic therapy. Uterine rupture usually results in death. Some animals will recover from calving paralysis but may require prolonged care and may not breed again.

Pulling on a calf should only be done when the presentation and posture of the calf are normal. This applies both to an anterior position (Figure 35.1) and a posterior position (Figure 35.3). Excess force should never be used in pulling a calf. In most cases, no more than two people should be allowed to pull, and then only when the cow strains. Lubricant and patience will often solve the tightest case. Use extreme caution if a mechanical puller is being used.

The first step is to examine the cow to check calf position and determine if assistance is necessary. It is generally easier to correct any abnormal presentation if the cow is standing. If a cow or heifer will not get up, she should be placed so she is not lying directly on the part of the calf to be adjusted. Thus, if the calf's head is turned back toward the cow's right flank, the cow should be made to lie on her left flank so that the calf's head is uppermost. This provides more room in the uterus for manipulation.

Once the calf is in a correct anterior or posterior position, delivery will be easier if the cow is lying down. When the calf's limbs are located, find out whether they are forelimbs or hindlimbs. To do this, start by feeling the fetlock and moving the hand up the limb. In the hindlimb, the next joint is the hock with the prominent point. In the forelimb there is also a prominent point, the point of the elbow, but before this is reached one can feel the knee joint, which is flat and has no prominences.

The calf may be alive or dead. Sometimes movements can be detected in a live calf by placing the fingers in the mouth, seizing the tongue or touching the eyelids.

Lubrication is key. Plenty of lubricant should always be used whenever correcting calf malposition, particularly if the birth canal or calf is dry. Attempts to repel (push back) the calf should be made between labor pains. Similarly, attempts to deliver the calf by traction will be a lot easier if they are made to coincide with the contractions of the cow.

Anterior Presentation

An anterior presentation is forefeet first, head resting on the limbs and the eyes level with the knees (Figure 35.1). In this presentation, the cow does not usually require assistance, unless it is a heifer at first calving, the calf is dead or the calf is too big for the cow.

If the calf is dead, tie a chain around the head behind the ears and pass it through the mouth. This will prevent the head from twisting when the limbs are being pulled. With a live calf, place a hand on the head, ensuring that the head is kept straight. Traction should not be exerted simultaneously on the head and limbs until the head enters the pelvis. A large calf, with shoulders too wide for the pelvis, is sometimes held up at this stage. If so, pull one limb only so the elbow and shoulder of one limb only enters the pelvis. Then, while

the pull on the limb is continued, the other limb is treated in the same way until both feet project equally from the genital passage. Now apply traction on both limbs and on the head until the head protrudes from the vulva, and from this stage the principal traction is exerted on the limbs again.

It can be seen that traction on both limbs at the same time will result in both shoulders entering the pelvis at once. If the shoulders of a wide-chested calf can be made to enter on a slant and can be pulled through in that position, delivery will be made easier.

IMPORTANT: Traction on the calf in the early stages should be exerted upward (in the direction of the tailhead) and not downward. Once the calf is in the pelvic cavity, traction should be straight backward and then downward. Therefore, the calf passes through the birth canal in the form of an arc.

If the passage of the hind end of the calf presents any difficulty, the body of the calf should be grasped and twisted to an angle of about 45 degrees. Delivery is then made with the calf half-turned on its side. This allows for easier passage of a calf with well-developed stifle joints.

Sometimes a calf gets stuck at the hips (hiplock). Do not just pull. Rotate the calf as described above or try turning the cow onto her back, then over onto the side opposite to the one she was found on and try some gentle assistance.

Posterior Presentation

Three to five percent of calves are born in a posterior presentation. In a posterior presentation, both the hindfeet are presented with the calf's spine upward toward the cow's spine (Figure 35.3), and the sole or bottom of the hooves will face upward. In a normal anterior presentation (head and forelimbs first), the hooves are downward. If the calf is on its back, however, the position of the hooves is reversed in each of these presentations.

In the posterior presentation, the head is the last part to be expelled, and there is a risk of suffocation or brain damage due to lack of oxygen. Delivery should be as quickly as possible by traction on the hind legs. Traction should be exerted on one limb until the corresponding stifle joint has been drawn over the pelvic brim. It may be necessary to push the other limb partly back into the uterus at the same time. In this way, the two stifle joints will enter separately into the pelvis and assist easier delivery.

After the first limb has been drawn back sufficiently, traction should be applied to both limbs simultaneously. If this does not succeed, cross one limb over the other and pull on the lower limb. This will make the calf rotate slightly to one side and delivery will proceed more smoothly.

The calf's tail may have a tendency to protrude upward and damage the top of the vagina. Be sure the tail is down between the legs by placing your hand on the tailhead while the calf is entering the pelvic cavity.

After delivery of posterior presentation, more careful attention should be given to removal of mucus from the mouth and nose because of a greater danger of suffocation than in an anterior presentation. The calf should be held up by the hindlegs and shaken vigorously so fluids may be expelled from the respiratory passages. Calves born in a posterior presentation have a five-times greater risk of dystocia and perinatal mortality than calves born in an anterior presentation.

Other Ideas on Pulling Calves

The chain should be tightly fastened above the fetlocks with a half-hitch below the fetlock before applying traction in anterior or posterior presentations. If it becomes necessary to pull on the jaw or head, try to do it by hand or use a soft cotton or nylon rope, being careful not to apply excessive tension, which might fracture the jaw or damage the spinal cord. If a rope is used, apply the rope behind the poll and through the mouth. Protect the birth canal from laceration by the sharp teeth by guiding the head with your hand. After the head and neck have passed through the cervix, traction should be applied to the legs only.

Traction should be applied in a steady, even manner. Jerky, irregular pulls are painful and dangerous. Only pull when the cow is straining. If you are pulling and a sudden obstruction occurs, stop and examine the birth canal and calf to find out what is wrong before proceeding. To avoid lacerations to the soft birth canal, time should be allowed for enlargement of the birth canal as the calf advances.

Abnormal Presentations

Figures 35.5 to 35.7 show presentation of the calf other than anterior or posterior presentations.

Two Front Legs Presented: Head Retained

If the head cannot be felt, do not assume the calf is coming backward. The two front legs may be presented and the head retained (Figure 35.5). Before pulling on the limbs, distinguish between forelimbs and hindlimbs as described earlier. Where the head is bent back into the right flank of the cow, it will be easier to correct if the left hand is used and vice versa. By grasping the muzzle, the ear or the lower jaw, or by placing the thumb and middle finger in the eye sockets, the head can be raised and directed into the pelvis. Pushing the calf back inside to make room for correcting the position of the head might help. Do not pull hard on the jaw because the jaw can be easily broken.

In all these cases, the head can be brought up and straightened more easily if the body of the calf is at the same time pushed farther back in the uterus. This can be done by placing the hand between the front legs and pushing back the chest, the head being pulled at the same time with aid of a chain placed on the lower jaw. Try to carry out all these operations when the cow is not straining vigorously.

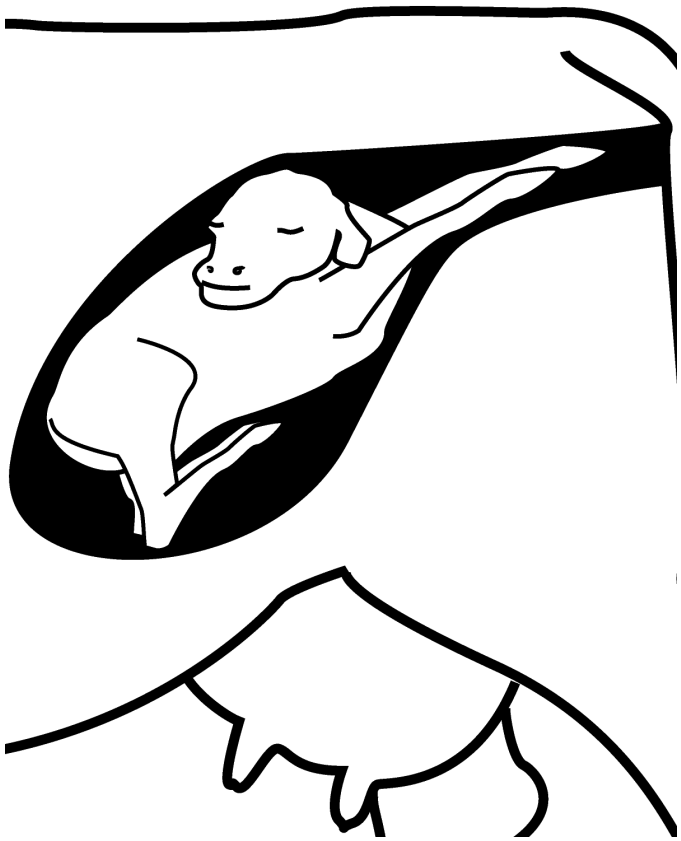


Figure 35.5. Two front legs presented with head back.

Head Between Forelegs

Sometimes the head falls well down between the legs (Figure 35.6). Replace one or both limbs into the uterus to raise the head by one of the methods described above.

Another method is to turn the cow on her back. The head of the calf will fall toward the cow's spine and then can be more easily guided into the pelvis by hand or a loop around the lower jaw.

Head Out: One or Both Forelegs Retained

The calf may have the head out, but one or both forelegs retained (Figure 35.7). Secure the head by placing a chain or rope behind the poll and through the mouth then lubricate the head and push it back into the uterus. Then search for the limbs one at a time. Each limb should be grasped just above the fetlock and bent at the knee. Cup the hoof with the hand when straightening the limb to prevent lacerations. Now push the bent knee toward the spinal column and push back to bend all the joints of the limb. Meanwhile the hand is gradually moved down the limb toward the fetlock. Now raise the fetlock over the pelvic brim and the leg can move forward.

If the hand alone does not work, chain the fetlock. Push the knee at the same time and pull the rope.

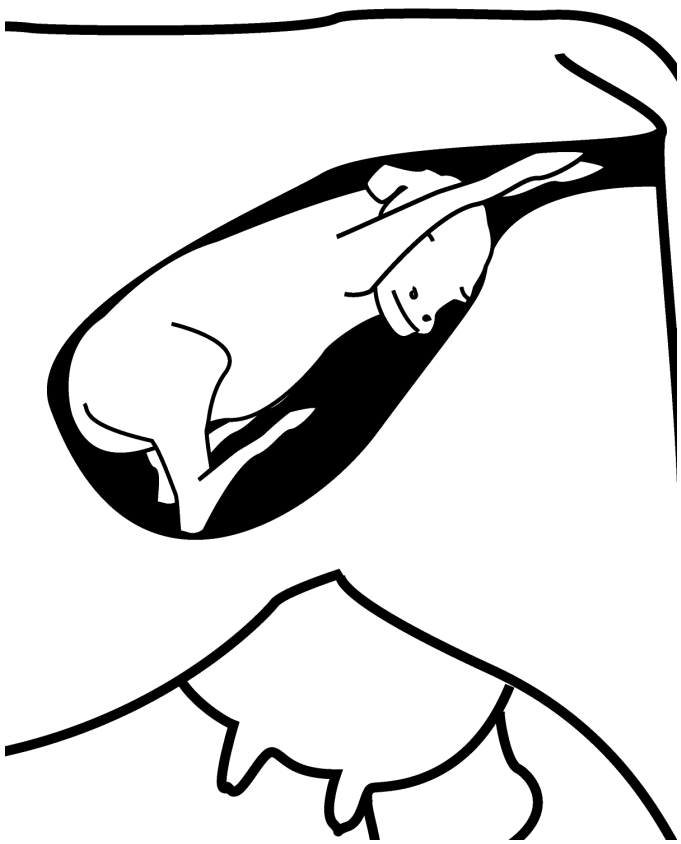


Figure 35.6. Two front legs presented with head back between legs.

Figure 35.7. Calf presented with its head in the birth canal but one or both forelegs retained.

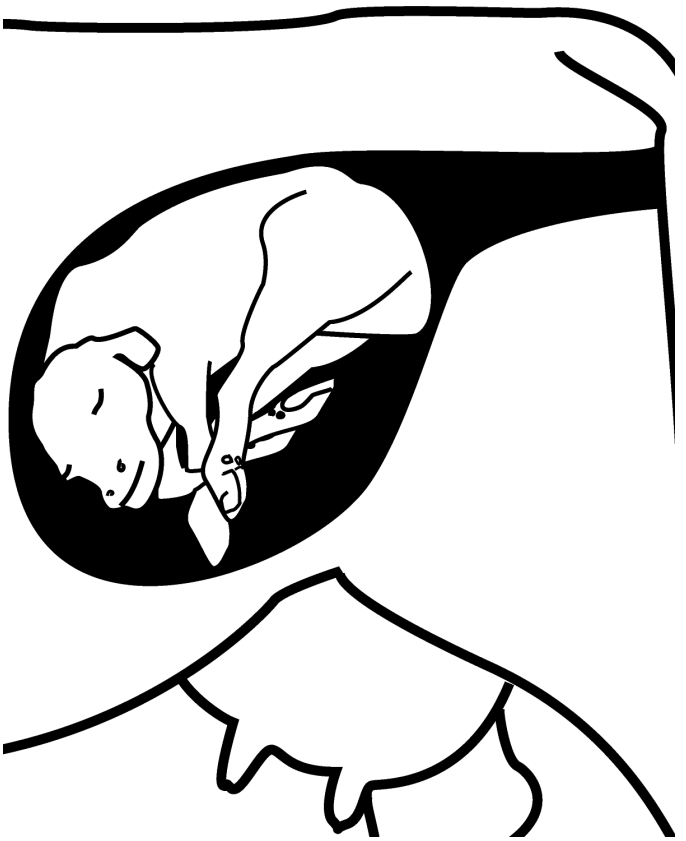


Figure 35.8. Calf presented in breech position.

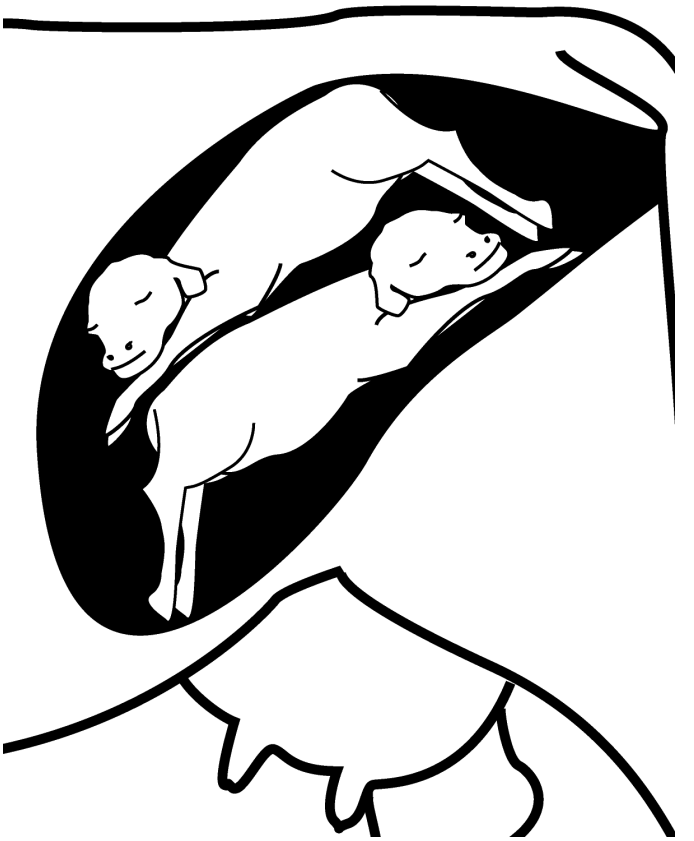


Figure 35.9. Twin calves entering the birth canal.

Breech Presentation

Figure 35.8 shows a breech presentation. The calf has to be repelled well back into the uterus. Then grasp a leg below the stifle and work a hand down to the foot. Place the hoof into the palm of your hand, withdrawing your arm until the foot is drawn over the pelvic brim. This manipulation is made easier by rotating the hock outward as the foot is pulled up and back.

Twins

If twins enter the vagina one at a time, there is no problem. However, occasionally twins are presented together and block the birth canal. In most of these cases, one comes head first and the other tail first (Figure 35.9). Extract the closest twin. If in doubt, first extract the twin presenting hindlegs after first repelling the other twin far into the uterus.

Before this, make sure both limbs belong to the same calf. To do this, feel along each limb to where it joins the body and feel along the body to the opposite limb. Rope each limb separately and identify the ropes for each twin. If one or both twins are abnormally presented, correct as in a single birth before attempting delivery.

Rotating a Calf at Parturition to Aid in Delivery

Pulling on a calf should only be done when the presentation, position, and posture of the calf are correct. This applies to both the anterior (forward) position (Figure 35.1) and the posterior (backward) position (Figure 35.3). A large calf with shoulders too wide for the pelvis, is sometimes held up at this stage (Figure 35.10). If so, pull one limb only so the elbow and shoulder of one limb only enters the pelvis. Then, while the pull on the limb is continued, the other limb is treated in the same way until both feet project equally from the genital passage. Now apply traction on both limbs and on the head until the head protrudes from the vulva. From this stage the principal traction is exerted on the limbs again. It can be seen that traction on both limbs at the same time will result in both shoulders entering the pelvis at once.

The pelvis has an oval shaped opening with the largest dimension being the vertical axis, and the smaller dimension is the horizontal width. If the shoulders of a large birth weight calf can be made to enter on a slant and can be pulled through in that position, delivery will be made easier. Apply traction that will allow the calf to be turned about 90 degrees so the widest part of the shoulders will match the largest dimension of the pelvic opening (Figure 35.11).

After the shoulders have passed the pelvic opening, the calf can be returned to the normal upright position because the torso is larger in the vertical dimension (Figure 35.12).

Hiplock is the next likely obstruction met when pulling a calf. If the passage of the hind end of the calf presents any difficulty, the body of the calf should be grasped and twisted to an angle of about 45 degrees. Delivery is then made with the calf half-turned on its side. This allows for easier passage of a calf with well-developed stifle joints.

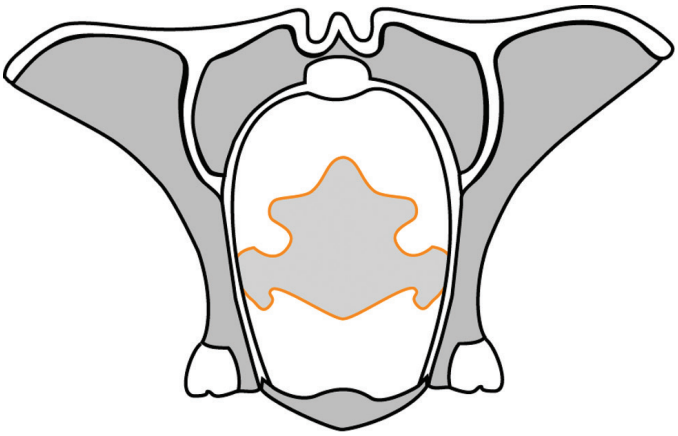


Figure 35.10. The shoulders or hips of a large calf may be wider than the horizontal axis of the pelvic opening.

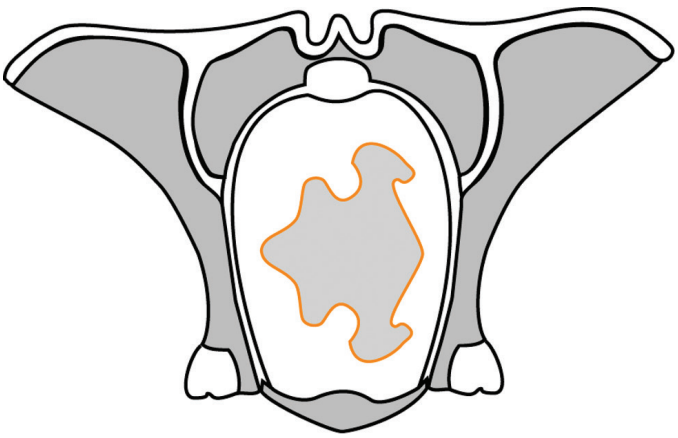


Figure 35.11. Rotation of the calf to match the widest dimensions of calf and pelvic opening.

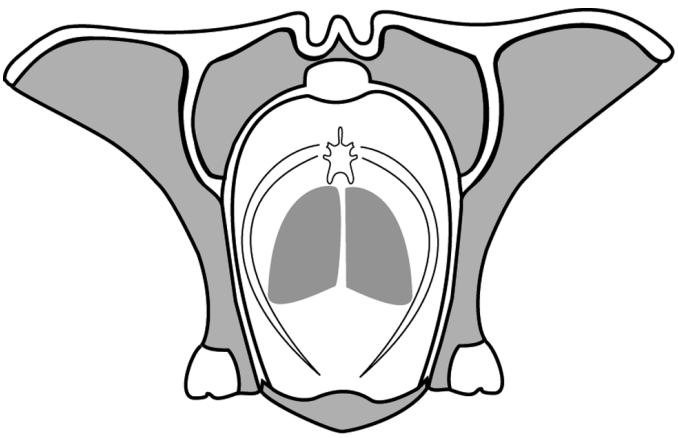


Figure 35.12. Rotating the calf back to the upright position to match the depth of the thoracic cavity with the depth of the pelvic opening.

Prolapses

Prolapses occasionally occur in beef cows. Most prolapses occur very near the time of calving. Two distinct kinds of prolapse exist.

Uterine prolapse requires immediate attention and if treated soon, most animals have an uneventful recovery. If they subsequently rebreed and become pregnant, there is no reason to cull animals suffering uterine prolapse after calving. Uterine prolapse is not likely to reoccur. Some may suffer uterine damage or infection preventing conception and should be culled. If the uterus becomes badly traumatized before treating, the animal dies from shock or hemorrhage. Uterine prolapse in dairy cows have been associated with hypocalcemia (Risco et al., 1984). Contact your veterinarian for immediate assistance with uterine prolapses.

Vaginal prolapse, which occurs before calving, is a heritable trait, however, and is likely to reoccur each year during late pregnancy. Such animals should not be kept in the herd. The condition will eventually result in the loss of cow, calf or both. Additionally, her female offspring would be predisposed to vaginal prolapse.

Research from the USDA station at Miles City, Mont., reported that 153 calvings of 13,296 calvings from a 14-year span were associated with prolapse of the reproductive tract (Patterson et al, 1981). Of those 153 prolapses, 124 (81%) were vaginal prolapses and 29 (19%) were uterine prolapses. The subsequent pregnancy rate following prolapse among first calf heifers was 28% and the pregnancy rate among adult cows following a prolapse was only 57.9%.

Summary

Many calving difficulties can be eliminated by proper development of replacement heifers and/or breeding first calf heifers to bulls that will sire calves with below average birth weights. Most importantly is to know when to help, when to quit, and when it is time to call the veterinarian. Remember the length of stage 2 of parturition is important to calf survival and if a problem cannot be corrected within 20 minutes to 30 minutes, seek assistance. To learn more about how to assist cows or heifers at calving, check out two videotapes available from a local Extension office. These two videos are called VT-323 Calving Management-Parturition (youtu.be/KvxtgQ_k7aI) and VT-324 Calving Management-Dystocia (youtu.be/yjBwwS59nEA). In the second video (VT-324), Dr. Larry Rice, Professor-Emeritus, demonstrates how to check for cervical dilation.

References

Doornbos, D.E., R.A. Bellows, P.J. Burfening and B.W. Knapp. 1984. Effects of dam age, prepartum nutrition, and duration of labor on productivity and postpartum reproduction in beef females. *Journal of Animal Science*. Vol. 59: pp 1-10.

Garry. F.B. and J.E. Lombard. 2015. Managing compromised and weak calves. Proceedings, The Range Beef Cow Symposium XXIV, November 17, 18 and 19, 2015, Loveland, CO.

Mee, J. 2008. Managing the Calf at Calving Time. AABP Proceedings Vol. 41: pp 35-43.

Mee, J. 2008. Managing the Calf at Calving Time. AABP Proceedings Vol. 41: pp 46-53.

Patterson, D.J., R.A. Bellows, and P.J. Burfening. 1981. Effects of caesarean section, retained placenta, and vaginal or uterine prolapse on subsequent fertility in beef cattle. *Journal of Animal Science*. Vol. 53: pp 916.

Patterson, D.J.; Bellows, R.A.; Burfening, P.J.; and Carr, J.B. 1987. Occurrence of neonatal and postnatal mortality in range beef cattle. *Theriogenology*. Vol. 28 No. 5. pp 557-71.

Putnam, M.R., L.E. Rice, R.P. Wettemann, K.S. Lusby, and B. Pratt. 1985. Clenbuterol (PlanipartTM) for the postponement of parturition in cattle. *Theriogenology*. Vol. 24. No. 4. pp 385-393.

Risco CA, Reynolds JP, Hird D. Uterine prolapse and hypocalcemia in dairy cows. *Journal of American Veterinary Medicine Association.* 1984 Dec 15; 185(12):1517-9. PMID: 6511623.

Sheldon, I.M., J. Cronin, L. Goetze, G. Donofrio, and H.-J. Schuberth. 2009. Defining postpartum uterine disease and the mechanisms of infection and immunity in the female reproductive tract in cattle. *Biol Reprod* 81:1025–1032. doi:10.1095/biolreprod.109.077370.

36 Herd Health

Rosslyn Biggs, DVM and Barry Whitworth, DVM

Objectives

- **Learn how to use commercial beef cow-calf health guidelines as an outline for designing a herd health plan.**

Developing a sound and practical commercial beef cow-calf herd health program requires more than obtaining a recipe from a cookbook, because production objectives may vary considerably between individual producers. Producers with knowledge about the production cycle on their premise should be working with veterinarians who have expertise about disease biology.

Herd health programs must be customized to meet the needs of individual producers. Herd health program choices are impacted by:

- geographic locations,
- climate/weather variations,
- housing,
- density at different points in the production cycle,
- resource availability,
- individual animal differences,
- nutritional status,
- exposure to non-herd cattle in shared grazing or across fence line,
- end use of cattle,
- marketing considerations and
- human population demographics.

Every rancher should develop a good working relationship with a local veterinarian in developing the herd health program. This should include proper animal drug usage and adherence to food safety principles. Successful herd health programs should be reviewed annually for changes in herd management and to incorporate new information. Beef quality assurance is of particular importance and the producer must be a part of the veterinarian-client-patient relationship to assure violative drug residues and damaging injection-site lesions do not occur.

Herd health programs often have focused on infectious disease treatment and prevention as well as parasite control. However, in modern production animal agriculture, the focus is on optimizing herd health, efficient production and maximizing net return to the business unit. Working closely with a veterinarian will allow identification of individual herd needs and development of customized health programs to address these variables and challenges.

Table 36.1 has been developed as a template to follow when initially developing herd health programs for commercial beef cow-calf operations. This table has been designed as simply as possible to minimize or eliminate many of the confusing issues related to these types of programs. Refer frequently to Table 36.1 for a more thorough understanding of the points stressed in this chapter.

The table is divided into columns and organized so producers can apply the information and guidelines to their own individual situations. Producers can utilize this table as a checklist to prepare for the events in their individualized production cycle.

1. The left-hand column identifies times in the production cycle when beef cattle are most commonly processed and decisions regarding health and business should be implemented. Recommendations designed around these times are more readily accepted by the producer and have the best potential for optimizing health of the entire herd.
2. The center column presents basic or minimal guidelines for most commercial beef cow-calf herds.
3. The right-hand column provides information producers of certain herds may need to address to optimize health and production. For the specific considerations outlined in this column, it is strongly recommended to consult a veterinarian.

Again, it is stressed that these are general guidelines and recommendations. Programs should be customized to meet the needs and objectives of every herd.

It is beyond the scope of this chapter to discuss details of goal setting; however, the health and viability of any business, including commercial beef cow-calf operations, must define long- and short-term goals. To determine if goals are being attained, pertinent information must be recorded. Accurate records can be used for measuring goals and measuring financial and production parameters of the business. Data collected must be reviewed and used

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 36.1. Commercial beef cow-calf herd health guidelines.

Time	*Basic program recommendations*[a]	*Other considerations to discuss with your veterinarian*[b]
Pre-calving	Evaluate facilities and environment Equipment: sterile, proper function Review protocol for monitoring and when to assist delivery Ensure record system data is current Monitor herd for nutrition and separate by age and BCS to manage feed intake appropriately	Quality frozen colostrum Scours vaccine
60 days pre-calving all females	If management is adequate, should not need any vaccinations Evaluate BCS (see chapter 20)	Scours vaccinations
Calf born	Individually identify Record birth Assure adequate colostrum	Dip navels Weigh calves Castrate Dehorn (complete)
Bulls	Viral respiratory diseases (IBRV, BVDV) Leptospirosis Parasite control program (location and season dependent)[c] Breeding soundness examination	PI_3V, BRSV Vibriosis
Start breeding heifers	Finish all calving. Start breeding heifers 30 days before cows	
Start breeding adult cows		
Remove bulls	40 days to 90 days after introducing, depending on goals	
Branding time Two months to four months	Individually identify (if not already performed): brand, ear tag Castrate Dehorn (complete) Clostridial: 7- or 8-way (location dependent) Parasite control program (location and season dependent)[c]	Brucellosis (bangs) - heifers - (marketing decision) (follow age restrictions) Viral respiratory diseases Leptospirosis Pinkeye Tetanus
Weaning Five months to nine months	Clostridial: 7- or 8-way (location dependent) 4-way or 5-way viral respiratory diseases (IBRV, BVDV, PI_3V, BRSV) Leptospirosis Parasite control program Weigh calves and evaluate BCS (see chapter 20) BCS and Pregnancy test cows and evaluate culling criteria	Brucellosis (bangs) - heifers - (marketing decision) (follow age restrictions) Preweaning/weaning vaccination program Weaning/post - weaning vaccination (location and season dependent)[c] program Pinkeye
Replacement heifers 13 months to 16 months	4-way or 5-way viral respiratory diseases (IBRV, BVDV, PI_3V, BRSV) Leptospirosis Clostridial: 7- or 8-way (location dependent) Parasite control program (location and season dependent)[c] Monitor growth: Rule of Thumb-heifers should weigh 65% of mature weight at start of breeding season	Make sure individually identified Vibriosis
Process adult cow herd	Viral respiratory diseases (IBRV, BVDV) Parasite control program (location and season dependent)[c] Leptospirosis Evaluate individual animals: udder, eyes, disposition, feet, joints, legs, soundness Pregnancy check and evaluate culling criteria Evaluate BCS (see chapter 20)	PI_3V, BRSV Anaplasmosis control Vibriosis

a These are general guidelines and recommendations. Individual herd programs may vary considerably. Consult your veterinarian for specific recommendations.

b Follow all label directions and your veterinarian's recommendations.

c See chapters 37 and 38.

to make informed business decisions. In other words, do not collect information just to be collecting information. Record systems for commercial beef cow-calf operations can be as simple as a pocket calendar or as technical as a software computer program. Regardless of the system chosen, it is imperative information is recorded and the system in place prior to calving. For more information about keeping records, refer to chapter 3.

This chapter will arbitrarily start with pregnant females just prior to calving and designate this occurrence or event as pre-calving.

Pre-Calving

The left column of Table 36.1 refers to occurrences in the cow-calf production cycle where business decisions should be made and implemented by producers. Producers should prepare personnel who will be involved in the process and evaluate the environment as early as possible, usually one week to four weeks prior to the first anticipated delivery or calculated calving date. One of the first places to begin is the evaluation of the facilities or the calving environment. If pregnant heifers and cows are to deliver in structural facilities, the facilities must be in good repair to avoid physical injuries to the dam and calf as well as personnel. Most structural facilities for calving purposes are only needed for part of the year; farmers and ranchers frequently store equipment and feedstuffs in the same areas. Therefore, calving areas or pens need to be properly cleaned and ready for use prior to the anticipated delivery of the first calf. Where heifers and cows are to deliver in open pasture or range conditions, the calving areas must be dry or well drained. If many females are anticipated to deliver in a short period of time, rotation of the calving areas should be practiced. By providing clean areas or rotating pastures, the buildup of potential disease-causing agents (pathogens) will be minimized. In certain locations and seasons, shelter may need to be provided for optimal health.

It is not uncommon for cattle to go into labor after normal working hours. In certain situations, such as dystocias (difficult births), physical assistance during the parturition (calving) process is needed. Timely intervention can mean the difference between life and death of the dam and her offspring and therefore, potential revenue for the producer. Delivery equipment such as fetal calf extractors (calf pullers), obstetrical (OB) chains and snares, protective sleeves for personnel, lubricant, etc. should be clean or sterile, in good working order and easily accessible.

Experienced personnel are not always available during delivery; therefore, employees, family members and neighbors are commonly asked to observe and assist during calving. A written protocol outlining normal events during parturition and the criteria indicating the need for intervention during the delivery process will increase the chance for a successful birth. Producers should review and discuss the protocol with all personnel involved in this phase of production to alleviate potential complications or problems that may arise.

Calves are born with simple immunity against many common diseases. Without additional protection against disease-causing agents, the chances of long-term survival or productivity are poor. Short-term passive immunity for the calf is provided by the dam's colostrum. In certain situations, neonatal (newborn) calves will not receive this protection. Therefore, as listed in the right-hand column of Table 36.1, a source of high-quality colostrum, which is the first milk containing antibodies after calving, should be available to administer to the deficient calf.

Following the approach of this chapter, the next focus should be on the event in Table 36.1, Calf born, which correlates to the time after the calf is born.

Calf Born

Records are one of the most important management tools used in evaluating the financial and productive health of commercial beef cattle enterprises. Profitable commercial beef herds need to cull nonproductive animals. Difficulty in delivering a live calf (dystocia) should be one criterion used in this process. Any assistance given in the delivery of the calf should be recorded for future evaluation of the cow. Also, the dystocia should be recorded on the bull's record. If an increased number of difficult births are associated with a particular bull, the producer may want to cull the bull.

Individual records on the neonatal calf should be started as soon after birth as possible. To create these records, the calf must be individually identified. Individually identifying newborn calves may not always be practical in every commercial operation; however, no matter which record system the producer uses, it is best to start an individual record as early in the animal's life as possible. In several instances, it is fairly easy to catch a calf that is less than 24 hours old and administer a unique identification, such as a bangle tag. This step is frequently not performed at this stage in the animal's life because it is not convenient for the producer.

The importance of colostrum and its role in the future of the calf's life from both a health standpoint and an end-product standpoint were discussed in the pre-calving section. A newborn calf vigorously nursing its dam shortly after birth will usually correlate to an adequate intake of colostrum. With first-calf heifers, the quality of colostrum is usually not as high as that of an older adult cow. Therefore, in cases where a partial failure of passive immunity transfer occurs, supplementing the newborn with high-quality colostrum may be necessary. Management changes may be needed to avoid the need for supplementation in the future.

Factors Affecting Passive Immunity

A successful cow-calf operation requires a large percentage of cows wean a live calf every year. A live calf at weaning time requires survival of the offspring from birth to weaning. Cattle that are healthy as calves, healthy as weaned stockers and remain healthy throughout finishing are more productive and generally are much more cost efficient. In addition, healthy cattle not repeatedly treated with antibiotics or other therapeutic products will have a higher

likelihood of producing a wholesome, high-quality carcass with fewer injection-site blemishes and no antibiotic or drug residue. As the percentage of cattle needing antibiotics for disease control or prevention dwindles, consumer confidence in the wholesomeness of beef should increase. As vertically integrated alliances become more popular, healthy calves that have strong natural or acquired disease immunity will be in greater demand.

Resistance to disease is greatly dependent on antibodies or immunoglobulins and can be either active or passive in origin. In active immunity, the body produces antibodies in response to infection or vaccination. Passive immunity gives temporary protection by transfer of certain immune substances from resistant individuals. An example of passive immunity is passing of antibodies from dam to calf via the colostrum. This transfer only occurs during the first 24 hours following birth, with the majority of the antibodies being absorbed in the first 12 hours of life.

At the USDA experiment station in Clay Center, Neb., Drs. Tom Wittum and Louis Perino monitored health events and growth performance in a population of range beef calves to identify associations of these factors with passive immune status. Blood samples were collected at 24 hours postpartum from 263 crossbreed calves to determine the amount of passive maternal immunity that had been obtained from colostrum. Growth performance and health events in the study population were monitored from birth to weaning and after weaning throughout the feeding period. The lowest levels of passive immunity were observed among calves that were sick or died prior to weaning. Calves with inadequate passive immunity had a 5.4 times greater risk of death prior to weaning, 6.4 times greater risk of being sick during the first 28 days of life and 3.2 times greater risk of being sick any time prior to weaning when compared to calves with adequate passive transfer. The risk of being sick in the feedlot also was three times greater for inadequate-immunity compared to adequate-immunity calves.

Passive immune status was associated indirectly with growth rates through its effects on calf health. Sickness during the first 28 days of life was associated with a 35-pound lower expected weaning weight. Respiratory disease in the feedlot resulted in a 0.09-pound lower expected average daily gain. Thus, passive immunity obtained from colostrum was an important factor determining the health of calves both pre- and post-weaning and indirectly influenced calf growth rate during the same periods.

Factors affecting the production of colostral antibodies by the cow:

A. Genetics of the dam

Genetics of the dam may influence both the quality and the quantity of the colostrum.

Genetics may influence the shape and size of the udder, which can impact calf intake as noted below.

B. Age of the dam

Mature cows commonly produce more colostrum than first-calf heifers of similar genetic makeup. Mature cows may provide additional protection in their colostrum due to their previous disease exposure and vaccinations.

C. BCS of cows

Research in Colorado found that calves from thin cows (less than BCS 5) had lower amounts of circulating antibodies at 24 hours of age than did calves from heifers in adequate to good body condition score (BCS 5 or BCS 6) at calving (Odde, Abernathy and Greathouse).

Factors affecting the absorption of colostral antibodies by the calf:

A. Timing of intake

Research has demonstrated absorption of the very large protein antibody molecules (also referred to as immunoglobulins) must occur in the first 24 hours of life (Besser and Gay). The intestinal lining of the baby calf undergoes changes (called intestinal closure), reducing the ability of the intestine to absorb the immunoglobulins. In fact, most absorption takes place in the first 12 hours or less. By the time the calf is six hours old, only 66% of the antibodies consumed can be absorbed. When the calf is 12 hours old, less than half of the available antibodies will be absorbed into the blood; and when the calf is 24 hours of age, intestinal closure is nearly complete. Sluggish or weak calves may take a long time to stand, and therefore a long time before looking for the teat to nurse. Anything that comprises the vigor of the baby calf can have an adverse effect on passive immunity.

B. Udder shape and size

Another factor shown to influence the transfer of passive immunity includes the shape and size of the dam's udder. Cows with large pendulous teats and/or with very low udder attachments may be difficult for the calf to locate and get the teat in its mouth to nurse.

C. Weak calves associated with difficult delivery

Calves subjected to a long, difficult delivery often are weakened and slow to rise. In addition, the respiratory acidosis resulting from the difficult birth can have an additional negative impact on the intestinal lining and its ability to absorb. This combination of advancing time and acidosis often means greatly reduced antibody absorption. Colorado State University scientists found greater concentrations of antibodies in the blood of calves born with quick, easy deliveries compared to those born after a long, difficult labor and delivery process (Odde, Abernathy and Greathouse).

D. Severe weather stress

Calves born under severe weather stress as well as those that have not bonded with the mother both have been shown to have reduced absorption capability,even if colostrum was available.

The development of lifetime identification, vertically integrated alliances and niche markets will heighten the need for calves with highly developed disease immunity. Management factors that enhance the development of the passive immunity include:

1. Provide proper replacement heifer development programs and adequate prepartum nutrition for the cow herd to ensure heifers are in a BCS 6 and cows are at least in a

BCS 5 at calving (see chapter 20).

2. Breed heifers to bulls that sire low-birth-weight calves and cows to bulls that sire moderate-birth-weight calves to reduce the incidence of difficult births.
3. Offer early, appropriate obstetrical assistance to heifers or cows observed in labor so the calf is not allowed to become extremely acidotic and weakened and therefore have inhibited immunoglobulin absorption or be unable to nurse the cow.
4. Calves born to first-calf heifers that have little colostrum or baby calves too weak to nurse naturally need to be given fresh or frozen colostrum. Dr. E. R. Homersoky and associates from the University of Calgary found a significant health advantage to giving 2 quarts of first milk within the first four hours of life compared to the previously recommended six hours. This needs to be followed with 2 more quarts within 12 hours.

Other Baby Calf Procedures

During the birthing process, the umbilical cord, from which the fetus has been receiving its needed life support during gestation, is open for a short time. During this short time, bacteria can enter through the umbilicus and gain entry into the blood stream of the newborn. Most of the time, the passive immunity transfer the calf receives through its intake of colostrum will eliminate the infection. However, in some situations the infection will overwhelm the system, causing complications. In situations with overwhelming infection challenges, disinfectant such as iodine or chlorhexidine should be applied to the navels of newborn calves. Dipping navel cords should be a short-term solution. Management needs to be evaluated and appropriate actions taken to avoid or eliminate the need to perform this procedure.

If management is progressive and can proactively determine the future purpose of individual animals, castration and dehorning can be performed at this time. It is frequently more practical and efficient to perform these two procedures at branding time rather than shortly after birth. These procedures and justifications will be covered in much more detail in the next section.

Branding Time

Historically, the term branding time designated the time when young cattle were processed and a mark was made using a hot iron brand to identify the owner. Cattle producers and veterinarians still use this term to indicate the time after all calves have been born and are worked together as a group. Calves are usually 2 months to 4 months of age, but the range can vary considerably between operations and even seasons. From a health standpoint, this is an opportune time to prepare the calf for where it is going, not where it is coming from.

Stress occurs anytime cattle are handled. Too much stress can affect performance and health. Processing young calves at branding time has a major advantage of allowing the calf to return to its familiar environment, including nursing its dam after the procedures have been completed. It is thought that returning the calf to its familiar environment minimizes some of the stress of handling, allowing the calf to perform more closely to its genetic potential, hence, increase production.

If individual identification has not already been performed, it must be done at this time. Even if this is the first opportunity to individually identify animals, records should have already been initiated on each calf through the dam's records. Individual records should be started or updated, depending on previous identification.

Bull calves to be harvested for meat can be castrated at this time. From both a production and an economic standpoint, performing this health procedure makes sense. From the production side of this equation, studies have demonstrated that implanted steers nursing cows can gain the same as bull calves nursing cows (Baker, et al.). From the economic side of this equation, steers are more valuable commercially at marketing times than are bulls of equal quality.

Four issues will be commented on regarding horned cattle in this section. Commercial producers should be aware of all four issues and the effect each has on production. The first involves behavioral characteristics of cattle. Cattle use their horns offensively in feedlot situations to gain advantages at the feed bunks and in establishing social order. When cattle use their horns to butt other cattle, muscle bruising occurs. Bruises have to be trimmed out at harvest, thus decreasing the value of the carcass. In the 2016 National Beef Quality Audit (NBQA-2016), bruises declined compared to NBQA-2011, but bruises on the round, loin, rib and chuck have significantly increased compared to NBQA-2011. Realistically, bruises cannot be totally eliminated; however, dehorning can eliminate bruises caused by horns.

Another issue concerns animal well-being. Cowboy heritage has been we do the things because of tradition. Modern operations are evolving from this type of philosophy because of the influence of the consumer. Consumers view animals as conscious beings that should be treated and cared for as such. The consumers want to be assured the product they consume has been produced with consideration to the well-being of the animal. Therefore, producers must be aware of these concerns and produce a product that meets the demand. Consumers view the well-being of dehorned cows housed with horned cattle may be compromised.

The third issue regarding horns pertains to safety of personnel handling and caring for the cattle. Injuries to producers, family members and employees can be serious, and thus, affect the efficiency of the operation. While dehorning will not eliminate all potential injuries, it will remove one of the causes of injury.

Finally, cattle with horns frequently are tipped or completely dehorned upon arrival at feedlots for the reasons mentioned above. In some situations, the sinus cavity extends into the base of the horn. When the animal is dehorned or closely tipped, the sinus cavity may be exposed. Infection can develop in this open sinus cavity. Successful treatment is very time consuming and expensive. Cattle with sinus infections are less productive, decreasing the potential

return to the producer.

Horns have no economic value commercially in the production of beef, so all horned animals should be dehorned at branding time when there are fewer complications and less stress.

One final thought on castration and dehorning, both of these procedures are painful. With consumers concerned about the welfare of animals, it is becoming more common to use local anesthesia and pain control when performing these procedures. Producers need to consult with their veterinarian about proper drug selections and amounts to prevent pain when castrating or dehorning cattle.

Veterinarians commonly recommend producers take advantage of the opportunity at branding time to start priming the animal's immune system against common diseases, for example, clostridial disease. Vaccination programs begun at branding time can reduce disease and death losses. *Clostridium* spp. are bacteria found in protective spores in the environment and can cause disease and death in cattle. *Clostridium* spp. have different predilection sites in the body of the animal. The most familiar of these clostridial diseases is blackleg, which causes severe muscle damage and death of tissue. The products available on the market are in the form of bacterin/toxoids (vaccines) and commonly include components or antigens against seven or eight different clostridial diseases. Hence, the vaccines are commonly referred to as a 7- or 8-way clostridial or blackleg shots. The choice of a 7- or 8-way vaccination will depend upon the geographic location of the herd and the amount and type of risk in the population. A local veterinarian will be most familiar with the needs in specific geographical locations and can make appropriate recommendations.

Another consideration at branding time is tetanus prevention. The causative organism of tetanus is *Clostridium tetani*. Tetanus is not a common entity in cattle. The disease may manifest itself in situations with devitalized tissue, contaminated wounds or surgical sites and/or an overwhelming challenge dose of the organism from the environment or contaminated equipment. Administration of tetanus prevention may be needed in these situations and should be included in the health program. Also, cattle producers that choose banding as the method of castration will need tetanus prevention.

The prevalence of disease will vary from one herd to another. In a recent national survey, respiratory disease was a commonly known cause of loss of unweaned beef calves, second only to weather-related loss USDA National Animal Health Monitoring System (NAHMS). The most common viruses involved in the bovine respiratory disease (BRD) complex include infectious bovine rhinotracheitis virus (IBRV, red nose virus), bovine viral diarrhea virus (BVDV), parainfluenza Type 3 virus (PI3V) and bovine respiratory syncytial virus (BRSV). Several vaccines for these diseases are available. In herds that experience a high incidence of BRD with an underlying viral component or herds at high risk of acquiring BRD, vaccination at this time may be beneficial.

Leptospirosis, commonly referred to as lepto, is a spirochete organism that can cause anemia and death loss in calves. The incidence of this disease can vary greatly within a small geographic area as well as from herd to herd. Different serovars or species of *Leptospira* infect calves. The veterinarian will be most familiar with which serovar(s) is/are important and the specific program that best benefits each herd.

Pinkeye is associated with the bacterium *Moraxella bovis*. Recent findings and veterinarians' experiences suggest there are multiple agents involved in pinkeye infection. Experience and field reports pertaining to the efficacy of including a pinkeye vaccination as part of a herd health program are ambiguous. If pinkeye is included in a vaccination program, producers must have a thorough understanding of all aspects of the pinkeye disease process.

Internal and/or external parasite control may be needed at branding time. A sound and economical parasite control program depends upon many factors, including the life cycle, source of nutrition and management. Recommended parasite control programs also vary depending on location and season (chapters 37 and 38).

Weaning

Weaning refers to the time when the calves are removed from their dams. Management of commercial beef cow-calf operations is extremely variable. The age at which a beef calf is weaned depends upon several factors including the producer's goals, financial aspects of the business, available feedstuffs, labor and facilities. In the U.S., beef calves are commonly weaned between 5 months and 9 months of age. The majority of weaned beef calves will be commingled into larger groups for stocker (grazing), backgrounding or preconditioning and finishing phases of production.

Weaning and commingling can be very stressful events in a calf's life – mentally, physiologically and physically. These stressors can increase the animals' susceptibility to disease by suppressing its immune system, and hence immune response to infectious agents. Exposure to disease-causing agents, called pathogens, can occur with commingling of cattle. The source of this exposure to infectious agents comes from normally appearing animals that are carriers of disease or from animals incubating the agents and have not had enough time to exhibit any clinical signs of illness.

Experience and university studies have concluded healthy animals perform better than animals that have been ill. Vaccines can reduce illness. When used as a management tool, vaccines, bacterins and toxoids can improve the health of the animal, allowing the individual to perform more closely to its genetic potential. Several good-quality products are available. While vaccinations are a useful tool, they do not prevent all sickness. Vaccinated animals can still get sick. Vaccinations do not take the place of sound management.

Prior to weaning, producers should determine which marketing option is best for the individual business. Recently, producer interest and participation in source-verified and/or process-verified special marketing sales has increased. Several state associations and individual livestock auction markets provide producers with marketing options by sponsoring special sales. Health guidelines have

been developed for each program and should be followed accordingly. These special sales provide buyers with a known health background of the cattle, allowing buyers to better manage risk in their operations. Producers should develop the mindset of preparing the animal for where it is going, not where it is coming from.

More in-depth information about the specific diseases and reasons for vaccinating cattle were provided in the previous section. At weaning, calves should be vaccinated against the clostridial diseases and respiratory viruses (IBRV, BVDV, PI3V, BRSV). Questions may be, "Which is the best brand of vaccine to use?" and "Should a killed or a modified live viral (MLV) vaccine be used?" There are so many variables concerning the environment, management and resource availability that there is no medical or scientific basis for a blanket recommendation for weaned beef calves. The best and most sound advice is to consult a veterinarian about the brands and types of products to be used.

Internal and/or external parasite control may be needed at this time. A sound and economical control program depends upon many factors. Please refer to chapters 37 and 38 for specific guidelines.

Brucellosis in cattle, also commonly known as bangs, is an abortion disease caused primarily by *Brucella abortus*. The bacteria can also affect humans, bison, goats, sheep and horses. All states in the U.S. are considered free from cattle brucellosis by the USDA. However, the presence of free-ranging bison and elk in the Greater Yellowstone Area (GYA), Yellowstone National Park and Grand Teton National Park and the area around those parks, threatens the brucellosis free-status of the surrounding states. The presence of brucellosis in free-ranging bison and elk in the GYA threatens the brucellosis status of the surrounding states and the health of their cattle and domestic bison herds, which are free of the disease. From a disease standpoint, Oklahoma cattle producers do not need to vaccinate their cattle for brucellosis. However, from a marketing standpoint, producers may want to consider vaccinating their heifers. Heifers vaccinated against brucellosis (official calfhood vaccination, OCV) may have a marketing advantage compared to females not vaccinated, since certain states still require brucellosis vaccination. Producers should evaluate their marketing options and replacement stock requirements to decide if vaccinating heifers against brucellosis has advantages. Currently in Oklahoma, heifers may be vaccinated against brucellosis between 4 months and 1 year of age. An opportune time to vaccinate against brucellosis is at weaning time, when most heifers will be between 5 months and 9 months of age. Age restrictions vary between states, and this particular vaccination must be administered by a USDA-accredited veterinarian.

Depending on prevalence of leptospirosis in certain areas, a lepto vaccine may need to be given at weaning. Producers need to visit with their veterinarian about adding this vaccine to their vaccination program.

Pinkeye vaccinations may be warranted in certain herds or situations. Again, all the agents need to be identified prior to implementing a pinkeye vaccination program.

Replacement Heifers

The replacement heifers' section refers to the time prior to breeding, when females chosen as replacement animals receive their final processing before joining the main herd. The future productivity of any commercial cow-calf herd depends on the quality of its replacements. Producers must view these replacements as contributors to the overall genetic improvement of the herd. These animals have tremendous impact on the future of the business on the production and economic standpoints. As such, these animals should be given the best chance from a health standpoint to start their productive careers in the herd.

The following prebreeding recommendations are for replacement heifers ranging in age from 13 months to 16 months. Individual identification should have already been performed and records started.

In most situations, the heifers should have been vaccinated against the common clostridial diseases. However, in instances where heifers have not received appropriate vaccinations against clostridial diseases (7- or 8-way) or in situations where an overwhelming challenge of these agents will likely occur, a booster vaccination is recommended.

As discussed above, it is impossible to make a blanket recommendation for a specific brand or type of vaccine. However, most professionals recommend a MLV vaccine including IBRV, PI3V, BVDV and BRSV be administered to replacement heifers at this time. The vaccinations should be administered at least 30 days prior to breeding.

As a replacement animal, the ability to cycle, conceive and carry a viable calf to term is critically important. Campylobacteriosis, also known as vibriosis, is a bacteria causing infertility. Vibriosis is transmitted sexually (venereally) and causes death of the developing fetus (early embryonic death). The first hint animals may be suffering from vibriosis is females coming back into estrus (heat) at abnormal times, such as cycling at 33 days to 38 days, instead of the normal 21-day intervals. Vibriosis is not a universal problem. The incidence of the disease can vary considerably. In problem areas, vaccination prior to breeding is another important management tool.

Leptospirosis was mentioned earlier in the branding time section as causing anemia and death loss in calves. It causes these problems, as well as reproductive problems in females, including replacement heifers. The disease generally causes abortions and infertility later in gestation. Herds experiencing a leptospirosis reproductive outbreak frequently report an unusual number of open cows after the calving season has finished. At the normal time of processing the adult herd, the cows were pregnant but did not deliver a calf. In areas experiencing a lot of reproductive problems caused by leptospirosis, vaccinations will be needed to minimize the loss due to this bacteria. It generally is recommended to include the leptospirosis vaccinations in the prebreeding program.

Internal and/or external parasite control may be needed at this time. A sound and economical control program depends upon many factors. Please refer to chapters 37 and 38 for specific guidelines.

Replacement heifers that have been managed following the general recommendations outlined above should have a good healthy start to their reproductive careers.

Adult Cow Herd and Bulls

Herd sires and the adult cow herd have similar needs from a health standpoint. The adult cow herd is generally processed once or twice per year. The primary health concern for the adult beef cow is reproductive diseases. Viral diseases that can cause reproductive problems included IBR and BVDV. Leptospirosis is a bacterium that can cause abortion and infertility. The incidence of vibriosis is very location dependent. In herds experiencing outbreaks of vibriosis, booster vaccination prior to breeding will be necessary. If possible, all of these vaccinations should be administered 30 days prior to turning the bull into the herd. If this is not possible, the beef cow herd should be vaccinated annually for these diseases.

Under normal conditions, any of the disease syndromes caused by clostridial pathogens such as blackleg are generally not a problem in adult cattle. Also, adult beef cows rarely experience clinical respiratory disease associated with PI3 or BRSV. From the individual cow's health, annual revaccination against these PI3, BRSV and blackleg is not necessary. However, vaccinations with PI3, BRSV and blackleg may benefit passive immunity to the calf and in those rare instances where herds may suffer from these pathogens.

Producers may have questions such as "Which is the best brand of vaccine to use?" and/or "Should a killed or a modified live viral vaccine be used?" Modified live vaccines must be used with caution with pregnant cattle. The best recommendation for producers is to work closely with their veterinarian and customize the program to meet the individual herd needs.

Anaplasmosis is a blood parasite. The parasite attaches to the animal's red blood cells (RBC). The animal's immune system recognizes the RBC with anaplasma parasites as abnormal and removes the red cells from circulation. The removal of RBC can result in a significant anemia. Clinical signs associated with anaplasmosis are age related and include fever, loss of appetite, depression, weight loss, abortion and death. Animals less than 1 year of age rarely, if ever, exhibit clinical signs because they have a very efficient bone marrow system to replace the damaged red cells. Animals between 1 year and 2 years of age may show clinical signs; however, death loss is unusual. Cattle more than 2 years of age that have not been previously immunized against the disease may exhibit severe clinical signs and may die. Transfer of blood during routine health management procedures, such as through contaminated vaccination needles or dehorning equipment, must be avoided. Consult with a veterinarian regarding the availability and use of vaccines available for anaplasmosis in your herd.

The parasite control program for the adult cow herd is based upon the type of parasites, challenges and goals of strategic deworming programs (chapters 37 and 38).

Many producers believe herd bulls do not need to be included in any type of health program. Neglecting the herd sire can be a very costly mistake. Bulls should receive basically the same vaccination program as the cow, which includes IBRV, BVDV and leptospirosis vaccinations. For the same reasons as discussed for adult cows, in rare instances, a PI3V, BRSV and vibriosis vaccination may be included.

Another important aspect of a sound health program is a breeding soundness examination on the bull prior to exposing him to the females. The breeding soundness examination should include examination of the reproductive anatomy, sperm motility, sperm morphology (physical characteristics), locomotion, eyesight and body condition score (chapter 20). A bull that passes the breeding soundness examination appears to be sound for breeding purposes as best as science can determine at that point in time. It is recommended the exam be performed prior to turning the animal in with the females. If a bull fails the exam, producers need enough time to replace the animal with a sound bull for the breeding season.

Sixty Days Pre-Calving, All Females

The last segment focuses on pregnant females prior to calving. If management is adequate throughout the year, females should not need any vaccinations within 60 days before the calving season begins. In some instances, pregnant females may need a scours vaccination in the hopes of being able to pass on some protection through their colostrum to their newborn calf. Common components of a scour vaccine are rotavirus, coronavirus, *Escherichia coli*, and *Clostridium perfringens* type C. If a scours vaccination is needed as part of the herd health program, producers should investigate the management of that herd very closely. In most instances, changes in management including calving environment, nutrition, etc. will correct any deficiencies, making vaccination unnecessary.

Conclusion

Evaluating the economic efficiency of herd health management procedures requires good recordkeeping. An in depth understanding of the circumstances affecting health and production are essential. In a closed herd for instance, the producer may get minimal benefit from a number of vaccines offered because animals are seldom exposed to the disease causing agents. At the other extreme, herds with frequent movement of animals may get minimal benefit from available vaccines, due to the lag time between vaccination and exposure.

It is hoped this chapter can be used as a template for producers and their veterinarians when designing a commercial cow-calf herd health plan.

References

Baker, J.F., J.E. Strickland and R.C. Vann (2000) Effect of Castration on Weight Gain of Beef Calves. *The Bovine Practioner* 34:124-126.

Besser, T.E. and C.C. Gay (1994) The Importance of Colostrum to the Health

of the Neonatal Calf. Veterinary Clinics of North America; Perinatal Mortality in Beef Herds.

Besser, T.E., O. Szenci and C.C. Gay (1990) Decreased Colostral Immunoglobulin Absorption in Calves with Postnatal Respiratory Acidosis. *Journal of the American Veterinary Medical Association* 196:1239.

Boleman, S.L. et al. (1998) National Beef Quality Audit – 1995: Survey Of Producer – Related Defects and Carcass Quality and Quantity Attributes. *Journal of Animal Science* 76:96-103.

Garry, F. et al. (1994) Comparison of Passive Immunoglobulin Transfer in Newborn Dairy Calves Fed Colostrum or One of Three Colostral Supplements. *Journal of Animal Science* 72 (Supplement 1):298. Abstract.

Homerosky ER, E. Timsit, E. A. Pajor, J. P. Kastelic and M. C. Windeyer. Predictors and impacts of colostrum Consumption by 4H after Birth in Newborn Beef Calves. *The Veterinary Journal*, October 2017 Vol.218: pp.1-6.

Jones, L.R., A.W. Taylor and H.C. Hines (1987) Characteristics of Frozen Colostrum Thawed in a Microwave Oven. *Journal of Dairy Science* 70:1941.

Lents, C.A. et al. (2000) Influence of Method of Castration of Bulls on Performance Before and After Weaning. Beef Research Field Day, Oklahoma State University Animal Science Department, October, Pg. 16-18.

Logan, E.F. (1977) The Influence of Husbandry on Colostrum, Yield and Immunoglobulin Concentration in Beef Cows. *British Veterinary Journal* 133:120.

McKeith, R. O., Gray, G. D., Hale, D. S., Kerth, C. R., Griffin, D. B., Savell, J. W., Raines, C. R., Belk, K. E., Woerner, D. R., Tatum, J. D., Igo, J. L., VanOverbeke, D. L., Mafi, G. G., Lawrence, T. E., Delmore, R. J., Jr, Christensen, L. M., Shackelford, S. D., King, D. A., Wheeler, T. L., Meadows, L. R., ... O'Connor, M. E. (2012). National Beef Quality Audit-2011: Harvest-floor assessments of targeted characteristics that affect quality and value of cattle, carcasses, and byproducts. *Journal of Animal Science*, 90(13), 5135–5142.

McKenna, D.R. et al. (2000) National Beef Quality Audit – 2000: Characteristics of Targeted Cattle and Carcass Characteristics Related to Quality, Quantity, and Value of Fed Steers and Heifers. *Journal of Animal Science* 80:1212-1222.

Radostits, OM, ed. (2001). *Herd Health: Food Animal Production Medicine*, 3rd ed. WB Saunders, Philadelphia.

Smith, G.C. et al. (2001) Improving the Quality Consistency, Competitiveness, and Market Share of Fed-Beef. The Final Report on the Third Blueprint for Total Quality Management in the Fed-beef (Slaughter Steer/Heifer) Industry. Submitted to the National Cattlemen's Beef Association, Englewood, Colorado.

Smith, G.C. et al. (2000) National Beef Quality Audit. Improving the Quality, Consistency, Competitiveness and Market Share of Fed-Beef. National Cattlemen's Beef Association.

Naylor, J.M. (1986) Colostrum and Passive Immunity in Food-Producing Animals. *Current Veterinary Therapy*. 2nd Edition. J.L. Howard. W.B. Saunders Co. Philadelphia, PA.

Odde, K.G., L.A. Abernathy and G.A. Greathouse (1986) Effect of Body Condition and Calving Difficulty on Calf Vigor and Calf Serum Immunoglobulin Concentrations in Two-Year Old Beef Heifers. CSU Beef Program Report, Ft. Collins, CO.

Petrie, L. (1984) Maximizing the Absorption of Colostral Immunoglobulins in the Newborn Dairy Calf. *Veterinary Record* 114:157.

USDA. (2000) Part II: Baseline Reference of Feed Lot Health and Health Management. USDA:APHIS:VS:CEAH, National Animal Health Monitoring System. Fort Collins, CO. #N335.1000.

Wittum, T.E. and L.J. Perino (1995) Passive Immune Status at Postpartum Hour 24 and Long-Term Health and Performance of Calves. *American Journal of Veterinary Research* 56:1149.

37 Internal Parasite Control

Justin Talley

Objectives

- **Realize potential negative impacts of internal parasites.**
- **Understand the biology of internal parasites.**
- **Present types of medications used to control internal parasites.**
- **Develop an understanding of the goals of a strategic deworming program.**
- **Concepts to consider when developing deworming programs for cattle.**

Veterinarians and producers realize the potential negative impact internal parasites can have on cattle performance, health, well-being and economic return. Parasitism can have subclinical effects such as suppression of the immune system, reduced weight gain, reduced conception rate and reduced milk production along with clinical effects such as anemia, diarrhea, rough hair coat and death.

Basic background information will be provided in this chapter to assist ranchers in understanding the biology of internal parasites. This information is a must before one can begin to develop a strategic deworming program. There are many different species of parasites and they vary considerably in their economic importance and life cycle. The focus will be primarily on gastrointestinal (GI) parasites (commonly referred to as stomach worms, intestinal worms or gut worms) involving the abomasum and the small and large intestines, liver flukes and the components to develop a strategic deworming program.

Internal Parasite Life Cycle

There are several stages in the life cycle of gastrointestinal worms (Figure 37.1). Part of the parasite's life is spent living inside the host animal and part in the environment outside the host. The life cycle can be grouped or divided into general stages:

- Developmental/free living stage.

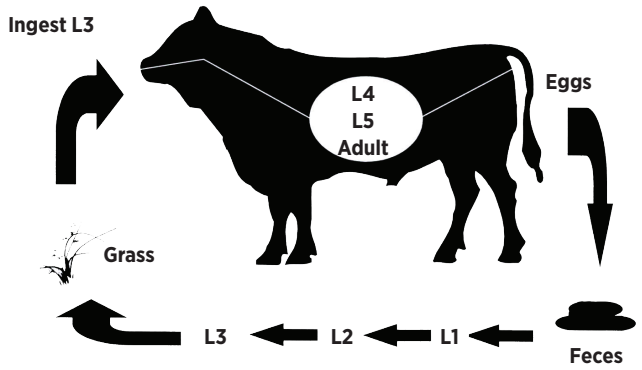


Figure 37.1. Life cycle of gastrointestinal worms.

  1. Outside the host and includes the egg and three larval stages (L1, L2 and L3).
  2. Significant portion of the parasite population in this stage.
- Prepatent stage/pre-adult.
  1. Inside the host and includes the ingested infective larval (L3) stage and the (L4) and (L5) stages.
  2. L4 can go into hypobiosis or arrested stage if outside environmental conditions are unfavorable for continuation of the life cycle (lengthening the period from ingestion to adult).
- Patent (adult) stage.
  1. Inside the host and has male and female worms that mate and produce eggs.
  2. Adults have a finite life span.
- Duration of prepatent period—ingestion of infective L3 → production of eggs.
  1. Duration of three weeks to four weeks in young cattle: ingest (L3) to produce eggs without hypobiosis.
  2. Duration of four weeks to six weeks in adult cattle: ingest (L3) to produce eggs without hypobiosis.

It is important to understand how these stages of the parasite interact with the environment, which stages can cause damage in the animal and the length of time the parasite spends in certain stages of its cycle.

There are gender distinctions in the adult stage of gastrointestinal worms: male and female. The adults

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

have a finite life span and spend their entire adult life in the digestive tract of the animal. After the female worm matures, she mates with the male to produce fertilized eggs (ova). A fertilized egg is passed into the environment from the animal through the manure. The developmental stage of the parasite's life cycle begins once the egg exits the animal and is deposited in the environment.

Once in the environment, the egg develops into the larval stage. The manure pat provides the necessary nutrients and a suitable environment for its development. The three larval stages of the parasite during the developmental period in the environment are designated as L1, L2 and L3, which correspond respectively to the 1st stage larvae, 2nd stage larvae and 3rd stage larvae. The L1 and L2 larvae are not infective to the animal. The L3 larvae can infect cattle and frequently are referred to as the infective larval stage, or infective L3. Larvae can accumulate in the environment to a large infective dose or challenge for the animal.

During the period outside the host, warm moist environmental conditions favor development of the larval stages. Larval stages are vulnerable to desiccation (drying out). Survival of the larvae is dependent on moisture, as is its ability to migrate onto forage to be consumed by a grazing animal. The moisture is most commonly in the form of rain or dewdrops. In the continental U.S., spring and fall generally equate to warm, moist conditions. Thus, the spring and fall seasons favor development of the parasite. The optimal temperature range for development of the parasite is 45 F to 85 F.

Parasites have adapted unique characteristics, allowing them to take advantage of the environment and cattle behavior during the developmental/free living stage. These unique characteristics equip the parasite to survive and complete its life cycle by infecting animals. One of the parasite's unique characteristics takes advantage of the grazing behavior of cattle and involves the movement of the larvae away from the manure pat. Cattle normally do not graze adjacent to a fresh pile of manure. It can be reasoned that the fresh odor might be offensive to the animal's sense of smell. As the natural decay and breakdown of the manure pat occurs, nutrients are dispersed into the soil. The plants adjacent to the manure pat take up the nutrients and with adequate moisture, become more succulent and nutritious for the grazing animal to consume. The plants are more appealing to cattle and the cattle begin to graze closer to the manure pat. In the L3 stage, the parasite can migrate away from its original location in the manure pat onto a blade of grass, increasing its chance to be consumed by a grazing animal. The transmission of the L3 larvae normally does not occur in dry lot production situations.

Another adaptive characteristic parasites have developed is the ability of the larval stage to survive on pasture grass and overwinter until the following spring. The larvae can survive for long periods of time in the fecal pat or the vegetative mat of the pasture. The third stage larvae/L3 larvae can survive freezing conditions and some species are resistant to hot, dry summers.

When springtime arrives, the infective larvae that have survived the winter are available for consumption by cattle along with the larval forms developed from eggs laid by infected cattle. This increase in the number of infective L3 on the pasture increases the likelihood of infecting grazing animals.

Once consumed by the grazing animal, the infective larvae (L3) are transported to an area of the digestive tract where further growth and development of the parasite occurs. Every species of internal parasite has a particular area of the digestive tract that is most ideal for its survival and further development. This area in the digestive tract is known as the predilection site. Upon arrival to the parasite's predilection site, larval development continues into a fourth stage or L4 larvae. At this stage, the larvae can follow one of two different paths of development.

When environmental conditions outside the host are NOT conducive for continuation of the parasite life cycle, for example extreme cold (fall/winter in northern latitudes) or extreme hot weather (late spring/summer in southern latitudes)—further development of the L4 larvae inside the host GI tract is inhibited. This inhibition of further development also may be affected by day length. This inhibition of development is termed hypobiosis. If the larvae become inhibited or arrested in their development, they are said to be in a hypobiotic or arrested or inhibited state. Some species (brown stomach worm, *Ostertagia ostertagi*) may enter the stomach or intestinal wall and become encysted within the glands of the digestive tract wall. Further development and maturation is halted until the environmental conditions outside the host are favorable. Once conditions become more conducive and the parasite's offspring have a better chance of reaching maturity, development continues and the encysted larvae reenter the gastrointestinal tract. The hypobiotic larvae then mature into a L5 or young adult. Damage to the animal's digestive tract may occur when parasites emerge from infected tissue.

This damage may be permanent and affect future production. The decrease in production is generally caused by local irritation of the stomach or intestinal tract or to hypersensitivity (allergic) reactions with continued exposure to the internal parasites. This often occurs when large numbers of encysted larvae reenter the gastrointestinal tract through a short period of time. The season for this arrested development of L4 varies in the continental U.S. and is dependent on where the cattle are raised.

In southern U.S. climates, parasites often enter hypobiosis in the summer with a subsequent increase in maturation of parasites and subsequent increase in pasture contamination in the fall. Summer in the southern areas of the U.S. is a harsh season with very hot temperatures, very dry to drought conditions and minimal lush forage growth. Thus, L4 potentially will arrest its development in cattle during the summer season in the south. If cattle are raised in middle latitudes of the U.S., hypobiosis can occur in either the summer or the winter season, depending on the environmental conditions.

In northern U.S. climates, parasites often enter hypobiosis in the fall with a subsequent increase in maturation of parasites and subsequent increase in pasture contamination in the spring. Winter in the northern

latitudes of the continental U.S. is a harsh season with cold temperatures and no lush growth of forages. This type of environment is not conducive to survival of the internal parasite. Therefore, L4 potentially will go into a hypobiotic state during the winter season in northern climates.

When the environmental conditions are conducive for the parasite's life cycle to continue, hypobiosis often does not occur and the parasite's life cycle continues from the ingested L3 to L4, then L5 or young adult stage. The young adults mature into adult parasites capable of producing fertile eggs. Male and female adults mate and produce fertile, potentially viable eggs. Thus, the cycle continues.

The period of development from ingestion of infective L3 until the adult parasites mature and are able to produce viable eggs is referred to as the prepatent period. It is extremely important for anyone involved in developing a strategic deworming program to understand the length of time for this period in the development of the parasite. It is the prepatent period, along with the mechanism or mode of action of dewormer medications that determine the appropriate time to deworm cattle. The length of time the parasite spends in the prepatent period is dependent upon the species of parasite, age of the host animal and outside environmental conditions, which might affect hypobiosis. For young cattle, the prepatent period of most of these parasites is generally three weeks to four weeks. For adult cattle, the prepatent period is generally four weeks to six weeks. The reason for a shorter duration to maturity for the parasite in younger animals is because the younger stock have not been exposed to the parasites to the extent of adult cattle in normal field conditions and thus, have not developed any appreciable degree of immunity.

Cattle Immunity and Preventive Health Programs

Although immunity to internal parasites develops with time in most cattle, adult cattle still harbor internal parasite infections. Veterinarians have done an excellent job communicating to producers the importance of a protective immune response in farm animals. Thus, most producers understand the importance of animals developing an adequate immune response to certain disease causing agents known as pathogens. Vaccines are administered prior to exposure to these agents, so animals can develop a memory immune response.

As discussed earlier, internal parasites have adapted unique characteristics to survive harsh conditions and allow them to perpetuate their species. With normal conditions as an animal grows and matures, it is continually exposed to a certain level of parasitism. This continual exposure to the parasite causes an immune response in a normal individual animal with a competent immune system. The type of immunity that develops will not necessarily eliminate the worms from the animal's digestive tract, but will suppress the reproductive capability of the internal parasite and reduce the infectability of newly acquired parasites. The adult animal can still have internal parasite infections, just fewer of them. The internal parasites can still reproduce; however, they will generally produce fewer eggs than parasites that infect younger nonimmune cattle. Therefore, adult cattle can still be a major source of pasture contamination for younger animals. Most parasitologists and veterinarians consider young cattle to be less than two years of age and adult cattle to be more than two years of age.

Classes of Dewormers

In the U.S., dewormer medications can be grouped into one of four primary classes of compounds, depending upon their mode or mechanism of action. The four classes of dewormers include the benzimidazoles, the imidazothiazoles, the macrocyclic lactones (MCL) and the tetrahydropyrimidines. Examples of the active ingredients in each class of compounds are provided in Table 37.1. Within each class of drugs, there are several different active ingredients (or individual chemicals). In general, the different active ingredients may possess unique characteristics compared to other actives within each class of compound. But within a class of drugs, the modes or mechanisms of action will be the same.

One of the distinguishing characteristics between the different active ingredients that is important when developing a deworming program is the residual killing activity. The residual killing activity refers to the period of time after a product has been administered that it will still kill the parasite if infective larvae are ingested. The residual killing activity may or may not be beneficial in all management situations. The time period can vary slightly between different species of internal parasites. Producers must work closely with their veterinarians to develop a preventive health program that meets their individual needs (Williams). Follow label recommendations for storage of deworming medications. Avoid excessive heat, cold and exposure to light to maintain effectiveness of medications.

Resistance to Dewormers

Documented resistance or tolerance to dewormer medications among the GI parasites of cattle is a concern for producers and veterinarians. Resistant parasites are not killed by dewormer medications at the rate of non-resistant parasites and this resistance can be passed or inherited from one generation of parasites to the next.

Table 37.1. Examples of active ingredients in the different classes of dewormer medications.

Benzimidazoles:	**Imidazothiazoles:**
Albendazole	Levamisole
Fenbendazole	
Oxfendazole	
Macrocylic Lactones:	**Tetrahydropyrimidines:**
Doramectin	Morantel
Eprinomectin	
Ivermectin	
Moxidectin	

Veterinarians and veterinary parasitologists are shifting their views on parasite control from one of parasite elimination to one of parasite management. Discuss the implications of any parasite control program with your veterinarian before implementation. Recommendations/ approaches to reduce parasite resistance may focus on:

- All treated animals must receive the calculated therapeutic dose (underdosing cattle may select for resistance).
  1. Weighing the animals allows for the calculation of the recommended dose of deworming medication or treatment.
  2. Though easier to administer the drug, absorption of topical/pour-on dewormers is quite variable, therefore other modes of administration such as injectable and oral routes are preferred or recommended (Leathwick).
- Monitor effectiveness of dewormers using fecal egg count reduction tests (FECRT) to determine if treatments achieved the expected efficacy.
- Consider selective treatment of different classes/ages of animals and not blanket treatment at a location.
- Consider NOT using different classes of dewormer on commingled cattle at intervals of less than two months.
- Consider leaving a portion of cattle untreated.
- Consider thoughtfully timed alternating classes of dewormers.
- Consider simultaneous use of multiple classes of anthelmintics versus single class anthelmintics or dewormers (Yazwinski et al. and Gasbarre).

Internal Parasite Control

Controlling internal parasites is a difficult balancing act between practical management and reducing anthelmintic resistance for cattle. Some considerations for developing a well-rounded internal parasite program should include the following:

1. Understand the three categories of how internal parasites impact cattle which are a) infection, b) economic and c) clinical (Craig)

   Infection: Certain cattle will always have a level of parasitism present but are not affected by those internal parasites usually due to immunity. This is known as infection. However, these animals can contribute to sustained parasite deposition onto pastures, so deworming these animals does little benefit to these individual animals but are beneficial to more susceptible stock such as calves and yearlings.

   Economic: There are several benefits of maximizing production efficiency in animals that are affected by parasites due to the economic impact the parasites are causing on the cattle operation. At certain times of the year, the benefit of deworming is to maximize efficiency by reducing the economic impact the parasites might cause within the production system. Usually, when the economic impact of parasites is considered, then the deworming program occurs with a specific management practice of scheduled deworming that either occurs once a year in the spring or twice a year with an anthelmintic application in spring and again in the fall.

   Clinical: The impact of having cattle exhibiting clinical signs of parasitism is the economic impact has already occurred and these animals are contributing to pasture contamination. So treating these animals is primarily to recover them without the benefits of increased performance or reduced pasture contamination.
2. While most deworming programs aim to reduce pasture contamination and increase the performance of the animals, there is increasing evidence that demonstrates deworming programs should be designed in a manner to reduce anthelmintic resistance.
3. Designing a deworming program that takes into consideration the benefits of reduced pasture contamination, increased performance and managing anthelmintic resistance can be as simple as knowing the chemical class the dewormer belongs to and not overusing products in one particular chemical class. For example, using white oral dewormers (benzimidazoles) continuously without utilizing products from the macrocyclic lactones can lead to parasite benzimidazole resistance and reduced performance due to the resistant worms.
4. Another consideration for managing anthelmintic resistance is utilizing the concept of refugia which can be impractical but obtainable when implementing deworming programs. Refugia is defined as proportion of the parasite population that is not exposed to a particular anthelmintic, which then allows those worms to escape selection pressure for resistance (Van Wyk). The impractical aspect is not deworming a certain number of animals and the obtainable aspect is some animals are not affected by certain parasites due to immunity. Consider animals that are not consistently co-mingled with high risk stock (calves, yearlings, replacement heifers) and reduce the number of animals receiving a dewormer.

Recommendations:

1. Work with your veterinarian to develop a comprehensive deworming program.
2. Understand the different classes of dewormers available in the cattle sector.
3. Consult with your veterinarian to conduct a Fecal Egg Count Reduction Test (FECRT) to determine how well your current dewormer is performing .
4. If the FECRT demonstrates low efficacy of a product then do not use the same product year after year as this will lead to resistance.
5. Consider utilizing injectable or oral applications when available.
6. Understand when new animals are brought into your herd, new parasites come with those animals.
7. Consider submitting fecal samples to your veterinarian from at least 10 animals in each herd so they can give you a description of the parasite burden within your herds.

Adult Cattle Deworming Recommendations

The recommendations for adult cattle more than 2 years of age, including breeding or herd bulls, assumes the purpose of the adult cattle in a herd is to produce offspring for replacements and/or marketing beef and the production of the offspring should be as efficient as possible. Controlled studies documenting a direct performance benefit of deworming adult cattle have produced inconsistent and varied results. With normal conditions, it is difficult to justify the practice of deworming adult cattle strictly from a performance benefit to the individual animal. However, pasture contamination should be of prime concern. Even though adult cattle develop a degree of immunity, they can be a significant source of pasture contamination for young stock. A non-treated cow and her non-treated calf may deposit millions of eggs onto a pasture in a grazing season. Even if only a small percentage of eggs hatch and the larvae survive, infective L3 larvae on the pasture are able to re-infect the donor or other animals in the pasture.

When adult and young cattle graze pastures simultaneously, producers should consider deworming the adult animals prior to turnout, minimizing pasture contamination with parasite eggs. If the adult cattle were dewormed the previous year in late fall or winter and the likelihood of acquiring an infection is minimal, the adult cattle should contribute very little to the initial contamination of the pasture at spring turnout. The pasture however, would still have some L3 infective larvae that would have survived through winter. Therefore, the adult cattle would acquire L3 larvae when they start to graze. As the prepatent period for the adult animals is four weeks to six weeks, the adult cattle would then start to contribute to pasture contamination after four weeks to six weeks from turn out. In situations where adult and young cattle graze together, the adult cattle should be dewormed at four weeks to six weeks after turnout to decrease the level of pasture contamination. If the medication has no residual killing activity, it will be another four weeks to six weeks (prepatent period is four weeks to six weeks) until cattle will start to shed fertile eggs and contribute to pasture contamination. Using the time interval of six weeks, plus another six weeks will be approximately 90 days of allowing the younger stock to graze parasite-safe pastures. If the dewormer medication has a longer residual killing activity such as two weeks to four weeks, then it would be eight weeks to 10 weeks after the administration before the adult animals would start to contaminate the pastures and the younger stock would be allowed parasite-safe grazing.

If the deworming history of adult cattle is unknown or they were not dewormed after summer/fall grazing, then they would be considered infected and could contribute to early pasture contamination. In this instance, producers should administer a deworming medication prior to turn out for spring grazing to eliminate the adult population as a source of early pasture contamination. If the dewormer medication did not have any residual killing activity, then the adults would start to contribute to pasture contamination four weeks to six weeks after turn out. If the dewormer medication has a longer residual killing activity, the amount of time would be added to the period after turn out to determine when the adult animals would start to contribute to pasture contamination.

Another situation indicating the need for deworming adult cattle occurs during the winter season, after the period of summer/fall grazing. During the winter in most of the continental U.S., adult cattle are provided hay and possibly a supplement. Feed expense generally accounts for the largest percent in the cost of raising or maintaining cattle, thus producers want the most benefit possible from the feedstuffs. Therefore, it is frequently recommended to administer a dewormer to the adult herd after the fall grazing period. This also will allow the adult animals to be considered fairly free of internal parasites at spring turnout onto summer grazing pastures.

Young Cattle Deworming Recommendations

Young cattle (less than 2 years of age) are the next group to consider when developing a deworming program. Milk is the primary source of nutrition for neonatal calves. The young calves learn grazing behavior from their dams starting at a few weeks of age. A rule of thumb to use regarding the time or age when young calves might benefit from the administration of a deworming medication is approximately 2 months of age or approximately 200 pounds of body weight. Studies have shown deworming the cow and her calf at this time (early grazing) provides a significant economic return. Calves less than 2 months of age or 200 pounds generally do not need to be treated for internal parasites. However, in certain conditions, such as severe drought or lack of milk production from the dam, young calves will start to graze earlier and can potentially develop internal parasite infections that affect their growth and production. In such instances, the diagnosis of parasitism must be confirmed by the veterinarian and appropriate medications administered to treat the problem. If conditions are such that a change in management would promote improved health and well-being of the animals, changes should be implemented.

If young calves are more than 2 months of age or more than 200 pounds at spring grazing turnout, one can assume they will start to acquire internal parasite infections on day one of grazing. With most production systems for fall-born calves, the chance of acquiring infective L3 during the winter months is minimal. From a practical standpoint, the calves will be weaned in early spring. A deworming program as described for weaned cattle less than 2 years of age will generally work best for those calves. They will start to contribute to pasture contamination three weeks to four weeks after turnout (prepatent period is three weeks to four weeks). The young cattle need to receive a dewormer medication at that time. If the dewormer medication does not have any residual killing activity, then the calves can start to acquire infective L3 and start to contaminate the pasture in another three weeks to four weeks. Therefore, the young calves will need to be administered another dose of dewormer medication at that time. With this dose, the calves will not contribute to the contamination for another

three weeks to four weeks. Thus, a total of nine weeks to 12 weeks (60 days to 90 days) will be allowed for the calves to graze parasite-safe pastures. If the dewormer medication has a residual killing activity of two weeks to four weeks, then the pasture contamination from these calves will be six weeks to eight weeks after their initial treatment. Consult a veterinarian and refer to product labels to determine the residual killing activity of the various products.

Weaned Cattle Deworming Recommendations

In a scientifically controlled study, beef steers were evaluated during the grazing period (118 days) through the finishing period (average 121 days) to harvest (Smith). The steers were purchased from various auction markets, grazed in southeastern Oklahoma and finished at a feedlot in Colorado. During the grazing trial, steers were grouped into a non-treated control group and a strategically dewormed group. At the conclusion of the grazing period, the strategically dewormed steers were 48 pounds heavier than the non-treated steers (Smith). With most stocker programs, deworming at turnout provides a good economic return.

During the finishing phase of production, both pasture treatment groups were randomly assigned to groups that either received a treatment of dewormer medication or were assigned to untreated control groups. The group that was dewormed during the grazing period and dewormed in the feedlot gained 103 pounds more than steers that never received a dewormer medication (Taylor). Steers that were strategically dewormed on pasture but did not receive any further treatments were 83 pounds heavier than the untreated control group (Taylor). Steers that were not administered a dewormer medication during the grazing period, but were administered a medication during the finishing phase were 63 pounds heavier than the control group (Taylor). The steers treated during the grazing and finishing phases of production produced the heaviest hot carcass weights, larger rib eye area and the highest marbling scores of the groups involved in the trial (Taylor). The internal parasite control program for weaned cattle less than 2 years of age (weaned calves, yearlings, replacement seedstock) is straightforward because the prepatent period will be the same, three weeks to four weeks, for all cattle.

Liver Flukes

Liver fluke infections can have an economically important effect on cattle production. They can impact health and productivity by reducing feed efficiency, weight gain, reproductive rates and responses to vaccinations (Zimmerman). Flukes can cause a loss of condition, anemia, bottle jaw and death. More importantly, they may be associated with liver condemnation at slaughter.

The liver flukes are geographically and topographically restricted in their distribution, unlike the more common internal parasites of cattle. Adult flukes reside in the bile ducts of the liver, passing eggs in the manure. The egg hatches and releases a free-swimming form that seeks out and penetrates a particular aquatic snail intermediate host. The tadpole-shaped cercariae (fluke stage) emerge from the snail and encyst on vegetation, inanimate objects, ideally in aquatic and high-humidity environments. The liver flukes are observed in areas maintaining populations of aquatic snails, as the snails are required for the life cycle and are an intermediate host for the flukes. Coastal marsh areas, irrigated pastures, streams and river valleys can support the snail intermediate hosts.

Depending on the product, both adult flukes and immature forms may be removed by treatment. Timing of administration is critical to controlling the fluke population in your herd. Proper timing of treatments varies with geographic areas. Consult a veterinarian for proper timing of administration of dewormers. Because the fluke life cycle includes snails, restricting access to snail-infested areas may be an important part of the control program.

Other Recommendations

Besides the administration of dewormer medications, other control measures have been investigated and utilized throughout the world with promising results. One method is to use rotational grazing, where cattle are rotated from one pasture to another during the period of time the animals will consume minimal numbers of parasites, hence grazing parasite-safe pastures. The use of rotational grazing also can increase the amount of forage harvested from a pasture and generally increase production efficiency. Some drawbacks to using rotational grazing systems include an increase in the amount of labor involved in moving the animals frequently, an increase in fencing costs and sometimes an increase cost of supplying water to the herd. Due to some parasites ability to survive for long periods of time, permanent pastures may have to be vacated for extended periods to prevent reinfestation. Alternatively permanent pastures can be baled for hay or tilled for wheat, etc. to reduce pasture contamination.

Another control method that has been used with beneficial results to control internal parasites is the rotation of species allowed to graze the pastures. This is effective because most parasites are species specific. For example, cattle parasites cannot survive when ingested by horses, goats or sheep. The species are rotated on a seasonal or annual basis. Small ruminants such as sheep and goats, along with horses are commonly used in a rotational sequence in this type of control system. In the U.S., most producers would not be able or willing to utilize this type of control method. However, in parts of the world where internal parasites prevent certain species from surviving on some pastures, this type of production system allows the producer to utilize available pastures.

Farmers and ranchers should consider selecting for parasite-hardy cattle. It has been found the majority of parasites are shed by only a small number of adults. Consider culling the animals that shed large numbers of parasite eggs.

Conclusion

Modern beef cattle production is considered a business. In general, optimal health is required for efficient production of cattle. Thus, recommendations about deworming programs must be justified from a cost-benefit viewpoint. Also, the development of anthelmintic resistance must be addressed by working with your veterinarian so deworming tools are not lost due to misuse or overuse of certain products.

Dewormer resistance is present but can be managed in cattle production systems. Anthelmintic resistance occurs because certain parasites have genetic features that allow them to respond to chemical attack (Kaplan). Another feature that allows resistance development is the high level of genetic diversity due to rapid development of population sizes (Kaplan). These two features not only allow parasites to survive deworming applications but also pass along those resistant genes to worms in different individual animals. Thus, it is important to manage resistance through management practices such as working with your veterinarian to determine if resistant populations are present in your herd by conducting regular fecal egg counts or fecal egg count reduction tests. Other management practices include the use of refugia (not treating certain animals), pasture management (burning, rotational grazing) and mechanical disruption of manure to reduce parasite development.

Cow-calf producers are frequently challenged to develop a parasite control program including both the adult cows and young calves. Theoretically, the cows should be dewormed based on the prepatent period of four weeks to six weeks and the calves on the prepatent period of three weeks to four weeks. However, in practice, the cows are frequently administered a dewormer medication at the same time as the calves, so pasture contamination is minimized. A significant percentage of most parasite populations is in the environment, not the final host. It is an important goal of the control program to reduce pasture contamination, reducing potential future exposure.

Because of the various factors involved in developing a practical control program, it is strongly recommended farmers and ranchers work closely with their veterinarians to develop a customized control program that will be most beneficial. A cheaper product may not necessarily equate to more profit. Select a dewormer meeting needs and backed by sound research data.

Endnote

Special thanks to Mason V Reichard, PhD, Veterinary Pathobiology, College of Veterinary Medicine, Oklahoma State University for reviewing this chapter.

References

Bliss, D.H. and R.O. Drummond (1999) Optimal Strategies for Combined Control of Internal and External Parasites of Cattle. *Large Animal Practice* Pg. 12-18.

Craig, T. M. 1988. Impact of internal parasites on beef cattle. *Journal of Animal Science* 66:1565-1569.

Gasbarre, Louise, (2014) Anthelmintic Resistance in Cattle Nematodes In the U.S., *Veterinary Parasitology*, 204(2014) 3-13

Kornele, M., M. McLean and A. O'Brian, (2014) Antiparasitic resistance and grazing livestock in the United States, *Journal of the American Veterinary Medical Association* Vol 244, No. 9, May 1, 2014

Kaplan, R.M. (2004). Drug resistance in nematodes of veterinary importance: a status report. *Trends in Parasitology* 20: 477-481.

Leathwick, D. M. and C. M. Miller, 2013, Efficacy of Oral injectable and Pour-On Formulations of Moxidectin against Gastrointestinal Nematodes In Cattle in New Zealand, *Veterinary Parasitology*, 191,293-300

Reinemeyer, C.R. (2000) Factors Affecting The Transmission and Control of Internal Parasites of Cattle. Proceedings: The College of Veterinary Medicine, Fall Conference for Veterinarians, November, Pg. 96-115.

Smith, R.A. et al. (2000) Pasture Deworming and (or) Subsequent Feedlot Deworming with Fenbendazole I Effects on Grazing Performance, Feedlot Performance and Carcass Traits of Yearling Steers. *The Bovine Practitioner* 34:104-114.

Taylor, R.F. et. al. (2000) Pasture Deworming and (or) Subsequent Feedlot Deworming with Fenbendazole II Effects on Abomasal Worm Counts and Abomasal Pathology of Yearling Steers. *The Bovine Practitioner* 34:115-123.

Van Wyk, J.A. (2001). Refugia – overlooked as perhaps the most potent factor concerning the development of anthelmintic resistance Onderstepoort. *Journal of Veterinary Research*, 68: 55-67.

Williams, J.C. et al. (1999) A Comparison of Persistent Anthelmintic Efficacy of Topical Formulations of Doramectin, Ivermectin, Eprinomectin and Moxidectin Against Naturally Acquired Nematode Infections of Beef Calves. *Veterinary Parasitology* 85:277-288.

Yazwinski, T. A., C. A. Tucker, J. W. Powell, L. Jones and E. Wray. (2013) Considerations for Control of Helminths in Stocker Cattle, *The Bovine Practitioner,* Vol. 47, No.2

Zimmerman, Gary, 2013. Bovine Fascioliasis with Empahsis on Fasciola hepatica, *The Bovine Practitioner*, Vol 47, No. 2

38 External Parasites on Beef Cattle

Justin Talley

Objectives

- **Discuss the types of external parasites.**
- **Present ways to control external parasites.**
- **Provide resources for updated pest control information.**

Introduction

Cattlemen in Oklahoma must possess some knowledge concerning external parasites on beef cattle because of their ability to transmit disease, causing economic loss. The external parasites most likely to have an economic impact on beef cattle in Oklahoma are the biting flies, lice and ticks. Cattle are affected to a lesser degree by nuisance flies such as house flies and face flies. Generally, only very large populations of external parasites may cause economic impact on beef cattle. The economic threshold may vary greatly between animals of a higher body score and those of a lower body score. Animals in good body condition score are much more tolerant of parasites than animals stressed by low nutrition or other external factors. Cattle producers must use sound management practices in regard to parasite control because fewer pesticides are now available and the overall residual effectiveness of many pesticides has been compromised by the development of resistance to specific classes of pesticides by some pests. Always read and follow label directions on any pesticide used for control on animals or surrounding premises.

Biting Flies

Horn Flies

Horn flies are the most abundant biting flies present during the spring and summer months on cattle in Oklahoma. Horn flies are small flies that feed on cattle in an inverted position with their head facing down. Both male and female horn flies take blood from the host and feed from 20 times to 30 times a day. Horn flies continually stay on the animal and only leave the animal for short periods to lay eggs. Typical feeding areas on cattle include the back, side, belly and legs of cattle. Horn fly populations begin building up in the spring as early as April and last until the first frost. The life cycle of horn flies lends itself to building large populations on cattle, if control is not implemented.

Horn flies complete an entire generation in as few as 14 days during the summer months, which leads to numerous generations of flies during six months to seven months. Horn flies have complete metamorphosis, which consists of eggs, larva, pupae and adults (Figure 38.1). The adult female fly must lay her eggs in fresh cow manure. The eggs hatch within 48 hours into first instar larva that feed in the manure pat and progressively grow into second and third instar larva. Third instar larva crawl from the manure pat to a drier area and pupate. Inside the pupal case, the adult fly forms and the adult will emerge from the pupal case and seek a suitable host, typically cattle. During mid fall, adults do not emerge and the horn fly spends the winter in the pupal stage.

Horn Fly Control

Horn fly control typically is implemented on cattle when the number of horn flies per animal reaches a threshold of

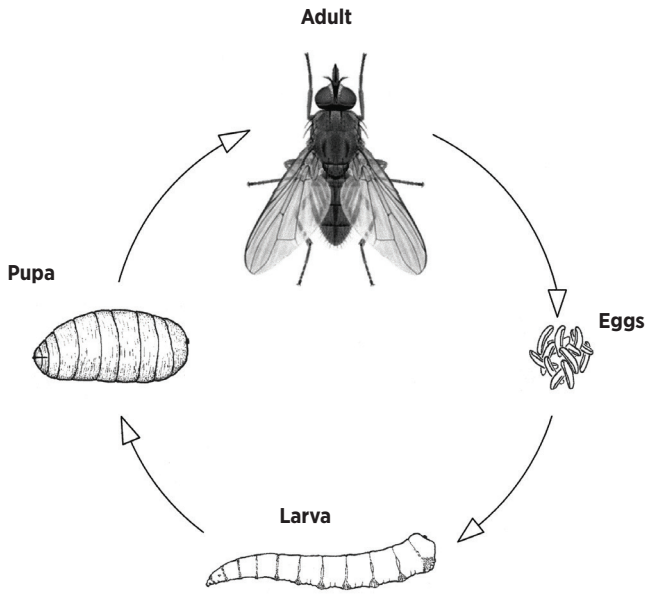


Figure 38.1. Horn fly life cycle.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

200 flies per head. The buildup of fly populations varies from year to year, according to the weather. Populations usually reach this threshold in late spring. Numerous pesticides and application techniques are available to use in the control of horn flies on cattle. Some of the more popular products include insecticides that are incorporated into ear tags and ready-to-use pour-on formulations of pesticides.

Other methods for applying pesticides include sprays, backrubbers, dust bags, paintball gun delivery applications and feed through additives. Many products are dual purpose and may be used either as a spray or in a backrubber application, according to label instructions. Some application methods are much more labor intensive than others. For instance, pesticide sprays must be applied thoroughly and cattle must be gathered to apply sprays properly. Pesticide sprays generally provide only three weeks of control. Materials applied by backrubbers and dust bags give good control as long as these devices are properly maintained. Cattle must be forced to use them or at least must use them frequently to be effective.

Regardless of the method of application, rotation between insecticidal classes is critical to managing insecticide resistance in horn fly populations. Endectocides, which have become very popular for use in controlling internal parasites in the past, will provide four weeks to five weeks of horn fly control, but these products are fairly expensive to use as the primary means of horn fly control. Timing the application of endectocides for control of internal parasites and cattle grubs late in the fly season will allow cattlemen to make one application and reduce two pest problems simultaneously.

Feed-through additives, which contain an insect growth regulator (IGR), can be effective for horn fly control by interrupting the fly life cycle in the manure pat. Developing larvae are not able to complete their development to the pupal stage. Feed-through additives are effective only when most of the cattle in a herd are consuming the required amount of IGR. Feed additives work best when non-treated cattle are not nearby, because horn fly populations will move from one herd to another.

Horn Fly Insecticide Resistance Management

1. Begin horn fly control procedures in the spring, when cattle average approximately 200 horn flies.
2. If ear tags are used, rotate the insecticide classes. Do not use a pyrethroid ear tag more than once every three years. Do not use an organophosphate ear tag more than two years in succession. Continuous use of ear tags in the same insecticide class will eventually result in horn fly resistance.
3. Remove ear tags at the end of the fly season or when they lose their effectiveness. Do not tag cattle more than once per fly season, regardless of insecticide class.
4. If additional horn fly control is needed later in the year, use sprays, pour-ons, paintball gun delivery applications, dusts or backrubbers. If possible, alternate insecticide classes when changing control methods.
5. If pyrethroid ear tags have failed to control horn flies in the previous year, pyrethroid insecticides in any form should not be used for at least two years. In the meantime, use non-pyrethroid ear tags, sprays, pour-ons, etc.

Ideal Rotation for Horn Fly Control

Abamectin → Organophosphate → Pyrethroid
Why?

- Chloride Channel Modulators (Abamectin) Resistance Group 6
- Cholinesterase inhibitors (Organophosphate) Resistance Group 1
- Sodium Channel Modulators (Pyrethroid) Resistance Group 3

Stable Flies

Stable flies are medium-sized flies resembling house flies. Stable flies feed on cattle with their head up and prefer to stay on the feet and legs of cattle. Both male and female stable flies take blood from the host and have a very painful bite. A study in Nebraska showed the economic threshold for stable flies in feedlot cattle was four per leg. Large populations of stable flies on range or pasture cattle often cause cattle to bunch and mill around and often cause them to stand in water when available. Stable flies also have complete metamorphosis, but their larva develop in moist, decaying organic matter associated with spilled feed, soiled hay or straw bedding. They particularly like areas where round bales were fed and the hay is trampled into the ground by feeding cattle. Stable flies are more of a problem with feedlot or confined cattle, but have become a problem on pastured cattle, especially in May and June before cattle are continually grazing summer pastures.

Stable Fly Control

The best method of control for stable flies is sanitation. Keeping cattle-holding areas clean and dry will remove the larval habitat and therefore prevent adult flies. Not allowing spilled feed to accumulate and keeping water troughs from leaking or overrunning are good management practices that aid in the reduction of stable flies. Unrolling round bales has proven effective in limiting stable fly development at round bale feeding sites. Insecticides applied as a spray to the legs will provide some control of stable flies for a week or two, but applications must be made frequently because residues do not last long. The use of sprays to try to control stable flies on pastured cattle is not economically feasible.

Horse Flies and Deer Flies

There are many species of horse and deer flies in Oklahoma. Seven or eight species can be considered significant pests depending on the location. Horse flies vary in size from .5 inches to 1.5 inches or longer. Female horse flies are vicious biters and peak populations of one species or another occur from June through September. Male horse flies do not bite. Horse and deer flies have complete metamorphosis, but generally only complete one generation per year. Many horse flies lay their eggs around

the edges of ponds and their larva develop in the moist mud along the perimeter of the pond, making control in the larval stage impossible. Some of the most important species in Oklahoma lay their eggs in the soil under thick layers of leaves in the heavily timbered areas of the state. Larva develop in the soil. Adult horse and deer flies prefer feeding on the legs and backs of animals. Heavy populations of adult horse flies can cause economic losses, but generally controlling them in a cost-effective manner is not possible. Because the female horse fly is only on the animal for a few minutes while taking a blood meal, it is difficult to get enough pesticide on the animal to deter the fly from feeding. The flies may receive enough pesticide to kill them after they leave the animal, but this is difficult to determine. Because horse flies are continually emerging throughout the summer and many species have an extensive flight range, there will be flies on cattle regardless of whether or not a pesticide treatment has eliminated some of the population. Some pesticides repel horse flies just after spraying the animal, but this is not a practical method of protection. Recently, traps have been promoted to trap out populations of horse flies, but these traps are expensive and numerous traps are required to reduce horse flies in a relatively small area.

Mosquitoes and Black Flies

Certain species of mosquitoes and black flies will feed on cattle in Oklahoma, but normally are not present in high enough populations for a long enough period to cause significant damage. Both of these groups of insects are most prevalent in the spring. Black fly immature stages only develop in running water of streams or rivers. Large populations sometimes occur in May and early June. Mosquito larva develop in standing water and pest populations on cattle are most often associated with water resulting from flooding or heavy rainfall that remains for a week to 10 days. Large populations sometimes occur in pasture areas that hold temporary pools of water. The primary threat from mosquitoes is their ability to transmit disease. The most recent mosquito-borne disease introduced into Oklahoma is the West Nile virus, but cattle are not susceptible to this disease. Horses are much more susceptible to mosquito-transmitted diseases than are cattle.

Nuisance Flies

House Flies

House flies do not bite cattle, as they only possess sponging mouthparts. However, they may cause extreme annoyance to animals when they are present in large numbers. House flies tend to aggregate on specific areas of the animal and can be severe nuisance pests of confined animals, especially calves. They often aggregate around the eyes and mouth because of the moisture secreted by the animal. House flies have complete metamorphosis and their larva develop in moist, decaying organic matter, especially accumulated manure, rotting feed and garbage. House flies will utilize areas associated with spilled feed and hay to lay eggs similar to the life cycle of stable flies. House flies are not often pests of pastured cattle unless such cattle frequent loafing sheds. Good sanitation around barns or feedlot situations is the best method of house fly control. Sprays inside buildings, referred to as premise sprays, also can be utilized to control adult house flies. Premise sprays can be sprayed on the surface areas inside of barns and the flies will contact the insecticide residue when they rest on these surfaces. Automated mist blowers can be used in barns to apply space sprays that will kill adult flies. Commercial baits also can be used to attract house flies to bait containing a pesticide. Baits typically attract only house flies and do not provide control for other fly species. None of these methods of control are relevant to beef cattle on pastures or range.

Face Flies

Although face flies at one time were a pest throughout the northeastern third of Oklahoma, they are now a pest in north-central Oklahoma with an expanded range as far west as Garfield county. Face flies do not bite cattle, but congregate almost exclusively around the eyes and nose. Because of their feeding habits around the eyes, they have been implicated in the transmission of pinkeye. Face flies have complete metamorphosis and the larva develop only in fresh cow manure. Insect growth regulators can be used to help control larva in the manure. Adult face flies are generally not resistant to pesticides and can be controlled with insecticidal ear tags or other control methods listed under horn fly control.

Lice

Lice populations are mainly a problem from November through March in Oklahoma. Lice are not a problem on cattle in the summer months because they are not able to tolerate warmer temperatures in populations high enough to cause noticeable symptoms. Cattle with lice infestations will scratch off their hair in affected areas and lick these areas because of irritation. Cattle can be examined for the presence of lice in a squeeze chute by parting the hair on the face, brisket, shoulders, hips and tail head. Cattle spread lice from one another by close contact and grooming. If control is implemented, all the animals in the herd must be treated. Ringworm and scabies also may present symptoms similar to lice infestations, so cattlemen should check carefully before treating. If in doubt, consult a veterinarian.

Lice have gradual metamorphosis, which consists of eggs, nymphs and adults. Lice must spend their entire life cycle on the host animal, meaning the eggs, three nymphal instars and adults are all present on the animal at the same time. Lice can go from the egg stage to the adult stage in as little as 16 days, depending on the species (Figure 38.2). There are four species of lice found on cattle in Oklahoma.

Biting Lice

The cattle biting louse does not actually bite the animal. Biting lice feed on organic matter on the surface of the skin. Just the presence of the louse causes general irritation, causing the animal to scratch and rub. Biting lice have a wide head to accommodate their chewing mouthparts, which makes their head appear wider than their thorax.

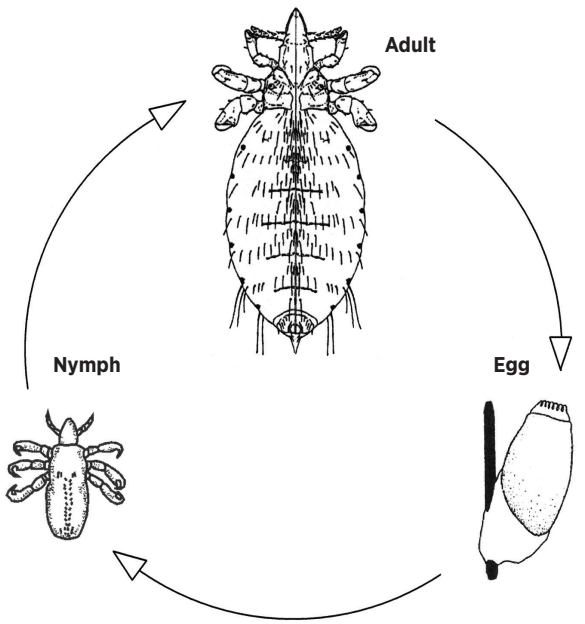


Figure 38.2. Louse life cycle.

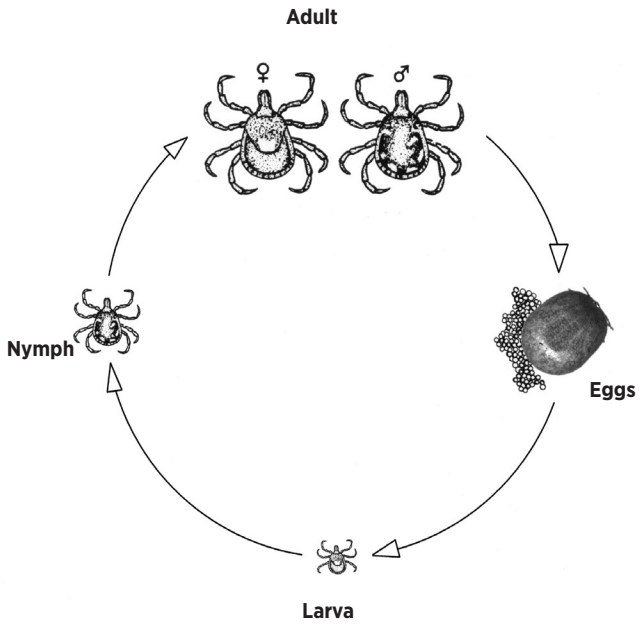


Figure 38.3. Tick life cycle.

Sucking Lice

Three species of sucking lice are present in Oklahoma: the short-nosed cattle louse, long-nosed cattle louse and little blue louse. These species all have narrow, pointed heads. All sucking lice have piercing, sucking mouthparts and pierce the skin to take blood from the animal. All three nymphal stages, as well as the males and females, suck blood. Even a small infestation of sucking lice can cause significant irritation. Lice populations can build very quickly if not treated soon after detection.

Lice Control

Many of the pesticides registered for horn fly control can be used to control lice. Check the label to be sure lice are listed. Several pesticide formulations specifically formulated for louse control also work well. A second treatment for lice control must be made two weeks to three weeks after the initial treatment because the developing eggs present at the time of initial treatment will hatch and the residual pesticide will likely not be of a concentration high enough to kill the newly emerging nymphs.

Ticks

Ticks are arthropods (jointed-legs) and are closely related to mites and spiders. Ticks have two body regions, no antennae, no wings and eight legs in the nymph and adult stages. Ticks have four life stages: egg, larva, nymph and adult. Eggs are always laid on the ground, never on a host. The latter three stages - larva, nymphs and adults - are all parasitic and must obtain blood from some type of host to reach the next stage or in the case of adults, to mate and lay eggs. The change from one stage to another, (larva to nymph or nymph to adult) is called a molt and each stage must take a blood meal to change or molt to the next stage (Figure 38.3).

Ticks may be grouped according to the number of host animals they feed on during their parasitic life cycle. If the larva, nymphs and adults feed and develop on the same host and do not leave the host to molt to the next stage, they are referred to as a one-host tick (e.g. winter tick and spinose ear tick). Those ticks that feed on different hosts in each life stage (larva, nymphs and adults) are referred to as three-host ticks (e.g. lone star tick, Gulf Coast tick, American dog tick and black-legged tick).

There are six species of ticks that commonly infest cattle at some time during the year in Oklahoma. Five of these species are referred to as hard ticks because they have a hard plate on the back. The common names of these hard ticks are the lone star tick, Gulf Coast tick, American dog tick, black-legged tick and winter tick. One pest species of cattle in some parts of Oklahoma is a soft tick known as the spinose ear tick. This tick species does not have a hard plate on its back. In fully engorged hard ticks, the body expands to as much as 10 times to 20 times its nonengorged size, which makes it difficult to see the hard plates. Do not mistake these engorged ticks for the one relatively rare soft tick species that occurs on cattle in Oklahoma. Not all of these tick species are uniformly distributed in Oklahoma and some areas of Oklahoma do not have severe tick problems. Please refer to the description of each species to determine the range of that species in the state.

Ticks also may be grouped according to when they are most abundant, normally the adult stage, on cattle or other large animals. This period when the ticks are most visible and abundant or active is known as their peak seasonal cycle. Thus, it is important to note what time of the year the different tick species and life stages are active. Four species of ticks are most common in the spring or early summer. Perhaps the two most important tick pest species on cattle in most of Oklahoma are the lone star tick and the Gulf Coast tick. Both of these species are most active on cattle from early spring, mid-March to late June. Another hard tick, the American dog tick, is most active from April

to the first of July. This tick is normally not a serious pest on cattle. The adults are often found on dogs and often are a serious pest for humans. The larva of the spinose ear tick, a soft tick, is often found in the ears of cattle in some parts of Oklahoma in the spring. Adults of the black-legged tick often are pests of cattle from late September until January and the one-host winter tick, as the name implies, is most abundant from November into March.

Lone Star Tick

The lone star tick is a three-host species and the most prevalent tick in the eastern half of Oklahoma. It has been collected from 44 Oklahoma counties and is most active on cattle from late March into early July. Male ticks can be found on deer and cattle as early as late January, but nymphs and adults usually begin the parasitic cycle about mid-March. Larva, nymphs and adults feed on cattle, although adults are most noticeable and probably cause the most irritation. Deleterious effects caused by this species are due to the tremendous number of ticks that can be found on an individual animal. This species attaches almost anywhere on the body, but often are found on the belly, legs and tail area of the animal. Adult lone star tick activity usually begins to subside by early July, although some nymphs and larva can remain active into the fall. Larva will feed on a wide variety of rodents, birds, wild carnivores, large hoofed animals and humans. Larva that fail to find a host and take a blood meal by late fall do not survive winter temperatures in Oklahoma. Nymphs and adults can overwinter and are the source of early season tick activity the following year.

Gulf Coast Tick

The Gulf Coast tick is a three-host species occurring in the eastern half of Oklahoma and is reportedly established in 33 counties in the state. Only the adult life stage, male and female, are on cattle and attach primarily on the internal and external surface of the ears, although some are located elsewhere on the head and neck. A severe infestation by this tick, 10 or more ticks per ear, may cause a deformation of the ear due to cartilage damage. This condition is known as gotch ear. Adults of this tick can be found on cattle beginning in mid-March lasting into July, with peak activity in April and May. Adult ticks have been recovered from coyotes as early as January and from white-tailed deer as late as November. The adult is the only life stage found on cattle and other large animals and carnivores. Larva and nymphs feed primarily on cotton rats and ground-dwelling birds (meadow larks, etc.) in pastures and adjacent wooded areas. Larva are active from May through October and nymphs are active from June through October. Unfed larva do not overwinter.

American Dog Tick

The American dog tick is a three-host species occurring throughout Oklahoma. This species is seldom a serious pest of cattle except in specific places, most often heavily wooded areas. Adults of this species are serious pests on many wild animals in heavily wooded areas and are serious pests of domestic pets, primarily dogs. The adult life stages are most active from late March into early July. The adults readily attack humans and are known to transmit the causative agent of Rocky Mountain spotted fever to humans in Oklahoma and the eastern U.S. Larva and nymphs feed primarily on cotton rats and white-footed mice throughout the year.

Black-legged Tick

The black-legged tick is a three-host species occurring in 39 counties, primarily in the eastern half of Oklahoma, although it has occasionally been collected in Comanche County. Adults of this species are only occasionally serious pests of cattle in some areas of Oklahoma. The adults most often are found on white-tailed deer and other wild animals although they do attack dogs, especially hunting or farm dogs that roam in areas deer frequent. The adult life stage is active from late September with peak populations in October and November, then tapering off through April of the following year. Nymphs that overwinter usually become active in March. The larva that hatch from eggs laid by females, which engorged during the fall or winter, begin infesting lizards (five-lined skink) and occasionally white-footed mice, about the first of June. Larva and nymphs feed primarily on lizards or field mice throughout the spring and summer, but do not attack cattle or humans in Oklahoma.

Winter Tick

The winter tick is a one-host species reported from 33 counties across the state, but occurs mostly in the eastern half of Oklahoma. As the name implies, this tick is most active in the winter, with larva first infesting large animals such as cattle, horses and deer starting in mid-October. As a one-host tick, the larva is the only stage seeking a host by crawling up on vegetation in one mass waiting for a host to brush by them. Larva and nymphs engorge and molt on the same animal. The adults appear 30 days to 35 days after the nymph starts feeding on an animal. Therefore, all three stages stay on the same animal for their entire life cycle. Individual animals can be infected with thousands of ticks. Adult populations peak from December through February but can be found in heavily infested areas until March. These ticks can be found all over the body, but often tend to concentrate in the udder areas and between the hind legs from the tail downward.

Spinose Ear Tick

The spinose ear tick is a one-host soft tick species reported from 23 counties in the state, but is not very abundant or much of a problem on cattle except in some very localized areas. The larval life stage becomes active in March and is the only stage that searches for a host. Larva attach in the hosts' external ear canal, where they feed and molt into the spine-covered nymphal stage. Nymphs may feed multiple times during a 30- to 200-day period, before leaving the host. Nymphs are the most commonly seen life stage and can cause a great deal of irritation in the ear canal. They typically are not abundant on the external part of the ear. The adult does not feed and lives on the ground around loafing areas or feed bunks. Adults become active in reduced light or darkness, primarily to mate.

Tick Control

Large tick infestations cause serious irritation and obvious damage to animals, although there is no threshold figure. If many ticks are visible on an animal, surely many more are present. Several pesticides are available for use in tick control. The most effective pesticide formulations are whole-body sprays and pour-on formulations of the synthetic pyrethroid insecticides. These insecticides attach to the hair and remain present for two weeks to three weeks. Many of these formulations are the same as those used for fly control. Be certain the label of any pesticide states can be used for control of ticks. One of the major costs associated with treatment of cattle for ticks is that the animals must be gathered and confined, because each animal needs to be treated thoroughly. The pesticide-impregnated ear tags will give control of only the Gulf Coast tick, which concentrates in the ears. This is expensive control because the tags would need to be applied in April. In most of Oklahoma, early application of ear tags would cause early expression of the resistance factor in horn fly populations and the ear tags probably would not provide adequate horn fly control into June and later. Ear tags will not provide control of the tick species attached elsewhere on the body. The self-use devices such as backrubbers and dust bags do not provide adequate tick control since many of the ticks are attached underneath the animals on the belly and around the udder area.

General Precautions for Livestock Insecticides

- **The label is the law. Always follow the application directions and safety precautions on the insecticide label.**
- Do not treat sick, convalescent or stressed cattle.
- Exceeding labeled use rates may result in illegal insecticide residues in the beef or possible harm to the animals.
- Always observe the preslaughter treatment interval. Treatment of animals closer to slaughter than the number of days prescribed on the label can result in illegal residues in the beef.
- Do not contaminate feed, feed or water troughs or allow runoff into streams, ponds, etc.
- Store insecticides properly and dispose of empty insecticide containers according to regulations.

Other Publications

- Current information on the control of external parasites for cattle is available at extension.okstate.edu or at the local Oklahoma Cooperative Extension Service Office.
- Entomology and Plant Pathology Web Page: entoplp.okstate.edu
- Extension Fact Sheets:
  - VTMD-7000 Beef Cattle Parasite Controls
  - EPP-7001 Common Ticks of Oklahoma and Tick-borne Diseases
  - EPP-7451 Agricultural Pesticide Storage
  - EPP-7453 First Aid for Pesticide Poisoning
  - EPP-7457 Toxicity of Pesticides

39 Implants and Their Use in Beef Cattle Production

Paul Beck, Ryan Reuter and David Lalman

Objectives

- **Discuss types of implants.**
- **Discuss the effects of implants.**
- **Present proper procedure for implanting.**

The term "implant" is used to refer to a group of products used in the cattle industry that increase the rate and efficiency of growth, both metabolic and economic. Implants contain natural or synthetic anabolic compounds that produce physiological responses in the animal similar to natural hormones. Implants are typically made of a powder that is compressed into a small pellet. The pellet is placed, or implanted, under the skin on the backside of the animal's ear. Each type or brand of implant has a specific applicator, referred to as an implant gun, which is used to properly administer the implant.

Safety of Implants

There is much concern expressed by consumer groups in the news and social media about using growth-promoting hormones in beef production systems. Table 39.1 shows the estrogenic activity of foods commonly consumed in the U.S.

Table 39.1. Estrogenic activity per 4 ounce serving of several common foods.[a]

Food	*Estrogen, ng*
Soybean oil	226,757
Cabbage	2,721
Wheat germ	453
Peas	453
Eggs	3,968
Ice Cream	680
Milk	15
Beef from pregnant cow	159
Beef from implanted cattle	2.5
Beef from non-implanted cattle	1.8

a adapted from Preston (1997)

Beef from steers and heifers fed for slaughter have a very low level of estrogenic activity, regardless of implant status. In fact, ice cream contains 272 times more estrogen than implanted beef (Preston, 1997). Common grain and vegetable sourced foods such as peas, wheat germ and cabbage have 180 to 1,000 times the estrogenic activity of implanted beef. Natural estrogen production in humans is much higher than many expect; a pregnant human female produces 90,000,000 nanograms of estrogen per day, a non-pregnant adult female 5,000,000 nanograms of estrogen per day, an adult male 100,000 nanograms of estrogen per day and a pre-pubertal child 40,000 nanograms of estrogen per day. So the safety of growth promoting implants is certain. The safety of implants is assured when FDA approved products are used according to their labels. History and several organizations including, but not limited to, the U.S. Food and Drug Administration, the World Health Organization and the Food and Agriculture Organization have concluded that the use of implants in beef production poses no safety risk to consumers.

Current Use of Implants

Implants have a long history of use in the beef cattle industry. The first commercial implant was introduced in 1957. Since then, the use of implants has been widely adopted by the cattle feeding and stocker sectors of the beef industry. According to a 1999 survey, 99% of all feedlot cattle are implanted at least one time during the finishing phase.

Two recent Oklahoma studies surveyed 729 producers who received the Beef Cattle Manual (Johnson, 2008 and Vestal et al., 2007). Thirty-seven percent of cow-calf producers with larger operations (more than 100 cows) indicated they implanted their steer calves, while only 9% of cow-calf producers with smaller operations (fewer than 100 cows) implanted their steer calves (Vestal et al., 2007). Approximately 60% of stocker producers implant their cattle (Johnson, 2008). In fact, 58.6% of cattle from designated stocker-only operations nearly always implanted their steers, while only 28.8% of steers from stocker operations that included a cow-calf component were implanted. Data from the 2008 National Stocker Survey shows that 78.6% of stocker operations with more

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

than 1,000 head implant their cattle, dropping to 52.7% in operations with less than 200 stockers.

Types of Implants

There are three types of compounds used in implants: estrogens, androgens and progestins. Estrogens mimic the effects of the naturally occurring hormone estrogen. Estradiol benzoate, estradiol 17-beta and zeranol are the primary estrogenic compounds used in implants. Alternatively, androgenic compounds mimic the effects of the naturally occurring hormone testosterone. Testosterone propionate and trenbolone acetate (TBA) are the principal androgenic compounds used in implants. Synthetic progesterone also is used in implants; however, its effect on the animal is less pronounced than the other two hormone analogues. Tables 39.2 (suckling calves), 39.3 (stocker cattle) and 39.4 (feedlot) list compound combinations and dosages supplied in commercially available implant products. Some commercially available implants have singular hormone activity, such as Ralgro with only estrogenic analogue zeranol or Finaplex containing only the testosterone analogue TBA, but most have combinations of hormone activity.

All implants are designed to release the compounds into the bloodstream of the animal slowly through time. Different implants are formulated to provide different lengths of time for all of the compounds to be released. This effective period or lifespan of the implant is commonly referred to as the "payout" period. Label claims of payout range from 60 days to 400 days. Factors that affect payout include formulation of the implant, proper administration of the implant and blood flow to the ear. Reimplanting provides longer-term benefits but reimplanting before the end of the payout period of the previous implant has not provided any additional effectiveness. Research conducted at the USDA ARS Southern Plains Experimental Range near Fort Supply shows this relationship (Table 39.5). Steers given an implant supplying estradiol and progesterone before turnout onto native range in the early summer did not respond to additional implants given in mid-summer (day 61 of grazing) with control steers not receiving an additional implant gaining 1.7 pounds per day and steers receiving either Estradiol and Progesterone or a combination implant supplying Trenbolone Acetate/Estradiol gaining 1.8 pounds per day during the late summer (Grigsby, unpublished data). This research shows that reimplanting before the end of

Table 39.2. Beef cattle implants approved for use in suckling calves and calves less than 400 pounds.

Steer	*Heifer*	*Implant*	*Company*	*Ingredient/dose*	*Relative potency*	*Payout*	*Reimplant*
x	x	Ralgro	Merck	36 g zeranol	Low	70 to 100	45 to 70
x		Compudose	Elanco	25.7 mg estradiol	Moderate	200	200
x		Encore	Elanco	43.9 mg estradiol	Moderate	400	400
x	x	Synovex-C	Zoetis	100 mg progesterone 10 mg estradiol benzoate	Low	70 to 100	55 to 90
x	x	Component E-C	Elanco	100 mg progesterone 10 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Low	70 to 100	

Table 39.3. Beef cattle implants approved for use in stocker calves and growing calves in confinement more than 400 pounds.

Steer	*Heifer*	*Implant*	*Company*	*Ingredient/dose*	*Relative potency*	*Payout*	*Reimplant*
x	x	Ralgro	Merck	36 g zeranol	Low	70 to 100	45 to 70
x		Compudose	Elanco	25.7 mg estradiol	Low	200	200
x		Encore	Elanco	43.9 mg estradiol	Low	400	400
x		Synovex-S	Zoetis	200 mg progesterone 20 mg estradiol benzoate	Moderate	90 to 120	70 to 100
x		Component E-S	Elanco	200 mg progesterone 20 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Moderate	90 to 120	70 to 100
	x	Synovex-H	Zoetis	200 mg testosterone propionate 20 mg estradiol benzoate	Moderate	90 to 120	70 to 100
	x	Component E-H	Elanco	200 mg testosterone propionate 20 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Moderate	90 to 120	70 to 100
x	x	Revalor-G	Merck	40 mg trenbolone acetate 8 mg estradiol	Moderate	100 to 140	100 to 120
x	x	Component TE-G	Elanco	40 mg trenbolone acetate 8 mg estradiol 29 mg tylosin tartrate (local antibiotic)	Moderate	100 to 140	100 to 120
x	x	SynovexOne Grass	Zoetis	150 mg trenbolone acetate 21 mg estradiol benzoate	Moderate	180 to 200	180 to 200

Table 39.4. Beef cattle implants approved for use in finishing cattle in confinement > 400 pounds.

Steer	*Heifer*	*Implant*	*Company*	*Ingredient/dose*	*Relative potency*	*Payout*	*Reimplant*
x	x	Ralgro	Merck	36 g zeranol	Low	70 to 100	45 to 70
x	X	Compudose	Elanco	25.7 mg estradiol	Low	200	200
x	x	Encore	Elanco	43.9 mg estradiol	Low	400	400
x		Synovex-C	Zoetis	100 mg progesterone 10 mg estradiol benzoate	Low	70	55 to 70
x		Synovex-S	Zoetis	200 mg progesterone 20 mg estradiol benzoate	Low	90 to 120	70 to 100
x		Component E-S	Elanco	200 mg progesterone 20 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Low	90 to 120	70 to 100
	x	Synovex-H	Zoetis	200 mg testosterone propionate 20 mg estradiol benzoate	Low	90 to 120	70 to 100
	x	Component E-H	Elanco	200 mg testosterone propionate 20 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Low	90 to 120	70 to 100
x	x	Synovex Choice	Zoetis	100 mg trenbolone acetate 14 mg estradiol benzoate	Moderate	100 to 140	70 to 100
x		Revalor -IS	Merck	80 mg trenbolone acetate 16 mg estradiol benzoate	Moderate	100 to 140	90 to 100
x		Component TE-IS	Elanco	80 mg trenbolone acetate 16 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Moderate	100 to 140	90 to 100
	x	Revalor -IH	Merck	80 mg trenbolone acetate 8 mg estradiol benzoate	Moderate	100 to 140	90 to 100
	x	Component TE-IH	Elanco	80 mg trenbolone acetate 8 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	Moderate	100 to 140	90 to 100
x		Revalor-S	Merck	120 mg trenbolone acetate 24 mg estradiol benzoate	High	100 to 140	90 to 100
x		Component TE-S	Elanco	120 mg trenbolone acetate 24 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	High	100 to 140	90 to 100
	x	Revalor-H	Merck	140 mg trenbolone acetate 14 mg estradiol benzoate	High	100 to 140	90 to 100
	x	Component TE-H	Elanco	140 mg trenbolone acetate 14 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	High	100 to 140	90 to 100
x	x	Revalor 200	Merck	200 mg trenbolone acetate 20 mg estradiol	High	100 to 140	90 to 100
x	x	Component TE-200	Elanco	200 mg trenbolone acetate 20 mg estradiol benzoate 29 mg tylosin tartrate (local antibiotic)	High	100 to 140	90 to 100
x		Revalor -XS	Merck	200 mg trenbolone acetate 40 mg estradiol benzoate	High	200	200
	x	Revalor -XH	Merck	200 mg trenbolone acetate 20 mg estradiol	High	200	200
	x	Finaplix - H	Merck	200 mg trenbolone acetate	High	70 to 100	60 to 100
x	x	Synovex Plus	Zoetis	200 mg trenbolone acetate 28 mg estradiol	High	150 to 200	150 to 200
x	x	Synovex One Feedlot	Zoetis	200 mg trenbolone acetate 28 mg estradiol	High	200	200

Table 39.5. Effect of reimplanting grazing steers previously implanted with an estradiol/progesterone implant in mid-summer before implant payout on late summer performance.

		Implant type		
	Control	*Est/Prog*[a]	*TBA/E*[b]	*P-value*
Steer weight, lbs				
July 18	596	599	598	0.80
September 27	708	719	721	0.37
Weight gain, lbs/steer	113.3	119.7	121.6	0.12
Average Daily Gain, lbs/day	1.7	1.8	1.8	0.12

Adapted from Grigsby et al. unpublished data.
a Est/Prog – supplied 200 mg progesterone and 20 mg estradiol benzoate.
b TBA/E – supplied 40 mg trenbolone acetate and 8 mg estradiol

the payout period of the previous implant provides little to no benefit.

Effects of Implants on Beef Cattle Performance

Nursing Calves

Implant products are available for calves weighing less than 400 pounds (Table 39.2). Implants cleared for use in nursing calves generally contain a lower dose of the active ingredient compared to products cleared for use in older cattle (Tables 39.3 and 39.4). These implants are typically administered when the calves are between two months and four months of age. Research has shown implants given during the suckling phase will increase average daily gain (ADG) of steer calves by approximately 0.10 pound per day. Response in heifers is slightly lower. Zeranol and estradiol benzoate/progesterone implants appear to produce a slightly better response than estradiol 17-beta products.

Most calf implants are designed for payout in approximately 100 days to 120 days. In some circumstances, the suckling period is long enough that reimplanting would be appropriate. Steer calves implanted twice with zeranol or estradiol benzoate/progesterone implants gained approximately 0.12 pounds per day more than nonimplanted control animals. The additional implant did not appear to have as much effect as the initial implant. Calves should be 30 days to 45 days old before they are implanted. Bull calves intended for breeding should not be implanted. Bull calves not intended for breeding should be castrated at the time of implanting, as one effect of the implant is possible inhibited scrotal development, which makes later castration more difficult.

Nursing Bull Calves Versus Nursing Implanted Steer Calves

Many producers follow the practice of leaving bull calves intact until weaning rather than castrating them. The idea is that natural hormones produced in the testicles increase ADG and weaning weight of the calves. Numerous research trials have shown implanted steer calves gain at a rate equal to, or greater than, bull calves. Castrating bulls as small calves, as opposed to when they are older, reduces overall stress on the calf. The stress and hormonal effects of castration at weaning can reduce post-weaning gain potential and the calf's ability to withstand diseases typically associated with weaning and marketing. This difference in post-weaning performance of bulls versus steers is recognized by cattle buyers, as indicated by the fact that steers will command a $5 to $10 per cwt. premium over intact bull calves. Producers wanting to maximize the value of male calves at weaning should consider early castration at birth or at two months to four months of age and use an implant approved for nursing calves.

Stocker Calves

Calves that are weaned and placed on grass or small grain pastures for a period of time before finishing in a feedlot are referred to as stocker calves. There are several implants available for stocker calves (Table 39.3). Implant research trials have shown an improvement in the ADG of stocker cattle from 8% to 20%. Numerous trials indicate that producers can expect a 10% to 15% (0.18 pounds per day to 0.27 pounds per day) improvement in ADG over nonimplanted controls. These studies were conducted through various lengths of time, but the average was approximately 150 days, which is a typical stocker grazing period. Research results are inconclusive concerning the value of one type of compound over the others.

Payout for stocker implants is generally in the range of 80 to 100 days, although several products are available with much longer payout periods. In June 2023 the FDA will no longer allow reimplanting of calves within a production phase unless it is specifically allowed on the label. Performance benefits will be lost after an implants effective payout period. Alternatively, implants designed for a longer payout time should be used as the initial and only implant to provide an active implant through a long grazing season.

The impact of keeping an active implant on performance is shown with steers grazing native range at the Klemme Range Research Station near Bessie, OK. These steers were implanted with combination implant supplying trenbolone acetate/estradiol (TBA/E) at receiving 60 days before grazing turnout on May 22, steers were either not reimplanted or were reimplanted with combination implant supplying TBA/E or estradiol and progesterone on July 23 (Day 62 of grazing) at the end of the expected payout period of the previous implant (Grigsby unpublished data). Table 39.6 shows the performance of the steers during the late summer grazing period from July 23 to September 30. Reimplanting with estradiol and progesterone following an initial combination TBAS/E implant provided no additional gain compared with controls that were not reimplanted, yet reimplanting with a combination implant supplying TBA/E combination increased average daily gain by 0.5 pounds per day compared with the non-reimplanted controls and by 0.9 pounds per day compared with the steers reimplanted with estradiol/progesterone. This shows the value of matching

Table 39.6. Effect of reimplanting grazing steers previously implanted with a trenbolone acetate/ estradiol combination (TBA/E) implant in mid-summer after implant payout on late summer performance.

		Implant Type		
	Control	*Est/Prog*[a]	*TB*[A/Eb]	*P-value*
Steer weight, lbs				
July 23	667	667	666	0.99
September 30	806	788	834	< 0.01
Weight gain, lbs/steer	165.6	138.0	200.1	0.01
Average Daily Gain, lbs/day	2.4	2.0	2.9	0.01

Adapted from Grigsby et al. unpublished data.
a Est/Prog – supplied 200 mg progesterone and 20 mg estradiol benzoate.
b TBA/E – supplied 40 mg trenbolone acetate and 8 mg estradiol

the payout period of implants with the length of ownership (in contrast with reimplanting prior to end of payout period shown in Table 39.5) as well as the importance of following the standard recommendation to follow initial implants with implants of equal or higher potency to see continued performance responses. Factors affecting stocker response to implants are numerous and include sex, weight, genetic gain potential, forage availability, diet quality, supplementation and environmental conditions. Research has shown that as ADG of nonimplanted controls increases (due to pasture quality or other factors), the response to an implant also increases. No adverse effects have been documented from implanting cattle that gain at very low rates. Figure 39.1 shows the implant response of steers stocked on wheat pasture at either 0.75 acres per steer (1.5 steers per acre; Low Gain) or 1.5 acres per steer (High Gain) by Williamson et al., 2014. Steers stocked for a low rate of gain without implants gained only 1.4 pounds per day while implanting increased gains by 0.28 pounds per day, a 20% increase in gain with implants. Steers stocked on wheat pasture for a high rate of gain had average daily gains of 2.19 pounds per day without implants, which was increased by 0.34 pounds per day to 2.53 with the implant, a 15% increase in gain. In this research, the increase in gains were similar even though the potential gains on pasture were quite different.

Research has indicated responses to implants, supplementation and ionophores are 100% additive in stocker cattle, and there may be a slight synergistic relationship. Full benefit should be expected from both the implant and the supplement program if both are used in stocker cattle. Figure 39.2 shows the gain response of steers grazing wheat pasture in the fall and winter to both growth-promoting implants and an ionophore (Beck et al., 2014). Steers in this experiment that were not supplied the ionophore nor given an implant gained 2.29 pounds per day, implanted steers not fed the ionophore gained 2.71 pounds per day—an increase of 0.42 pounds per day. Feeding an ionophore increased gains by 0.20 pounds per day whether they were implanted or not, so steers fed an ionophore and implanted gained 0.6 pounds per day than steers not implanted or fed an ionophore, which increased net returns by $42 per steer.

Feedlot Cattle

Implants are used extensively by the feeding industry in the U.S. to improve ADG and feed efficiency. The finishing period can range from 120 days to 240 days. A single implant may improve ADG by 0.35 pound per day in steers and 0.25 pound per day in heifers. Feed conversion may be improved by 0.5 pound of feed per pound of gain. Aggressive feedlot implant programs can result in up to a 21% improvement in daily gain and an improvement in feed conversion up to 11%. This increased efficiency and weight gain produces a significant economic return. An implant program for finishing cattle must evaluate numerous factors, including decisions concerning timing of implant, ingredient of implant and number of implant times. There are many different options available for implanting finishing calves (Table 39.4) ranging from very conservative (low-potency hormone levels) to very aggressive (high-potency hormone

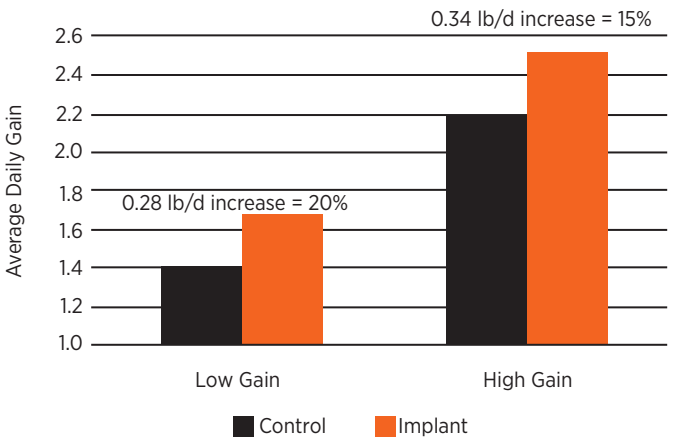


Figure 39.1. Implant response by steers grazing wheat pasture stocked to achieve either a low (1.5 steers per acre) or high (1.5 acres per steer) rate of gain during the winter and early spring. (Adapted from Williamson et al., 2014.)

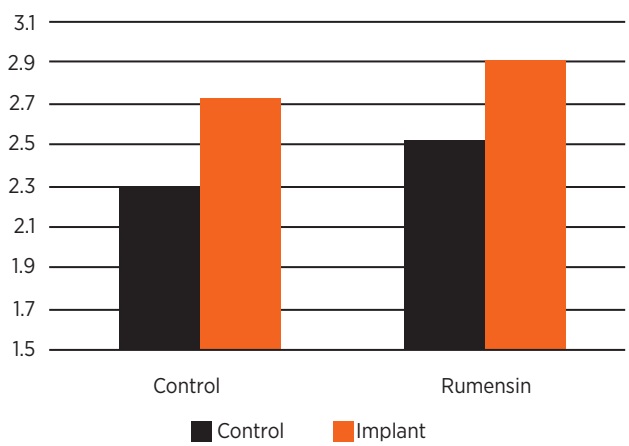


Figure 39.2. Gain response of steers grazing wheat pasture to growth promoting implants and an ionophore (monensin). (Adapted from Beck et al., 2014.)

levels). Selection of implant program depends on previous management history, genetics of the animal and production and marketing goals.

Implants can have pronounced effects upon carcass characteristics of cattle. In general, when cattle are fed the same number of days, implants improve carcass weight and ribeye area, while decreasing marbling scores. With these circumstances, implants may reduce the percentage of cattle grading at least USDA Choice by 2% to 24%. Implants also may slightly increase skeletal maturity, which also impacts USDA Quality Grade. Type of implant, gender and genotype of the animal all influence these responses. However, if cattle are harvested at constant back fat thickness, implants may have little to no impact on quality grade.

Barham et al. (2012) finished two sets of calves either directly after preconditioning 63 days (calf-fed) or as yearlings following an extensive 133-day low-growth stocker period that were managed with either aggressive implanting (implants administered at weaning, during grazing [yearlings only], at arrival to feedyard and reimplanted during finishing) or delayed implanting (implants administered only at reimplanting during finishing). Breeding selection for the herd of one set of calves had been for carcass quality and growth; while the herd for the second set were selected for maternal hybrid vigor and growth traits. The aggressive implant program increased growth and hot carcass weights of both calf-feds and yearlings from both herds. In the first herd (the one selected for carcass quality), aggressive implanting program reduced marbling scores of both the calf-feds and yearlings, and the impact was greatest in yearlings with the percentage of USDA Choice quality grade or greater: decreased from 95% in delayed implant to 45% in aggressively implanted cattle. While in the second herd (not selected for carcass quality), marbling score, USDA quality grade and the percentage USDA Choice was not affected by an implant program. This research indicates that aggressively implanting cattle prefinishing with high genetic propensity for marbling during a period of restricted nutrition can have a large impact on subsequent carcass quality, yet marbling and carcass quality of cattle with limited genetic selection for those traits are not affected by implant program prefinishing. For a complete review of feedlot implant effects, see Duckett and Owens, 1997.

Lifetime Implanting Strategies

In the modern beef industry, it is fairly common for cattle to receive three or more implants during their lifetime. For producers who operate in only one segment of the industry, the implant decision is simple. However, for producers who retain ownership of an animal through two or more phases and market cattle on a carcass merit price grid, implant decisions become more complex. It is possible implants administered in one phase can have carryover effects in subsequent phases, however in many studies, this carryover effect has not materialized (Reuter and Beck, 2013). Implants approved for suckling calves are less potent than those approved for stockers, which are less potent than many feedlot implants. A strategy to maximize lifetime gain of the animal while minimizing deleterious effects on carcass quality and animal behavior is an implant program using increasingly potent implants. During the suckling phase, a low-potency implant will be used, followed by one or two moderate implants in the growing phase, followed by a moderate implant upon placement in the feed yard, then a high-potency implant 80 days to 100 days before slaughter. The effects of multiple implants on marbling scores may become more dramatic as three or more implants are used during the animal's lifetime. Producers who retain ownership of animals through more than one production phase should evaluate their overall implant program for the way their cattle are being marketed. Factors to consider are the feed cost, the base value of additional carcass weight, the Choice-Select spread and the potential value of marketing cattle into specialty, non-hormone treated cattle (NHTC) programs.

Implanting Replacement Heifers

Producers often raise the question, "Is it safe to implant replacement heifers?" Research has shown heifer calves intended for use as breeding animals can be implanted one time between 45 days of age and weaning with no significant effect on subsequent conception rates or calving difficulty. Heifers implanted immediately at birth, following weaning or multiple times prior to weaning had significantly lower conception rates compared to heifers receiving a single implant prior to weaning.

Most producers should be able to identify potential replacements heifers at weaning. The producer can then implant the stocker heifers to improve gain and not implant the heifers intended for breeding. See chapter 29 for a more thorough discussion of implanting replacement heifers.

Table 39.7 Effect of pre-finishing implants on carcass quality of calves shipped directly to the feedlot after preconditioning (CALF-FED) or shipped to the feedyard as yearlings following wheat pasture managed for low rate of gain (LOW GAIN) or high rate of gain (HIGH GAIN).

	CALF-FED		*LOW GAIN*		*HIGH GAIN*	
	No implant	*Implant*	*No implant*	*Implant*	*No implant*	*Implant*
Hot carcass weight, lbs	682	680	703	710	760	781
Rib eye area, inch^2	11.5	11.5	12.2	13.2	13.6	13.5
Marbling Score	559	508	492	427	471	468
Quality Grade	CH0	CH0	CH$^-$	CH$^-$	CH$^-$	CH$^-$
% Choice	100	95	100	74	89	85

Adapted from Williamson et al., 2014.

Economics

Implants are one of the most cost-effective technologies available to cattle producers. Stocker implants typically return more than $15 for every $1 invested. Implants effectively increase growth rate, increase protein deposition and improve feed efficiency resulting in approximately a 7% overall reduction in the cost to produce beef (Lawrence and Ibarburu.). Consider this example of the economic potential of implanting unweaned calves: A nursing calf, implanted at three months of age and 150 days before weaning may gain 0.10 pound per day for 150 days. The 15 pounds additional weaning weight could have a value of $1.00 to $2.00 per pound for a total of $30. The implanting cost is approximately $0.85. Here, the net return would be $29.15 per calf sold.

Alternative production systems such as organic, NHTC or "natural," generally do not allow cattle to be implanted. Producers who want to use these production systems should ensure the premiums they receive for these cattle will offset the reduced production and efficiency implants (and other technologies) offer. Historically, these premiums have not been adequate to offset the lost production (Maxwell et al., 2015).

Some regions (i.e. the European Union) and countries do not allow the use of implants at all.

Beef Quality Assurance

Implant Location

The only approved implantation site for all brands of implants is subcutaneously in the middle one-third of the back of the ear. The implant must not be closer to the head than the edge of the auricular cartilage ring farthest from the head. The procedure to insert the implant should be done under conditions as sanitary as possible. Cleaning the ear, keeping equipment clean and using a sharp needle are all recommended. Problems with ear abscesses are the most common cause of implant defects and are usually related to poor sanitation while implanting. Proper animal restraint makes the implanting placement more accurate and the procedure safer for the handlers. Follow all manufacturers' recommendations for implant administration.

Figure 39.3 shows the correct location. The Food and Drug Administration (FDA) no longer allows implants to be placed at the base of the ear.

Implanting Procedure

A qualified and trained individual should be assigned the task of implanting. Employing the following steps will greatly diminish the incidence of implanting errors, such as abscesses, crushed pellets or missing implants. Achieving an active, undamaged uncontaminated implant in each calf is the goal. Speed will come with practice; it is better to do it right the first time than to have to go back and fix mistakes. Similarly, it is much better to take time and do it right than to pay for an implant and not realize a $20 to $30 per head advantage because the job was done incorrectly.

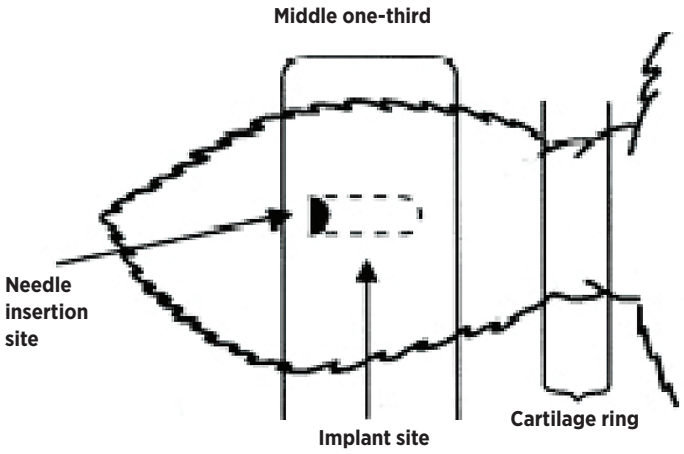


Figure 39.3. The correct location for implants.

1. Read the label for all animal health products. Ensure the correct dosage, location and procedures are followed. Ensure the product is labeled for use in the class of animal to which it is being administered. Any deviation from label directions carries the potential for stiff legal penalties and should be directed by a licensed veterinarian.
2. Obtain all of the necessary equipment to maintain sanitation. A tray and large sponge soaked in a disinfectant should be used to store the implant applicator between uses. An extra needle for the applicator should be available in case the needle becomes dull, burred, bent or broken. A clean table out of the way of flying debris should be used to store the applicator and implants between uses.
3. Become familiar with the operation of the implant applicator.
4. Properly restrain the animal to prevent movement. If necessary, further restrain the head by use of a halter.
5. Inspect the animal's ear. Check for previous implants or abscesses, presence of ear tags or ear tag holes, mud, manure or other debris. Clean and dry the implant area by wiping with a paper towel and disinfectant. Do not attempt to implant through mud or manure.
6. Wipe the needle through the sponge to disinfect it. Pull the tip of the needle across the sponge with the bevel facing down against the sponge to clean out any material inside the needle.
7. Pinch the tip of the animal's ear between the thumb and index finger of the left hand (for the left ear). Place the tip of the applicator needle against the ear at a slight angle, bevel side up or away from the ear, at the outer edge of the implant zone.
8. Slide the needle under the skin of the ear and insert it fully. Make sure it is under the skin and not in the cartilage or punctured all the way through the ear. If the needle skips off the back of the ear, return to step number 5.
9. Slide the needle back out of the ear slightly and pull the trigger to deposit the implant and withdraw the needle completely. (Figure 39.4)

10. Feel the implant site to ensure the pellets were correctly deposited, not bunched up or crushed (Figure 39.5).
11. Return the applicator to the tray and wipe across the sponge to disinfect it.

Other Issues

- Implants have no slaughter withdrawal, as the ear is always removed as offal during the slaughter process.
- No implants are cleared for use in classes of cattle besides calves, stockers and feedlot animals. This includes breeding animals, cull cows, dairy cattle and veal calves.
- Implants should not be administered at birth due to hormonal development of the calf. Label instructions specify a minimum of 30 days or 45 days of age for administration of calf implants, depending on the implant.
- Implants should be stored properly to maintain effectiveness. Store in a clean, dry place in a plastic bag sealed to keep out moisture and debris. Consult the label for storage temperature.
- If possible, implant cattle on dry days when the cattle are dry and free of mud. This will reduce the incidence of abscesses.
- One implant manufacturer offers a line of implant products that include both the anabolic compound pellet and a pellet containing a dose of the antibiotic Tylan™. The purpose of the antibiotic pellet is to dissolve soon after administration and reduce the incidence of implant site abscesses.

Figure 39.4.

Figure 39.5.

Animal Health

Implants are suspected to directly cause, or be associated with, several undesirable changes in animals. Responses normally associated with reproductive processes are observed in heifers, including signs of estrus, vaginal or rectal prolapses, development of the udder and other problems. Implants may increase the incidence of bullers in steers. Bullers are steers that will stand to be mounted similar to the behavior of a cow in estrus. However, it is thought that bulling is caused by a physiological defect in the animal and implants merely exacerbate this condition. Estimates of the frequency of the occurrence of bullers range from 1% to 4%.

References

Barham, B., P. Beck, S. Gadberry, J. Apple, W. Whitworth and M. Miller. (2012) Effect of age entering the feedlot and implant potency on animal performance, carcass quality, and consumer acceptance of beef. *The Professional Animal Scientist* Vol. 28. Pg. 30.

Beck, P. A., T. Hess, D. Hubbell, D. Hufstedler, B. Fieser and J. Caldwell. 2014. Additive effects of growth promoting technologies on performance of grazing steers and economics of the wheat pasture enterprise. *Journal of Animal Science*. Vol. 92. Pg. 1213.

Duckett, S. and F. Owens. (1997) Effects of implants on performance and carcass traits of feedlot steers and heifers. Proceedings: Impact of Implants on Performance and Carcass Value of Beef Cattle. Oklahoma State University, P-957. Pg. 63.

Johnson, R. (2008) Adoption of Recommended Management Practices in Stocker Cattle Production. M.S. Thesis. Oklahoma State University.

Lawrence, J. D. and M. A. Ibarburu. Iowa State University. econ2.econ.iastate.edu/faculty/lawrence/documents/GET7401-LawrencePaper.pdf

Maxwell, C. L., B. C. Bernhard, C. F. O'Neill, B. K. Wilson, C. G. Hixon, C. L. Haviland, A. N. Grimes, M. S. Calvo-Lorenzo, D. L. VanOverbeke, G. G. Mafi, C. J. Richards, D. L. Step, B. P. Holland, C. R. Krehbiel. 2015. The effects of technology use in feedlot production systems on feedlot performance and carcass characteristics, *Journal of Animal Science*, 93(3):1340–1349, https://doi.org/10.2527/jas.2014-8127.

Preston, R. (1997) Rationale for the Safety of Implants. Proceedings: Impact of Implants on Performance and Carcass Value of Beef Cattle. Oklahoma State University, P-957. Pg 199.

Reuter, R. R. and P. A. Beck (2013). Southern Section Interdisciplinary Beef Symposium.: Carryover effects of stocker cattle systems on feedlot performance and carcass characteristics. *Journal of Animal Science*. Vol 91, Pg. 508.

USDA-NAHAS. Survey - Changes in the U.S. Feedlot Industry: 1994-1999 (August 2000) National Animal Health Monitoring System, United States Department of Agriculture.

Williamson, J. A., R. R. Reuter, J. A. Apple, C. B. Stewart, H. C. Gray and P. A. Beck. (2014) Growth promoting implants and nutrient restriction prior to feeding: effect on finishing performance, carcass composition, carcass quality, and consumer acceptability of beef. *The Professional Animal Scientist*. Vol. 30. Pg. 485.

Vestal, M. et. al. (2007) Cow-calf Production Practices in Oklahoma – Part I. OSU Extension Fact Sheet AGEC-245, Oklahoma Cooperative Extension Service, Oklahoma State University,

40 Cattle Handling and Working Facilities Design

Ray Hunke, Bob LeValley and Brian Freking

Objectives

- **Discuss important safety considerations for both humans and cattle.**
- **Identify the proper design, construction and operation of a cattle-handling facility.**

Facility design and effective stockmanship are key considerations in moving cattle efficiently through working chutes and alleyways. Not only is it important to reduce stress and increase the welfare of cattle from a consumer prospective, it is also important to maintain the safety and wellbeing of humans.

The Human Element

For those who work in production agriculture, physical risks are inherent on a daily basis. In fact, agricultural occupations are consistently ranked as some of the most dangerous. A study conducted by researchers in the Department of Biosystems and Agricultural Engineering at OSU described conditions associated with 150 cattle-handling injury cases on 100 Oklahoma cow-calf operations. The study showed more than 50% of injuries in these situations were due to human error, while equipment and facilities accounted for about 25% of the perceived causes. In most cases, a better understanding of how an animal may respond to human interaction and to its immediate surroundings will help keep the worker from becoming an injury victim.

Human error is the primary cause of many types of accidents. These errors in judgment and action are due to a variety of reasons, but occur most often when people are tired, hurried, upset, preoccupied or careless. Remember, the human physical, psychological and physiological factors greatly affect the occurrence of life-threatening accidents. Using this information in combination with proper cattle-handling techniques can reduce the risk of injury.

Animal Behavior

Understanding cattle behavior can help farm and ranch workers avoid dangerous situations. Dr. Temple Grandin, Colorado State University animal behavior specialist, says handling practices can be less stressful to the animals and safer for the handler if one understands the behavioral characteristics of livestock. An animal's physical structure, psychological makeup, environment and individual personalities can influence behavior.

An animal's senses function like those of a human; however, most animals detect and perceive their environments very differently compared to the way humans detect and perceive the same surroundings. While cattle have poor color recognition and poor depth perception, their hearing is extremely sensitive relative to humans. Knowing these characteristics can help to better understand why cattle are often skittish or balky in unfamiliar surroundings.

Animal Vision

Cattle have panoramic vision, meaning they can see in all directions, except directly behind, without moving their head. Additionally, cattle have poor depth perception, especially when they are moving with their heads up. To see depth, they have to stop and put their heads down. For this reason, unfamiliar objects and shadows on the ground are the primary reasons for cattle balking and delaying the animals behind them. This is why handling and working facilities should be constructed to minimize shadows.

Cattle have a tendency to move toward the light. If working cattle at night, use frosted lamps that do not glare in the animals' faces. Position these lights in the area where you are moving cattle, such as a trailer or barn.

Flight Zone

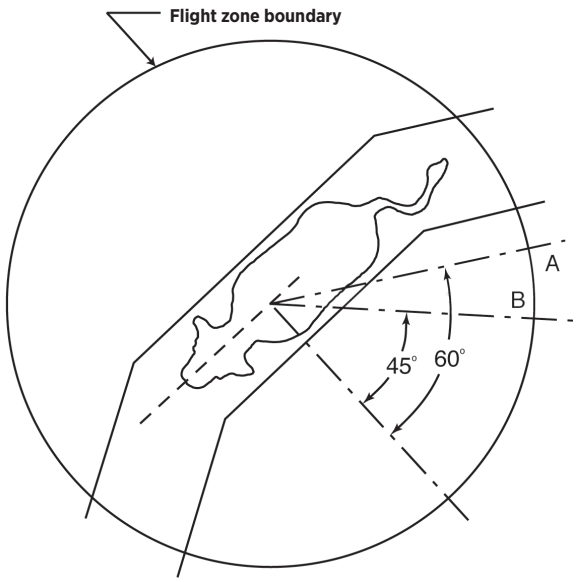
Moving a cattle herd takes some knowledge and understanding of the animals' flight zone. The flight zone is an animal's personal space. When a person penetrates

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

the flight zone, the animal will move, and conversely when a person retreats from the flight zone, the animal will stop moving. Understanding the flight zone is the key to easy, quiet handling of cattle.

The size of an animal's flight zone depends on its fearful or docile behavior, the angle of the handler's approach and the animal's state of excitement. Cattle handlers should work at the edge of the flight zone at a 45- to 60-degree angle behind the animal's shoulder (Figure 40.1). Cattle will circle away from the worker. The flight zone radius can range from 5 feet to more than 25 feet for feedlot cattle, and as far as 300 feet for range cattle. If a person is within the flight zone, the animal moves away or retreats.

When moving cattle, avoid approaching them directly. Try to work them close to the point of balance, moving back and forth on a line parallel to the direction the animal is traveling.



Animal movement **stops** if handler is in position "A." Handler moves to position "B" to start movement.

Figure 40.1. Flight Zone.

Additional Handling Tips

Effective stockmanship has become an important term to the cattle industry, and many ranches are training employees. Effective stockmanship gives consideration to five basic principles of cattle behavior.

1. Cattle want to see you.
2. Cattle want to go around you.
3. Cattle want to be with, and will go to other cattle.
4. Cattle want to remove pressure.
5. Cattle can only have one main thought at a time.

Understanding herd instinct is important. Cattle follow the leader, and are motivated to follow each other. Each animal should be able to see others ahead of it. Make single-file chutes at least 20 feet long; 30 feet to 50 feet for larger facilities. Do not force an animal in a single chute unless it has a place to go. If the cow balks, it will continue balking.

In crowding pens, consider handling cattle in small groups of up to 10 head. The cattle need room to turn. Use their instinctive following behavior to fill the chute. Wait until the single-file chute is almost empty before refilling. A crowding gate is used to follow the cattle, not to shove against them. If a lone animal refuses to move, release it and bring it back with another group. An animal left alone in a crowding pen may become agitated and attempt to jump the fence to rejoin the herd.

Corral Systems Design

Corral and working facilities are constructed to confine cattle safely and efficiently for close observation and to perform routine health and management procedures. Good cattle-handling systems make working livestock easier with limited manpower. The operation of any cattle facility depends on cattle behavior, corral design and the skill and technique of the handler.

Holding and Sorting Cattle

Pens

Pens serve several purposes, including catching and holding cattle being worked, sorting cattle into groups and holding cattle being quarantined. When designing and constructing pens for working facilities, consider the following:

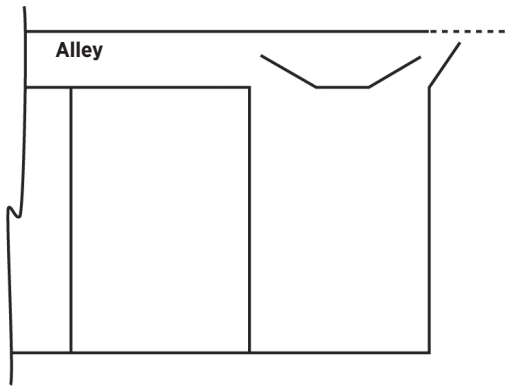
- Provide at least 20 square feet per head for mature cattle.
- Size pens for a maximum of about 50 head of mature cattle.
- Larger, wider pens can make effective sorting difficult for a single worker.
- Pens too small or narrow can result in workers entering the animal's flight zone. The smallest pen dimensions should be no less than 16 feet.
- Too few pens can make separating animals difficult. This also can put workers at risk, as they must physically enter pens with large numbers of agitated animals. Consider adding a 14-inch wide pass-through for worker escape in pen corners.
- Use proper gate placement to facilitate animal movement from pen to pen and to other areas. Poor animal movement puts workers at risk by having to force the movement. If there are too few gates, some animals can become separated. Thus, when animals enter the alley, separated herd mates will follow along the inside of the pen. This is often referred to as backwash. There may be problems guiding these pen-bound animals back to the exit gate as their herd mates move away from them down the alley. Separated animals can become confused or agitated, putting workers at further risk.

Sorting Facilities and Alleyways

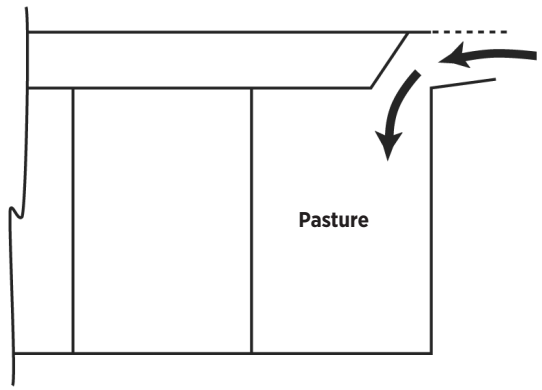
Keep the design of sorting facilities and alleyways simple. They should provide adequate catch pen space to accommodate cattle being moved to and from holding areas.

Several pens are usually preferred rather than one large holding pen. More pens allow larger groups to be sorted into smaller, more manageable sized groups. For most small operations, a single alley is used for sorting as well as moving cattle to and from the working area. Depending on the number of holding pens, an additional return alley may be beneficial. This return alley allows for a continuous flow of cattle from holding to working areas and back to their original pen.

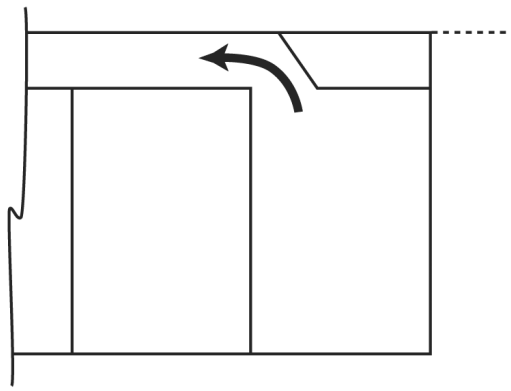
Alley width should be 12 feet to 14 feet with a 10-foot minimum. Wider alleys can make it easier for cattle to escape around you. Alleys that are too narrow fail to give the animals room enough to maneuver. The double-gate system allows the movement of cattle out of holding pens and into the sorting alley with cattle headed in the desired direction (Figure 40.2). This greatly reduces sorting time and prevents animal backwash.



A. All gates partly open.



B. From pasture to holding pen.



C. From holding pen to alley.

Figure 40.2. Double-gate system.

Working Facilities

Crowding Area

The most popular option in the design of a crowding area is the circular tub design. The crowding area should be designed and located so cattle can be easily moved into this area from a common sorting alley that is fed by adjacent holding pens. A circular crowding area with totally enclosed sides and crowding gate is effective because the only escape route visible to the cattle is through where the working or loading chute exits. This facilitates animal flow and worker safety. For safest results in cattle movement and ease of cleaning, use a roughened, broom-finish concrete floor to provide an all-weather surface.

The crowding gate also should be solid and designed to prevent animals from reversing the gate's direction. Do not overload the crowding area. Too many animals make the process more difficult on the handlers because animals can block the chute entrance. Do not enter a crowding area with animals if they become bunched. Release pressure from the gate to allow for some movement to free the bottleneck.

A catwalk around the outside of the crowding pen allows workers to maneuver animals toward the chute, while avoiding direct animal contact. Position the catwalk about 36 inches below the top of the fence.

Another option that works well to maneuver cattle into the working chute is a "Bud Box." The concept is named after its designer, the late Bud Williams. The idea, like curved allies and crowding tubs, is to use the animal's natural instinct on itself. Cattle naturally like to return to larger spaces or, more specifically, use their flight instinct to remove themselves from dangerous situations. This perceived "dangerous" situation is created in working facilities by putting "pressure" on cattle due to confined areas and human interaction.

Figure 40.3 demonstrates the design of the "Bud Box." Cattle are moved into the sorting alley from the adjacent holding pens. They are then simply driven past the working chute into the box and a gate is closed adjacent to the working chute. As cattle slowly turn around to exit the box they easily find the opening to the working chute and enter single file. One major difference between a tub system and the Bud Box system is that the Bud Box requires the handler to be in the small pen with the cattle, whereas in the tub system, the handler does not enter the tub and remains behind the crowding gate. Consequently, successful use of the Bud Box system is especially dependent on not overcrowding the small Bud Box pen. The positioning and movement of the handler also is more critical with the use of the Bud Box system.

Working Chute

The working chute should be curved with totally enclosed sides. Cattle move more freely because they cannot view the handlers or squeeze chute until they approach the palpation cage or rear gate of the squeeze chute.

Sloped sides in the working chute restrict the animal's feet and legs to a narrow path, which reduces balking and

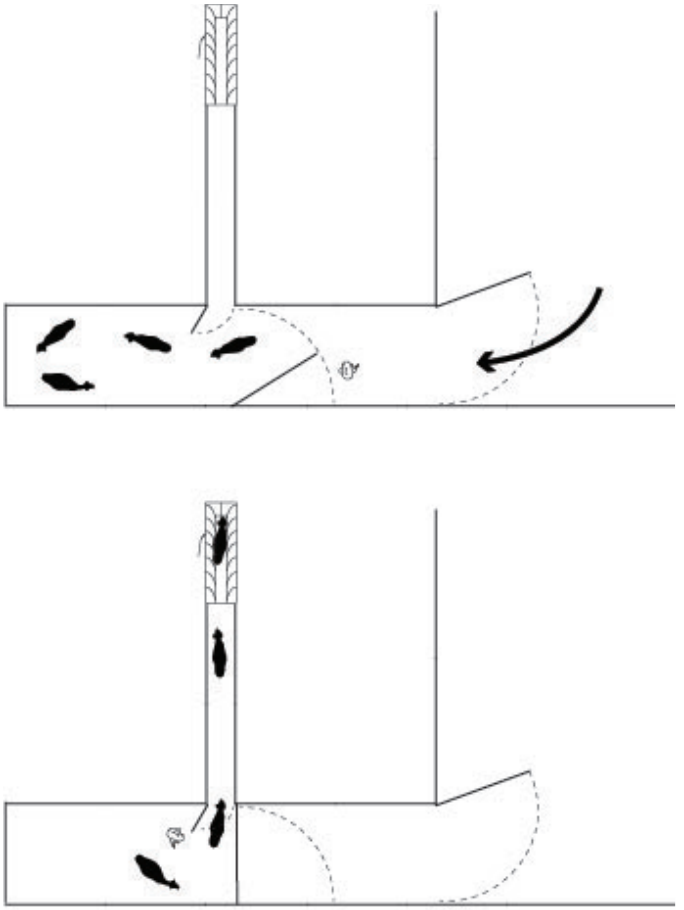


Figure 40.3 The design of the Bud Box. Gates should be the full width of their respective alley.

helps prevent an animal from turning around. Sloping sides work well in most cow-calf operations because different sizes of cattle can be worked efficiently in the same chute.

Recommended width for the bottom of the chute is 16 inches, while the top should be about 28 inches (Table 40.1). For large-framed cattle, the top width dimension for cattle more than 1,200 pounds should be increased 2 inches. To accommodate large-framed bulls, it may be necessary to increase the top width by 4 inches or more.

Another chute type consists of straight sides. Many chutes are designed to have adjustable widths to fit both cows and calves. Straight-sided chutes often have open sides that work extremely well with trained employees. Whether using a curved or straight chute, the handler must leave the flight zone of the animal and walk past the point of balance before re-entering the flight zone to move them forward.

Overhead restrainers prevent cattle from rearing up, turning around or falling backward in the chute. Restrainers are generally located 60 inches above the floor of the chute. Some restrainers can be adjusted to accommodate different cattle heights. Restrainers are more effective if adjusted to keep an animal's head down. Emergency release panels are highly recommended with or without the use of overhead restrainers. Release panels can be constructed as movable crowding chute side panels that can be opened to release animals that have fallen in the chute and become lodged.

Solid side panels on working chutes hamper the use of the traditional scotch pole to prevent cattle from backing up. With solid-sided chutes, backstops are normally suspended or mounted from above. All backstops work on the same principle. The metal tee pipe is hinged, so it releases in the direction of the flow toward the squeeze chute, but will not hinge back beyond vertical in reverse. Most pipe backstops are telescoped so they can be adjusted up or down to accommodate cattle of different heights. Backstops should be adjusted to block an animal 6 inches to 8 inches below the top of the tailhead. Backstops are normally held in a vertical position using chains or rubber bumpers. Bumpers have the advantage of holding down the noise when the stop falls back into position. A noisy stop can cause cattle to balk.

Inserting pipes through the sides to the working chute to prevent animals from backing up can be hazardous to workers. If backstops are not installed, and pipes must be used, be sure the pipe is between the cattle and worker. If not, a worker can be caught between the pipe and the chute or fence if the person is not properly positioned and the animal backs up before the pipe is extended through the chute. Also, avoid standing on the fence or rails or extending arms and hands between or over fencing.

Table 40.1. Working chute dimensions.

	Animal size		
Type of working chute	*To 600 pounds*	*600 to 1,200 pounds*	*More than 1,200 pounds*
Vertical sides			
Width	18 inches	20 to 24 inches	26 to 30 inches
Length (minimum)	20 feet	20 feet	20 feet
Sloping sides			
Width at bottom, inside clear	13 inches	15 inches	16 inches
Width at top, inside clear	20 inches	24 inches	28 inches
Length (minimum)	20 feet	20 feet	20 feet
Fence			
Height (minimum)	45 inches	50 inches	60 inches
Depth of posts in ground (minimum)	30 inches	30 inches	30 inches

Squeeze Chute

Squeeze chutes are used extensively throughout Oklahoma. All chutes, whether manual or hydraulic, consist of the same basic components: headgate, squeeze section, tailgate and, most importantly, a side escape to allow animals to be removed quickly if they are in distress. At times, cattle tend to kneel or lay down in a chute, which can cause the animal to choke. Many newer chutes include a breast bar that prevents cattle from laying down. Some chutes also include a neck extender to restrain the head for animal and operator safety. Another useful option is a scale under the chute. This allows for proper dosage when administering antibiotics and wormers when measuring performance and weight gain.

Whether using a manual or hydraulic chute, it must be well maintained. Lubricating chute components, inspecting and replacing any worn or broken parts, plus regular cleaning will help prevent the spread of diseases and maintain animal footing. Make sure workers are familiar with possible pinch points on the chute. It is important to be aware of the positioning of handles that open and close the headgate, sides and tailgate in case quick action is needed to remove an animal. Also, inspect the rope in rope-and-pulley devices and replace it if there are any signs of fraying. Finally, avoid contact with animals if they are not properly restrained. If an animal is not properly caught and restrained by the squeeze chute, release the animal and bring it through the chute again. Never attempt to keep the animal from flailing or try to push it into proper position.

Conclusion

The proper design, construction and operation of a cattle-handling facility is important to ensure safe working conditions for animals and humans. Understanding the inherent behavior of cattle, plus working them slowly and quietly, will reduce injuries and help make the operation run more smoothly and efficiently.

References

Apple, K., R.L. Huhnke and S.L. Harp (1995) Modern Corral Design. OSU Extension Circular E-938, Cooperative Extension Service, Oklahoma State University.

Borg, R. (1993) Corrals for Handling Beef Cattle. Alberta Agriculture, Food and Rural Development, Edmonton, Alberta, Canada.

Grandin, T. (1989) Behavioral Principles of Livestock Handling. *The Professional Animal Scientist*, 5(2).

Huhnke, R.L., D.J. Hubert and S.L. Harp (1997) Identifying Injuries Sustained on Cow-Calf Operations in Oklahoma. ASAE 975010. American Society of Agricultural Engineers, St. Joseph, MI.

National Cattlemen's Beef Association. Beef Quality Assurance Cattle Care and Handling Guidelines. (2015) Denver , Colorado.

41 Waste Management

Douglas W. Hamilton

Objectives

- **Discuss beneficial elements available in cattle manure.**
- **Learn how solids content affects the handling characteristics of manure.**
- **Learn how stockpiled feedlot manure can be used as fertilizer.**
- **Learn how to capture fertilizer from grazing beef cattle.**
- **Determine if a cattle operation is subject to environmental regulations.**

Manure

Food and nutrients must move through an animal's digestive tract for proper digestion to take place. When the digested material leaves the animal's body, it becomes manure. By definition, manure is a mixture of feces, urine, bedding material and added water. Feces are the semi-solid materials that exit the digestive system through the large intestine and anus. Urine is a liquid solution of waste products cleaned from the blood stream by the kidneys that exits the animal by way of the bladder and urethra.

Manure Constituents

Manure is made up of water, living and dead microorganisms, undigested food, plant nutrients, and salt. The daily production of selected manure constituents per 1,000 pounds of cattle live weight is given in Table 41.1. Definitions are given in Table 41.2. The values for confined cattle were developed using a mass balance of digestible nutrients fed, retained and excreted in a feedlot setting. The values for grazing cattle were derived experimentally in England using two sets of nearly mature (1,100 pounds to 1,250 pounds), two-year old Holstein-Simmental cross heifers and steers. Grazing intensity was determined by measuring grass height through the grazing period and limiting grazing intensity to maintain the ecological diversity of pastures. Although the study took place in a much more humid climate, the grazing intensities shown in Table 41.2 are similar to range grazing in Oklahoma.

Table 41.3 gives the distribution of plant nutrients between feces and urine. Generally speaking, the more-mobile plant nutrients (nitrogen and potassium) are found in urine and the less-mobile nutrients (phosphorus and calcium) are found in feces. A good amount of nitrogen also is found in feces, tied up as protein in microbial biomass and undigested feed. Thinking about manure as equivalent fertilizer: feces are a slow-release nitrogen and phosphorus

Table 41.1. Manure excreted per 1,000 pounds liveweight (1 AU)[1] of beef cattle.

	Confined cattle[2]		*Grazing cattle[3]*	
Manure Constituent	*Non-lactating cow*	*Growing calf 450 lbs to 750 lbs*	*Two-year-old heifers and steers moderate grazing*	*Two-year-old heifers and steers light grazing*
Weight (lbs AU^{-1} day^{-1})	104	77	51	37
Volume (ft^3 AU^{-1} day^{-1})	1.7	1.2	-	-
Fecal Total Solids Content (% wet basis)	12	12	12	12.5
Total Solids (lbs AU^{-1} day^{-1})	13	9.2	4.9	4.6
Volatile Solids (lbs AU^{-1} day^{-1})	11	7.7	-	-
N (lbs AU^{-1} day^{-1})	0.35	0.45	0.21	0.14
P (lbs AU^{-1} day^{-1})	0.08	0.08	0.02	0.015
K (lbs AU^{-1} day^{-1})	0.25	0.29	-	-
Ca (lbs AU^{-1} day^{-1})	0.16	0.135	-	-

1 1,000 pounds liveweight = 1 Animal Unit (AU)
2 ASABE, 2019 and USDA-NRCS, 2008
3 Orr et al, 2010

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 41.2. Definition of terms.

Manure	The combination of feces, urine, bedding and added water collected from a poultry or livestock confinement area.
Feces	The solid or semi-solid materials exiting an animal's digestive system through the large intestine and anus.
Urine	The liquid solution of waste products cleaned from the blood stream by the kidneys that exits the animal by way of the bladder and urethra.
Weight	Mass of manure excreted.
Volume	Space taken up by excreted manure.
Total Solids	Sometimes written as TS, total solids are measured by measuring the wet mass of manure, weighing again after the manure has been dried for 24 hours at 215 F, and dividing the dry mass by the wet mass. Total solids can be suspended (floating particle) dissolved (salts), volatile (organic) or fixed (ash).
Volatile Solids	Sometimes written as VS, volatile solids are the portion of total solids that ignite when heated to 1,022 F. VS content is a rough measure of the organic matter content of manure.
Plant Nutrients	The major plant nutrients (sometimes called macronutrients) are nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S) and magnesium (Mg). Macronutrients are elements needed in relatively large quantities for plant growth. Micronutrients include boron (B), chlorine (Cl), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), molybdenum (Mo) and cobalt (Co). Small quantities of micronutrients are needed to regulate plant growth. Some micronutrients can be harmful to plants and animals in large doses.

Table 41.3 Distribution of plant nutrients between feces and urine.

	Feces	*Urine*
Source material	*Intestinal bacteria and undigested feed*	*Waste products cleaned from the blood stream by kidneys*
Fertilizer Analogy	Slow release N-P-Ca fertilizer	Liquid urea-potash fertilizer
Distribution of nitrogen	30%	70%
Distribution of phosphorus	100%	0%
Distribution of potassium	10%	90%
Distribution of calcium	95%	5%

fertilizer with some liming capacity; urine is liquid urea-potash fertilizer.

Environmental Effect of Manure

Manure constituents can be either good or bad depending on how they end up in the environment. Fecal bacteria can render water undrinkable and unswimmable. Organic matter (represented by VS in Tables 41.1 and 41.2) adds tilth and moisture-holding capacity to the soil. But if it ends up in streams and ponds, organic matter is a strong pollutant. Microorganisms living in water eat organic matter, grow and remove dissolved oxygen fish need to live in the water. Plant nutrients (N, P, K) help crops to grow, but if the same nutrients run off into water, they can cause aquatic plants and algae to grow, which also removes oxygen dissolved in the water.

Manure Consistency

Consistency defines the physical properties of manure. Unfrozen manure can exist as liquid, slurry, semi-solid or solid depending on the concentration and shape of manure particles (Figure 41.1). The main difference between liquids and slurries is that slurries contain suspended particles. Semi-solids can act as either a liquid or a solid, depending on how much pressure is applied. Most of the time, semi-solid manure acts like a solid. It stacks and can be moved with a shovel. But, stepping on a fresh cow pie might cause it to squirt like a liquid.

Figure 41.2 shows how consistency relates to solids content for swine, poultry and cattle manure. Notice that this figure does not have bars for liquids. This is because manure, being a mixture of feces and urine, always contains solid particles associated with the feces. The dotted line in the figure gives the solids content and consistency at which feces are excreted. Cattle manure is excreted at around 12% total solids. In this concentration range, cattle feces are a semi-solid (cow patties usually stack up in the pasture). Care must be taken, because changing an animal's diet may change the consistency of its manure. Changing cattle from a high-forage to a high-grain diet usually makes their manure more liquid. Another thing to remember is the 'as excreted' line in Figure 41.2 only shows consistency as the feces are excreted. Adding bedding absorbs urine and increases the solids concentration of feces. This makes manure more solid and easier to handle with shovels, bucket loaders and conveyers. Adding water makes manure more liquid, which makes it easier to transport in channels and pipelines.

Using Feedlot Manure as Fertilizer

Manure that has been laying in a feedlot, or stored in a stockpile is not the same as excreted manure. After lying exposed, wetting and drying, freezing and thawing, feedlot manure loses most of the nutrients it had when

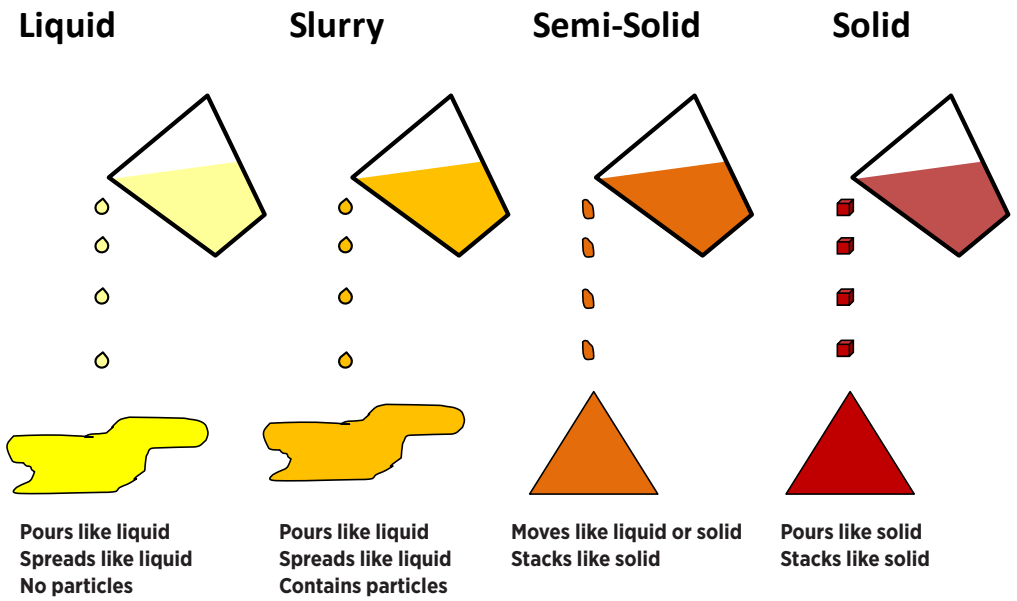


Figure 41.1. Consistency of manure.

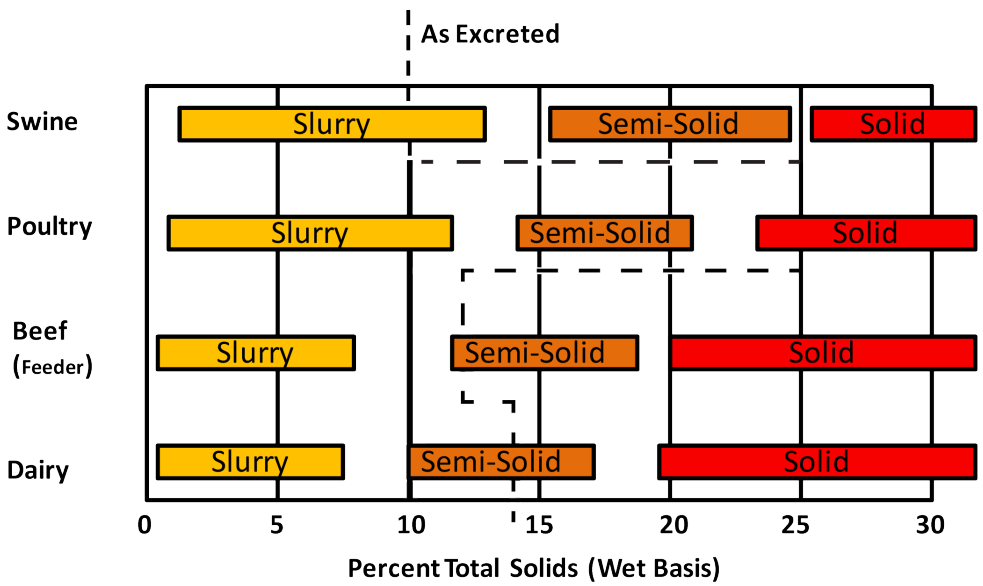


Figure 41.2. Relationship between manure solids content and consistency. Source: USDA-NRCS.

it was excreted. That does not mean feedlot manure is bad fertilizer, however. Some typical fertilizer values of stockpiled feedlot manure analyzed by the OSU Soil, Water and Forage Analytical Laboratory are given in Table 41.4. Overall, feedlot manure is similar to a 1-1-1 fertilizer. Also, it provides organic matter to the soil and has some liming value. To capture the most benefit from land application, follow these steps:

1. Take a representative sample of the manure and have it analyzed for plant nutrients (see OSU Extension fact sheet PSS 4288, *Sampling Animal Manure*).

Table 41.4. Fertilizer value of typical feedlot manure in Oklahoma on an "as is" basis (from PSS-2250, Using Stockpiled Feedlot Manure as Fertilizer).

	Percent Composition (%)	*Average Concentration on a Mass Basis (lb/ton)*
Total Solids	20 to 55	-
Total N	1.7 to 2.4	24
Organic N	1.3 to 1.9	20
Phosphate (P_2O_5)	1.5 to 2.1	21
Potash (K_2O)	1.7 to 2.3	25

2. Multiply the fertilizer value by the availability factors in Table 41.5 to determine the long-term plant-available fertilizer value of the manure.
3. Take a representative sample of the soil in the field you want to spread manure (See OSU Extension fact sheet PSS 2207, *How To Get A Good Soil Sample*).
4. Calculate manure application rate using the plant available nutrients in the manure and the most limiting nutrient (usually, but not always phosphorus) in the soil test recommendation for the yield goal and the crop to be grown.
5. Use commercial fertilizer to supplement manure nutrients.

To read about land application of feedlot manure in greater detail, consult OSU Extension fact sheet PSS-2250, *Using Stockpiled Feedlot Manure as Fertilizer*. It is always best to test manure before applying. But, if you have a rough idea of the tons of manure to spread, you can use the typical values of Table 41.5 to estimate nutrients available, combined with soil testing and yield estimates to determine land needed to spread.

Table 41.5 Long term availability of manure fertilizer elements after application.

Nutrient	*Amount of nutrient available for plant growth over several growing seasons (%)*
Nitrogen (N)	70
Phosphorus (P)	80
Potassium (K)	80
Calcium (Ca)	80

Nutrient Recycling in Grazing Systems

Grazing beef cows, calves and stockers are under-appreciated fertilizer dispensers. Plant nutrients are directly deposited on pasture free of charge. The long-term plant availability values given in Table 41.5 apply to the "as excreted" manure. In addition, half of manure nitrogen is available in the first year after deposit.

One big difference between spreading stockpiled manure and manure spread by grazing is, with grazing, feces and urine are applied separately. Although cattle generally defecate and urinate shortly after one another, the nutrients are applied in separate locations. So, cattle deposit aqueous urea fertilizer in one spot, and slow-release organic nitrogen in another. Stocking rate has a large impact on nutrient distribution. With light stocking density, cattle tend to concentrate nutrients in shady areas, near water and near feeders. Also, cattle tend to not eat grass near a fresh (or even an old) cow pie. By skipping spots covered with feces and eating grass where cow pies are less common, cattle move nutrients away from heavily grazed areas and deposit it in heavily manured areas, reducing overall pasture fertility.

Distribution of plant nutrients by cattle is maximized under rotational grazing with stocking density matched to forage growth. It is also a good idea to drag pastures with a chain harrow after rotating cattle through a paddock. Dragging distributes fecal nutrients and reduces selective grazing. Dragging also helps to control parasites and distributes perennial seeds throughout the pasture.

Since most of the nutrients deposited by cattle stay on the pasture, grazing is a good way to maintain fertility in already fertile fields. Once a field has reached an adequate soil test phosphorus index, grazing maintains the phosphorus fertility of the soil almost indefinitely. You cannot expect grazing to increase the fertility level of a poorly fertilized field, however. Without supplemental fertilization, forage production tends to follow stocking rate. If the soil cannot grow much forage, cattle do not eat much forage. If cattle do not eat much forage, they do not deposit much fertilizer. If other factors for forage growth (deep soil, adequate moisture, adequate organic matter) are sufficient, adding supplemental fertilizer to a pasture for a few years can boost forage production. Afterwards, grazing maintains the soil fertility level and reduces the need for supplemental fertilizer.

The values of Table 41.1 should be used as a starting point to manage soil and forage resources. Use soil and forage testing to constantly monitor a field's condition and adjust stocking density and fertilizer application rates to maximize production while taking advantage of the free nutrients cattle are applying to the pasture.

Regulations Covering Use of Manure in Grazing Systems

In most situations, cattle managed in pasture systems will not fall under state or federal environmental regulations. Use good pasture and soil fertility management, and limit cattle access to streams to control water pollution. There are three cases, however, under which a permit may be required:

1. The operation has more than 1,000 head of cattle and the animals are confined in an area without growing vegetation for more than 45 days in a 12-month period.
2. The operation has more than 300 head of cattle, the animals are confined in an area without growing vegetation for more than 45 days in a 12-month period and a stream or other liquid conveyance drains the confinement area.
3. An agent of the federal or state regulatory agency has inspected the operation and determined that it is causing water quality degradation.

If an operation falls under any of these conditions, contact the Oklahoma Department of Agriculture, Food and Forestry - Division of Agricultural Environmental Management.

References

ASABE Standards. (2019) *Manure Production and Characteristics*. D384.2. St. Joseph, MI: American Society of Agricultural and Biological Engineers.

Hamilton, D.W. (2011a) What is a Waste Management System?, OSU Extension Fact Sheet BAE-1734. Stillwater, OK: Oklahoma Cooperative Extension Service.

Hamilton, D.W. (2001b) Consistency of Manure/Liquid Mixtures, OSU Extension fact sheet BAE-1751. Stillwater, OK: Oklahoma Cooperative Extension Service.

Orr, R. J., B. A. Griffith, J. E. Cook and R. A. Champion, (2011) Ingestion and excretion of nitrogen and phosphorus by beef cattle under contrasting grazing intensities. *Grass and Forage Science*, 67,111-118.

Silvera, M. L., J. M. B. Vendramini, H. M. da Silva and M. Azenha. (2019) Nutrient Cycling in Grazed Pastures, SL376. Gainesville, FL: IFAS Extension.

USDA-NRCS. (2008) *Agricultural Waste Management Field Handbook.* Washington, DC: United States Department of Agriculture, Natural Resources Conservation Service.

Woolsey, C. (2016) Dragging pastures: are the benefits worth the cost? Progressive Forage. Jerome, ID: Progressive Publishing.

Zhang, H. and D.W. Hamilton (1998) Using Stockpiled Feedlot Manure as Fertilizer. OSU Extension Fact Sheet PSS-2250. Stillwater, OK: Oklahoma Cooperative Extension Service.

Websites with Regulation Information

U.S. EPA, Division of Water Pollution Control (Washington, DC).

U.S. EPA, National Agricultural Compliance Assistance Center (Kansas City, MO) epa.gov/agriculture/

U.S. EPA, Region 6 (Dallas, TX) epa.gov/region6/

Oklahoma Department of Agriculture, Food and Forestry – Division of Agricultural Environmental Management (OKC, OK) ag.ok.gov

42 Biosecurity

Barry Whitworth, DVM and Rosslyn Biggs, DVM

Objectives

- **Discuss the importance of biosecurity.**
- **Provide an example of a biosecurity program.**

What is Biosecurity?

Biosecurity is the development and implementation of management procedures to reduce or prevent unwanted diseases from entering the herd population, as well as limit or prevent the spread of disease within the farming operation. These threats can be considered potentially harmful to the health and well-being of the herd. Obvious threats for most, if not all, operations include viral, bacterial, protozoan and rickettsial infectious diseases. Genetic disorders, toxins and parasites also can be hazards.

To develop a biosecurity program or protocol, the producer, along with their veterinarian, must evaluate the risk factors for the entities considered. To understand risks, the specific operation or business goals must be clearly outlined.

Producers must decide the level of risk they are willing to accept in their herd. When estimating the potential impact of a disease or problem on a unit, consider the level of risk and the economic consequences of that potential problem. It is obvious that unit biosecurity levels will differ with marketing strategies. The commercial cow-calf producer who retains ownership through slaughter will not have the same concerns as the seedstock operator or the person marketing in international trade channels. The input from a qualified veterinarian as a component of the development and implementation of a herd health and biosecurity program cannot be overemphasized. Farmers and ranchers can practice many levels of biosecurity on their farms (Table 42.1).

Management and caregivers can easily become overwhelmed with detailed biosecurity protocols; therefore, it is recommended to begin with a simple approach when developing and implementing biosecurity programs. The protocols should be adjusted as needed, as certain threats are eliminated and new ones appear. Biosecurity plans should be reviewed as needed and at a minimum once each year.

Table 42.1. Levels of biosecurity.

1. Closed herd [specific pathogen free (SPF)].
2. No entry or reentry of animals.
3. No entry of new animals, but reentry allowed.
4. Entry of new animals, known medical records and isolation.
5. Entry of new animals, known medical records and no isolation.
6. Entry of new animals, no medical records and no isolation.

Source: Thompson.

Biosecurity considerations developed on the farm by producers and their veterinarians will be discussed in this chapter. Federal and State biosecurity protocols have been developed by USDA-Animal and Plant Health Inspection Service-Veterinary Services (USDA-APHIS-VS) and State Animal Health Officials. Veterinarians at the Federal and State levels support personnel across the nation who provide constant vigilance to protect and improve the health, well-being, quality and marketability of our nation's animals, animal products and veterinary biologics. Biosecurity at the herd level depends on the individual producer and their veterinarian to design strategies to prevent entry of costly diseases.

The Significance of Biosecurity

Farmers and ranchers frequently ask, "Why should I have a biosecurity protocol for my specific operation?" One of the primary reasons to follow a sound protocol is for the overall well-being of the animals under their care. By addressing the well-being of the cattle, the animals have the potential to perform up to their genetic potential and produce the best return to the farmer or rancher.

The effects of the introduction of unwanted disease into a herd can include:

- Reduced reproductive efficiency by affecting pregnancy rates and causing early embryonic deaths, abortions, stillborns, congenital defects and birth of weak calves.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

- Decreased production from reduced weaning weights, daily gain and feed efficiency and days off feed due to illness.
- Animals born persistently infected with a disease that serves as a source of infection to other susceptible animals.
- Increased death rates.
- Reduced marketing options.

With increased scientific information available on the pathogenesis, transmission and diagnosis of diseases such as BVDV, Johne's Disease and others, the liability associated with selling infected animals will likely increase. A slaughter-only option to a seedstock producer can be devastating. Similarly, as other countries embark on programs to control or eliminate specific pathogens, these issues may become the focus of future trade negotiations. With the stakes so high, biosecurity should be a priority in day-to-day management decisions of cattle operations.

The APHIS Area Veterinarian in Charge (AVIC) and State Veterinarian serve as reliable information sources for producers needing advice concerning diseases that limit access to intrastate, interstate and international trade markets.

Threats

Frequently, animal health care professionals initially focus on common infectious diseases caused by viruses, bacteria and protozoa. Farmers and ranchers also must realize biosecurity also involves genetic, toxic and parasitic agents of disease. Before a biosecurity protocol can be appropriately developed, the status of the herd or population must be determined. Review of production records and interpretation of appropriate diagnostic tests must occur to assess the herd status. In many situations, genetic and parasitic problems may be present without presenting obvious clinical signs in the cattle to the farmer or rancher. Toxins or infectious agents can also be present in a subclinical state and go unrecognized.

Veterinarians and producers must develop a program or protocol to address both clinical and subclinical disease. They must decide whether to make efforts to eliminate or contain the disease in their herd. Biocontainment is a plan or program for controlling a problem or problems already present in a herd or population. Typically, biocontainment protocols initially focus on reducing the problem to minimal levels. Elimination or eradication may be the next logical phase of the protocol.

Threats for the health and well-being of the individuals and the herd, addressing issues for consideration and management, and prevention strategies are classified in Table 42.2.

If a problem is diagnosed within the herd, decisions must be made regarding the response. Should the producer and veterinarian be focused on control or containment, reduction of problem to acceptable levels, or elimination or eradication of the problem? Decisions must address the management and movement of animals, people, vehicles, equipment and nutrition sources. Health practices should be reviewed. The focus should be on planning, education and accurate recordkeeping.

Often, only the replacement animal is considered. Special biosecurity issues will differ with the age, sex and reproductive status such as open; pregnant whether through natural pregnancy, artificial insemination or embryo recipient; or nursing. Also, to be considered as herd additions are semen and embryos, which require the same origin scrutiny as a live animal.

In reviewing sources of potential threats to biosecurity, all aspects of the farming operation should be considered.

Commodity feeds – Quality control in commodity feeds includes analysis for incoming ingredients and using select suppliers that have quality control programs in place and who stand behind their products. Some ingredients are naturally more perishable than other feed ingredients. Most incoming feed ingredients should be evaluated for moisture, color, odor, texture, presence of foreign material, heat damage, mold or other spoilage. Presence of any suspected problems requires further testing. Feed concentrates that include corn, barley, cottonseed, canola, soybeans, etc. can be sources of *Salmonella* spp. Keeping a sample of suspected feedstuffs for later testing in a cool but not frozen state is a good practice. Feed fats should be analyzed for moisture, free fatty acid content, rancidity and impurities, or should be purchased from a source that guarantees the analysis of their products. Ruminant-derived animal protein feeds are prohibited for use in cattle feed under current federal law.

Feed storage, processing and handling – Harvesting and storing feeds at the correct moisture level will help prevent contamination by molds, mycotoxins and pathogenic bacteria and improves feed efficiency. Forages, corn silage, alfalfa, hay, etc. can serve as sources of *Salmonella* spp. when irrigated with contaminated water. Improper harvesting and storage can lead to clostridial infections. Equipment used for loading feed should be routinely inspected for leaks in the hydraulics or other fluids. These fluids can be toxic if ingested and pose a residue threat. Clean tractors and equipment routinely. When equipment is used for other nonfeed purposes, such as a front-end loader for manure handling, clean and disinfect it again before using it for feeding purposes. Never store crop chemicals, petroleum products or other potentially hazardous material in areas near where feed is stored, mixed or processed.

Other Sources of Potential Threats

Water sources can be a source of *Salmonella* spp., *E. coli* or *Cryptosporidium* infections. Water also can present exposure to unacceptable levels of pesticides, herbicides and sulfur.

Herd members can be exposed via fence line contact and participation at shows and fairs.

Wildlife can be a source of parasitic and infectious diseases.

Ticks, other blood-sucking insects and contaminated needles and surgical instruments can be significant in the transfer of *Anaplasma marginale*, the anaplasmosis-causing organism, as well as other blood-borne diseases.

Table 42.2. Management and prevention strategies.

Potential threat	*Things to consider*	*Prevention options*
Genetic	calving ease/ dystocia reproductive exams on heifers calving watch nutrition for dam	select sires
	congenital abnormalities recognize abnormalities consult DVM and diagnostic labs for diagnosis prevent exposure to toxins and infectious disease	know genetics
	Heritable conditions identify diseases that are inherited in your breed	know genetics
Toxins	feedstuffs pasture and range plants water sources environment contamination chemicals pesticides herbicides petroleum products fertilizers	observe cattle behavior in drylot and pasture secure storage of feedstuffs identify potential toxic plants follow correct and appropriate application protocols testing of water and feed know run-off patterns know various water sources
External Parasites		
	lice flies ticks grubs	understand life cycles of parasitic agents follow recommended insecticide/parasiticide application rules
Internal Parasites		
	coccidiosis cryptosporidiosis anaplasmosis babesiosis stomach and intestinal(gut) worms liver flukes lungworms	effective pasture and lot management to control re-infection strategic deworming; test and treat as recommended by your veterinarian consider risk of contamination of re-used needles and non-sterilized surgical equipment (vaccination, dehorning, castration, calving chains and equipment) understand life cycles of parasitic agents utilize insect, bird and wild animal control programs as appropriate to disease
Pathogens or Infectious		know origin of herd for herd additions
VIRAL	bovine viral diarrhea (BVDV) blue tongue virus (BTV) infectious bovine rhinotracheitis (IBRV) bovine leukosis virus (BLV) vesicular stomatitis virus (VSV) rabies foreign animal disease (FAD)	utilize laboratory sampling and necropsy to confirm diagnosis increase level of immunity (good nutrition, etc.) and vaccinate as advised isolate new additions sanitation manage disposal of dead stock to prevent reinfection and contamination isolate sick or infected animals monitor animals to diagnose disease early and begin appropriate treatment Identify areas of pathogen build up: calving areas, hospital pens, common chute and processing areas consider risk of contamination of re-used needles and non-sterilized surgical equipment (vaccination, dehorning, castration, calving chains and equipment)
Bacterial		
	brucellosis/bangs *Brucella abortus* Johne's Disease *Mycobacterium avium* sub spp. *Paratuberculosis* TB *Mycobacterium bovis* salmonella pinkeye *Moraxella bovis*	General prevention considerations: Test core herd and new arrivals and make decisions regarding culling or treatment; utilize insect, bird and wild animal control programs as appropriate to disease; consider use of commercial colostrum to reduce spread of certain diseases from cow to calf; follow recommended sanitation procedures to limit spread and cross contamination.

(cont'd)

Table 42.2. Management and prevention strategies. (cont'd)

E. Coli blackleg leptospirosis vibriosis trichomonas Manheimia hemolytica Pasteurella multocida Histpophilus somnus	
Protozoal coccidiosis *Eimeria* spp. cryptosporidum toxoplasma	
Rickettsial *Anaplamsa marginale* Anaplasmosis prions BSE Bovine Spongiform Encephalopathy scrapie (sheep)	
Violative Residues administration of medications contaminated feedstuffs	Follow label directions or veterinary instructions about prescription feed, water, injectable, oral, topical see notes in the section What are Threats? on commodity feeds and storage and processing

Transport vehicles for livestock, feed, rendering trucks, etc. including buckets and tires can spread diseases.

Human visitors and workers, including employees, family members, feed and delivery personnel, Extension educators, livestock haulers, nutritionists, sales representatives, renderers, veterinarians, processing crews and visitors all can be both a source of threats and a means to spread threats.

Farm pets and stray dogs infected with *Neospora caninum* in feces can serve as a source of this parasitic organism. When cattle consume feedstuffs contaminated with infected dog feces, abortions may occur. In addition, dogs and cats can be a source of rabies.

Communication

- Review clinical signs of animal diseases, Discuss and train all caregivers and managers in disease basics.
- Contact a private veterinarian, Extension educator, state department of agriculture, federal officials or local industry organizations for updates on situations, information or actions needed. Maintain current list of contact information.

Physical Security

- Post signs outlining security procedures in place at the operation.
- Ensure all gates are locked and secured.
- If possible, move animals away from pastures located along major roads and away from areas where they cannot be adequately monitored.
- Do not leave trucks or vehicles loaded with livestock or feed unattended at truck stops.
- Do not allow visitors or unknown persons onto the property.
- Post signs at the entrances to your operation indicating the operation is under increased surveillance and no visitors can enter without permission.

Biosecurity

- Consider canceling participation in shows, fairs and exhibits at times of high risk.
- If visiting farms is a must, wear disposable boots or rubber boots that can be disinfected or disposed.
- Avoid livestock and poultry for at least 10 days to 30 days after visiting premises with sick livestock or poultry or after returning from a foreign country.
- Wash clothing and footwear using an APHIS-approved disinfectant after contact with sick livestock or poultry.
- Clean nostrils and fingernails and wash hair and bathe thoroughly after contact with sick livestock or poultry.
- After visiting foreign farms, dispose of clothing, shoes, equipment, cameras and other items difficult or impossible to disinfect.
- Use shower-in and shower-out facilities following visits to foreign countries, if possible.
- Account for the recent movements and health history of all newly introduced animals at their premises of origin through accurate recordkeeping.
- Account for the recent history of potentially contaminated equipment and animal transport vehicles, including renderers' trucks that may be used to haul carcasses away from the premises.
- Purchase feed only from suppliers who have a quality assurance program for the safe manufacturing, storage and delivery of their products.

- Prevent feed and water from coming into contact with animal waste or other potentially contaminated animal, chemical or physical products.
- If water contamination is suspected, test it and establish its safety before giving it to animals.
- Control all movement of people, vehicles and equipment on and off property to reduce the risk of disease transmission. This may include measures such as locking unguarded entrances, repairing boundary fences and enforcing strict biosecurity measures for people, vehicles and equipment at all times.
- Do not contaminate personal, clothing or equipment at foreign fairs, zoos or other livestock or poultry events.
- Do not wear items such as jewelry, watches or hairpieces when working around animals, since these items cannot be successfully disinfected.
- Do not bring any meat or animal products from foreign countries onto property. Do not bring equipment onto property that has been used around foreign or sick livestock or poultry.
- Do not use feed equipment to handle manure.
- Sanitation procedures to consider are prevention of cross contamination of water, feed, buckets, cleaning brushes, manure, bedding, feeding and mixing equipment, clothing and boots.

Monitor

- Increase the number of times per day that livestock are observed.
- Report sick animals or unexpected death losses to the veterinarian.
- Watch for and report any observations of sick or dead birds, fish or insects.
- Monitor feed and chemical storage areas for tampering or unauthorized entrance.
- Watch for unusual packages or containers, especially those found in unlikely or sensitive areas.
- Verify the source of all incoming animals, feed, supplements, equipment and individuals prior to moving them into the animal area.
- Scrutinize the actions of personnel on the farm, the entry of unnecessary personnel and deviations from normal operations.

Prepare

- Conduct an operation vulnerability assessment by looking at the operation, determining possible areas of vulnerability and correcting them.
- Practice MBWA—management by walking around.
- Review reporting systems and phone numbers in case of a possible foreign animal disease or other emergency. These numbers should include those of the State Veterinarian, Federal Area Veterinarian in Charge, local law enforcement and USDA Veterinary Services.
- Prepare contingency plans in case of attack, quarantines or stop movement requirements.
- Ensure at least one week's worth of feed and water is on hand in the event animals are quarantined.
- Minimize the addition of animals to the operation.

Elements of a Good Biosecurity Plan

For many operations, biosecurity protocols are usual everyday practices that just simply need to be put down on paper and reevaluated as necessary. The first step to developing a biosecurity plan involves identifying a biosecurity manager and consulting with the herd veterinarian. Plans should be in writing and address both the structural components of the farm or ranch along with operational practices. A good biosecurity plan includes:

- designated biosecurity manager,
- description of operation scope,
- map of operation,
- personnel training ,
- personnel and visitor practices,
- physical protective measures such as a line of separation and designated parking areas,
- movement of vehicles and other equipment,
- feed, hay and water,
- movement of animals,
- herd health protocols,
- semen and embryo movement,
- carcass disposal,
- waste management and
- wildlife and pest management.

Conclusion

Biosecurity is an important issue for producers and veterinarians. This chapter provides a resource for what to do initially in the event of a biosecurity hazard.

Biosecurity is a term used to describe programs for preventing the introduction of threats considered potentially harmful to the health and well-being of the herd. Biosecurity goals occur at the national, state and herd level to protect animal and human health and economic well-being of the citizens at an individual and national level.

Biosecurity areas of importance include herd replacements, fence line contact animals, embryos, recipient cows, semen, feedstuffs, water, livestock shows, livestock auctions, wildlife populations, rodents, pets, insects, vehicles and humans. Replacement animal programs include pre-shipment herd of origin information, pre-shipment testing, isolation, post-shipment testing and commingled herd monitoring.

Effects of introduced diseases in a beef cow-calf operation are:

- decreased reproduction efficiency,
- decreased productivity,
- increased morbidity (illness),
- increased mortality (death),
- decreased cash flow and equity and
- loss of marketing options - international, interstate and intrastate - between farms and ranches.

Biosecurity levels range from a closed herd to free entry with no pre-entry testing, no herd of origin medical records or

no quarantine/isolation period. Disease risk level accepted is each individual's decision. Veterinarians are an integral part of any biosecurity program. They are an important source of information concerning diseases, diagnostic testing, vaccination needs and other informational sources.

A biosecurity program is like an insurance policy for the health and productivity of the herd. Producers, with the help of a qualified veterinarian, must make decisions about the risk tolerance level they will accept, based on the chances of a disease occurring and the expected economic losses from the disease. When the risk tolerance level is determined, then appropriate risk management measures can be initiated.

There is no program for all biosecurity measures; there are tools available to control many of the infectious diseases jeopardizing cattle operations. These tools can be adapted to the individual objectives for each herd and can be implemented successfully. However, there must be planning, commitment and education of all personnel throughout the operation to attain the goals set for an effective infectious disease control (biosecurity) program.

Additional Information on Biosecurity can be found at:

Healthy Farms Healthy Agriculture:
healthyagriculture.org/

Secure Beef Supply:
securebeef.org

BQA National Manual:
bqa.org/resources/manuals

References

An Introduction to Infectious Disease Control on Farms (Biosecurity). (2000) A BAMN Publication. For copies contact: AFIA, Dorann Towery, 1501 Wilson Blvd., Suite 1100, Arlington, Virginia, 22209, or phone 703-524-1921.

Thompson, J. U. (1997) Implementing Biosecurity in Beef and Dairy Herds. Proceedings: *American Association of Bovine Practitioners* 30: 8-14.

43 Livestock Mortality Management

Brian Pugh

Objectives

- **Discuss the importance of proper livestock mortality management.**
- **Explore common mortality disposal methods.**
- **Present the steps for livestock mortality composting.**

Introduction

Livestock mortality is an issue faced by every livestock farming operation. Proper management of on-farm animal mortalities is vital for proper nutrient management and disease control. Improper disposal of dead animal carcasses, such as abandonment, may cause odor nuisance and the resulting leachate (carcass fluids) can negatively impact surface water and groundwater quality. If the animal died of an infectious disease, pathogenic bacteria and viruses may be present within the carcass. These pathogens can be spread by insects, rodents, predators and subsurface or aboveground water movement, as well as through direct contact with other livestock or poultry, leading to increased disease transmission risks. For these reasons, best management practices should be followed when reacting to animal mortalities. Furthermore, most states, including Oklahoma, have regulations requiring proper disposal of livestock and poultry mortalities making unacceptable practices, such as abandonment, illegal.

Common Livestock Mortality Disposal Methods

Burial

Perhaps the most common method of disposal is burial. When proper guidelines are followed, burial can be a safe option. However, poor site selection, such as sandy soils or areas with high water tables, may pose a threat to groundwater contamination. Studies have shown zones of nitrogen accumulation years following burial of livestock in pits. Furthermore, burial does not recycle nutrients for forage growth as carcasses are buried too deep for nutrient uptake by most plants. Oklahoma burial guidelines include construction of a pit at least 300 feet away from waterways and at least 1 foot higher than any floodplain level (Figure 43.1). Carcasses should be covered with at least 2.5 feet of topsoil after placement in the pit. For more detailed information on carcass burial, refer to Oklahoma Statutes Title 21, Sections 1222 and 1223.

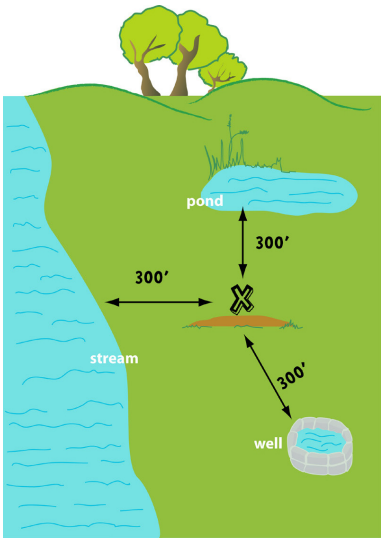


Figure 43.1. Site selection for burial.

Landfills

Disposing of carcasses at a licensed landfill that accepts animal mortalities is another form of burial. Landfills may require notification before delivery and/or documentation from a licensed veterinarian stating the cause of death. Landfill tipping fees should be assessed and may range from $20 per ton to $40 per ton. Other considerations are transportation costs and breaches of biosecurity by moving carcasses off-farm. As with burial, nutrients from the carcass are not recycled and increasing landfill volume is not a sustainable practice. For a list of Oklahoma landfills accepting dead animals, visit extension.okstate.edu/programs/poultry-waste-management-education.html

Incineration

Incineration is a safe and effective means of carcass disposal, especially from the standpoint of biosecurity. The

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

carcass is completely consumed by fire and heat within a self-contained incinerator. This process destroys pathogens by achieving high temperatures. Any remaining ash can be mixed with manure and land-applied following a nutrient management plan. Incineration is mainly designed for smaller carcasses and fuel costs should be considered. An air quality permit may be required. Due to odor and emission concerns, open air incineration is not allowed in Oklahoma unless the animal died of an infectious or contagious disease. It is often difficult to build an open fire that is hot enough to fully consume the carcass. Open air incineration should only be conducted during certain emergency disease management situations and with regulatory permission.

Rendering

Rendering is a heat-driven process that cooks the product between 240 F and 290 F while killing pathogens and converting the carcass into a value-added product, such as an animal feedstuff. These feedstuffs, such as meat and bone meal, are generally used as pet food ingredients. Fat is another byproduct used to produce rubber, soap or biodiesel. Although rendering is a very effective method, there are limited rendering services available. The transportation expense of collecting small volumes creates a financial obstacle for most rendering companies. Furthermore, federal regulations require that the brain and spinal cord be removed from cattle 30 months of age and older prior to rendering. This practice was implemented to further strengthen existing safeguards against bovine spongiform encephalopathy (BSE) disease transmission risks but it also has increased processing costs for rendering plants. Some rendering facilities will still collect routine livestock mortalities, while some require the producer to transport carcasses to the plant. Fees may be associated with this service. Rendering can be a viable option if locally available. Biosecurity and disease transmission risks should be considered when allowing vehicles on the farm and when transporting carcasses off-farm. Visit poultrywaste.okstate.edu for a current list of available rendering services.

Composting

Composting dead animals is an inexpensive, biosecure and environmentally sound approach to addressing the issue of carcass disposal (Figure 43.2). By definition, composting is a controlled biological decomposition process that converts organic matter into a stable, humus-like product. The carcass (nitrogen source) is buried in a bulking agent (carbon source), such as wood shavings, allowing for the proper carbon-to-nitrogen ratio (C-N) required by microorganisms to successfully decompose the carcass, while absorbing excess moisture and filtering odor (Figure 43.3). The high temperatures (130 F to 150 F) achieved through proper composting will destroy most pathogens. Microorganisms will degrade the carcass, leaving only a few small bone fragments, which are brittle and break easily (Figure 43.4). This valuable byproduct can then be land-applied as a fertilizer source, adding nutrients and organic matter to the soil or recycled for new compost piles. Proper management is key for composting to be effective. As with burial, site selection is important. The site should be located in an area that does not pose a risk to surface or groundwater contamination.

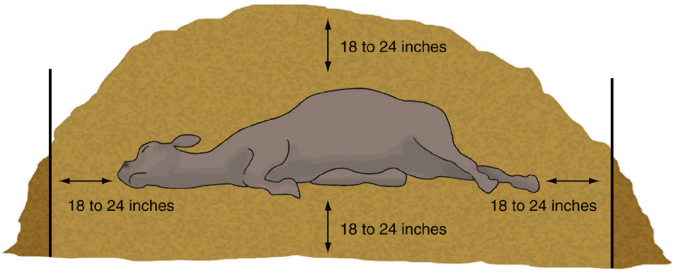


Figure 43.2. Livestock mortality compost pile.

Figure 43.3. Livestock mortality compost pile with barrier.

Figure 43.4. Brittle bone and humus-like material remains of a 700-pound stocker following 150 days of composting.

Steps to Composting Livestock Mortalities

- Construct a barrier with livestock panels.
- Prepare a carbon pad at least 18 inches deep.
- Place animal in center, ensuring the carcass is at least 24 inches from the pad edge.

- Lance rumen to deflate gas buildup.
- Add water until carbon source is damp, but not wet.
- Cover carcass with at least 18 inches of carbon material.

Catastrophic losses are best composted in windrows of bulking agent due to the increased quantity of carcasses (Figure 43.5). Height, width and length of these windrows are dependent on the size and amount of carcasses to be composted. For both routine and catastrophic composting, piles must be appropriately managed to achieve proper decomposition and prevent scavenger invasion. Emergency management plans should be in place for catastrophic losses. With large numbers of mortality, more than one option may be necessary. For more information on livestock mortality composting, refer to OSU Extension fact sheet AFS-8220, *On-Farm Mortality Composting of Livestock Carcasses*.

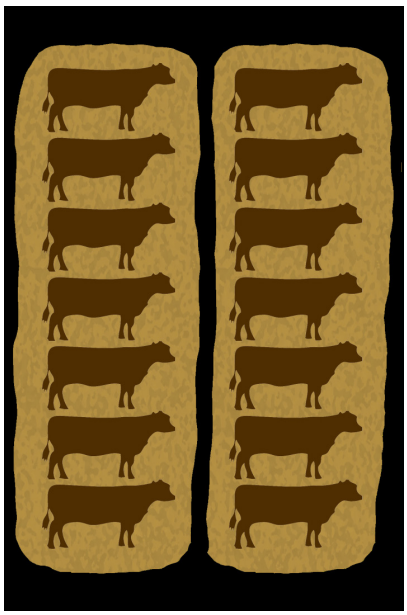


Figure 43.5. Windrow composting for multiple mortalities.

Conclusion

Proper livestock mortality disposal is essential to the sustainability and environmental stewardship of farming operations. In addition, state laws regulate disposal methods. These methods should adequately dispose of animal carcasses without negatively affecting the environment, while remaining economical to the producer. Incineration, rendering and composting are common methods preferred for carcass disposal. Each method recycles nutrients, producing a usable byproduct. Local availability and cost may limit both incineration and rendering. When properly managed, composting livestock mortalities is a safe, effective option for most producers to consider.

References

Payne, J. and B. Pugh, 2010. BAE-1749, *On-farm Mortality Composting of Livestock Carcasses*. Oklahoma Cooperative Extension Fact Sheet. Stillwater, OK.

Payne, J., 2009. BAE-1748, *Proper Disposal of Routine and Catastrophic Livestock and Poultry Mortality*. Oklahoma Cooperative Extension Fact Sheet. Stillwater, OK.

44 Beef Grading Standards

Gretchen Mafi, David Lalman and Greg Highfill

Objectives

- **Present USDA beef carcass and yield grading standards.**
- **Present USDA feeder cattle grading standards.**

USDA Beef Carcass Quality and Yield Grading Standards

Acceptability and value of beef carcasses are determined primarily by two characteristics – eating quality and cutability or yield of sellable beef. USDA grades for beef carcasses identify certain well-defined indicators of quality and cutability and furnish a system for sorting beef into smaller, similar segments (grades). Grades facilitate uniform market reporting, provide a tool for expressing and comparing prices and to enhance marketing and merchandising of beef. Grades also have been promoted as a buying guide for consumers and as a means for reflecting consumer preference back through the marketing system to producers.

Current Grading System

The USDA beef carcass grading system includes two separate grades: quality and yield. Quality grades reflect the expected palatability of cooked beef cuts, for example, tenderness, juiciness and flavor. Yield grades identify carcasses for differences in cutability, such as the percentage yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck.

Grading is a voluntary service, provided by the Agricultural Marketing Service of USDA and should not be confused with meat inspection, which is conducted by the Food Safety and Inspection Service of USDA, a compulsory service that determines the wholesomeness of meat for human consumption and includes responsibilities for sanitation, product labeling, etc. Packers pay a fee for grading and may designate whether they want a carcass graded or not.

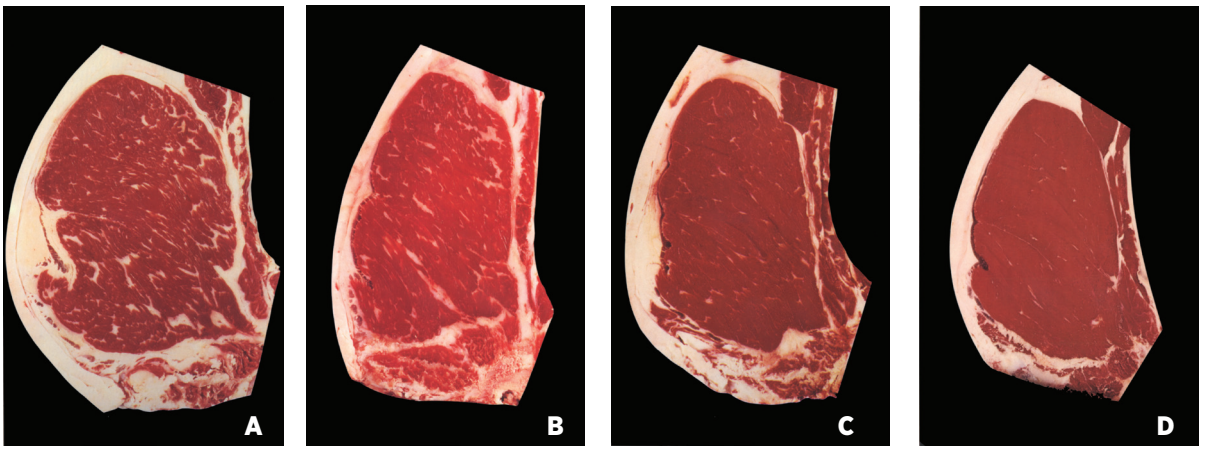
Quality Grading

The eight USDA quality grades are: prime, choice, select, standard, commercial, utility, cutter and canner. Each USDA quality grade relates to a distinct combination of quality indicating characteristics including marbling, firmness and maturity. Essentially all prime, choice and select beef harvested in major packing facilities in the U.S. is officially graded, while very little beef representing the other grades are officially graded. Prime beef is intended primarily for use by high-end restaurants, but is becoming increasingly popular in some retail outlets. Choice and select grade represents the vast majority of beef at retail and food service. Carcasses in the remaining grades are merchandised as processed beef products, blended to trimmings from fed beef to increase lean percentages of ground beef or, if suitable, the middle meats are utilized.

Qualification for a particular quality grade is determined by evaluating the carcass class, maturity, degree of marbling in the ribeye between the 12th and 13th ribs and firmness of the lean, with maturity and marbling being the most important.

Maturity groups A, B, C, D and E, from the youngest to oldest, are determined by evaluating skeletal and lean maturity. The most recent change to beef grading occurred in 2017 when USDA began utilizing dentition (teeth) as the first indicator of maturity. All carcasses deemed under 30 months of age based on dentition and with skeletal maturity less than "D" are graded as "A" maturity. If carcasses have dentition greater than 30 months, maturity is evaluated based on skeletal ossification. Cartilage becomes bone and lean color darkens with increasing age. Skeletal maturity involves evaluating ossification of the cartilage and bone visible in the sacral and lumbar vertebrae as well as the cartilage located on the dorsal surface of the spinous processes of the thoracic vertebrae also known as buttons. Also evaluated are the size, shape and color of the rib bones. Lean color tends to darken from light red to dark red and lean texture tends to become coarser in appearance with advancing maturity. Overall maturity is established by balancing skeletal and lean maturity, with skeletal maturity receiving the most emphasis. Examples of USDA quality grades for A maturity cattle are shown in Figure 44.1.

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html



A. Low Prime – slightly abundant

B. High Choice – moderate

C. Low Choice – small

D. Select – slight

Figure 44.1. USDA quality grades of beef. Source: National Livestock and Meat Board Official USDA Marbling Photographs.

As a general rule, prime, choice, select and standard grades are restricted to beef from young cattle, dentition less than 30 months or either A or B maturity; however, B maturity cattle are not eligible for the select grade. Likewise, the commercial, utility, cutter and canner grades normally are comprised of carcasses produced by cattle of advanced maturity including C, D and E maturity. Carcasses produced by bullocks, which are A maturity bulls, are not graded.

The second major quality grade determining factor is marbling or intramuscular fat, which is flecks of fat within the muscle. The 10 degrees of marbling are: abundant, moderately abundant, slightly abundant, moderate, modest, small, slight, traces, practically devoid and devoid. Figure 44.2 shows how marbling and maturity are combined to determine the carcass quality grades. To qualify for a particular grade, carcasses also must meet a minimum lean firmness requirement that differs depending upon maturity.

Special consideration is given to dark-cutting beef. Dark cutters sometimes result if cattle are severely stressed 12 hours to 24 hours prior to slaughter. Such stress results in a reduced muscle sugar content prior to slaughter; therefore, muscle pH is not lowered to normal fresh meat pH of 5.6 and remains high. This results in both failure of the muscle color to brighten (bloom) upon exposure to air and a sticky condition of the lean. Varying degrees of dark-cutting beef from slightly shady to black-cutters can be identified. Dependent on the degree to which this characteristic is developed, carcasses can be discounted up to one full quality grade.

Cutability or Yield Grading

USDA yield grades for beef carcasses were officially adopted in June 1965. Yield grades from the highest to the lowest are designated 1, 2, 3, 4 and 5 (Figure 44.3). Expected

Relationship between marbling, maturity and carcass quality grade[1]

Degree of Marbling	Maturity[2] A[3]	B	C	D	E
Slightly Abundant	Prime			Commercial	
Moderate					
Modest	Choice				
Small				Utility	
Slight				Select	
Traces					
Practically Devoid	Standard			Cutter	

1 Assumes that firmness of lean is developed with the degree of marbling and that the carcass is not a "dark cutter."
2 Maturity increases from the left to right (A through E).
3 The A maturity portion of the figure is the only portion applicable to bullock carcasses.

Figure 44.2. Carcass quality grades. Source: American Meat Science Association.

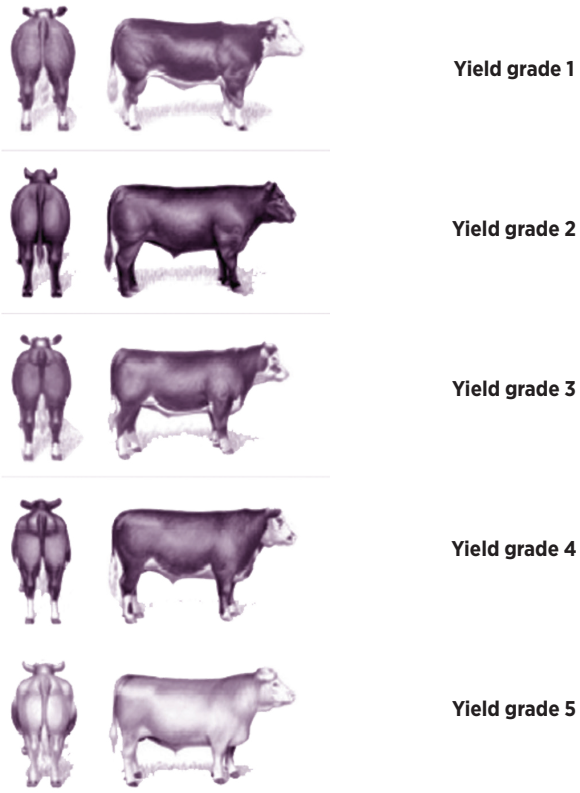


Figure 44.3. USDA yield grades. Source: USDA.

Table 44.1. Relationship between yield grade and average percentage boneless, closely trimmed retail cuts and total yield of semi-boneless, closely trimmed retail cuts.

Yield grade	*Percent BCTRC*[a]	*Percent TRC*[b]
1	53.5	82.0
2	51.2	77.4
3	48.9	72.8
4	46.6	68.2
5	44.3	63.6

a BCTRC = Percentage of carcass weight in boneless, closely trimmed retail cuts from round, loin, rib and chuck.

b TRC = Percentage of carcass weight in semi-boneless, closely trimmed retail cuts from the entire (total) carcass.

average percentage yields by yield grade for both boneless, closely trimmed, retail cuts from the round, loin, rib and chuck (BCTRC) and semi-boneless, closely trimmed retail cuts from the entire carcass (TRC) are presented in Table 44.1. Yield grades are determined by:

1. The thickness of external fat over the ribeye at the 12th rib, adjusted for other than typical distribution of fat elsewhere on the carcass.
2. The percentage (as a percent of hot carcass weight) of kidney, pelvic and heart fat.
3. The surface area in square inches of the ribeye muscle.
4. The hot carcass weight.

These grade-determining factors can be used in the following equation to estimate yield:

2.5
+ 2.5 (adjusted fat thickness, inches)
\+ .20 (kidney, pelvic and heart fat, percent)
\+ .0038 (hot carcass weight, pounds)
– .32 (ribeye area, square inches)
= Yield Grade

USDA Feeder Cattle Grading Standards

Official Feeder Cattle Standards were first issued in 1964. These standards were amended in 1979 and again in 2000. Feeder cattle grading standards were originally used more extensively in the eastern U.S. There, marketing feeder cattle by commingling ownership and packaging by grade and weight is popular due to the small average cow herd size. Nevertheless, the feeder cattle standards have become the descriptive standards used by most of the feeder cattle industry nationwide.

Since 1979, significant changes have occurred in beef cattle genetics and beef production practices. Major changes include nearly 10 times the number of cattle breeds, fewer small-framed cattle, greater genetic potential for growth, a significant increase in carcass size, the use of more aggressive growth promoting implants and various other changes in cattle feeding management. Finishing rations now include greater protein and energy density with less fiber. Technologies, such as ionophore feed additives and growth promoting implants, approved through the Food and Drug Administration, have resulted in heavier carcass weights with a higher percentage of carcass lean red meat yield.

The feeder cattle grades are based on differences in frame size and muscle thickness, two important genetic factors affecting feeder cattle value. Frame size relates to skeletal height and length in relation to an animal's age. Currently, three frame sizes are used in the grading system: large, medium and small (Figure 44.4). By categorizing cattle this way, one can make a rough estimate of the weight at which, under normal feeding conditions, an animal will produce a carcass of a given quality grade. Large-framed cattle must be fed to heavier weights to reach the same quality grade as small-framed cattle.

Frame Size Standards

Large Frame (L) – Feeder cattle that possess typical minimum qualifications for this grade are healthy, have large frames and are tall and long bodied for their age. Steers and heifers are not be expected to produce U.S. Choice carcasses (about 0.50 inch fat at 12th rib) until their live weights exceed 1,250 pounds and 1,150 pounds, respectively.

Medium Frame (M) – Feeder cattle that possess typical minimum qualifications for this grade are healthy, have slightly large frames and are slightly tall and slightly long bodied for their age. Steers and heifers are expected to

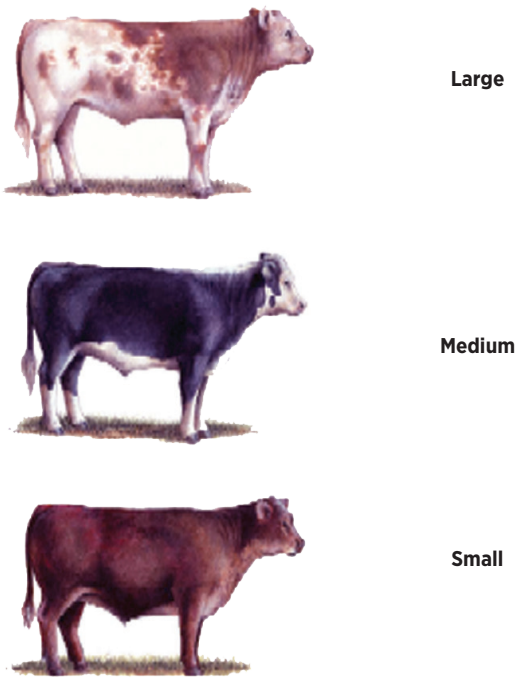


Figure 44.4. USDA frame size. Large- and medium-frame pictures depict minimum grade requirements. Small-frame picture represents an animal typical of the grade. Source: USDA.

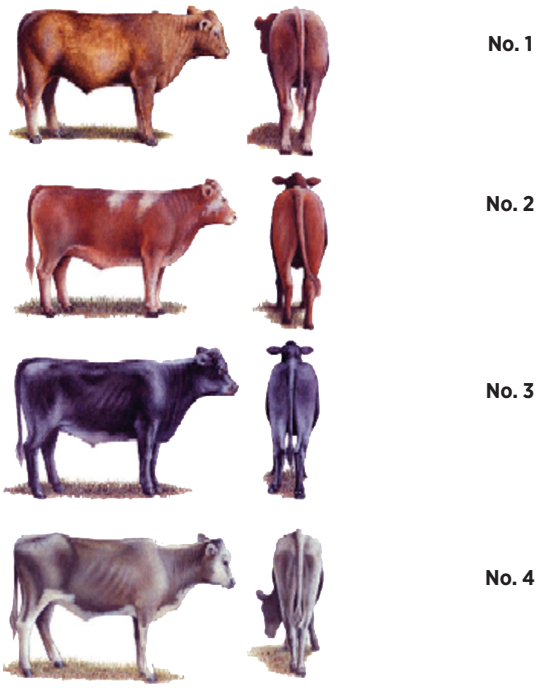


Figure 44.5. USDA muscle thickness standards. No. 1, No. 2 and No. 3 thickness pictures depict minimum grade requirements. No. 4 picture represents an animal typical of the grade. Source: USDA.

produce U.S. Choice carcasses (about 0.50 inch fat at 12th rib) at live weights of 1,100 pounds to 1,250 pounds and 1,000 pounds to 1,150 pounds, respectively.

Small Frame (S) – Feeder cattle included in this grade are healthy, have small frames and are shorter bodied and not as tall as the minimum for the Medium Frame grade. Steers and heifers are expected to produce U.S. Choice carcasses (about 0.50 inch fat at 12th rib) at live weights of less than 1,100 pounds and 1,000 pounds, respectively.

Table 44.2. USDA frame size classifications and expected harvest weight at Low Choice quality grade.

	Small frame	*Medium frame*	*Large frame*
Steers	< 1,100 lbs	1,100 to 1,250 lbs	> 1,250 lbs
Heifers	< 1,000 lbs	1,000 to 1,150 lbs	> 1,150 lbs

Source: USDA Standards for Grades of Feeder Cattle.

Muscle Thickness Standards

Muscle thickness is related to the ratio of muscle to bone at a given degree of fatness. Four muscle thickness grades are currently used, No. 1, No. 2, No. 3 and No. 4, from thickest to thinnest, respectively (Figure 44.5). The result is a relatively strong relationship with the USDA carcass yield grading system with thicker muscled feeder cattle producing carcasses with a higher percentage of lean red meat.

Based on extensive research and requests from the feeder cattle industry, this updated feeder cattle grading system was implemented Oct. 1, 2000. Table 44.2 summarizes the estimated harvest weight at low choice quality grade for steers and heifers in the three frame size categories.

Changes also have been implemented for the muscle thickness grading standards to incorporate four, rather than three grades. Obviously, this change allows for more specific description of cattle with heavy and moderate muscling.

No. 1 – Feeder cattle that possess minimum qualifications for this grade usually display predominant beef breeding. They must be healthy and moderately thick throughout. They are moderately thick and full in the forearm and gaskin, showing a rounded appearance through the back and loin, with moderate width between the legs, both front and rear. Cattle show this thickness with a slightly thin covering of fat; however, cattle eligible for this grade may carry varying degrees of fat.

No. 2 – Feeder cattle that possess minimum qualifications for this grade usually show a high proportion of beef breeding and slight dairy breeding may be detected. They must be healthy and tend to be slightly thick throughout. They tend to be slightly thick and full in the forearm and gaskin, showing a rounded appearance through the back and loin with slight width between the legs, both front and rear. Cattle show this thickness with a slightly thin covering of fat; however, cattle eligible for this grade may carry varying degrees of fat.

No. 3 – Feeder cattle that possess minimum qualifications for this grade are healthy and thin through the forequarter and the middle part of the rounds. The forearm and gaskin are thin and the back and loin have a sunken appearance. The legs are set close together, both front and rear. Cattle show this narrowness with a slightly thin covering of fat; however, cattle eligible for this grade may carry varying degrees of fat.

No. 4 – Feeder cattle included in this grade are healthy animals, which have less thickness than the minimum requirements specified for the No. 3 grade.

Instrument Grading

Technology to improve the accuracy and uniformity of U.S. beef grading has been evident to producers, packers and retailers for some time, and even to U.S. Congress for more than 30 years, since the U.S. General Accounting Office reported the need for improvement. An outstanding historical review of instrument assessment of beef carcass yield and quality was presented by Woerner and Belk (2008). The beef industry has long sought objective methods to measure yield and quality factors of beef carcasses and cuts, as a prediction of cutability (red meat yield) and/or palatability (specifically tenderness). Table 44.3 presents a chronological summary of instrument grading approval dates by the USDA, including ribeye area, yield grade and marbling assessment. Instrument grading initiatives are based on the premise that grading accuracy, precision and consistency benefits all segments of the beef industry – production to consumption. Thus, by increasing accuracy, precision and consistency, carcasses would more likely be classified correctly into their respective USDA Quality Grades (QG). An instrument to assess marbling score (MS) of beef carcasses would reduce the variation that has long existed between graders, shifts and plants.

Video image analysis (VIA) has proven to be a viable objective measure of carcass cutability traits and was approved by the USDA for assessment of the LM area and officially assigning USDA Yield Grades. Performance requirements for instrument marbling evaluation (PRIME I; USDA, 2006a) were developed utilizing information from Moore et al. 2006. The instrument approval process described in PRIME I is a two-phase approach:

Phase I: Demonstration of the repeatability of marbling score prediction on stationary beef carcasses.

Phase II: Demonstration of the accuracy and precision of marbling score prediction at line speeds. Supervisors of USDA served as the "gold standard" for evaluation of MS during the approval process.

Table 44.3. USDA MRP AMS Livestock, Poultry and Seed Program instrument grading chronological summary.

Factor/grade	*Date*
Ribeye area	**February 2001**
Instrument first approved	February 2001
Official Use	August 2001
USDA yield grade	**March 2005**
Instrument first approved	June 2005
Official Use	March 2007
ADDENDUM A - fat thickness	**March 2007**
Instrument first approved	March 2007
Marbling score	**June 2007**
Instrument first approved	November 2006
Grade Line Divergence Investigation	
Study 1: Instrument Data Review	September 2007
Study 2: Image Review	November 2007
Grade Line Review with Industry	November 2007
Grade line Alignment with Grader Input	
Instrument Data Review	September 2008
Image Review	November 2008
Grade Line Review with Industry	February 2009
Official Use of Instrument Grading	September 2009

In June 2006, CVS (Computer Vision System; RMS Research Management Systems, USA, Inc., Fort Collins, CO) and VBG2000 (E+V Technology, Oranienburg, Germany) met the rigorous performance requirements of PRIME I to assess MS. The instruments incorporate several variables including the amount, size and distribution of fat (marbling) present within the exposed ribeye, as well as variables of lean and fat color. Once approved through PRIME I by the USDA Agriculture Marketing Service Livestock, Poultry and Seed Program (USDA-AMS LPS), companies and technology providers must obtain approval through PRIME II (USDA, 2006b). Individual establishments utilizing instruments to assess MS for beef carcasses must conform to the operational procedures outlined in PRIME II. Specifically, PRIME II states: demonstration of a documented-program, in-plant procedures and verifications that ensure accurate and precise determinations are made by properly calibrated and verified instruments (USDA, 2006b). The approval process utilizes thousands of carcasses at multiple locations in assessing the predictive accuracy of an instrument and ensuring the functionality of the technology relative to the U.S. beef carcass population.

Gray et al. (2012) and Moore et al. (2012) surveyed commercial beef processing facilities across the nation to evaluate quality and yield grade characteristics assessed by instruments and by USDA personnel, respectively, of carcasses for the 2011 National Beef Quality Audit (NBQA). This is the first NBQA where instrument grading was being utilized for assessment of MS. The instrument assessment data (Gray et al., 2012) showed similar frequencies to in-plant chilled carcass assessments (Moore et al. 2012): USDA prime – 2.7% and 2.1%; USDA choice – 61.5% and 58.9%; USDA select – 31.5% and 32.6%; other – 4.3% and 6.3%, respectively. In addition, these studies found very similar mean MS for in-plant assessments of Small40 (Moore et al., 2012) and instrument assessments of Small50 (Gray et al., 2012). These results are extremely positive for the credibility of instrument grading and its relationship to field grading assessments. The use of instruments to grade beef carcasses definitely adds more consistency and uniformity to the system; ultimately ensuring beef producers are being fairly compensated for the cattle they produce and that consumers are receiving the quality of beef they expect.

Certified Beef Programs

The first USDA certified beef program was initiated in 1978, Certified Angus Beef. This program focused on branding Angus beef and marketing to consumers as higher

quality than typical commodity beef. Specifications were outlined for the program, such as more than 50% black hide, no *Bos indicus* influence, adequate marbling, A-maturity and at least a modest degree of marbling to qualify. The USDA grading service would "certify" carcasses and identify them with G-1 stamp (government schedule 1), as well as the USDA accepted stamp. The number of certified programs increased slowly, but the early 2000s saw rapid growth, leading to more than 100 current USDA Certified Beef Programs. These programs have many different requirements and can include both live animal and carcass specifications. The purpose of certified programs is to distinguish products from commodity beef to offer some attribute, for which consumers would be willing to pay a premium. Some certified programs utilize lean carcasses with lower quality grades for marketing to consumers looking for cuts with lower percentage fat.

In addition to certified beef programs, many other beef products are "branded." All certified programs are branded beef programs because they have a specific brand name associated with them. However, not all branded beef is certified. Both programs can be confusing and misleading to consumers, but importantly, if consumers have a positive eating experience from beef labeled with a certain brand, they are likely to be a repeat buyer and vice versa.

Conclusion

Federal grading standards are presented to familiarize producers with USDA's standards for beef carcass quality and yield grading as well as feeder cattle grading. These grading standards provide benchmarks that can be used to improve carcass quality and uniformity. Grading standards also facilitate uniform market reporting, provide a tool for expressing and comparing prices and enhance merchandising of beef. Many attempts have been made to improve USDA grading standards by using other tools or instrumentation. These instruments can be used in combination with USDA grades, but cannot fully take their place. The USDA grades are a worldwide market tool for fresh beef.

References

Gray, G. D., M. C. Moore, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, T. E. Lawrence, K. E. Belk, D. R. Woerner, J. D. Tatum, D. L. VanOverbeke, G. G. Mafi, R. J. Delmore Jr., S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows and M. E. O'Connor. 2012. National Beef Quality Audit - 2011: Survey of instrument grading assessments of beef carcass characteristics. *Journal of Animal Science* 90:5152-5158.

Moore, M. C., G. D. Gray, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, K. E. Belk, D. R. Woerner, J. D. Tatum, J. L. Igo, D. L. VanOverbeke, G. G. Mafi, T. E. Lawrence, R. J. Delmore Jr., L. M. Christensen, S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows and M. E. O'Connor. 2012. National Beef Quality Audit - 2011: In-plant survey of targeted carcass characteristics related to quality, quantity, value and marketing of fed steers and heifers. *Journal of Animal Science* 90:5143-5151.

USDA. 2006a. Performance requirements for instrument marbling evaluation (PRIME I). Demonstration of repeatability, accuracy and precision. Livestock, Poultry and Seed Program, Agric. Marketing Ser., USDA, Washington, DC.

USDA. 2006b. Performance requirements for Instrument Marbling Evaluation (PRIME II). Implementation and verification of operational procedures. Livestock, Poultry and Seed Program, Agric. Marketing Ser., USDA, Washington, DC.

Woerner, D. R. and K. E. Belk. 2008. The history of instrument assessment of beef. Report submitted to the National Cattlemen's Beef Association, Denver, CO.

45 Beef Quality Assurance

Bob LeValley; Rosslyn Biggs, DVM and Barry Whitworth, DVM

Objectives

- **Define the purpose of beef quality assurance.**
- **Identify specific quality challenges within the beef industry.**
- **Outline beef quality assurance guidelines.**

History and Mission of Beef Quality Assurance

The Beef Quality Assurance (BQA) program was first implemented in 1982 by producers and the United States Department of Agriculture Food Safety Inspection Service (USDA-FSIS). The purpose was to avoid violative drug residues in beef. Since that time, the BQA program has been expanded to include other factors influencing overall beef quality (Figure 45.1). The BQA principles are similar to those developed by Pillsbury for the quality control program for supplying food to the NASA space program. Their program, the Hazard Analysis Critical Control Point Program (HACCP), gained USDA acceptance and is presently the outline for quality assurance programs in packing houses and processing facilities. Using HACCP, control points have been identified in the beef production system, through which producers can implement management practices to improve and prevent potential hazards, while securing food safety and quality (Table 45.1).

Through the efforts of the American Association of Bovine Practitioners and national and state cattlemen's associations, "Key Practices" have been established (Figure 45.2). The objective of the Oklahoma BQA program is to educate cattle producers and other industry professionals regarding the BQA guidelines and to encourage the adoption of BQA principles. The overall goal of the Oklahoma BQA program is to improve beef quality characteristics by minimizing the occurrence of violative residues, pathogen contamination and carcass defects and by improving carcass leanness, cutability and palatability. The Oklahoma BQA program is a cooperative effort between beef producers, the Oklahoma Beef Council, OSU Extension and other industry groups. The BQA program acts as a catalyst to encourage use of the latest science and technology to meet expectations about beef quality and safety.

Figure 45.1. The BQA Program is intended to maximize consumer confidence concerning beef.

Industry Quality Challenges – Quality Audits

The importance of BQA can be seen when reviewing the top-quality defects identified in a series of National Beef Quality Audits (Table 45.1). These audits were intended to document carcass characteristics and defects in the cattle harvested and processed for beef in the U.S. To date, six audits have been conducted (1991, 1995, 2000, 2005, 2011 and 2016) surveying cattle that had been fed high-grain diets in feed yards prior to harvest. These audits are referred to as

All Web addresses given in this chapter are subject to change. The links to these websites will be updated regularly at the Master Cattleman website at extension.okstate.edu/programs/master-cattleman.html

Table 45.1. Examples of control points impacting the BQA program.

Process	*Control point*	*Potential quality concerns*
Breeding and genetics	Planned breeding system Sire selection Replacement female selection Culling	Carcass characteristics Health Performance Temperament
Herd health and cattle handling	Processing cows and calves: at branding at weaning Receiving breeding cattle Receiving and processing stocker cattle Shipping cattle	Bruises Drug residues Injection site lesions Carcass characteristics Health Temperament Dark cutters
Transportation	Trailer design and size	Cattle injury Driving techniques Bruising, injury Cattle handling during loading/unloading Dark Cutters Biosecurity Health
Parasite control	Internal parasite control External parasite control	Injection site lesions Withdrawal times Performance Hide damage
Nutrition and grazing management	Herbicide application Blending feed Purchasing feed	Drug residues Feed additives Ruminant derived protein Thin cows
Culling management	Timely marketing Shipping culls	Carcass characteristics Bruising Condemnation Downer cows Health

fed-cattle or fed-beef audits. Additionally, four market cow and bull quality audits have been conducted (1994, 1999, 2007 and 2016) to represent average characteristics and defects of nonfed sources of beef.

Fed-Cattle Quality Audits

To assess the current quality and consistency status of U.S. fed steers and heifers, university researchers evaluated about 8,000 (Navigating Pathways to Success, Beef Quality Audit, 2016) live cattle for attributes related to transportation and mobility, and about 25,000 carcasses on the slaughter floor for characteristics that can affect quality and value of cattle, carcasses and byproducts. This research was conducted at 17 U.S. beef processing facilities. Researchers also studied 9,106 carcasses in 30 processing facilities to assess various characteristics that determine quality and value, including quality and yield grade, weight and marbling. These assessments represented about 10% of a day's production at each plant. Comparing data from 2016 to the previous five surveys assesses progress in improving quality, while providing a benchmark for future beef industry educational and research efforts.

Several of the quality indicators have changed with time. For example, the percentage of fed cattle with horns has declined substantially since 1995. Likely, the majority of this improvement is due to trends in breed selection among producers (more polled cattle), while it is also possible more producers are dehorning cattle compared to previous years.

The frequency of hide defects due to branding has decreased, but bruising has slightly increased. The good news is the 2016 audit reported 77% of the bruises were classed as minimal in severity. Minimal classification means that less than one pound of surface trimming is required.

The incidence of dark cutters has declined since the 1991 audit and continues to range from 1.9% to 3.2% since the 1995 audit. Of particular concern, liver condemnations were substantially greater in the 2016 audit compared to 2011 while the frequency of lung condemnations continue to increase in the industry. Head and tongue condemnations declined substantially in 2016.

The percentage of cattle grading Prime and Choice continues to increase while the percentage of cattle grading Select continues to decrease. While there is not a clear pattern in yield grades since the 2011 audit, it does appear there are fewer cattle qualifying in the leaner categories (yield grade 1 and 2) and more qualifying for the fatter categories (yield grade 4 and 5).

According to results from the most recent audit (2016), the sum of quality grade, yield grade, weight, hide defects

and condemnations average nearly $49 per head, or a total of more than $1 billion annually. Excessive fat and inadequate marbling were identified as the two major value loss items. Together, these two defects account for about 58% of total value losses.

Market Cow and Bull Quality Audits

In 2016, audits were conducted at 18 cow and bull processing facilities across 10 states. In this audit, holding-pen (live animal) audits were conducted at the packing facilities as well as harvest-floor assessments (hide-on and hide-off assessments) and cooler audits. Table 45.2 shows the frequencies of defects identified in the holding-pen audits.

Of particular interest is the high incidence of hide damage from brands, scratching and scarring (Table 45.3). Nearly 64% of beef cows had no brand, while 5.6% had multiple brands, which causes greater devaluation to the hide. The dollar value lost due to hide brands and latent damage in 2016 was estimated to be $7.47. Producers can place brands on the shoulder or hip, rather than the rib to minimize value loss of the hide

There has been an upward trend in body condition scores for beef and dairy cows since 2007, while body condition for bulls has remained nearly the same. Data show there is a greater frequency of over-conditioned beef cows (BCS 8 and 9) and a lesser frequency of cows that are too thin (BCS 1 and 2) than reported in 2007. Researchers classified 7.6% of beef cows as having a body condition score of 1 or 2. Muscle score can be used as a measure of condition and fitness. The beef cow population in the audit has continued to show a drastic improvement in muscling. Nearly 35% of cows were classed as inadequately muscled in 2016, compared to 61% in 2007. The degree of muscling in cattle can be attributed to genetics, previous plane of nutrition and/or animal health. As cows decline in body condition, they lose muscling as well as fat.

Nearly one out of every 10 beef cows had horns. Horns may contribute to the extremely high incidence of bruising in cow carcasses as shown in Table 45.4. Forty-three percent of bulls and 64% of cows had no bruises, with the majority of bruises being classed as "minimal" in severity. Minimal severity means less than one pound of surface trim is

Table 45.3. Frequency (%) of defects identified in holding-pen audits of non-fed cattle.

	Percent of cows		
	1999	*2007*	*2016*
Eye lesions	4.3	3	1.0
Lumpy jaw	1	0.4	1.2
Small horns and scurs	10	8.4	5.3
Large horns	13	10.8	4.5
Brands, beef cows only	60.0	31.3	35.7
Hide scratching or scarring	61.0	45.3	
Hide damage from insects	2.4	3.0	
Lameness caused by arthritis or injury	13.0	16	13
Inadequate muscling, beef cows only	44.4	61	35
Body condition score of 1 or 2 (extremely thin, beef cows only)	2.3	10.0	7.6
Body condition score of 3 or 4 (thin, beef cows only)	38.3	41.1	
Body condition score of 8 or 9 (extremely fat, beef cows only)	4.5	4.2	3.6

Source: National Market Cow and Bull Quality Audit.

Table 45.2. Frequency of carcass, hide and offal defects and carcass traits.

National Beef Quality Assurance Key Practices

BQA

- Provide personnel with training/experience to properly handle and care for cattle. (Code of Cattle Care)
- Make timely observations of cattle to ensure basic needs are being met.
- Provide facilities that allow safe, humane and efficient movement and/or restraint of cattle.
- Use appropriate methods to humanely euthanize terminally sick or injured livestock and properly handle carcasses.

Cattle Care

- Abuse of cattle is not acceptable under any circumstances.
- Provide personnel with timely training/experience to properly handle and care for cattle.
- Make timely observations of cattle to ensure basic needs are being met.
- Design, provide and regularly inspect facilities (fences, corrals, loadouts, alleys, etc.) to help ensure safe and easy animal movement and restraint.
- Keep feed- and water-handling equipment clean.

Biosecurity

- Evaluate the biosecurity risks on your operation and follow a plan to help mitigate risk.
- Recognize and mitigate the biosecurity risks associated with the introduction of new cattle and inter-herd/operational traffic.
- Apply basic sanitation practices to equipment, vehicles and clothing to decrease the chance of microbial contamination.
- Prevent contamination of feed and feeding equipment.

Herd Health

- Develop a herd health plan that conforms to good veterinary and husbandry practices appropriate for the region where cattle are raised.
- Provide disease prevention practices to protect herd health including access to veterinary medical care.
- Follow all FDA/USDA/EPA guidelines and label directions for each product.
- Use FDA approved feed additives including those requiring a veterinary feed directive (VFD) in accordance with label requirements. The FDA requires all VFD records to be retained for two years and available upon FDA request for inspection.
- Keep extra-label drug use (ELDU) to a minimum and only when prescribed by a veterinarian working under a Veterinary/Client/Patient Relationship (VCPR).
- Properly administer products labeled for subcutaneous (SQ) administration in the neck region.
- When available, use products approved for SQ, intravenous (IV), and intranasal (IN) or oral administration rather than products

administered intramuscular (IM) as all products can cause tissue damage when administered IM.
- Always ensure products labeled for IV-only are never given by any other route of administration because of the potential for causing violative residue at the injection site.
- When available, use injectable products with low dosage volumes and follow the proper spacing of injections.
- Administer products labeled for IM in the neck region only – no exceptions, regardless of age.
- Do not administer more than 10cc of product per IM injection site.
- Use the appropriate needle size for injections and never reuse a bent needle.
- Do not market compromised, terminally ill and/or non-ambulatory cattle.
- Humanely euthanize non-ambulatory animals using appropriate methods.

Transporting

- Knowingly inflicting physical injury or unnecessary pain on cattle when loading, unloading or transporting is not acceptable.
- Handle/transport all cattle in such a fashion to minimize stress, injury and bruising.
- Use vehicles to transport cattle that provide for the safety of personnel and cattle during loading, transporting and unloading.
- Follow these guidelines when transporting your own livestock:
  - Perform a structural check of trailer/truck and tires prior to loading livestock.
  - Inspect trailer/truck for cleanliness (biosecurity) as well as broken gates that may injure/bruise cattle.
  - Check weather and route to ensure a safe and uneventful trip.
  - Verify withdrawal on any animals to be sold.
  - Verify all animals are fit to ship.
  - Back up square and evenly to loading chute.
  - Load using low-stress handling practices.
  - Pull away from the chute slowly and drive smoothly to allow cattle a chance to gain their balance in transit.
  - Minimize time in transit by limiting stops and using prior preparation to ensure an organized event.
- Follow additional guidelines when contracting for your cattle to be hauled:
  - Establish good communications/logistics with both the trucking company and receiver of the livestock.
  - Request the truck to arrive clean for loading to decrease biosecurity risks.
  - Ask hauler contractor/driver for proof of BQA Transportation Certification.

Recordkeeping

- Employ strict adherence to pre-harvest withdrawal periods on product labels and to extended withdrawals as determined by a veterinarian within the context of a VCPR.
- Identify all animals with appropriate individual and/or group identification methods.
- When cattle are treated/processed individually or as a group, record the following information:
  - Individual animal identification, or for group treatment/processing, record group or lot identification
  - Date treated
  - Product administered and manufacturer's lot/serial number
  - Dosage
  - Route and location of administration
  - Earliest date animal(s) will have cleared the withdrawal period
  - Name of individual administering the treatment
- Whenever possible, transfer all processing and treatment records with the cattle to the next owner or production level.
- Inform prospective buyers of any cattle that have not met pre-harvest withdrawal times.
- When applicable, keep complete records when formulating or feeding medicated feed rations.
- Maintain records of any pesticide used on pasture or crop that could potentially lead to violative residue.
- Keep records for a minimum of two years or longer as required by law/regulations (e.g. three years for Restricted Use Pesticides).

Nutrition

- Ensure cattle have access to adequate water supply and appropriate nutrition.
- Avoid feed and water interruption longer than 24 hours.
- Only use feedstuffs and feed ingredients of satisfactory quality.
- Under certain circumstances (e.g. droughts, frosts and floods) test feedstuffs or other dietary components to determine the presence of substances that can be detrimental to cattle well-being such as nitrates, prussic acid, mycotoxins, etc.
- Use only USDA-, FDA- and EPA-approved products for use in cattle; these products must be used in accordance with the product label.
- Analyze suspect feedstuffs prior to use and seek supplier assurance of feed ingredient quality.
- Do not feed ruminant-derived protein sources per FDA regulations.
- Support feeding of by-product/co-product ingredients with sound science.

Environmental Stewardship

- Manage forage and water resources with appropriate principles to optimize production while protecting or enhancing the environment.
- Use, store and dispose of all pesticides with care and according to label directions.
- Monitor and manage key environmental control points that affect soil and water resources.
- Properly dispose of carcasses.

Worker Safety

- Maintain a safe workplace and use appropriate personal protective equipment when needed.
- Train employees and others working at your operation on safe practices in using equipment, handling cattle, handling animal health products and working around potentially hazardous areas.

Emergency Action Planning

- Develop and maintain an emergency action plan.
- Inform everyone involved in your operation what to do in case of an emergency.

removed due to bruise damage. Certainly, bruising can be caused by many things besides horns, such as poorly designed and maintained cattle working facilities, overzealous and impatient human handlers and overcrowding in working facilities and trucks. There needs to be a continued emphasis on proper handling to reduce bruising and the associated loss in carcass value.

Actual carcass traits are shown in Table 45.5. Average carcass weight in cows was only 686 pounds. Light carcasses in cows can be largely attributed to high incidence of light-muscled cows in thin body condition, resulting in low dressing percent.

Table 45. 4. Incidence of bruises and severity of trim loss in market cows and bulls.

Severity of Bruises	*Percent of cows*		
	1999	*2007*	*2016*
Extreme	2.4	5.4	1.4
Critical	21.6	12.4	4.9
Major	41.7	30.9	45.1
Minimal	77.2	36.7	67.3
No bruise	11.8	36.6	35.9

Source: National Market Cow and Bull Quality Audit.

Table 45.5. Overall means of carcass traits in market cows and bulls.

Carcass Trait	*Cows*	*Bulls*
Carcass weight, lbs	*686*	*878*
Muscling[a]	2.4	3.0
Fat thickness, inches	0.29	0.14
Fat color[b]	3.2	2.4
LM Area, In^2 (loin muscle)	10.0	12.2

a Muscling score is a subjective measurement (1 =1 lightly muscled, 5 = heavily muscled).
b Fat color score is a subjective measurement (1 = white fat, 6 = yellow, oily fat).
Source: National Market Cow and Bull Quality Audit.

Table 45.6. Targets to improve fed-beef carcass characteristics.

Trait	Target (%)
Yield Grade	
1	10
2	45
3	40
4	5
5	0
Quality Grade	
Prime	5
Upper 2/3 Choice	35
Low Choice	35
Select	25
Standard/Ungraded	0
Carcass Weight lbs.	
<600	0
600-800	20
801-900	30
901-1,000	50
>1,000	0

Meeting the Challenges – BQA Guidelines

Management to Improve Carcass Composition and Quality

Fed-Cattle

Improving quality and consistency of fed-beef carcasses begins first with understanding the industry targets for carcass traits and selecting carcass targets appropriate for the specific operation's type of cattle and production

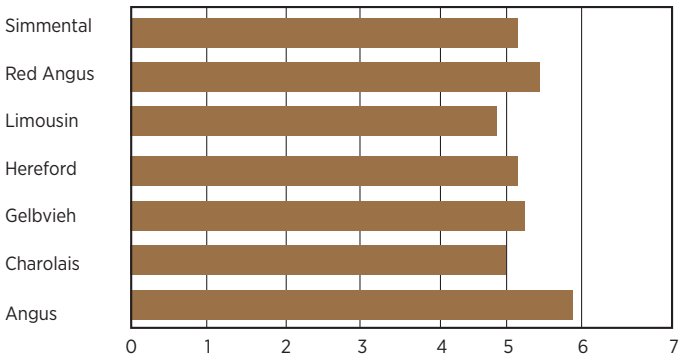


Figure 45.2. Breed of sire influences on marbling score. (Courtesy Kuehn & Thallman)

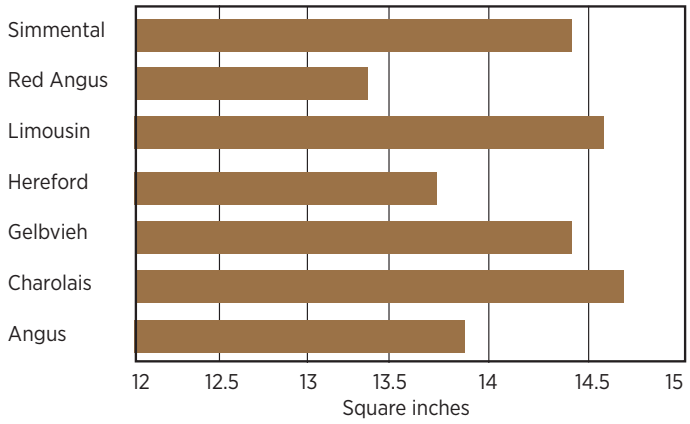


Figure 45.3. Breed of sire influence on rib eye area. (Courtesy Kuehn & Thallman)

environment and/or production system. Targets for carcass defects (injection-site blemishes/lesions, bruises, dark cutters, liver condemnation, etc.) are zero. Industry targets for carcass weight, yield grade, quality grade, ribeye area and other characteristics vary depending on the marketing program for which the cattle are being targeted. For example, the USDA currently has registered more than 70 Certified Beef Programs, all of which have varying carcass targets. Specifications for each of these certified beef programs can be viewed atams.usda.gov/services/auditing/certified-beef-programs.

Based on the National Beef Quality Audit (NBQA) data, carcass composition remains the area where the greatest amount of fed-beef value can be recaptured. Lost opportunities due to quality grades cost the industry $15.75 per head of fed cattle marketed (2016 NBQA). Inappropriate yield grades, as a result of excess fat and/or inadequate muscling, costs the industry $12.91 per head, compared to $5.93 per head in 2011. This decrease in loss of value occurred partly because fewer carcasses are actually assigned a yield grade and more emphasis is given to the marketing of animals to specific programs. To further achieve improvements in these areas, general fed-beef carcass targets are suggested in Table 45.6.

Producers need to establish and follow a methodical plan to make significant progress in improving feed yard performance and carcass composition of their cattle. The

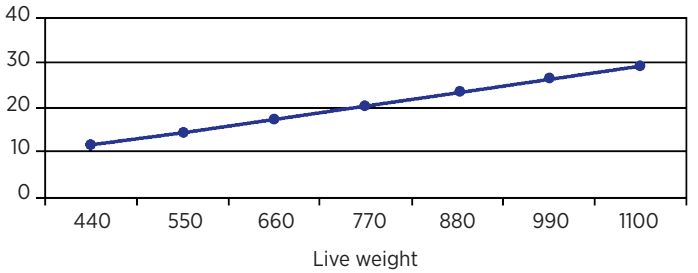


Figure 45.4. Influences of weight (time on feed) on body fat composition.

first step in this plan should be to determine the relative performance and carcass characteristics of cattle at present and to identify a marketing program that best fits cattle management programs. For producers who typically sell calves at weaning or do not care to retain ownership on large numbers of calves, this information can be difficult to obtain. Establishing a relationship with buyers and feeders may be a method to obtain the desired performance data. The use of EPD's and genomic information in breeding programs can certainly help a producer improve cattle performance in areas of interest.

Once carcass targets and current performance have been established, the second step is to use the information gathered to set clear goals for improving feed yard and carcass performance. For example, reducing average yield grade of steer progeny by .25 units within three years, or increasing the percentage of cattle grading average choice by 5% within the same three years may be appropriate goals. The third step is to develop and initiate an action plan to facilitate goal achievement, and the final step is to monitor progress. Chapters 25 through 28 have an extensive discussion of herd improvement through breeding programs by using EPD and genomic information in the selection of replacement females and sires.

Many factors are involved in determining final carcass composition (fat versus lean) and marbling. Some of the major factors known to influence carcass composition are genetics for muscularity (cutability) and marbling, time on feed, age placed on feed, nutritional history prior to being placed on feed, implant regime, season of the year and incidence and severity of sickness. Several of these factors interact with one another to further complicate the issue.

Genetic tools, such as breed selection, within-herd selection (for example culling and replacement heifer retention) sire selection and mating systems are likely the most powerful tools available to producers in influencing feed yard performance and carcass composition. While feed yard performance and carcass composition become more important with time, care must be taken to avoid overemphasizing selection for these traits at the risk of ignoring or even damaging other important genetic traits. Cow herd reproductive performance, milk production and mature size are examples of traits that must be balanced or improved through time, while improvements in carcass composition are achieved.

Breed or breed type has an influence on carcass characteristics. Researchers at the USDA Meat Animal Research Center report across-breed EPD tables on an annual basis. This allows producers to adjust EPDs to a specific baseline and accurately compare sires from two different breeds. Across breed EPD in Table 27.1 is found in this manual. Figures 45.2 and 45.3 show average marbling score and rib eye area (REA), respectively for selected breeds. Calves sired by Angus and Red Angus have higher marbling scores compared to calves sired by Charolais, Gelbvieh, Limousin, Simmental and Hereford. Conversely, calves sired by Continental breeds of cattle (Charolais, Limousin, Gelbvieh and Simmental) produce carcasses with higher REA (higher cutability) compared to calves sired by English breeds of cattle (Angus, Red Angus and Hereford).

It should be recognized sires are available within each breed that excel in producing carcasses with higher-than-breed-average quality grades and lower-than-breed-average yield grades. By selecting a breed or breed combination of cattle, and by applying selection principles and mating systems appropriate for the production system and marketing program, producers can make substantial improvement in feed yard performances and carcass characteristics through time.

Age placed on feed is often thought to play a major role in feed yard performance and carcass characteristics. This variable is frequently closely related to and compounded with days on feed. It is not uncommon for cattle to be placed on feed anywhere from 2 months to 18 months of age in the U.S. However, two very common production systems in Oklahoma are to place calves on feed at weaning—about 5 months to 9 months of age (calf-fed) or to place them on feed as yearlings, when they are anywhere from 11 months to 16

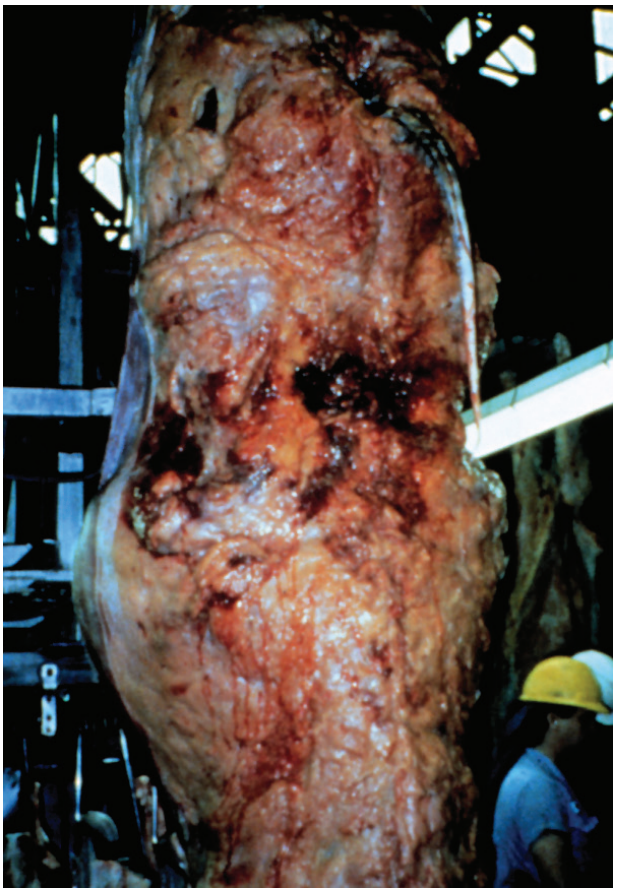


Figure 45.5. Bruises cost the cattle industry $22 million annually.

months old. Obviously, time on feed varies dramatically, depending on the rate of gain during the stocker phase, frame size of cattle, fleshiness of the cattle at different times and market conditions. Several experiments have been conducted to document differences in carcass characteristics and feed yard performance among calf-fed versus yearling-fed production systems. In general, when cattle from both production systems are fed to a constant back fat endpoint, yearling-fed cattle, compared to calf-fed cattle, have heavier placement weights, increased intake, faster rates of gain, poorer feed conversion, less days on feed and larger live carcass weights.

Surprisingly, the research indicates that average quality grade and yield grade are not substantially different, assuming the cattle are harvested at a constant back fat thickness. Therefore, according to this research, the choice of production system primarily influences live carcass weight. Thus, carcass weight parameters defined in the targeted marketing program and the type of cattle (large versus medium frame) should be considered in this decision. Many other factors will be involved in this decision as well, such as market conditions and available ranch resources.

Days on feed is highly and positively correlated with live body weight, body fat (Figure 45.4), carcass weight, yield grade and, to a lesser extent, percent grading choice or higher. Therefore, producers can use days on feed as a powerful tool to manipulate back fat thickness and yield grade. Previous history of the ranch's cattle is necessary to use as a benchmark and to determine if days on feed should be increased or decreased.

It is well documented that sickness reduces feed yard performance, carcass weight and percentage of cattle grading choice and higher (Lalman and Smith, 2000). Therefore, any management steps taken to minimize the risk of sickness and the severity of sickness will ensure optimum feed yard and carcass performance.

Cows and Bulls

Improving characteristics of non-fed beef carcasses is primarily an issue of market timing and culling management. Research concluded that cows in a BCS 6 at harvest optimized returns to producers and processors, based on quality grade and lean meat yield (Apple, 1999). Therefore, cattle with physical disorders, such as arthritis and stifle joint infections should be marketed before they become excessively thin (less than BCS 4).

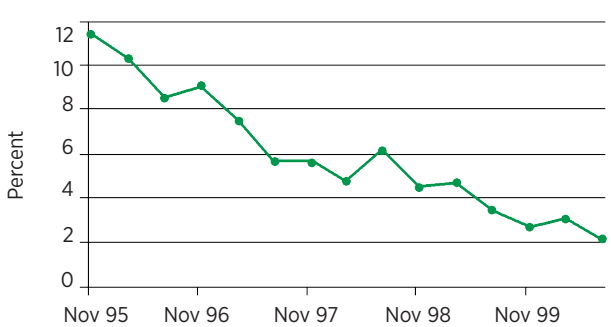


Figure 45.6. Incidence of injection-site lesions in fed-beef sirloin top butts.

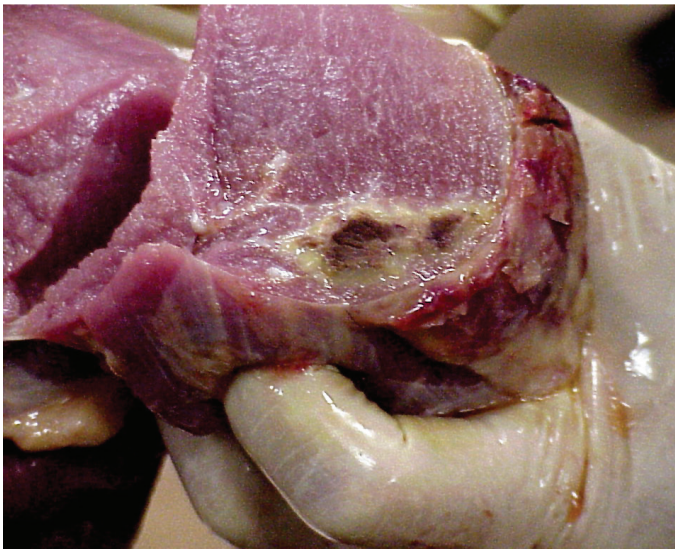


Figure 45.7. Fluid-filled injection-site lesion. Source: Boyles.

Each year, producers should examine the teeth or mouth of cows 8 years of age and older. Any cow developing a broken mouth or having lost several teeth should be either marketed before she loses substantial weight and condition or put on a culling list to be identified and culled at the earliest opportunity.

Managing cows to gain weight before marketing may be a profitable alternative, if the animals are healthy and high-quality forages or moderate- to low-cost concentrate feeds are available. When healthy thin cows are not lactating and are grazing high-quality forage such as spring and early summer grass or wheat pasture, they can gain one full body condition score in about 30 days. High-concentrate feeding programs also can be used to rapidly improve body condition of thin healthy cows. However, producers should recognize that feed conversion in mature cows is not very efficient compared to growing cattle. In fact, most studies suggest feed conversion in thin cows receiving a high concentrate ration (85% to 95% concentrate) is in the neighborhood of 9 pounds to 10 pounds of feed per pound of weight gain. This compares to a conversion of between 5.5 pounds to 7 pounds of feed per pound of weight gain in calves and yearlings. Cows that do not raise a calf should be marketed before they become excessively fat.

Disabled or downer cattle are no longer allowed in the food chain and should be humanely euthanized on the farm with the direction of a veterinarian.

Minimizing Dark Cutters

Dark cutters result from preharvest stress, which depletes muscle glycogen stores. Without sufficient glycogen in the carcass, lactic acid cannot be produced to reduce the pH of the meat. The result is dark, firm and dry lean. Inclement weather, growth promotants, genetics, disposition and handling practices before harvest all play a role in causing dark cutters. Using low-stress animal handling techniques and good management practices greatly reduces incidences of dark cutters.

Table 45.7. Guidelines for needle selection for cattle.

	Route of administration								
	SQ (1/2- to 3/4-inch needle) Cattle Weight			IV (1 1/2-inch needle) Cattle Weight			IM (1- to 1 1/2-inch needle) Cattle Weight		
Injectable viscosity	<300	300 to 700	>700	<300	300 to 700	>700	<300	300 to 700	>700
Thin example: virus vaccine	18 gauge	18 to 16 gauge	16 gauge	18 to 16 gauge	18 to 16 gauge	16 to 14 gauge	20 to 18 gauge	18 to 16 gauge	18 to 16 gauge
Thick example: oxytetracycline	18 to 14 gauge	18 to 14 gauge	14 gauge	18 to 16 gauge	18 to 16 gauge	16 gauge	18 to 16 gauge	18 to 16 gauge	16 gauge

Select the needle to fit the cattle size (the smallest practical size without bending).

Minimizing Carcass Bruising

Approximately 39% of fed beef and 64% of market cow and 43% of bull carcasses exhibited bruising (Figure 45.5). While the frequency of bruising has increased as reported in the 2016 audit, the severity of bruising has decreased, with a high percentage of bruises classed as minimal. Producers can have a tremendous impact on reducing the incidence of this value-degrading defect. Bruising from improper cattle handling and management is costly to the cattle industry. An understanding of cattle behavior will facilitate handling, reduce stress, reduce bruise defects and improve both handler safety and animal welfare.

Any protruding objects such as broken boards, nails or exposed bolts should be removed/repaired from working facilities. This also includes horns, which should be removed by breeding selections or manually. Tipping of horns does not reduce bruising as most of the horn is still present. Protruding objects at times may be easily identified. They will typically be shiny or rubbed and often have tufts of hair. Corners and sharp objects that cannot be removed may need to be padded. Rubber tires or pieces of hose work well to soften the impact on cattle.

Gates and flooring also can cause bruising. Make sure not to throw a gate into the side of an animal, as it may become wedged between the gate and the fence. Concrete flooring also will require scoring with an 8-inch diamond pattern with one-inch deep groves, so cattle can gain traction when handled.

Figure 45.8. Correct injection site. Source: Boyles.

Processing, Treatment and Use of Animal Health Products

A series of audits designed specifically to monitor the incidence of injection-site lesions in top sirloin butts of fed beef began in November 1995 and continued in March, July and Noember of each following year. As an example of how improvement can be made with improved awareness—resulting in an industry-wide management change—injection-site blemishes declined from a high of 11.4% in 1995 to a low of 2.06% in July 2000 (Figure 45.6). Much of this dramatic improvement can be attributed to beef producers in each segment moving injection sites from the hip to the neck region.

However, the results of the first market cow and bull quality audit in 1994 showed the percentage of injection-site lesions in nonfed cattle was found to be 28.9%. In the 1999 audit, which included cull dairy cows, this number increased to 40.9%; however, in the 2007 audit, this number decreased to 33%. Contrary to popular belief, not all beef from market cows is marketed as ground beef. For example, ribeye rolls and rounds from market cows and bulls are used in products such as Philly steak and roast beef sandwiches.

Moving the injection-site area to the neck stops damage to expensive steak cuts and allows easier identification of these lesions in the processing plant. There is a negative relationship between meat tenderness and injection sites, including injection sites with no visible lesion. All intramuscular (IM) injections, including sterile water, create permanent damage at the time the product was administered, regardless of the age of the animal. At the very least, tenderness is reduced in a 3-inch area surrounding the injection site (Figure 45.7).

Correct administration of any injection is a critical control point in beef production and animal health. Producers can help to avoid product discounts as a result of abscesses and lesions, and maximize the effectiveness of the animal health product being used by following these simple procedures:

1. Use well-designed cattle-restraining facilities to make the job of giving injections in the proper location safer and easier. Improper animal restraint is the cause of most bent needle problems. By providing proper restraint, the appearance of broken needles in beef products can be avoided. In the event a needle is broken off in the neck muscle, a veterinarian should be immediately contacted and the broken needle surgically removed. A broken needle is an emergency and time will be of the essence. Broken needles migrate in tissue and will be impossible to find if not immediately handled, requiring the animal to be destroyed. Under no circumstances should animals with broken needles be sold or sent to a packer.
2. Use the needle size proper for the situation (Table 45.7).
3. Purchase high-quality needles, change needles often—every 10 head to 15 head — and discard damaged needles or needles contaminated by feces or irritating chemicals. Use only a sterile needle to pull vaccine or medicine from a bottle. This keeps the contents in the bottle sterile.
4. Properly dispose of used or damaged needles. Place the needles in a hard plastic or rigid cardboard container with a secure lid. Label the container Sharp Objects for Disposal.
5. Give injections according to label instructions. Route descriptions follow: subcutaneous (SQ) means under the skin, intramuscular (IM) means in the muscle, intravenous (IV) means into the vein, orally (PO and/or O) means in the mouth or in water and (MF) indicates medicated feeds.
6. Check product labels closely and administer the product as specified on the label. Select products that have subcutaneous (SQ) as an approved route of administration. Remember to tent the skin for SQ injections unless advised otherwise by the manufacturer.
7. All injections must be administered in front of the point of the shoulder, approximately 1.5 inches or more only, no exceptions. (Figure 45.8).
8. Administer less than 10 cc per IM injection site unless a larger volume is recommended on an approved label.
9. During bad weather, take extra care so the injection site is free of manure and dirt, and syringes and needles are clean and disinfected. Injecting cattle during wet weather increases the potential for carrying a contaminant into the injection site.
10. Overall sanitation of equipment and the working area, as well as the cleanliness of employees and coworkers will reduce injection-site defects. A sound educational effort directed at people handling the cattle offers great potential for helping eliminate or minimize these problems.

Responsible Drug/Vaccine Use

The United States Food and Drug Administration (FDA) is responsible for determining the market status of animal drugs, based in part upon whether or not it is possible to prepare adequate directions for use with which a layperson can use the drugs safely and effectively. The two basic classes of drugs available to livestock producers are over-the-counter (OTC) and prescription (Rx) drugs. A drug with significant potential for toxicity in humans or animals (or other harmful effects), may have a unique method of use or requires other special considerations for its use and usually labeled as a prescription drug. Such products can be used or dispensed only by or on the order of a licensed veterinarian and the label must bear the legend: Caution: Federal law restricts this drug for use by or on the order of a licensed veterinarian. Always read the label and follow the directions of your veterinarian.

Withdrawal Times

A withdrawal time may be indicated on the label of certain medications. This is the period of time that must pass between the last treatment and when the animal will be slaughtered or milk used for human consumption. For example, if a medication with a 14-day withdrawal period was last given on August 1, the withdrawal would be completed on August 15 and would be the earliest the animal could be harvested for human consumption. All federally approved drugs will include the required withdrawal time

Veterinarian _____ **Phone** _____

Address _____ **Date** _____ **Expires** _____

Owner/Farm _____ **Animal ID** _____ **Species** _____

Active Ingredients/Concentration _____

Quantity _____ **Drug Trade Name** _____

Indications _____

Directions - Give _____ **cc/bolus/oz** _____ **times each day for** _____ **days**

Drug withdrawal time for slaughter _____ **days**

Test for Residues - Urine _____ **Blood** _____

Figure 45.9. Example of a label a veterinarian may use for extra-label drug use.

for that drug on the product label or package insert. These withdrawal times can range from zero days to 60 days or more. It is the producer's responsibility to be aware of withdrawal times of any drugs used in their operation.

Unacceptable levels of drug residues detected in edible tissues collected at harvest may result in trace-back, quarantine and potential fines or jail time. Substantial economic losses may result for the individual producer as well as negative publicity for the entire beef industry. Producers are responsible for residue problems and should follow these three rules:

1. Do not market animals for food until the withdrawal time listed on the label or as prescribed by the veterinarian has elapsed.
2. Use only medications approved for cattle and exactly as the label directs or as prescribed by a veterinarian.
3. If ever in doubt, rely on the veterinarian-client-patient relationship established with a veterinarian. Consult your veterinarian with all questions and concerns.

Extra-Label Drug Use

Over-the-counter (OTC) drugs can be purchased from multiple sources and must be used as directed on the label. For example, most procaine penicillin G products are labeled for use at 1 cc per cwt. and are given intramuscularly (IM). Therefore, a 600-pound calf would get 6 cc IM. Producers are not allowed to change the dose or give it by any other route, such as subcutaneously (SQ). OTC products must be used exactly as labeled.

Extra-label use is defined as the actual or intended use of a drug in a manner not in accordance with the label. Under the provisions of the Animal Medicinal Drug Use Clarification Act of 1994, the FDA recognized the professional judgment of veterinarians, and allows the extra-label use of drugs (either OTC or Rx) by veterinarians under certain conditions. Extra-label use is limited to situations when the health of an animal is threatened or suffering, with death as a possible result from failure to treat, and only by or under the supervision of a veterinarian. Veterinarians only may consider using drugs (OTC or Rx) in an extra-label manner when there is no approved drug labeled for such use. The veterinarian will establish an extended withdrawal period and record patient ID as well as document when withdrawal periods are met. The product also will have additional labeling for producer reference (Figure 45.9).

It is important to establish a veterinarian-client-patient-relationship (VCPR) and extra-label drug use may only be used within the scope of the VCPR. For a VCPR to exist, the veterinarian has assumed the responsibility for making clinical judgments regarding the health of the animal(s) and the need for medical treatment and the client has agreed to follow the veterinarian's instructions. Also, the veterinarian must have sufficient knowledge of the animal(s) to initiate at least a general or preliminary diagnosis of the medical condition of the animal(s). This means the veterinarian has recently seen and is personally acquainted with the keeping and care of the animal(s) by virtue of an examination of the animal(s) or by medically appropriate and timely visits to the premises where the animal(s) are kept.

The privilege of extra-label use of drugs is not permitted in animal feeds. A veterinarian cannot use or prescribe drugs for use in feed in any manner except for the approved use and at the approved dosage. Extra-label use of drugs in treating food-producing animals for improving rate of weight gain, feed efficiency or other production purposes is prohibited. Some specific drugs are completely prohibited for extra-label use in food-producing animals including chloramphenicol, clenbuterol, diethylstilbestrol, dimetridazole, ipronidazole, other nitroimidazoles, furazolidone, nitrofurazone, fluoroquinolones and glycopeptides.

Drug Storage

Drugs, vaccines, implants and other animal health products usually have specific storage requirements. Some, but not all, require refrigeration and all should be stored in a clean place where they cannot become dirty or contaminated. Observe and obey the manufacturer's recommended storage instructions for each product used. Where refrigeration is needed, be sure the refrigerator is kept clean and is located in a safe, clean place that is not likely to be overheated or contaminated by dirt or manure. The temperature should be monitored with a thermometer. Animal health products should be stored away from the feed ingredient or mixing areas unless they are regularly mixed feed additives. Storage of bottles of partially used medication or vaccine is discouraged because they may have become contaminated and could cause infections or tissue reactions if reused. Purchase of animal health supplies in containers holding the number of doses typically used in a day of processing animals is encouraged.

Syringe Care

Inadequate vaccine syringe cleaning is frequently responsible for localized infections associated with vaccination. If the infection is severe, it may become generalized and the animal may die.

Injection-site swelling is common, especially when vaccines such as clostridial bacterins are given SQ. If the swelling is hard, it could be due to getting the subcutaneous injection too deep and penetrating part of the first layer of muscles. If this is the cause, consider using a "B-Bevel" 5/8-inch needle or a short (1/2-inch or 3/4- inch) regular bevel needle. The injection point on the B-Bevel needle is shorter than a regular injection needle.

Sterile disposable syringes will virtually eliminate injection-site infections. If you require multiple-dose syringes, several brands of disposable sterile automatic vaccine syringes are available.

Syringe Cleaning Steps

1. Clean only the external syringe surface with soap, water and a brush.
2. Rinse the inside components of the vaccine syringe, including tubes and connectors with distilled or deionized water near the boiling point (greater than 180 F).
   - This is accomplished by drawing water hotter than 180 F into the syringe and squirting it out. Three to

five rinses should be adequate.
- Remove as much water from the inside of the syringe as can be squirted out and let the syringe cool before using. Heat kills modified live vaccine (MLV) products.
- DO NOT use soap or disinfectant on internal components as residues may kill MLV vaccines and may alter killed vaccine efficacy.

3. Store the vaccine syringe in a dust free, dry (low humidity) environment.
   - It is best if the newly cleaned vaccine syringe is stored in a new plastic zip bag and placed in the freezer.

Vaccine Handling Precautions

Attention to details while storing, handling and administering vaccines can determine the outcome of the herd health program. The following practices will enhance the effectiveness of the program.

- READ THE LABEL.
- Purchase new vaccines and store them in a refrigerator.
- Purchase vaccines in containers holding the number of doses appropriate for the task at hand. Storing partially used containers may lead to infections at injection sites, resulting in ineffectiveness of the vaccine.
- Never use an outdated drug or vaccine.
- Use transfer needles to reconstitute vaccines. In general, place one end of the needle into the sterile liquid, and the other in the bottle containing the freeze-dried cake of vaccine. A vacuum should immediately pull the liquid down. If not, discard the vaccine, as it may not be effective. Some products require special transferring techniques. Special instructions will be included on the label.
- Modified live vaccine begins to degrade, or lose effectiveness, after about 90 minutes. Do not mix too much vaccine at one time. Direct sunlight also degrades the products, so keep vaccines and syringes in a cooler while working cattle. When using a large bottle of vaccine, mix thoroughly at first and gently shake the bottle often.
- Do not use the same syringes to inject modified live and killed products. A trace of killed product can harm the effectiveness of the modified live product.
- Clean the top of the vaccine bottle before inserting needles. To avoid contaminating the vaccine, do not put the needle used to inject animals back into the vaccine bottle. Change needles every 10 uses to 15 uses. Discard any bent needles.
- Never mix vaccines or other animal health products. Mixing unlike products can destroy their effectiveness. Use only approved combinations.
- A dangerous practice is to store veterinary drugs in the feed room. This is especially true for pesticides, which could be accidentally mixed into a feed ration.

Care and Husbandry Practices

Sound animal husbandry practices – based on research and decades of practical experience – are known to impact the well-being of cattle, individual animal health, herd productivity and carcass quality. Because cattle are produced using a variety of management systems, in very diverse environmental and geographical locations in the U.S., there is not one specific set of production practices that can be recommended for all cattle producers to implement. Personal experience, training and professional judgment are key factors in providing proper animal care. Following are suggestions when putting a Beef Quality Assurance system into place within a beef production enterprise.

Figure 45.10. Providing a balanced diet is a critical component of BQA.

Biosecurity

Biosecurity is a practice designed to prevent the spread of disease by minimizing the movement of biologic organisms (viruses, bacteria, rodents, etc.) onto and within your operation. Preventing, or at least minimizing, cross contamination must be a primary focus of all activities on a livestock operation.

Biosecurity can be very difficult to maintain because of the very complex interrelationships between management, biologic organisms and biosecurity. Biocontainment may be the only practical control for many diseases. While developing and maintaining biosecurity is difficult, it is the least expensive and most effective means of disease control available. Disease prevention programs will not work without detailed attention to biosecurity.

Livestock Facilities

Facilities (fences, chutes, shelters, etc.) should be maintained in good working condition and cleaned periodically to provide efficient movement and reduce stress when working cattle. Corrals, pens and chutes should be the proper size for the number of animals and the type of processing being done. This allows for proper ventilation and reduces stress on animals while in confinement. Good drainage of water is essential to reducing stress and increasing the health of animals in confinement. Sharp objects and protrusions can result in bruising and should be avoided whenever possible. Equipment to restrain cattle should allow for quick and secure restraint to minimize

Figure 45.11. Cow with BCS of 4.

Figure 45.12. Cow with BCS of 7.

Figure 45.13. Quality control of the feed supply is a critical control point of BQA.

stress or injury to the animal or the operator. Experienced and trained personnel should operate restraining equipment.

Beef cattle are produced in a variety of production settings, from pasture and range to dry lot and confinement facilities. When behavioral and physiological characteristics of cattle are matched to local conditions, beef cattle thrive in virtually any environment without artificial shelter. However, during extreme weather conditions, cattle should have access to well-drained resting areas and/or to natural or constructed shelter.

Transportation

Maintaining a safe working environment for both cattle and people is an essential part of cattle transportation. Simply inspecting loading facilities and trailers for safe operation prior to loading helps prevent any unwanted accidents from occurring.

Proper maintenance and inspection of the loading facilities, vehicle and the trailer can prevent injury. A good time to inspect the trailer is once it has arrived and is in place, but before loading the animals. Trailer tires and floors often are the most worn parts of the trailer. Tires should be in good condition, properly inflated and free of dry rot. Floors should be clean and well-maintained. Cattle can easily lose traction on dirty or wet flooring, which can cause injury. Wood floors are common in many stock trailers and should be inspected, as they can deteriorate through time, especially if the trailer is not cleaned after use. Some stock trailers use rubber flooring or mats. These increase traction for animals and often stand up to urine and manure better than wood floors. If mats are used, ensure the floor is dry after cleaning because the mat can trap moisture underneath.

Sorting and loading practices also can help prevent injury to both workers and animals. Sorting cattle by size prior to loading prevents injury to smaller animals. This allows the trailer to be loaded according to its designed specifications and load limits. Before loading, the trailer needs to be properly positioned without open space on the sides or a gap between the trailer and the working facility. This will prevent cattle from getting a leg or neck caught while approaching the trailer. When loading cattle, leave enough room for animals to stand. Overcrowding can cause cattle to be trampled and injured inside the trailer. For smaller loads, partition cattle into appropriately sized areas by closing off interior gates rather than leaving the entire area open. This will increase stability for both cattle and the trailer. Producers also should plan for weather-related stress conditions while transporting cattle and plan accordingly. There is now a BQA Transportation certification program that can be accessed along with additional information regarding cattle transportation at BQA.org.

Nutrition and Feedstuffs

Nutrition

Cattle should have access to an adequate quantity and quality of nutrients for body maintenance and growth (Figure 45.10). For grazing cattle, the primary nutrient source is forage. There are times, however, when supplementation or complete feeding is required, such as during winter when adequate forage is not available or when forage quality is low. In these cases, producers are challenged with designing a feeding or supplementation program designed to match

the forage supply. This can be difficult because nutrient requirements of cattle vary according to age, sex, weight, body condition, stage of production and environmental temperature. Specific guidance for formulating effective supplementation programs and rations for cattle are provided through local OSU Extension offices and at the Beef Extension website at beefextension.okstate.edu. Tabular values of nutrient requirements for various classes of cattle are available, and tables showing typical nutrient values of common feeds are provided. Additionally, easy-to-use computer software is available for producers to download and use.

Cattle should have access to an adequate supply of clean water at all times. Water requirements vary greatly, and consumption will normally range from 1 gallon per 100 pounds of body weight during cold weather, to nearly 2 gallons per 100 pounds of body weight during hot weather.

An excellent tool to evaluate the effectiveness of an animal's current nutritional status is the body condition scoring (BCS) system (Figures 45.11 and 45.12). Scores range from 1 (very emaciated) to 9 (obese or excessively fat). The optimum range for cows at calving time is BCS 5. Cows calving below BCS 5 produce less colostrum, lower-quality colostrum and have decreased milk production. Nutritional stress can impact the animal's health and immune system, thereby emphasizing the need for the proper balance of protein and energy to the nutritional needs of cattle.

Feedstuffs

Since most beef cattle operations purchase feeds from outside sources, quality control of the supply is a critical control point in beef quality assurance (Figure 45.13). Maintaining feed records and closely adhering to feed additive label directions and withdrawal times also should be considered critical control points. Feeding byproduct ingredients should be supported with sound science. Ruminant-derived animal protein feeds are not allowed to be used under current federal law. High-risk byproduct ingredients include fats, rendered byproducts and other plant-based byproducts, such as glycerol from corn-based ethanol production. These may be single loads or batches that will be fed to cattle for a prolonged period of time. If purchasing fats and oils, monitor for potential contaminants. Letters of guarantee from companies supplying these materials may be requested that state these materials have been tested.

Veterinary Feed Directive

Under the Animal Drug Availability Act (ADAA) of 1996, congress created a new category for drugs called veterinary feed directive (VFD) drugs. Prior to this new rule, all drugs were classified by the Food and Drug Administration (FDA) as over-the-counter (OTC) or prescription (Rx) drugs. A VFD drug is an animal drug intended for use in or on animal feed that requires the supervision of a licensed veterinarian.

VFD drugs are not prescription drugs. Prescription drugs are not mixed in or on animal feed. Prescription drugs may be used under certain conditions in an extra-label manner, which is not permitted for VFD drugs. VFD drugs are not governed by state pharmacy laws unlike prescription drugs, which are governed.

Until now, only a select few drugs have been designated VFD drugs. On June 3, 2015, the Food and Drug Administration (FDA) released the final version of the amended new animal drug regulation for the VFD drugs (21CFR558.6). The revised rule changed all OTC feed grade antimicrobials considered medically important antimicrobial drugs (drugs that are important for therapeutic use in humans) to VFD drugs. Some of the common OTC beef cattle drugs used in or on feed affected by the change in the rule are chlorotetracyline, neomycin, oxytetracycline and sulfas. A few drugs not considered important in human medicine such as ionophores, coccidiostats, bacitracins, bambermycin, carbadox and pleuromutilin continues to be available OTC.

In keeping with the FDA's theme of judicious use of medically important antimicrobials, pharmaceutical companies have voluntarily agreed to remove any growth-performance claims from the label of VFD drugs. This means using any of these drugs for weight gain or improved feed efficiency is prohibited. Emphasis is placed on using these drugs for prevention, control and treatment of diseases with the oversight of a veterinarian.

VFD feeds may only be purchased with a VFD order. A VFD order is a written statement that a licensed veterinarian issues after examining and diagnosing an animal(s) condition. When the veterinarian deems it necessary to treat, control or prevent the disease, they may order the use of a VFD drug or combination VFD drug in or on animal feed. A producer may obtain a VFD order from their veterinarian, provided they have a proper Veterinary-Client-Patient-Relationship (VCPR). The definition of a VCPR is defined by the federal regulation as:

1. A veterinarian has assumed the responsibility for making the medical judgements regarding the health of (an) animal(s) and the need for medical treatment; and the client (the owner of the animal or animals or other caretaker) has agreed to follow the instructions of the veterinarian.
2. There is sufficient knowledge of the animal(s) by the veterinarian to initiate at least a general or preliminary diagnosis of the medical condition of the animal(s).
3. The practicing veterinarian is available for followup in case of adverse reactions or failure of the regimen of therapy. Such a relationship can only exist when the veterinarian has recently seen or is personally acquainted with the keeping and care of the animal(s) by virtue of examination of the animal(s) and/or by medically appropriate and timely visits to the premises where the animal(s) are kept.

A valid VFD should contain the following information:

- Veterinarian's name, address and phone number.
- Client's name, address and phone number.
- Premises at which the animals specified in the VFD are located.
- Date of VFD issuance.
- Expiration date.
- Name of VFD drug.

Figure 45.14. Check the product label for grazing restrictions following application of pesticides on grazing lands.

- Species and production class of animals to be fed.
- Approximate number of animals.
- The indication for which the VFD is issued.
- The level of VFD drug in the feed and the "Duration of Use."
- The withdrawal time, special instructions and cautionary statement.
- "Reorders or Refills."
- The statement: "Use of feed containing this veterinary feed directive (VFD) in a manner other than directed on the labeling (extra label use) is not permitted."
- An affirmation of intent for combination VFD drugs.
- Veterinarian's signature.

Premises is a description of where the animals are located. It needs to be specific enough for someone not familiar with the area to find those animals. A producer may include landmarks, GPS information or pen numbers in addition to an address to help better describe the location.

The "expiration date" specifies the last day a VFD feed can be fed, not the date the drug becomes ineffective. In the drug approval process, some drugs have this information included on the label, but not all. For those drugs without a specified date, the veterinarian will assign an "expiration date" not to exceed six months. Producers may not feed the VFD feed beyond the "expiration date." If a producer cannot complete the therapy before the "expiration date," the producer should contact their veterinarian and obtain a new VFD.

The "duration of use" determines the length of time that the animal feed containing a VFD drug is allowed to be fed to the animals.

Some producers may question the difference between "expiration date" and "duration of use." The "expiration date" is the last day the feed may be fed. The "duration of use" is number of days of therapy. For instance, if a VFD drug has an "expiration date" of 45 days and a "duration of use" of 14 days, the producer has 45 days to obtain the VFD feed and complete the 14 days of therapy. If the VFD drug label does not specify the "expiration date" or "duration of use," then the veterinarian will specify those dates, which may not exceed six months.

During the drug approval process if a reorder (refill) is approved, then a veterinarian is permitted to authorize a reorder. If the label is silent on reorders, a veterinarian may not authorize a reorder.

"Extra-label" use of VFD drugs or OTC drugs in feed is strictly forbidden by the producer or the veterinarian. A producer may not feed the VFD feed in a manner different than the label specifies. Examples of "extra-label" use are feeding to a different species, feeding at a different concentration, feeding longer than the "duration of therapy" or feeding past "expiration date."

A VFD drug may be combined with another VFD drug or OTC drug if specified by the label of the VFD drug. A veterinarian must specifically allow for a VFD drug to be combined with another VFD drug or OTC drug in the VFD order.

A producer has certain responsibilities when feeding a feed containing a VFD drug. A producer is responsible for feeding a feed with a VFD drug according to the label written by the veterinarian. They must not feed the VFD feed beyond the expiration date. Lastly, a producer must maintain a copy of the VFD order for a minimum of two years and provide a copy of the VFD order for inspection and copying, if requested by the FDA.

If a producer wishes to obtain more information about veterinary feed directives, they may view the document Code of Federal Regulations, Title 21, chapter I, Subchapter E, Part 558 or go to fda.gov/AnimalVeterinary/DevelopmentApprovalProcess/ucm071807.htm .

Figure 45.15. Mycotoxin contaminated corn prior to harvest.

Contamination from Pesticides

Pesticides are an important tool in livestock production to control insects and weeds. However, inappropriate use of these products can lead to chemical residues in beef, unsafe human exposure to chemicals and groundwater contamination. Consequently, only agricultural chemicals approved for application to land grazed by livestock or on land where feedstuffs are removed for animal consumption

at a later time should be used (Figure 45.14). Be sure to follow label directions and observe grazing restrictions on pastures, rangeland and crops treated with pesticides. Store all chemicals (pesticides, lubricants and solvents) away from feed supplies. The final step in ensuring the safe use of pesticides is to document usage and observe appropriate withdrawal times before marketing cattle. Pesticide use records should be maintained for a minimum of three years.

Oklahoma Pesticide Law requires the registration of all pesticides distributed, sold or offered for sale within the state. Each pesticide product must be registered annually with the Consumer Protection Services Division of the Oklahoma Department of Agriculture, Food and Forestry. This law also provides for the sampling and chemical analysis of pesticides distributed, sold or offered for sale in the state. Under the Pesticide Law, it is unlawful to distribute, sell or use any registered pesticide in a manner inconsistent with its labeling.

The Environmental Protection Agency is directed by federal law to classify all pesticides for either general use or restricted use. Pesticides classified for general use may be purchased by the general public and applied according to the label directions. Pesticides classified for restricted use may be purchased and applied only by certified applicators or individuals working with the direct supervision of a certified applicator.

A certified applicator is any individual who is certified to use or supervise the use of any pesticide that is classified for restricted use. Applicator certification is available in several classes, including: Private Applicator, Commercial Applicator, Noncommercial Applicator and Service Technicians. Information on the appropriate certification class and certification procedures can be obtained through your OSU Extension office or through the Oklahoma Department of Agriculture, Food and Forestry's Consumer Protection Services Division (405-521-3864 or oda.state.ok.us/cps/index.htm).

Mycotoxins

Mycotoxins are naturally occurring chemicals produced by fungi. They can be found in grains and forages, and if present in sufficient concentrations, can cause reduced feed consumption, weight loss, abortions and residues in meat and milk products. Mycotoxins can be produced in feedstuffs prior to harvesting or during storage. Mycotoxins may include vomitoxin, aflatoxin, fumonisin and zearalenone. Guidelines established by the Food and Drug Administration and the Oklahoma Animal Disease Diagnostic Laboratory for allowable concentration of aflatoxin (one of the most common mycotoxins in Oklahoma) contamination in feedstuffs for cattle are:

Lactating dairy cattle	20 ppb[1]
Immature livestock	20 ppb
Breeding cattle	100 ppb
Finishing cattle	300 ppb

[1] Parts per billion.

Mycotoxin production in the field is very difficult to control (Figure 45.15). Drought conditions and hail frequently predispose grain to infection by toxic fungi. Consequently, incoming feed ingredients, including freshly harvested feed grains and forage, should be monitored for possible mycotoxin contamination. Storing feed and grain at low moisture content and temperatures will help prevent fungus growth. Apply chemical preservatives according to label directions to ensure complete coverage of the feed or grain. Monitor and aerate treated feed or grain the same as dry grain.

Cleanliness in feed storage facilities, transportation equipment and feeding areas reduces possible mycotoxin contamination of feeds. Remove caked and molded grain from transport trucks, storage bins, conveyors and feeding troughs. If the presence of mycotoxins is questionable, a feed sample should be submitted to a qualified laboratory for quantitative analysis.

No Ruminant-Derived Protein

No ruminant-derived protein sources can be fed. As of 1998, federal regulations prohibit the feeding of certain mammalian protein sources. The regulations primarily impact the feeding of meat meal and bone meal derived from ruminants. This restriction is a key critical control point to prevent the establishment or amplification of bovine spongiform encephalopathy in the U.S. through the consumption of specified risk material. Tallow, blood byproducts, gelatin products and milk products are excluded by the regulation and are acceptable for use in ration formulations.

Feed Additives and Medications

The use of medicated feeds for livestock is regulated by the FDA. Feed mills that mix certain premixes are required to register with the FDA and are subject to routine inspections. Other feed-mixing facilities, including on-farm mixing facilities are not required to register with the FDA but are required to follow Current Good Management Practices (CGMPs). CGMPs include the following:

1. Facilities and equipment should be constructed and maintained to minimize vermin and pest infestation; allow proper maintenance and cleaning; accurately produce feed of intended use; and prevent accidental contamination from fertilizer, pesticides or other contaminants.
2. Quality assurance of feed products through identification, storage, inventory control, documented corrective actions and adherence to label instructions.
3. Proper equipment cleanout procedures to prevent carryover.
4. Proper labeling and complete records of feed formulations.

A more complete document outlining CGMPs for non-registered feed mills is available from the FDA at fda.gov/.

Only FDA-approved medicated feed additives should be used in rations. Extra-label use of feed additives is illegal and

strictly prohibited. To avoid violative residues, withdrawal times must be strictly followed. Complete records must be kept when formulating or feeding medicated feed rations. Records are to be kept a minimum of three years.

Records

Importance of Records

Recordkeeping, either on a computer or handwritten, is a critical management tool. Inventory and usage records can point out inefficiencies, theft and negligence. With today's narrow profit margins, correct inventory management is essential.

To ensure consumer confidence and maintain market share, producers must be able to document the use and safety of beef products. The industry must be able to prove it has tight control of risk factors with a residue potential through effective documentation. As a result, consumer confidence will be strengthened and regulatory pressures will be reduced.

Animal health products are costly items. Accurate records can highlight inefficiencies on an animal-by-animal basis and prevent ineffective administration of treatments. Furthermore, this information tells the veterinarian the treatments administered and allows for validation of treatment recommendations. This may require the veterinarian to adjust treatment regimens as animals and environmental conditions change. Records are very important to business success. Regulatory inspections by the FDA, USDA, EPA or OSHA will prove the necessity of good records. Effective documentation showing appropriate compliance with training, inventory control, use orders, animal identification, withdrawal and disposal will help avoid liability from a residue contamination. Should a feed yard be cited for a residue violation and that feed yard believes a mistake in identity has been made, good records may be the only proof of compliance. Records also will indicate the complete listing of pharmaceutical products used at the feed yard. Accusations that certain drugs have been used can be avoided when the feed yard can prove it does not use that specific compound.

Computer record systems make extensive evaluation easy and efficient; however, hand-kept record systems are still very effective. Each system has its own merits, so select the best system for your beef production unit.

Veterinary Drug Order

A Veterinary Drug Order (VDO) is a veterinarian-approved list of medications used in the operation and fits BQA guidelines (Figure 45.16).

The VDO should include all products that have a withdrawal time, including vaccines, antiparasitic drugs and all injectables (including vitamins). When all medications, vaccines, etc. are managed as if they are prescription items, an additional measure of quality assurance and safety is obtained.

All cattle medications and vaccines should be included on the VDO and should be updated at the same time the treatment protocol plan is updated.

Treatment Protocol Plan

Ask a veterinarian to develop a treatment protocol plan specific to the operation (Figures 45.17). Keep the treatment protocol plan on file at the treatment facility.

This concept of a treatment protocol plan may be more familiar to feed yards and larger stocker operations. However, it is a valuable management practice for cow-calf producers as well. It is simply writing a plan for what treatment(s) are to be used when cattle get sick for various reasons.

Also, write a plan for follow up and/or alternative treatments if the initial treatment does not produce the desired result.

The plan should be reviewed regularly and updated at least every 90 days or as often as is appropriate. When updating the protocol plan, previous versions also should be kept on file for a year or for reference for treatments that have worked in previous situations. When the plan is updated, it must have a veterinarian's signature and date recorded.

Accurate records also allow knowledge of exactly what is going into each animal or group of animals (Figure 45.18). This information prevents the re-administration of treatments that have previously failed to work. Furthermore, the information tells the consultant/veterinarian what treatments are being applied and what treatment recommendations are being followed to assess whether treatment regimens need to be adjusted.

Individual treatment records are useful for specific treatment of disease or injury to one specific animal. Group treatment records are used when vaccinations or mass medication treatments are administered to the herd. Both record types are similar, but it is important to maintain them separately for quick reference. This will make it easier for cattle to be checked and cleared to assure all withdrawal times have been met. A copy of all treatment records also should be transferred with the cattle at the point of sale, and buyers must be informed if cattle have not met withdrawal times.

Conclusion

Producers can have a positive impact on the quality and consistency of beef products by implementing BQA guidelines. The goal of the BQA program is to assure the consumer that all cattle shipped from a beef operation are healthy, wholesome and safe, and their management has met all government and industry standards.

References

Animal Drugs, Feeds and Related Products. 21 CFR pt.558 (1975).

Animal Drugs, Feeds and Related Products. 21 CFR pt.530 (1975).

Apple, J.K. (1999) Influence of Body Condition Score on Live and Carcass Value of Cull Beef Cows. *Journal of Animal Science* 77:2610-2620.

Boykin, C.A. et al. National Beef Quality Audit - 2016: In-plant survey of carcass characteristics related to quality, quantity, and value of dead steers and heifers. *Journal of Animal Science*. 2107.95:2993-3002.

Boyles, S. et al. (2001) Ohio Beef Quality Assurance. The Ohio State University.

Code of Federal Regulations, Title 21, chapter I, Subchapter E, Part 558
Code of Federal Regulations, Title 21, chapter I, Subchapter E, Part 530
Cundiff, L.V. et al. 2004. Germplasm Evaluation Program. Progress Report No. 22.
Eastwood, L.C. et al. National Beef Quality Audit -2016: Transportation, mobility and harvest-floor assessments of targeted characteristics that affect quality and value of cattle, carcasses and by-products. Transl. Anim. Sci.2017. 1:229-238.
FDA. 2015. #120 Guidance for Industry. Veterinary Feed Directive Regulation Questions and Answers. fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/ucm052660.pdf.(Accessed 8 September 2015.)
FDA. 2012. #209. Guidance for Industry. The Judicious Use of Medically Important Antimicrobial Drugs in Food Producing Animals.
FDA. 2013. #213. Guidance for Industry. New Animal Drugs and New Animal Generic Combination Products Administered in or on Medicated feed or Drinking Water of Food-Producing Animals: Recommendations. fda.gov/downloads/AnimalVeterinary/GuidanceComplianceEnforcement/GuidanceforIndustry/UCM299624.pdf. (Accessed 8 September 2015.)
Gray, G. D., M. C. Moore, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, T. E. Lawrence, K. E. Belk, D. R. Woerner, J. D. Tatum, D. L. VanOverbeke, G. G. Mafi, R. J. Delmore Jr., S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows and M. E. O'Connor. 2012. National Beef Quality Audit - 2011: Survey of instrument grading assessments of beef carcass characteristics. *Journal of Animal Science* 90:5152-5158.
Guidance for Industry #120: Veterinary Feed Directive Regulation Questions and Answers.
Guidance for Industry #209: The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals.
Guidance for Industry #213: New Animal Drugs and New Animal Generic Combination Products Administered in or on Medicated Feed or Drinking Water of Food-Producing Animals: Recommendations.-
Hale, D. S. et al. 2007. National Market Cow and Bull Beef Quality Audit-2007: A Survey of Producer-Related Defects. Final Report to the National Cattlemen's Beef Association, Centennial, CO.
Harris, M.K. et al. National Beef Quality Audit -2016: Transportation, mobility, live cattle and carcass assessments of targeted producer-related characteristics that affect value of market cows and bulls, their carcass, and associated by-products. *Translational Animal Science*. 2017.1:570-584.
Kuehn, L. A. and R. M. Thallman. 2014. Across-Breed EPD tables for the Year 2014 Adjusted to Breed Differences for Birth Year of 2012. Proc. Beef Improvement Federation 46th Annual Research Symposium and Annual Meeting, Lincoln, Nebraska. June 18-21, 2014. pp 134-159.
Lalman, D. and R. Smith. (2000) Effects of Preconditioning on Health, Performance and Prices of Weaned Calves. OSU Fact Sheet ANSI-3529.
Moore M.C. et al. 2012. National Beef Quality Audit-2011: In-plant survey of targeted carcass characteristics related to quality, quantity, value, and marketing of fed steers and heifers. *Journal of Animal Science* 90:5143-5151.
Moore, M. C., G. D. Gray, D. S. Hale, C. R. Kerth, D. B. Griffin, J. W. Savell, C. R. Raines, K. E. Belk, D. R. Woerner, J. D. Tatum, J. L. Igo, D. L. VanOverbeke, G. G. Mafi, T. E. Lawrence, R. J. Delmore Jr., L. M. Christensen, S. D. Shackelford, D. A. King, T. L. Wheeler, L. R. Meadows and M. E. O'Connor. 2012. National Beef Quality Audit - 2011: In-plant survey of targeted carcass characteristics related to quality, quantity, value, and marketing of fed steers and heifers. *Journal of Animal Science* 90:5143-5151.
McKeith R.O. et al. 2012. National Beef Quality Audit-2011:Harvest-floor Assessments of Targeted Characteristics that Affect Quality and Value of Cattle, Carcasses and Byproducts. *Journal of Animal Science* 90:5135-5142.
McKenzie K. et al. National Beef Quality Audit-2016: Assessment of cattle hide characteristics, offal condemnations and carcass traits to determine the quality status of the market cow and bull beef industry. *Translational Animal Science*.2018.2:37-49
National Cattlemen's Beef Association. A Producer's Guide for Judicious Use of Antimicrobials in Cattle. (2001)
National Cattlemen's Beef Association. 2019: National Manual, Beef Quality Assurance Denver, Colorado. Accessed 4/27/20 and available atbqa.org/resources/manuals.
National Cattlemen's Beef Association. Beef Quality Assurance National Guidelines.(2001) Denver, Colorado.
Navigating Pathways to Success: 2016 National Beef Quality Audit Executive Summary: 2016 National Beef Quality Audit Executive Summary. Accessed 4/27/20 atbqa.org/national-beef-quality-audit.
Navigating Pathways to Success: 2016 National Beef Quality Audit - Market Cow and Bull Executive Summary. Accessed 4/27/20 at bqa.org/national-beef-quality-audit.
Smith, G.C. et al. (2000) National Beef Quality Audit. Improving the Quality Consistency, Competitiveness and Market Share of Fed-Beef. National Cattlemen's Beef Association.
USDA. 2006a. Performance requirements for instrument marbling evaluation (PRIME I). Demonstration of repeatability, accuracy, and precision. Livestock, Poultry, and Seed Program, Agricultural Marketing Services, USDA, Washington, DC.
USDA. 2006b. Performance requirements for Instrument Marbling Evaluation (PRIME II). Implementation and verification of operational procedures. Livestock, Poultry, and Seed Program, Agricultural Marketing Services, USDA, Washington, DC.
Woerner, D. R. and K. E. Belk. 2008. The history of instrument assessment of beef. Report submitted to the National Cattlemen's Beef Association, Denver, CO.

Veterinary Drug Order

The following products are to be used at_____.

Brand Name & Company	Lot Numbers	Number of Doses	Date Purchased	Dates Used	Withdrawal Time	Expiration Date

Figure 45.16. Example of a veterinary drug order. This form may be copied.

Treatment Protocol Plan

Disorder: _____

Indications for treatment (symptoms of affected animals): _____

_____

_____

_____

Primary Treatment

Product/active ingredient: _____

Dose: _____

Route of administration: _____

Duration/frequency of treatment: _____

Withdrawal period: _____

Other comments: _____

_____

_____

Secondary Treatment

Product/active ingredient: _____

Dose: _____

Route of administration: _____

Duration/frequency of treatment: _____

Withdrawal period: _____

Other comments: _____

_____

_____

Prevention

Product: _____

Dose: _____

Route of administration: _____

Withdrawal: _____

Special instructions: _____

_____

_____

_____

_____

_____

Veterinarian signature: _____

Figure 45.17. Example of a treatment protocol plan. This form may be copied.

Health Treatment Record for Cattle

ID/group description	Date of treatment	Comments/symptoms/ temperature	Product used	Serial/ lot numbers	Route[1] and location[2] of administration and dosage	Withdrawal date	Person giving treatment

[1] SQ (Subcutaneous); IM (Intramuscular); O (Oral).
[2] RN (Right Neck); RE (Right Ear); LN (Left Neck); LE (Left Ear).

Keep This Record for Three Years

Figure 46. 18. Example of a treatment record for cattle. This form may be copied.

Appendix 1: Gestation Table

Gestation table (based on 283 days).

Breeding date	*Due date*	*Breeding date*	*Due date*	*Breeding date*	*Due date*	*Breeding date*	*Due date*	*Breeding date*	*Due date*	*Breeding date*	*Due date*
Jan 1	Oct 10	Mar 3	Dec 10	May 3	Feb 9	Jul 3	Apr 11	Sep 2	Jun 11	Nov 2	Aug 11
Jan 2	Oct 11	Mar 4	Dec 11	May 4	Feb 10	Jul 4	Apr 12	Sep 3	Jun 12	Nov 3	Aug 12
Jan 3	Oct 12	Mar 5	Dec 12	May 5	Feb 11	Jul 5	Apr 13	Sep 4	Jun 13	Nov 4	Aug 13
Jan 4	Oct 13	Mar 6	Dec 13	May 6	Feb 12	Jul 6	Apr 14	Sep 5	Jun 14	Nov 5	Aug 14
Jan 5	Oct 14	Mar 7	Dec 14	May 7	Feb 13	Jul 7	Apr 15	Sep 6	Jun 15	Nov 6	Aug 15
Jan 6	Oct 15	Mar 8	Dec 15	May 8	Feb 14	Jul 8	Apr 16	Sep 7	Jun 16	Nov 7	Aug 16
Jan 7	Oct 16	Mar 9	Dec 16	May 9	Feb 15	Jul 9	Apr 17	Sep 8	Jun 17	Nov 8	Aug 17
Jan 8	Oct 17	Mar 10	Dec 17	May 10	Feb 16	Jul 10	Apr 18	Sep 9	Jun 18	Nov 9	Aug 18
Jan 9	Oct 18	Mar 11	Dec 18	May 11	Feb 17	Jul 11	Apr 19	Sep 10	Jun 19	Nov 10	Aug 19
Jan 10	Oct 19	Mar 12	Dec 19	May 12	Feb 18	Jul 12	Apr 20	Sep 11	Jun 20	Nov 11	Aug 20
Jan 11	Oct 20	Mar 13	Dec 20	May 13	Feb 19	Jul 13	Apr 21	Sep 12	Jun 21	Nov 12	Aug 21
Jan 12	Oct 21	Mar 14	Dec 21	May 14	Feb 20	Jul 14	Apr 22	Sep 13	Jun 22	Nov 13	Aug 22
Jan 13	Oct 22	Mar 15	Dec 22	May 15	Feb 21	Jul 15	Apr 23	Sep 14	Jun 23	Nov 14	Aug 23
Jan 14	Oct 23	Mar 16	Dec 23	May 16	Feb 22	Jul 16	Apr 24	Sep 15	Jun 24	Nov 15	Aug 24
Jan 15	Oct 24	Mar 17	Dec 24	May 17	Feb 23	Jul 17	Apr 25	Sep 16	Jun 25	Nov 16	Aug 25
Jan 16	Oct 25	Mar 18	Dec 25	May 18	Feb 24	Jul 18	Apr 26	Sep 17	Jun 26	Nov 17	Aug 26
Jan 17	Oct 26	Mar 19	Dec 26	May 19	Feb 25	Jul 19	Apr 27	Sep 18	Jun 27	Nov 18	Aug 27
Jan 18	Oct 27	Mar 20	Dec 27	May 20	Feb 26	Jul 20	Apr 28	Sep 19	Jun 28	Nov 19	Aug 28
Jan 19	Oct 28	Mar 21	Dec 28	May 21	Feb 27	Jul 21	Apr 29	Sep 20	Jun 29	Nov 20	Aug 29
Jan 20	Oct 29	Mar 22	Dec 29	May 22	Feb 28	Jul 22	Apr 30	Sep 21	Jun 30	Nov 21	Aug 30
Jan 21	Oct 30	Mar 23	Dec 30	May 23	Mar 1	Jul 23	May 1	Sep 22	Jul 1	Nov 22	Aug 31
Jan 22	Oct 31	Mar 24	Dec 31	May 24	Mar 2	Jul 24	May 2	Sep 23	Jul 2	Nov 23	Sep 1
Jan 23	Nov 1	Mar 25	Jan 1	May 25	Mar 3	Jul 25	May 3	Sep 24	Jul 3	Nov 24	Sep 2
Jan 24	Nov 2	Mar 26	Jan 2	May 26	Mar 4	Jul 26	May 4	Sep 25	Jul 4	Nov 25	Sep 3
Jan 25	Nov 3	Mar 27	Jan 3	May 27	Mar 5	Jul 27	May 5	Sep 26	Jul 5	Nov 26	Sep 4
Jan 26	Nov 4	Mar 28	Jan 4	May 28	Mar 6	Jul 28	May 6	Sep 27	Jul 6	Nov 27	Sep 5
Jan 27	Nov 5	Mar 29	Jan 5	May 29	Mar 7	Jul 29	May 7	Sep 28	Jul 7	Nov 28	Sep 6
Jan 28	Nov 6	Mar 30	Jan 6	May 30	Mar 8	Jul 30	May 8	Sep 29	Jul 8	Nov 29	Sep 7
Jan 29	Nov 7	Mar 31	Jan 7	May 31	Mar 9	Jul 31	May 9	Sep 30	Jul 9	Nov 30	Sep 8
Jan 30	Nov 8	Apr 1	Jan 8	Jun 1	Mar 10	Aug 1	May 10	Oct 1	Jul 10	Dec 1	Sep 9
Jan 31	Nov 9	Apr 2	Jan 9	Jun 2	Mar 11	Aug 2	May 11	Oct 2	Jul 11	Dec 2	Sep 10
Feb 1	Nov 10	Apr 3	Jan 10	Jun 3	Mar 12	Aug 3	May 12	Oct 3	Jul 12	Dec 3	Sep 11
Feb 2	Nov 11	Apr 4	Jan 11	Jun 4	Mar 13	Aug 4	May 13	Oct 4	Jul 13	Dec 4	Sep 12
Feb 3	Nov 12	Apr 5	Jan 12	Jun 5	Mar 14	Aug 5	May 14	Oct 5	Jul 14	Dec 5	Sep 13
Feb 4	Nov 13	Apr 6	Jan 13	Jun 6	Mar 15	Aug 6	May 15	Oct 6	Jul 15	Dec 6	Sep 14
Feb 5	Nov 14	Apr 7	Jan 14	Jun 7	Mar 16	Aug 7	May 16	Oct 7	Jul 16	Dec 7	Sep 15
Feb 6	Nov 15	Apr 8	Jan 15	Jun 8	Mar 17	Aug 8	May 17	Oct 8	Jul 17	Dec 8	Sep 16
Feb 7	Nov 16	Apr 9	Jan 16	Jun 9	Mar 18	Aug 9	May 18	Oct 9	Jul 18	Dec 9	Sep 17
Feb 8	Nov 17	Apr 10	Jan 17	Jun 10	Mar 19	Aug 10	May 19	Oct 10	Jul 19	Dec 10	Sep 18
Feb 9	Nov 18	Apr 11	Jan 18	Jun 11	Mar 20	Aug 11	May 20	Oct 11	Jul 20	Dec 11	Sep 19
Feb 10	Nov 19	Apr 12	Jan 19	Jun 12	Mar 21	Aug 12	May 21	Oct 12	Jul 21	Dec 12	Sep 20
Feb 11	Nov 20	Apr 13	Jan 20	Jun 13	Mar 22	Aug 13	May 22	Oct 13	Jul 22	Dec 13	Sep 21
Feb 12	Nov 21	Apr 14	Jan 21	Jun 14	Mar 23	Aug 14	May 23	Oct 14	Jul 23	Dec 14	Sep 22
Feb 13	Nov 22	Apr 15	Jan 22	Jun 15	Mar 24	Aug 15	May 24	Oct 15	Jul 24	Dec 15	Sep 23
Feb 14	Nov 23	Apr 16	Jan 23	Jun 16	Mar 25	Aug 16	May 25	Oct 16	Jul 25	Dec 16	Sep 24
Feb 15	Nov 24	Apr 17	Jan 24	Jun 17	Mar 26	Aug 17	May 26	Oct 17	Jul 26	Dec 17	Sep 25
Feb 16	Nov 25	Apr 18	Jan 25	Jun 18	Mar 27	Aug 18	May 27	Oct 18	Jul 27	Dec 18	Sep 26
Feb 17	Nov 26	Apr 19	Jan 26	Jun 19	Mar 28	Aug 19	May 28	Oct 19	Jul 28	Dec 19	Sep 27
Feb 18	Nov 27	Apr 20	Jan 27	Jun 20	Mar 29	Aug 20	May 29	Oct 20	Jul 29	Dec 20	Sep 28
Feb 19	Nov 28	Apr 21	Jan 28	Jun 21	Mar 30	Aug 21	May 30	Oct 21	Jul 30	Dec 21	Sep 29
Feb 20	Nov 29	Apr 22	Jan 29	Jun 22	Mar 31	Aug 22	May 31	Oct 22	Jul 31	Dec 22	Sep 30
Feb 21	Nov 30	Apr 23	Jan 30	Jun 23	Apr 1	Aug 23	Jun 1	Oct 23	Aug 1	Dec 23	Oct 1
Feb 22	Dec 1	Apr 24	Jan 31	Jun 24	Apr 2	Aug 24	Jun 2	Oct 24	Aug 2	Dec 24	Oct 2
Feb 23	Dec 2	Apr 25	Feb 1	Jun 25	Apr 3	Aug 25	Jun 3	Oct 25	Aug 3	Dec 25	Oct 3
Feb 24	Dec 3	Apr 26	Feb 2	Jun 26	Apr 4	Aug 26	Jun 4	Oct 26	Aug 4	Dec 26	Oct 4
Feb 25	Dec 4	Apr 27	Feb 3	Jun 27	Apr 5	Aug 27	Jun 5	Oct 27	Aug 5	Dec 27	Oct 5
Feb 26	Dec 5	Apr 28	Feb 4	Jun 28	Apr 6	Aug 28	Jun 6	Oct 28	Aug 6	Dec 28	Oct 6
Feb 27	Dec 6	Apr 29	Feb 5	Jun 29	Apr 7	Aug 29	Jun 7	Oct 29	Aug 7	Dec 29	Oct 7
Feb 28	Dec 7	Apr 30	Feb 6	Jun 30	Apr 8	Aug 30	Jun 8	Oct 30	Aug 8	Dec 30	Oct 8
Mar 1	Dec 8	May 1	Feb 7	Jul 1	Apr 9	Aug 31	Jun 9	Oct 31	Aug 9	Dec 31	Oct 9
Mar 2	Dec 9	May 2	Feb 8	Jul 2	Apr 10	Sep 1	Jun 10	Nov 1	Aug 10		

Index

A

accrual-adjusted income statement — 19
accuracy — 78, 207 229, 231, 232, 239, 249-254, 265, 266, 298, 383, 384
acid detergent insoluble nitrogen (ADIN) — 161
acidosis — 151, 164-167, 203, 216, 223, 279, 317, 328
additives — 10, 95, 167, 194, 197, 201, 204, 207, 213, 217, 223-225, 273, 344, 381, 399, 401
adjusted 205-day weight — 238
adjusted yearling weight — 238
adjustment factors — 233, 236, 237, 239, 245, 251
ADIN *(see acid detergent insoluble nitrogen)*
Animal and Plant Health Inspection Service (APHIS) — 369, 370, 372
alfalfa — 113, 150, 151, 159, 167, 178, 191, 203, 204, 208, 210, 223, 224, 272, 274, 280, 311
alliances — 12, 30, 89, 91, 100, 328
American dog tick — 346, 347
amino acids — 132, 134, 179
Agricultural Marketing Services (AMS) — 383
anaplasma marginale — 370
anaplasmosis — 332, 370-372
antibodies — 219, 327, 328
APHIS *(see Animal and Plant Health Inspection Service)*
artificial insemination (AI) — 99, 231, 234, 243, 250, 263, 270, 272, 285-288, 293, 295, 300-302, 289-293, 296-299, 370
asset turnover ratio — 25, 28
average daily gain — 95, 98, 99, 216, 220, 221, 237, 238, 268, 272, 273, 352

B

bacteria — 127-129, 132, 134, 175, 273, 298, 316, 329-332, 364, 369-371, 375, 394
balance sheet — 18, 25, 28
bangs — 326, 331, 371
barley — 74, 117, 118, 153-155, 157, 160, 172, 175, 207, 370,
Beef Improvement Federation (BIF) — 227, 233-235, 237-240, 248, 250, 251, 265, 280
beef quality assurance (BQA) — 286, 325, 355, 374, 385, 388, 394-396, 399-401
behavior — 210, 214, 241, 291, 293, 295, 315, 318, 329, 336, 339, 354, 356, 357, 358, 361, 371, 390, 395
best management practices — 7, 103, 104, 117, 297, 375
BIF *(see Beef Improvement Federation)*
birth weight — 135, 177, 191, 228-230, 232, 233, 235, 237, 245, 248, 250, 254, 268, 312, 316, 322, 323
blackleg — 219, 268, 269, 273, 290, 330, 332, 372
bloat — 151, 132, 164, 165, 166, 167, 174, 207, 209-214, 217
blue tongue virus (BTV) — 371
bovine leukosis virus (BLV) — 371
bovine respiratory syncytial virus (BRSV) — 219, 263, 325, 330-332
bovine spongiform encephalopathy (BSE) — 12, 83, 84, 273, 372, 376, 398
bovine viral diarrhea virus (BVDV) — 219, 326, 330-332, 370, 371
BAQ *(see beef quality assurance)*
breeding soundness — 29, 168, 233, 235, 236, 240, 252, 281, 282, 290, 332
brown stomach worm (See *O. ostertagia*)
brucellosis — 331
budgeting — 25, 101
budgets — 18, 19, 28, 35, 67, 107, 109, 214
bull test stations — 235, 284
BRSV *(see bovine respiratory syncytial virus)*
BSE *(see bovine spongiform encephalopathy)*
BTV *(see blue tongue virus)*
BLV *(see bovine leukosis virus)*
BVDV *(see bovine viral diarrhea virus)*

C

calcium — 121, 131, 134, 159, 164, 165, 168, 172-174, 176, 177, 179, 182, 204, 208, 209, 211, 213, 215, 216, 225, 316, 364
calf crop — 5, 24, 29, 30, 34, 35, 66, 82, 95, 96, 194, 245, 257, 259, 273, 275, 281, 282, 285, 293, 310, 318
calf death loss — 23, 24
calving — 16, 22-24, 29, 35, 79, 82, 83, 95, 96, 121, 133-135, 138, 172, 177, 180, 181, 185, 188, 189, 190, 192, 193, 219, 228, 229, 232-237, 240, 244, 252, 257, 258, 267, 268, 270, 271, 273-276, 282, 285, 290-293, 306, 309-313 315-319, 323, 326-329, 331, 332, 354, 371, 395
calving percentage — 23, 29
carbohydrates — 112, 127, 128, 223, 150, 152, 279
carcass — 24, 80, 89, 91, 99, 100, 162, 165, 211, 221, 227, 229, 233, 238, 239, 245, 248, 249, 254, 255, 256, 258, 265, 279, 328, 340, 354, 375-377, 379, 381-385, 388, 389, 390
carcass quality — 91, 239, 354, 380, 384, 394
carrier animal — 264, 265
cash flow — 16-19, 25, 28, 30, 35, 37, 63, 65, 67-69, 191, 373
castration — 7, 83, 91, 93, 220, 329, 330, 352
cattle grubs — 344
cattle inventory — 3, 22
cellulose — 150
central bull test — 232, 280
Certified Beef Programs — 3383, 384, 388
CGF *(see corn gluten feed)*
Chicago Mercantile Exchange (CME) — 71, 72, 84
chin-ball markers — 295
chromosome — 261-263
CIDR — 303
clostridial — 29, 90, 219, 269, 273, 326, 330-332, 370, 394
CME *(see Chicago Mercantile Exchange)*
cobalt — 148, 158, 175, 179-181, 223, 364

coccidiosis — 223, 371, 372
cold stress — 132
colostrum — 29, 133, 219, 274, 311, 326-329, 332, 371, 395
composite — 244, 255, 256, 258, 270
compost — 376
concentrate feeds —132, 172, 189, 225, 390
conception —133, 254, 267, 270, 273, 281, 290, 291, 294, 300, 311, 313, 316, 335, 354
conception rates — 133, 273, 281, 291, 300, 311, 316, 354
condemnations — 386, 387
confinement — 67, 82, 205, 364, 366, 395
contemporary group — 238, 247, 248, 279, 280
contracts — 33, 41, 73, 78, 84
cool-season forages — 172
copper — 148, 152, , 172, 175-177, 180, 182, 183, 214, 364
corn gluten feed (CGF) — 160, 162, 163, 175, 199, 214
corral design — 358
correlation — 97, 228, 229, 243, 250, 252, 279
cost of production — 3, 5, 21, 30, 37, 83, 237
country-of-origin labeling (COOL) — 11
coverage price — 71, 74
CP *(see crude protein)*
crossbreeding — 24, 28, 251, 253-259, 263, 265, 316, 328
crude protein (CP) — 118, 125, 132, 133, 152, 160-166, 168, 190, 193, 197-202, 209, 214, 215, 217, 223
cull (culled, culling) — 34, 36-39, 64, 66-68, 79, 80, 89, 90, 96-99, 101, 248, 265, 271, 274, 276, 323, 327, 356, 391
cull cows — 17, 38, 67, 68, 79, 80, 86, 98, 89, 90, 96-98, 101, 356
custom feed (custom feeding) — 89, 91, 100, 101
custom hire — 64, 109, 110, 115

D

dark cutters — 380, 386, 390
DDG *(see dried distillers grain)*
debt coverage ratio — 27
debt-to-asset ratio — 27
deer flies — 344, 345
dehorning — 6, 83, 91, 94, 220, 329, 330, 332, 386
deworming — 93, 221, 332, 335, 337-341
dicalcium phosphate — 158, 182, 204, 213, 224, 225
digestibility — 106, 109, 132, 149-152 160, 161, 163, 164, 166, 173, 175, 193, 197-199, 201, 203, 211
digestion — 128, 129, 132-134, 149, 152, 160, 165, 191, 197, 199, 201-203, 214, 363
disease — 12, 29, 40, 60, 78, 84, 118, 134, 172, 175, 179, 185,219-221, 223, 256, 257, 263-265, 269, 273, 281, 290, 293, 318, 325, 328, 330-332, 337, 345, 369, 370, 372-376, 394, 398, 399, 401
disposition — 241, 390
DM *(see dry matter)*
DNA
  bases — 262
  markers — 261, 262, 265, 266
  testing — 265
donor cows — 301, 302
dressing percentage — 67
dried distillers grain (DDG) — 161, 162, 202, 204
dry matter (DM) — 107, 109-116, 118, 131-134, 148, 150, 151, 162-167, 175, 179, 190, 193, 201, 204, 205, 208-211, 214-216, 223, 228
dystocia — 29, 234, 240, 245, 274, 275, 312, 315-317, 320, 323, 327, 371

E

E. coli — 12, 370
embryo transfer — 248, 263, 268, 301-303, 305, 306
effective neutral detergent fiber (eNDF) — 151, 152, 279
eNDF *(see effective neutral detergent fiber)*
enterprise —
  alternatives —79, 81
  analysis — 16, 276
  budget — 17-19, 67, 82, 109, 115, 313
equity — 16, 18, 25, 27, 30, 52, 55, 63-66, 68, 81, 373
ergocalciferol — 179
expected progeny difference (EPD) — 99, 229, 231-235, 237, 239, 241, 243-249, 250-253, 263, 265, 266, 323, 343, 388, 389
extra label use of drugs — 397
EPD *(see expected progeny difference)*

F

facilities — 12, 16, 34-36, 67, 96, 98, 210, 220, 280, 326, 327, 357-359, 372, 376, 379, 383, 386-388, 391, 394, 395, 399, 401
fall forage — 117, 119, 120
family living expenses — 27, 63, 66, 67
fasting period — 222
fat — 134, 152, 161-163, 165, 167, 178, 185, 187, 221, 222, 228, 232, 238-240, 268, 274, 279, 318, 354, 376, 380-383, 388-390
FCIC *(see Federal Crop Insurance Corporation)*
Federal Crop Insurance Corporation (FCIC) —72
fed cattle — 71, 72, 100-102, 131, 159, 165, 166, 189, 199, 386, 391
feed nutrient composition — 152
feedstuff — 150, 153, 163, 165, 179, 198, 205, 272, 327, 330, 339, 370, 372, 373, 376, 395-398, 402
females exposed — 23, 24
fertility — 29, 117, 120, 177, 178, 209, 210, 211,229, 234-236, 253, 257, 265, 268, 279, 287, 289, 290, 295, 296, 299, 304, 331, 366
fescue — 104, 106, 114, 153, 154, 163, 164, 166, 171, 172, 174, 177, 181, 183, 194, 222, 246, 312
fetus — 133,269, 273, 315-317, 329, 331
fiber — 76, 111, 127, 128, 134, 150, 151, 161, 163-168, 197, 199, 207-210, 215-217, 224, 239, 279, 281, 381
finance —
  efficiency — 7, 23, 24-25, 60, 355
  lease — 16, 27, 30, 33-42, 65, 67, 68, 74, 77, 99, 103, 120
  ratios — 18, 25-29
  records —15, 16, 18, 19, 22-24, 30, 34, 35, 67, 74, 76, 78, 95, 96, 109
  stress — 15, 19, 25, 26, 63, 65, 67-70

financial plan — 16, 18, 19, 30, 37, 67
first hollow stem — 117, 119-121, 215
fleshiness — 83, 94, 221, 389
flies — 124,343-345, 370
  horse — 344, 345
  face — 124, 343, 345
flight zone — 357, 358, 360
flushing the embryo — 303, 304
follical-stimulating hormone (FSH) — 301, 393, 304
Food Safety Inspection Service (FSIS) — 385
forage — 7, 9, 10, 16, 22, 28-31, 37, 38, 40, 63-67, 69, 71, 73-77, 79-83, 86, 97, 100, 101, 103-107, 109, 111-121, 123-125, 127, 131-134, 149-155, 159-163, 165, 167, 168, 171-183, 185, 189-195, 197-217, 221, 222, 233, 252, 268, 270, 271, 274, 276, 280, 279, 282, 283, 310, 312, 313, 336, 337, 340, 353, 364-366, 370, 375, 390, 395, 398, 402
foreign animal disease (FAD) — 371, 373
founder — 132, 151, 164-167, 192, 216
frame score — 240
frame size — 132, 240, 222, 289, 312, 381, 382, 389
fringe benefits — 51, 58, 59
frothy bloat — 207, 209, 211
FSIS *(see Food Safety Inspection Service)*
FSH *(see follical-stimulating hormone)*

G

gasteroinintestinal parasites — 335-341
GE-EPD *(see genomic-enhanced EPDs)*
genetic
  abnormalities — 177, 236, 253, 254, 262, 265, 371
  selection — 227-229, 231-234, 237, 238, 241, 243, 245, 247-249, 252-254, 256, 258, 259, 261, 265, 266, 330, 354, 267, 270, 271, 286, 293, 300, 301, 302, 305, 306, 316, 386, 389, 390
  genetics — 10, 11, 24, 34, 79, 80, 82, 83, 91, 99, 100, 188, 189, 192, 227, 228, 231, 247, 250, 254, 261, 266, 269, 285, 301, 302, 328, 354, 371, 381, 386, 387, 389, 390
genome — 227, 249, 261-263, 354
genomic-enhanced EPDs (GE-EPD) — 265, 266
genotype — 227, 261, 262, 265, 354
germination — 117=8, 119, 154
gestation — 10, 23, 29, 133, 134, 148, 190, 220, 235, 283, 285, 304, 306, 309, 317, 329, 331, 407
GnRH *(see gonadotropin releasing hormone)*
gonadotropin releasing hormone (GnRH) — 286, 288, 289. 291, 303
grading — 11, 273, 305, 354, 379, 381-384, 386, 389, 390,
grazing systems — 105, 106, 121, 125, 340
growing programs — 83, 191, 197, 198, 201, 204, 205, 272, 273
Gulf Coast tick — 346-348
gut worms — 335

H

HACCP *(see Hazard Analysis Critical Point Program)*
handling — 34-36, 39, 85, 91, 113, 163, 168, 220, 224, 240, 291, 293, 296-298, 329, 357, 361, 363, 370, 386, 388, 390, 392, 394, 401, 402
harvesting — 29, 36, 103, 109-111, 114, 115, 204, 370, 398
hay — 16, 28, 33, 35-37, 40, 63-67, 69, 73, 74, 77, 94, 95, 99, 103, 107, 109, 110-119, 128, 131-134, 150, 151, 153, 155, 160, 161, 163-167, 171-173, 178, 179, 188, 189-193, 195, 199, 201-205, 211, 220-235, 272, 274-276, 280, 282, 283, 294, 310, 311, 313, 339, 340, 344, 345, 370, 373
Hazard Analysis Critical Point Program (HACCP) — 385
health guidelines — 325, 326, 331
heat
  detection —288, 289, 291, 293, 294
  stress — 132, 310, 311, 314
heifer
  cost —36, 38, 39, 82, 221, 257
  pregnancy — 22, 23, 29, 96, 133-137, 180, 187-192, 208, 228, 229, 234, 244, 246, 247, 266, 270, 252, 268, 269-271, 273-275, 288, 290, 293, 294, 296, 302, 304, 305, 316, 317, 323, 326, 365, 370, 372
  replacement — 17, 21, 22, 34, 35, 36, 38, 39, 79, 81, 82, 132, 133, 136-138, 160, 193, 229, 245, 247, 249, 250, 254, 255, 257-259, 267, 269, 271, 273, 274, 276, 293, 310, 313, 323, 326, 329, 331, 332, 338, 354, 355, 389
hemicellulose — 150, 151
hemophilus — 269
herd
  age — 81
  health program — 29, 81, 91, 219, 256, 257, 282, 306, 325, 330, 332, 337, 394
  liquidation — 52-55, 63, 64, 66, 68, 69, 80, 89
  reporting — 232, 233, 234, 248
  size adjustment —81
heritable (heritability) — 227-229, 234, 241, 243, 248, 250, 251, 253, 254, 265, 271, 273, 302, 371, 323
heterosis — 30, 227, 254-259, 270
  individual — 254, 256-258
  retained — 255, 257-259
heterozygous — 253, 261, 262, 265
high temperature germination sensitivity — 118
homozygous — 253, 261, 262, 264, 265
host animal — 128, 197, 335, 337, 345, 346
hot carcass weight — 128, 197, 335, 337, 345, 346
hydration — 151
hypersensitivity — 336
hypobiosis — 335-337

I

IBRV *(see Infectious Bovine Rhinotrachetis Virus)*
ID *(see identification)*
identification (ID) — 13, 59, 232, 236, 293, 325, 329, 331, 391, 402
immune system — 229, 133, 219, 224, 330, 332
immunize (immunizations) — 268, 269, 276, 273
implants — 36, 95, 132, 221, 222, 268, 349, 350, 352-356, 381, 393
inbreeding — 253, 254
  depression — 253
income — 5, 7, 15-19, 22, 24-28, 30, 31, 33, 35, 37-41, 51-60, 63-70, 78, 92, 94, 103, 207
industry trend — 1, 89

Infectious Bovine Rhinotrachetis Virus (IBRV) — 326, 330-323, 371
inheritance — 30, 69 263, 265
injections — 172, 223, 269, 286-290, 303, 304, 325, 328, 386, 388, 391, 392, 394, 401
insurance — 16-18, 34, 36, 37, 39-41, 54, 58, 59, 71-76, 84, 101, 109, 115, 374
interest expense — 26-28
interim EPD — 249
internal audit — 67
Internal Revenue Service (IRS) — 25, 30, 35, 51, 54, 59, 60 64, 68, 69
international units (IU) — 178, 179, 214, 223, 225
intramuscular (IM) — 232, 239, 380, 391-393, 401
intravenous (IV) — 172, 391, 392, 401
introduced forages — 104, 107
inventory — 2, 3, 10, 18, 22, 26, 27, 56, 58, 78, 80, 234, 269, 297, 399
investment — 5, 15-19, 21, 22, 27, 29, 30, 33, 36, 38-41, 34, 54-56, 63-65, 67, 68, 70, 79, 81, 100, 109, 110, 112, 114, 188, 221, 225, 266, 275, 293
iodine — 148, 176, 180, 181, 223, 329
ionophores — 201, 203, 207, 212, 213, 217, 273, 353, 396
iron — 175-177, 180, 181, 214, 329, 364
IRS *(see Internal Revenue Service)*
isolation — 315, 373, 374, 369
IV *(see intravenous)*

J

K

KCL *(see potassium chloride)*
K_2CO_3 — 173

L

lactating — 105, 131-135, 138, 148, 168, 172, 181, 286, 310, 312, 313, 390, 398
land ownership — 15, 31, 40, 109
lean maturity — 379
leptospirosis — 269, 326, 330-332, 372
LGM *(see livestock gross margin)*
libido — 176, 252, 281
lice — 343, 345, 346
lignin — 127, 150, 151
limit
  fed — 131, 160, 204, 205, 217
  feeding — 205
lipids — 149, 152, 279
liquidity — 18, 24, 25
livestock
  caretaker — 41, 397
  gross margin (LGM) — 71-73
  lease agreement — 33, 35, 40, 42
Livestock Risk Protection Program (LRP) — 71, 72, 84
lone star tick — 346, 347
LRP *(see Livestock Risk Protection Program)*

M

machinery costs — 5, 16-18, 25, 27, 29, 30, 33, 35-37, 41, 67, 68, 109, 110, 114, 115
macrocyclic lactones — 337, 338
magnesium — 148, 165, 194, 172, 174, 180-183, 208, 209, 211, 213,214, 223-225, 364
mammary — 268
manganese — 148, 177, 180, 181, 183
manure — 36, 156, 193, 220, 223, 299, 336, 340, 341, 343-345, 355, 363-366, 370, 373, 376, 392, 393, 395
marbling — 238, 239, 229, 251, 340, 354, 379, 380, 383, 384, 386, 387, 389, 400,
market approach — 40
marketing — 1, 7, 9-13, 15, 16, 21, 22, 28, 30, 37, 40, 63, 65-67, 72, 73, 79-86, 89-101, 113, 207, 217, 221, 222, 245, 252, 256-258, 273, 309, 310, 313, 325, 326, 329, 330, 333, 339, 352, 354, 369, 370, 373, 379, 381, 383, 384, 385, 386, 388, 389, 390, 397
maternal — 24, 136-138, 228, 229, 233, 235, 244, 245, 248, 249, 252, 254-258, 316, 328, 354
mating systems — 227, 253-255, 257-259, 389
mature weight — 133, 145-147, 228, 229, 235, 245, 249, 252, 254-258, 316, 328, 348, 354
maturity — 10, 38, 52, 104, 109, 131, 173, 180, 190, 201, 209, 210, 212, 215, 221, 222, 229, 236, 238, 240, 273, 274, 279, 302, 336, 337, 354, 379, 380, 384
MCL *(see macrocyclic lactones)*
medicated feeds — 392, 399
mega calories — 134, 152, 280
melengestrol acetate (MGA) — 286-288
metabolizable — 133, 152, 280
metabolizable protein (MP) — 133
methionine — 174, 175
methyl cobalamin — 179
microbial fermentation — 129, 186
microorganisms — 123, 127, 129, 132, 133, 168, 173-175, 178, 179, 363, 376
mineral antagonists — 171
mission — 15, 252
molybdenum — 175, 176, 364
morbidity — 180, 373
mosquitoes — 345
most probable producing ability (MPPA) — 237
MPPA *(see most probable producing ability)*
muscle thickness — 382

N

National Association of Animal Breeders — 297
NBQA *(see National Beef Quality Audit)*
NCBA *(see National Cattlemen's Beef Association)*
NCE *(see national cattle evaluation)*
National Beef Quality Audit (NBQA) — 329, 383, 385, 388
national cattle evaluation (NCE) — 249, 231, 232, 234, 239, 243, 244, 247-249
National Cattlemen's Beef Association (NCBA) — 21

navel — 326, 329
NDF *(see neutral detergent fiber)*
NDS *(see neutral detergent solubles)*
needles — 332, 370, 371, 391, 392, 394
NEg *(see net energy gain)*
NEm *(see net energy maintenance)*
neonatal — 327, 339
net energy gain (NEg) — 134, 139-147, 152-158, 225
net energy maintenance (NEm) — 134, 135, 139-147, 152-158, 225
neutral detergent fiber (NDF) — 150-158, 207-210, 214, 279
neutral detergent solubles (NDS) — 150
nitrogen — 114, 118, 120, 132, 133, 134, 150, 152, 161, 174, 178, 191, 192, 194, 197, 198, 201, 202, 209, 212, 223, 261, 296-298, 363, 364, 366, 375, 376
  free extract — 150
  liquid — 296-298
  nonprotein —191, 192, 174, 200, 201, 223
nonruminants — 132, 134
nutrients — 109, 114, 118, 120, 131, 133, 135, 139-146, 159, 162, 189, 190, 193, 336, 375, 376

O

oats — 74, 117, 118, 172, 207
Oklahoma Quality Beef Network (OQBN) — 82, 91-95
omasum — 127, 129
on-farm testing — 232, 280
O. ostertagia (brown stomach worm) — 336
operating costs — 15-18, 40, 64, 68, 109, 110, 189
operating expense — 25, 27, 34
OQBN*(Oklahoma Quality Beef Network)*
Osteomalacia — 172, 173, 179

P

palatable — 163, 167, 173, 174, 181, 194, 210, 222-225, 268, 287
palpation — 234, 235, 271, 273, 299, 302, 360
parasite control — 221, 269, 325, 330-332, 338, 340, 341, 343, 386
parasites — 124, 125, 221, 269, 325, 330-332, 338, 340, 341, 343, 386
passive immunity — 327-329, 332
pathogens — 327-329, 332
pelvic area — 240, 315
PEM *(see polioencephalomalacia)*
phosphorus — 106, 120, 134, 159, 164, 168, 172-174, 179, 182, 203, 204, 208, 211, 214, 363, 364, 366
phosphorylation —179
pinkeye — 330, 331, 371, 345
polioencephalomalacia (PEM) — 160, 175
potassium — 120, 159, 173, 174, 183, 208, 214, 364
potassium carbonate — 173
potassium chloride (KCL) — 173
preconditioning — 7, 82, 89, 90-96, 99, 161, 219-223, 225, 330, 354
predilection site — 330, 336
pregnancy percentage — 23, 29, 311
preweaning — 222, 276
price risk management — 67
production cycle — 23, 28, 30, 77, 325, 327
prostaglandin — 286, 287, 290, 291
protein — 11, 13, 35, 37, 96, 105, 106, 109, 113, 114 118, 125, 128, 129, 131-134, 149, 150, 152, 159-168, 173-181, 185, 188-195, 197-205, 209, 212-214, 217, 222-225, 233, 363, 272, 274, 283, 286, 310, 312, 313, 328, 355, 370, 381, 386, 395, 389, 402
protozoa — 128, 132, 369, 370
provitamins — 178, 182
puberty — 133, 229, 235, 268-273, 276, 285, 279

Q

quality —
  assurance — 12, 325, 372, 385, 396, 399
  grade — 97, 238, 354, 379-382, 389, 390
  product — 330
quarantine — 72, 373, 374, 358, 392

R

rangeland — 74, 77, 103-105, 107, 123, 125, 397
rate of return on farm assets — 22, 25, 30, 36
rate of gain — 164, 197, 200, 221, 223, 276, 353, 389
rations — 37, 67, 97, 100, 101, 131, 133, 159, 160, 162-167, 172, 174, 179, 203-205, 210, 221, 223, 224, 233, 271-273, 381, 390, 394, 395, 398, 399, 402
rebreeding — 23, 96, 133, 134, 176, 185, 188, 192, 193, 235, 331, 270, 274, 275, 282, 313, 317, 332
receiving — 55, 100, 120, 133, 163-165, 179, 202, 203, 219, 222-225, 248, 258, 262, 280, 317, 329, 338, 350, 352, 354, 379, 383, 390
reduced fertility — 268, 279, 302
regulations — 12, 60, 68, 72, 348, 363, 366, 375, 376, 398, 402
reinfestation — 340
repayment capacity — 18
reproduction — 23, 34, 30, 129, 134, 172, 176, 182, 234, 273, 286, 373
restructuring — 64, 70
retained ownership — 66, 67, 79, 81-84, 238, 311
return on equity (ROE) — 27. 40
ribeye — 228, 232, 238, 239, 246, 247, 354, 266, 379, 381, 383, 388, 391
rickets — 179
risks — 12, 13, 16-18, 21, 27, 33-35, 38-41, 52, 57, 63, 67, 68, 70, 73-76, 83-86, 89, 91, 95, 97-101, 04, 106, 113, 115, 124, 151, 163, 164, 167, 172, 174, 176, 181, 182, 207, 214, 219-221, 224, 225, 231, 240, 250, 252, 253, 257, 263-265, 269, 276, 281, 310, 316, 317, 320, 328, 330, 331, 338, 349, 357, 358, 369, 371-375, 376, 389, 390, 396, 398, 399, 401,
ROE *(see return on equity)*
rotational crossbreeding — 252, 261, 263, 264
rumen — 127-129, 133, 134, 151, 152, 163, 164, 166-168, 173, 175, 176, 178, 179, 191, 197, 198, 199, 209, 210, 220, 223, 224, 313, 370, 377

ruminal fermentation — 132, 133, 165, 215
ruminants — 10, 127, 132, 134, 150, 158, 164, 165, 168, 175, 178-180, 197, 340, 398, 402
rye — 74, 104, 117, 118, 163, 193, 207, 222

S

scrotal circumference — 229, 233, 235, 236
semen placement — 299, 303
share arrangements — 34, 38-40
sire summary — 231, 247
SNP — 261, 262
specific coverage — 71, 72
spinose ear tick — 347
spreadsheet — 18, 28, 38, 42, 66, 91, 94-96, 101, 276
stable flies — 344
Standard Performance Analysis (SPA) — 21, 22, 28, 30, 31, 35, 309, 313
stocker — 1, 10, 21, 28, 30, 67, 79, 81-83, 89, 91, 98, 99, 106, 121, 124, 131, 159, 164, 167, 171, 174, 182, 189, 191, 197, 199, 201, 202, 207-217, 218-221, 273, 327, 330, 340, 349, 350, 352-356, 366, 374, 376, 386, 389, 399
stocking (rate or density) — 28, 29, 34, 103, 104, 106, 109, 121, 123, 124, 134, 200-202, 207, 210-212, 214-217, 282, 366
storage
  cost — 111, 113
  cover — 112
  loss — 111, 112, 115
  orientation — 112
  site — 112, 172
supplemental
  income — 18
  nutrients — 190, 198, 204, 207, 220

T

tank management (related to AI) — 293
temperament — 246, 306
terminal crossbreeding — 251, 256-258
TDN *(see total digestible nutrients)*
therapeutic — 328, 338, 396
ticks — 124, 343, 346-348, 371
total digestible nutrients (TDN) — 114, 118, 133-136, 140-147, 152-158, 160, 163, 164, 166, 168, 190, 197, 198, 200, 203, 204, 212, 214, 280
trace minerals— 159, 106, 172, 175,-176, 179, 181, 200, 204
tuberculosis (TB) — 257, 371

U

udder and teat size scoring — 235
ultrasound — 229, 232, 233, 239, 246, 266, 301, 304-306
urea — 114, 133, 165, 166, 191, 173, 175, 202, 223, 364, 366

V

vaccine — 219, 221, 269, 276, 331, 332, 391, 393, 394
vibriosis — 40, 331, 332, 372

W

waste management — 363-366, 373
weaning — 7, 10, 22-24, 29, 66, 79, 81-84, 90-94, 96, 99, 101, 106, 124, 172, 177, 191, 194, 219-225, 227-230, 232, 233, 234-238, 241, 243-245, 246-248, 250-252, 258, 266-269, 271, 272, 276, 280, 285, 309, 310, 312, 313, 326-238, 330, 331, 352, 354, 355, 370, 386, 388, 389
weaning weight — 22, 24, 29, 81, 83, 124, 177, 191, 194, 227-229, 233, 235, 237, 238, 243-248, 250, 252, 258, 267, 280, 285, 310, 313, 328, 352, 355, 370
wheat — 40, 76, 97, 100, 104, 106, 117-121, 153, 155, 157, 158-160, 164-166, 172, 174, 182, 191, 193, 199, 201, 204, 207-217, 223-225, 273, 274, 279, 312, 349, 353, 390
whole herd reporting — 233, 234
withdrawal — 57, 287, 386, 391, 393, 396, 396, 399, 400-404

X

Y

yield grading — 379, 382, 384

Z