18 Alternative Feeds

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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 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-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.

Figure 18.1. Dried distillers grains with solubles in meal and pellet form compared to corn.

Figure 18.2. Wet distillers grains with solubles.

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 gain[a]	$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.

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.

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.

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.