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TO: Clientele in Animal Agriculture

RE: 1982 Animal Science Research Report

This report represents the combined efforts of many people - scientists, graduate students, herdsmen, laboratory technicians, student employees, secretaries, donors of funds and services and producer-cooperators -- all dedicated to the challenge of developing new, useful knowledge and making it available to you.

This report contains an annual summary of our research and is as such a reflection of our total research program in Animal Science, which includes 40 active research projects in nutrition, physiology, genetics, foods and management, with beef cattle, dairy cattle, sheep, swine and poultry. Most of the research covered in this report was done at Stillwater and Ft. Reno.

If this report does not address your most critical problems, please let us hear from you. We welcome your suggestions because our commitment is to serve Animal Agriculture.

Yours truly,

Bob Totusek

Robert Totusek, Head
Animal Science Department

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CONTENTS

PHYSIOLOGY

NUTRITION—COW-CALF AND STOCKER

NUTRITION—FORAGE EVALUATION

NUTRITION—FEEDLOT

GENETICS—ANIMAL BREEDING

RESEARCH IN PROGRESS

The articles in this publication have been subjected to peer review for scientific merit, adequacy of experimental procedures and correctness of interpretation.

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Reproductive Characteristics of Young Boars Exposed to 8 or 16 Hours of Light Daily

J. E. Minton, R. W. Fent
and R. P. Wettemann

Story in Brief

Crossbred boars were exposed to either 8 or 16 hours of fluorescent light daily from 75 to 175 days of age to determine the influence of duration of daily light exposure on growth rate, testicular characteristics and endocrine function. Growth rate was similar between the two groups of boars. However, serum concentrations of testosterone, the areas under plotted 12-hr testosterone profiles and the number and magnitude of testosterone secretory spikes were elevated in boars exposed to 16 hours of light. Serum luteinizing hormone (LH) concentrations were not influenced by treatment. Infusion of gonadotropin releasing hormone (GnRH) resulted in similar concentrations of LH in both groups of boars. Serum testosterone response to GnRH-mediated LH release was greater at 0.5 and 1.0 hr following GnRH in boars exposed to the longer photoperiod, but was similar between both groups of boars thereafter. Testicular and epididymidal weights and sperm reserves were not significantly influenced by treatment. We conclude that exposure of young boars to 16 hr of light daily enhances testicular endocrine function compared to boars exposed to 8 hr of light.

Introduction

The duration of daily light that animals are exposed to regulates certain physiological processes. Reproductive cycles of sheep and horses are directly affected by the duration of photoperiod. In addition, exposure to longer daylengths accelerates growth rate of both nonseasonally (cattle) and seasonally breeding animals (sheep). Since the pig is not a seasonal breeder, the influence of duration of photoperiod on reproductive development and growth rate has received little attention.

Data obtained in recent years suggests that boars which are exposed to increased photoperiods are more sexually aggressive, and semen can be collected at a younger age compared to boars exposed to shorter photoperiods. Limited information is available on the extent to which duration of photoperiod affects testicular endocrine and spermatogenic function of the young boar. Consequently, we designed an experiment to evaluate the influence of duration of daily light exposure on growth rate, testicular characteristics and serum concentrations of LH and testosterone of young boars.

Experimental Procedures

A total of 30 pairs of full-sib crossbred boars of Duroc, Landrace, Spot and Yorkshire breeding were used in three replicates for this study. Each boar of a full-sib pair was assigned to either 8 or 16 hours of light daily from 75 to 175 days of age. All boars were maintained on solid concrete floors and supplied with feed and water ad libitum. Body weights were obtained every two weeks throughout the experiment.

When the boars averaged 160 days of age, a venous catheter was placed in each of 10 boars from both treatment groups. Serum samples were obtained at 30-minute intervals for 12 hours. Then, 200 μg of GnRH were infused, and serum was obtained at frequent intervals for 4 hours. All serum samples were analyzed, using specific radioimmunoassays, to determine concentrations of LH and testosterone.

All boars were castrated at about 175 days of age. One testis from each boar was saved and weighed, a sample of testicular parenchyma was homogenized and sperm numbers were determined by microscopic count. The epididymides were removed from the testes and sectioned into pieces containing the head and body (capita-corpora) and the tail (cauda). These tissues were weighed and homogenized and sperm numbers were determined.

Results and Discussion

Average daily gain tended to be increased for boars exposed to 8 hours of light daily (1.70 ± 0.07 lb/day) compared to boars in the longer photoperiod (1.59 ± 0.04 lb/day), but this difference was not statistically significant (Table 1). Testicular weights and weights of the capital-corporal and caudal epididymides were similar for boars in both treatment groups. Likewise, sperm reserves in the epididymides were not influenced by photoperiod. But, there was a tendency for boars exposed to 16 hours of light daily to have more sperm in their testes.

Table 1. Characteristics of boars exposed to 8 or 16 hours of light daily

Criteria	Duration of photoperiod 8 hr	16 hr
Number of boars	25	28
ADG (lb/day)	1.70 ± .07[a]	1.59 ± .04
Testicular wt (g)	281.3 ± 15.9	278.3 ± 14.5
Total testicular sperm ($x10^9$)	25.2 ± 2.4	30.3 ± 3.3
Capital-corporal wt (g)	28.6 ± 1.5	29.6 ± 1.5
Total capital-corporal sperm ($x10^9$)	28.0 ± 3.2	26.8 ± 3.0
Caudal wt (g)	31.8 ± 2.1	30.8 ± 1.6
Total caudal sperm ($x10^9$)	69.5 ± 13.2	57.0 ± 7.1

[a]Mean ± SEM.

Average serum LH concentrations (Table 2) were not influenced by treatment. In addition, the frequency and magnitude of LH secretory spikes and the area under plotted 12-hr LH profiles were similar for boars in both treatment groups. In addition, the LH release in response to GnRH infusion did not differ significantly between boars in either treatment.

Table 2. Serum LH and testosterone in boars exposed to 8 or 16 hours of light daily

Criteria	Duration of photoperiod			
	8 hr		16 hr	
	LH	Testos-terone	LH	Testos-terone
Number of boars	9	9	10	10
Concentration (ng/ml)	1.4 ± .1[b]	3.2 ± .8[c]	1.5 ± .1	4.9 ± .8[c]
Area under 12-hr curve (ng•hr/ml)	16.1 ± 1.3	35.9 ± 9.2[c]	17.8 ± 1.3	57.7 ± 8.8[c]
Secretory spikes[a] per 12 hr (no)	2.3 ± .3	1.7 ± .4[d]	2.5 ± .3	2.8 ± .4[d]
Magnitude of secretory spikes (ng/ml)	2.0 ± .2	7.1 ± 1.1[c]	2.1 ± .2	9.5 ± 1.1[c]

[a]Increases in serum concentrations greater than one SD above the mean.
[b]Mean ± SEM.
[c]Significant difference, 8 hr vs 16 hr ($p<0.10$).
[d]Significant difference, 8 hr vs 16 hr ($p<0.05$).

Boars exposed to 16 hours of light daily had increased ($p<0.10$) serum testosterone concentrations (4.9 ± 0.8 ng/ml; Table 2 and Figure 1) compared to boars exposed to 8 hours of light (3.2 ± 0.8 ng/ml). Even though secretory spikes of LH were not influenced by treatment, boars in the longer photoperiod had more

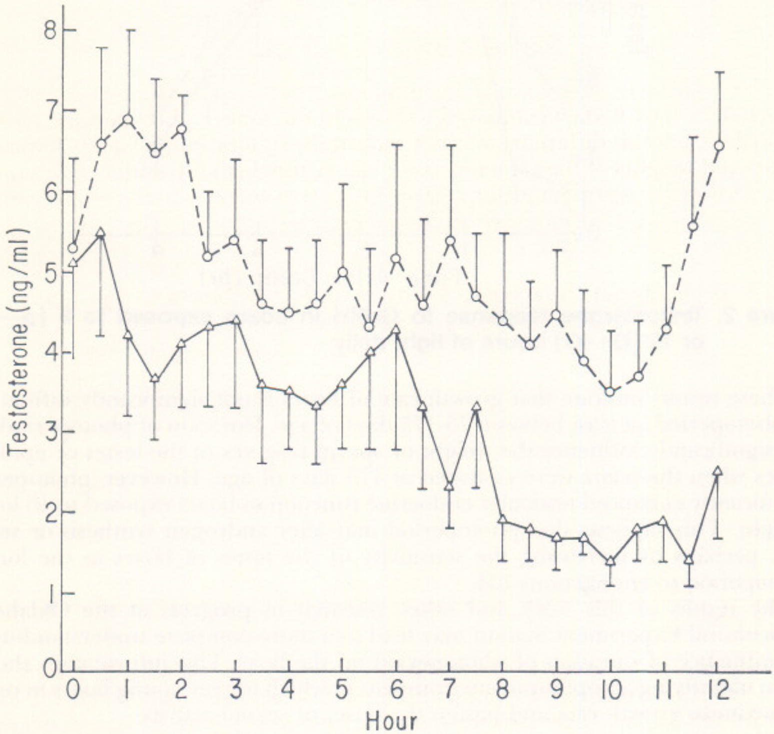

Figure 1. Average testosterone concentrations in boars exposed to 8 (Δ—Δ) or 16 (O– –O) hours of light daily

testosterone secretory spikes per 12 hours ($p<0.05$), and these spikes were of a greater magnitude ($p<0.10$) than those observed for boars in 8 hours of light per day. The increased frequency and magnitude of testosterone pulses (and perhaps altered testosterone clearance rate) resulted in an increased area under plotted testosterone profiles ($p<0.10$) for boars in 16 hours of light. Serum testosterone response to GnRH-mediated LH release was greater in boars exposed to 16 hours of light per day at 0.5 and 1.0 hr following GnRH treatment, but testosterone concentrations were similar for boars of both treatment groups thereafter (Figure 2).

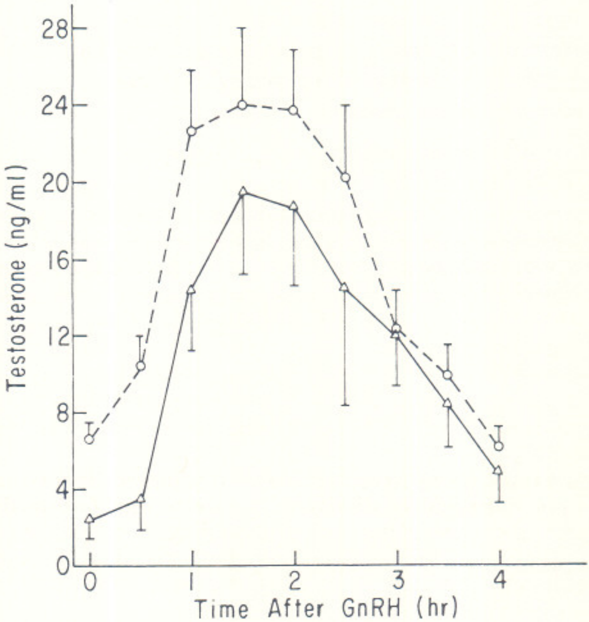

Figure 2. Testosterone response to GnRH in boars exposed to 8 (Δ—Δ) or 16 (O– –O) hours of light daily

These results indicate that growth rate of boars is not significantly influenced by photoperiod, at least between 75-175 days of age. Duration of photoperiod did not significantly influence the weight or sperm reserves of the testes or epididymides when the boars were castrated at 175 days of age. However, photoperiod significantly enhanced testicular endocrine function in boars exposed to 16 hours of light. This suggests that photoperiod may alter androgen synthesis or secretion, perhaps by increasing the sensitivity of the testes of boars in the longer photoperiod to endogenous LH.

The results of this work and other research in progress at the Oklahoma Agricultural Experiment Station may lead to a more complete understanding of the influence of duration of photoperiod on the boar. This information should aid in identifying an optimum environment in which to rear young boars in order to maximize growth rate and hasten the onset of sexual activity.

Influence of Prepartum Nutrition on Reproductive Performance and Plasma Glucose, Protein and Esterified Fatty Acids in Range Cows

R.J. Rasby, R. P. Wettemann, K.S. Lusby, B.R. Pratt and E.J. Turman

Story in Brief

Sixty-eight mature, pregnant Hereford Cows were used to determine blood constituents prior to calving when subjected to different prepartum nutritional regimes. Starting November 19, 1980, one group of cows was supplemented to maintain their November weight until calving. Three other groups were fed a low level of nutrition from November 19 to January 22, 1981; then the level of nutrition was increased for two of the three groups. One group was fed to return to their November weight by calving (low-high) and another group was fed to maintain their weight until calving (low-moderate). The third group was fed to continue to lose weight (low-low), so that approximately 10 percent of the November weight was lost by the time of calving. All animals were treated alike after calving.

Projected weight losses were probably not achieved because of a mild winter, but losses were in the desired directions. Total esterified fatty acids in plasma were not affected by treatment. However, plasma glucose and protein were affected by treatment. When nutrition was increased, the concentration of glucose and protein in plasma were increased. Pregnancy rates ranged from 74 to 95 percent for the various treatments.

Introduction

Many factors dictate the interval from calving to first estrus and subsequent ovulation in beef cows. One factor, the level of winter nutrition, or energy intake during the final trimester of gestation, affects pregnancy rate the following breeding season.

The nutritional requirement of a cow increases tremendously during the last trimester of pregnancy to meet the needs of the rapidly growing fetus. In addition, changes are also taking place in the placenta. Many essential hormones that regulate reproductive functions are produced by the placenta and fetus. Fetal and placental hormones produced during late pregnancy may influence constituents found in the blood plasma of range cows, or plasma constituents may regulate reproductive processes. Glucose is the major source of energy at the cellular level and may influence secretion of hormones. Total plasma protein may indicate the health of the animal, or it may be related to protein metabolism. Esterified fatty acids in the plasma are related to fat absorption. Therefore, this experiment was designed to determine the changes in blood constituents that occur during late pregnancy and to relate these changes to subsequent rebreeding performance in range cows on different levels of winter nutrition.

Materials and Methods

Sixty-eight pregnant, mature Hereford cows were maintained on native tallgrass range at the Range Cow Research Center, 12 miles west of Stillwater. Starting November 19, 1980, one-fourth of the cows were randomly assigned to a moderate level of nutrition so as to maintain their November body weight until calving. The remaining animals were assigned to a low level of nutrition so they would lose about 7.5 percent of their November weight by January 22, 1981 (approximately 45 days prepartum). At this time the nutritional levels of the cows were altered. One-third of the cows remained on the low level of nutrition (low-low group) so they would lose about 10 percent of their November weight prior to calving; another group (low-high) was changed to a high level of nutrition so they would gain back their November weight by the time of calving; and a third group (low-moderate) was fed the same level of nutrition as the moderate group to calving. It was anticipated that the moderate, low-low, low-high and low-moderate cows would lose about 0, 10, 0 and 7.5 percent, respectively, of their fall weights prior to calving. Therefore, during the 45 days before calving, moderate cows would be maintaining weight, low-high cows would be gaining weight, low-moderate cows would be gaining weight but at a lower rate than low-high cows, and low-low cows would be losing weight. Feed levels were adjusted on the basis of body weights taken every 2 weeks and are summarized in Table 1. All cows were managed in the same pasture after calving and supplemented at the same rate.

Table 1. Feeding program

	Nutritional treatment		
Date	Moderate	Low	High
Nov. 19, 1980	21 lb of 41% protein CSM[a] pellets/week	5 lb of 41% protein CSM pellets/week	
Jan. 22, 1981	21 lb of 41% protein CSM pellets/week	5 lb of 41% protein CSM pellets/week	30 lb of 41% protein CSM pellets/week
Postpartum	28 lb of 41% protein CSM pellets/week		

[a]41% protein cottonseed meal pellet.

Body condition scores of the cows, based on visual appraisal, were determined independently by at least two individuals at monthly intervals for the duration of the experiment. The scores were based on a scale from 1 = very thin, to 9 = very fat. Blood samples were collected at 2-week intervals starting January 22, 1981, until calving. Plasma protein was measured with a refractometer. Plasma glucose and total esterified fatty acids were quantified by colorimetric methods.

Results and Discussion

Winter weight losses for the low treatments were not achieved even at the low supplemental level (Table 1), probably as a result of an unusually mild winter with no snow and warmer temperatures than normal. However, as indicated in Table 2, body weight losses were in the direction desired. Moderate cows lost 2.8

Table 2. Percent weight change at 45 days prepartum[a] and at calving[b]

Nutritional treatment	45 Days prepartum	Calving
Moderate	1.5 ± .9	−2.8 ± 1.8
Low-Low	−1.8 ± 1.0	−5.3 ± 1.3
Low-Moderate	−1.2 ± .8	−1.4 ± .8
Low-High	0 ± .8	+2.0 ± 1.2

[a]Weight change from November.
[b] Weight change from November prior to calving, does not include calving loss.

percent of their fall weight prior to calving, low-low cows lost 5.3 percent of their fall weight, low-moderate cows lost 1.4 percent of their fall weight and low-high cows gained 2.0 percent of their fall weight.

Body condition scores were similar for all treatment groups on November 19 and did not differ significantly on January 22, although cows on the low-moderate and low-high treatments had slightly lower scores than the other two groups (Table 3). By March 19 (the average calving date for all cows), the moderate cows had decreased .5 units from November, low-low cows had decreased .8 units, low-moderate cows had decreased .5 units and low-high cows had decreased only .2 units from November. The low-high cows had a reduction in body condition although they gained weight because the gain was associated with an increase in weight of the calf and placental fluids.

The concentration of total esterified fatty acids (TEFA) was not affected by treatment at any time period prepartum (Table 4). Cows, regardless of the treatment, had a concentration of approximately 25 mg/100 ml TEFA in plasma.

Table 3. Body condition score[a] for cows maintained on different prepartum nutritional treatments

	Nutritional treatment			
Date	Moderate	Low-Low	Low-Moderate	Low-High
Nov. 19, 1980	6.5 ± .2	6.5 ± .1	6.4 ± .1	6.5 ± .2
Dec. 18, 1980	6.4 ± .1	6.3 ± .1	6.1 ± .1	6.3 ± .1
Jan. 22, 1981	6.0 ± .1	6.1 ± .1	5.8 ± .1	5.6 ± .2
Feb. 19, 1981	6.5 ± .1	6.0 ± .1	6.2 ± .1	6.4 ± .1
Mar. 19, 1981	6.0 ± 0	5.7 ± .1	5.9 ± .1	6.3 ± .2

[a] 1 = very thin, 9 = very fat.

Table 4. Influence of nutrition and stage of gestation on total esterified fatty acids (mg% on triacetin basis) in range cows

		Nutritional treatment			
Period	Days prepartum	Moderate	Low-Low	Low-Moderate	Low-High
1	0-11	25.3 ± 1.3	24.2 ± 1.6	23.9 ± 1.4	27.3 ± 1.4
2	12-25	26.7 ± 1.4	23.6 ± 1.5	24.9 ± 1.0	28.0 ± 1.2
3	26-39	27.8 ± 1.4	25.7 ± 1.4	25.8 ± 1.3	25.1 ± 1.0
4	40-53	25.5 ± 1.9	24.7 ± .7	24.6 ± 1.1	23.2 ± 1.4
5	54-67	25.7 ± 2.5	23.0 ± 1.2	22.7 ± 1.0	23.7 ± 1.2
Average		26.3 ± .7	24.3 ± .6	24.5 ± .5	25.5 ± .6

Plasma glucose concentrations (Table 5) were affected by treatment at some time periods prepartum. The moderate cows at period 2 (between 12 and 25 days before calving) had lower glucose concentrations than did the low-low, low-moderate or low-high (P<.1). At periods 2 and 3 the glucose concentrations of low-low cows were less than those for low-moderate and low-high cows (P<.1 and P<.025 in periods 2 and 3, respectively). This indicates that as nutrition increased, the glucose concentration also increased.

Plasma proteins (Table 6) were influenced by treatment. Low-low cows had significantly lower concentrations of plasma protein at period 2 than did low-moderate and low-high cows (P<.01). Plasma protein concentrations were also reduced in low-low cows at period 4 (P<.005) compared to low-moderate and low-high cows. This period was about 45 days prepartum and was near the time the supplementation was increased for the low-moderate and low-high cows. A difference in the treatment groups at this specific period indicates that when cows are changed from a low level of nutrition to a higher level, plasma proteins also increase.

The reproductive data (Table 7) indicate that acceptable reproductive performance was obtained with moderate nutrition. Interpretation of the effects of these nutritional treatments on reproductive performance is difficult with the limited number of cows per treatment. This experiment will be replicated for 4 years to evaluate the effect of these treatments on the interval from calving to estrus and on conception and conception rate.

Table 5. Influence of nutrition and stage of gestation on plasma glucose (mg%) in range cows

Period	Days prepartum	Nutritional treatment			
		Moderate	Low-Low	Low-Moderate	Low-High
1	0-11	61.3±4.8	54.7±1.3	59.6±.7	59.3±2.2
2	12-25	52.6±1.8*	54.0±1.6	58.5±1.1	56.0±1.5
3	26-39	53.9±1.9[a,b]	52.0±1.3[a]	58.7±1.6[b]	55.6±1.9[b]
4	40-53	54.7±.9	54.1±1.2	54.7±1.4	59.6±2.1
5	54-67	55.9±1.7	54.3±1.7	61.2±4.8	61.7±2.0
Average		55.5±1.2	53.7±.6	58.4±.8	57.9±.9

[a,b]Means in a row with different superscripts differ (P<.025).

Table 6. Influence of nutrition and stage of gestation on plasma protein (%) in range cows

Period	Days prepartum	Nutritional treatment			
		Moderate	Low-Low	Low-Moderate	Low-High
1	0-11	7.5±.15	7.3±.13	7.5±.10	7.6±.12
2	12-25	7.3±.11[a,b]	7.1±.01[a]	7.5±.09[b]	7.4±.10[b]
3	26-39	7.1±.15	7.1±.09	7.3±.08	7.2±.13
4	40-53	7.1±.15[c,d]	6.8±.09[c]	7.2±.08[d]	7.2±.11[d]
5	54-67	7.1±.18	6.8±.07	7.0±.11	7.3±.09
Average		7.2±.06	7.0±.05	7.3±.04	7.3±.05

[a,b]Means in a row with different superscripts differ (P<.01).
[c,d]Means in a row with different superscripts differ (P<.005).

Table 7. Influence of prepartum nutrition on pregnancy rate of range cows

Level of nutrition	No. pregnant/No. exposed	(% pregnant)
Moderate	11/12	(92)
Low-Low	13/17	(76)
Low-Moderate	18/19	(95)
Low-High	15/19	(79)

This study, when complete, will provide much information on the relationships between winter supplemental feeding programs, body weight loss, body condition score, blood metabolites and reproductive performance of range cows. These data should allow us to determine desirable winter feeding programs and assist in the elucidation of causes of extended intervals from calving to first estrus.

Effect of Dexamethasone on Gonadotropin Secretion in Postpartum Anestrous Range Cows

R.P. Wettemann, T.W. Beck, E.J. Turman and B. Pratt

Story in Brief

An extended interval from calving to first estrus in beef cattle may be associated with environmental stress and, suckling which increase the secretion of adrenocorticotropic hormone (ACTH) by the pituitary gland. Increased secretion of ACTH causes greater amounts of corticoids to be secreted by the adrenal gland. This experiment was designed to determine if treatment of anestrous cows with dexamethasone, a synthetic corticoid, would inhibit the release of ACTH by the pituitary and, as a result, alter secretion of the luteinizing hormone (LH) and alter the interval from calving to estrus. Treatment with dexamethasone did not influence the percentage of cows in estrus by 85 days after calving, however, it tended to lengthen the interval from calving to first estrus in those cows that exhibited estrus. The pattern of LH secretion was altered for several days after treatment.

Introduction

Studies with laboratory animals suggest that exposure to stressful conditions alters secretion of pituitary hormones. Stresses imposed before breeding have been found to influence different stages of the reproductive process in many species, presumably by acting through the nerve pathways which stimulate secretion of ACTH from the pituitary. When rats are adrenalectomized and ovariectomized, the secretion of ACTH increases, and the increase in gonadotropins normally occurring after castration is not observed. This would suggest that the pituitary cannot react to ovariectomy by increasing pituitary output of gonadotropins when it needs to secrete increased amounts of ACTH in an attempt to increase the output of corticoids from the adrenal gland to combat the stress. A similar situation may exist in postpartum cattle. Environmental stress and the suckling stimulus cause release of ACTH, which could cause gonadotropin secretion to be inhibited and could result in abnormally long postpartum intervals from calving to first estrus.

Treatment of cycling heifers with synthetic corticoids will decrease serum concentrations of endogenous corticoids by decreasing ACTH secretion, but luteal function is maintained, and estrous cycle lenghts are increased (Kanchev et al., 1979). These data and work by others suggest that corticoids may be involved in the regulation of gonadotropin secretion. Therefore, treatment of postpartum cows with dexamethasone (a synthetic corticoid) should inhibit ACTH, which is normally released due to stress and suckling, and may enhance gonadotropin secretion, thus stimulating ovarian activity.

Materials and Methods

Fall calving Angus and Hereford cows were maintained on tall grass native range with a sterile bull wearing a chinball marker to detect estrus. At 35 to 41 days postpartum, 11 Angus and 6 Hereford anestrous cows were randomly assigned by breed to receive injections of dexamethasone ($n=8$) or saline ($n=9$). Three days before treatment, cows were transported 12 kilometers from the range and confined in a barn.

On day 0, cows were treated intramuscularly with 20 mg of dexamethasone or saline (control). On day 1, a cannula was inserted in a jugular vein, and blood samples were collected at 10-minute intervals for 3 hours. On day 2 cows were retreated with 20 mg of dexamethasone or saline, and on day 3 blood samples were obtained at 10-minute intervals for 3 hours. On day 4, cows were treated with 5 mg of dexamethasone or saline, returned to the range and run with bulls wearing chinball markers. Serum LH was quantified in samples obtained at the frequent bleeding period on days 1 and 3 to determine gonadotropin secretion.

Results and Discussion

Five of eight cows treated with dexamethasone and six of nine control cows exhibited estrus by 85 days postpartum. Treatment of cows with dexamethasone tended ($P<.10$) to lengthen the interval from calving to first estrus compared to control treatment in those cows that were in estrus (69 ± 5 vs 58 ± 6 days, respectively).

Serum LH concentrations were similar for Angus and Hereford cows. Serum LH averaged 1.85 ng/ml and was not affected by dexamethasone treatment. However, there were significant interactions between sampling day, sampling time and dexamethasone treatment (Figure 1). This suggests that serum LH concentrations were affected differently by dexamethasone treatment on the two sampling days. The number of increases in LH that were more than one standard deviation greater than the average, during a sampling day, were not influenced by treatment.

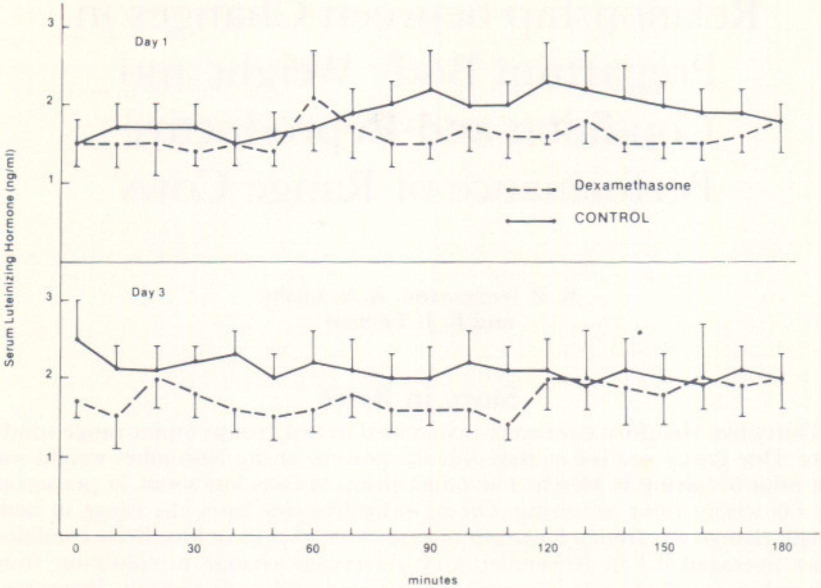

Figure 1. Serum luteinizing hormone concentrations after treatment with dexamethasone

In contrast to the original hypothesis, this experiment suggests that treatment of anestrous beef cows with dexamethasone may delay the onset of the first postpartum estrus. In addition, concentration of serum LH may be altered for several days after treatment.

Literature Cited

Kanchev et al, 1979. J. of Reprod. and Fert. 48:341.

Relationship between Changes in Prepartum Body Weight and Condition and Reproductive Performance of Range Cows

R. P. Wettemann, K. S. Lusby
and E. J. Turman

Story in Brief

Thirty-five Hereford cows were maintained in two groups under range conditions. One group was fed so that only 3.5 percent of the November weight was lost prior to calving in March. The other group of cows lost about 14 percent of the fall weight prior to calving. On an individual cow basis, the range in body weight change was from a 5 percent increase to a 20 percent loss. Body condition score averaged 6.1 in November, and percentage change in condition from November to calving was between +23 percent and −43 percent. Percentage changes in body weight and body condition score during the winter before calving were both correlated with days to first estrus and days to conception, and the correlations were of similar magnitudes. Therefore, either body weight change or body condition score change before calving can be used to estimate rebreeding performance.

Introduction

Only about 70 to 75 percent of beef cows wean a calf each year. A major reason for this reduced calf crop is that about 15 percent of the cows are not pregnant at the end of the breeding season. In many cases, the cause of cows being open after the end of the breeding season is the failure of these cows to resume normal estrus cycles after calving.

The ovary is nonfunctional, and estrus does not occur for varying lengths of time during the postpartum period. Level of nutrition before and after calving has been shown to have a major influence on how quickly ovarian function is resumed after calving. Obviously, the level of nutrition provided the cows also affects body weight and condition. Therefore, the purpose of this study was to evaluate the relationships among changes in prepartum body weight and body condition with the intervals from calving to first estrus and to conception in range cows.

Materials and Methods

Spring calving Hereford cows were maintained in two groups under native tall grass range conditions. One group of 18 cows was fed so that the November body weight was maintained through the winter until the time of calving. The other group of 17 cows was fed so that they would lose 10 to 15 percent of the November weight by the time of calving. Feed levels (supplemental protein) were adjusted on the basis of body weights taken every two weeks. Body condition scores, based on visual observations, were determined independently by three individuals on November 14 and March 8. The scores were based on a scale from 1 = very thin, to 9 = very fat. Cows were exposed to bulls wearing chin-ball markers to aid in detecting breeding activity. Days to conception was calculated by subtracting 283 days from the date of birth.

Results and Discussion

The characteristics of the cows used to determine what relationship precalving weight and body condition change have with reproductive performance are listed in Table 1. The large variation for the traits would be expected since the cows were divided into two groups and maintained during the winter on two levels of nutrition. At the start of the trial (November) these Hereford cows weighed between 755 and 1250 pounds and body condition scores ranged from 4.7 to 8.0. Just prior to calving in the spring, cows weighed from 5 percent more to 20 percent less than they did in the fall and the percentage change in body condition score ranged from +23 to -43 percent.

Table 1. Characteristics of spring calving Hereford cows used to determine the relationships between weight and condition changes and reproductive performance

Characteristic	Average	Minimum	Maximum
Number of cows	35	—	—
November weight (lb)	986	755	1250
November body condition score[a]	6.1	4.7	8.0
Precalving weight (lb)	893	655	1160
Precalving body condition score	5.1	3.8	6.5
Weight change (November to precalving) (%)	−9	+5	−20
Body score change (November to precalving) (%)	−14	+23	−43
Calving to first estrus (days)	70	35	109
Calving to conception (days)	73	39	127

[a]1 = very thin, 9 = very fat.

As observed in previous research, the percentage decrease in body weight from November until just prior to calving was correlated with days to first estrus ($r=.58; P<.01$) and days to conception ($r=.60; P<.001$). The relationships among percentage weight lost before calving and days to first estrus and days to conception are plotted in Figure 1. Each 10 percent of body weight lost before calving delayed first estrus by about 19 days and delayed conception by about 16 days.

Use of body condition score allows the evaluation of potential reproductive performance of cows without weighing them. The relationships between percentage change in body condition score from mid pregnancy (November) to calving, and days to first estrus and days to conception are depicted in Figure 2. The percentage decrease in body condition score during the winter before calving was correlated with days to first estrus ($r=.61; P<.005$) and days to conception ($r=.62; P<.001$). These correlations are of similar magnitude as those between body weight change and days to estrus and conception. Thus, either body weight change or body condition score change can be used to estimate potential rebreeding performance.

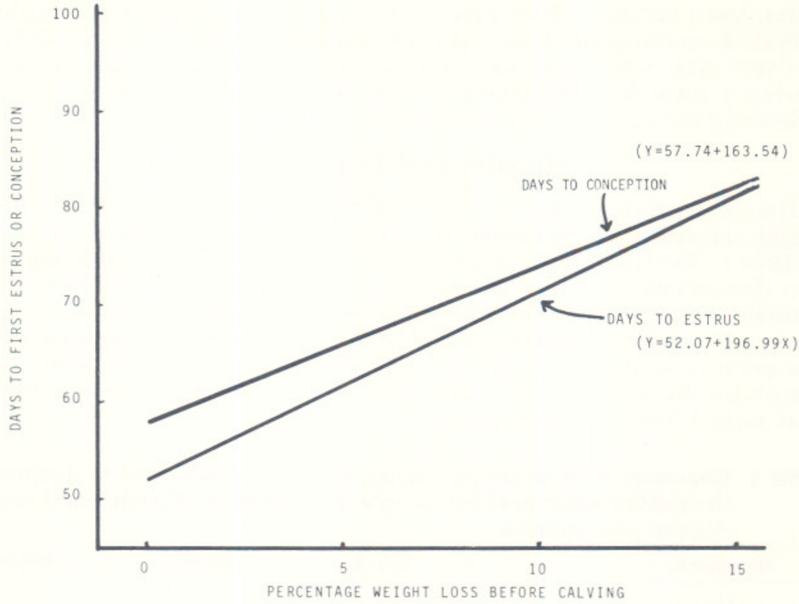

Figure 1. Relationships between percentage body weight lost before calving and days to first estrus and conception in Hereford range cows

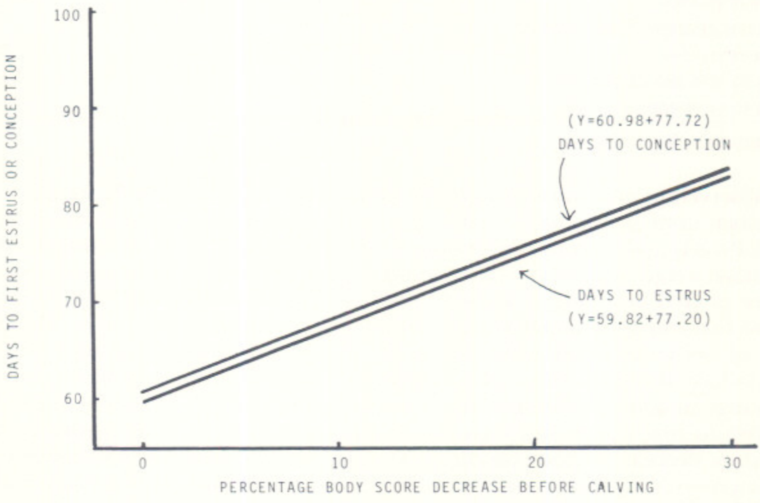

Figure 2. Relationships between percentage decrease in body condition score before calving and days to first estrus and conception in Hereford range cows

A 20 percent decrease in body condition score from November to calving in the spring (a cow changing from a 6.0 to a 4.8) would be associated with an additional 15 days to first estrus after calving compared to a cow that maintained body condition. Similarly, a 20 percent decrease in body condition score would be associated with an additional 16 days to conception.

This study reemphasized the relationship between weight loss during pregnancy and rebreeding performance. Either body weight loss or change in body condition are good indicators of potential reproductive performance of range cows.

A Comparison of Different Breeds for Growth Rates, Performance Traits and Scrotal Circumference in Young Beef Bulls

J. H. Baker, J. R. Kropp,
E. J. Turman and D. S. Buchanan

Story in Brief

Performance data and testicular measurements from 497 Hereford, Polled Hereford, Angus, Brangus and Charolais bulls were collected from December 19, 1979, through April 2, 1981, at Oklahoma Beef, Incorporated, a performance bull test station. The on-test age of these bulls was approximately 7 months, and they remained on-test for 140 days.

Charolais bulls were taller, heavier, faster gaining and trimmer, and they possessed larger rib eye areas than the other breeds. Hereford, Polled Hereford and Angus bull on-test and off-test hip heights were similar (43.2 in.), while Brangus (44.5 in.) and Charolais (45.8 in.) were taller, representing differences in breed frame and mature size. However, skeletal growth as measured by hip height growth rate per day was similar for all breeds, averaging. 0328 in. per day or 1 in. per month. Average daily gains on test were very similar for Charolais, Polled Hereford, Angus and Brangus bulls, ranging from 3.37 to 3.58 lb per day, while Hereford bulls gained slightly less (3.18 lb per day).

Angus bulls had the largest on-test scrotal circumference measurement (27.7 cm) while the Hereford and Polled Hereford bulls had the smallest (25.6 cm). Brangus, Angus and Charolais were similar in their off-test scrotal circumference

(35.2 cm) with Hereford and Polled Hereford bulls being smaller (33.3 cm). Scrotal size tended to increase at the rate of 1.7 cm per month while on test.

Brangus, Angus and Polled Hereford bulls tended to be fatter off-test (.44 in.) than Hereford (.38 in.) and Charolais bulls (.21 in.). Rib eye area measurements of 15.1, 13.5, 13.0, 12.6 and 12.5 were recorded for Charolais, Angus, Hereford, Brangus and Polled Hereford bulls, respectively.

Introduction

In beef cattle herds, the level of reproductive performance of both cows and bulls is probably the single most important factor contributing to gross returns. Therefore, it is especially important to understand all the factors influencing the reproductive performance of the bull. One such factor is testicular size, with scrotal circumference being the most common measurement of size.

With the influence of many breeds of beef cattle in this country, there has been some concern about whether these breeds are similar in their skeletal growth, performance and testicular growth. Most cattlemen would agree that there are definitely size differences in many breeds, but their growth rates are not clearly defined.

The purpose of this study was to evaluate the breed differences between scrotal circumference in young beef bulls and their respective growth traits as measured by linear hip height, body weight and average daily gain on a performance test program.

Materials and Methods

This study utilized performance data and testicular measurements from Hereford, Polled Hereford, Angus, Brangus and Charolais bulls on test at Oklahoma Beef, Incorporated, a performance bull test station, located 8 miles west of Stillwater. A total of 497 bulls in 20 different groups were placed on test, and 485 bulls completed the 140-day test period. Twelve bulls were removed because of health or unsoundness.

All bulls were approximately 7 months of age when placed on test. The bulls were acclimated to the feed and surroundings for a 14-day warm-up period prior to beginning the official 140-day gain test. Therefore, all bulls completed test at approximately 12-13 months of age. Different breeds were fed different rations (Table 1); therefore, breed and ration effects could not be separated. The Hereford and Polled Hereford bulls were fed the same ration; however, the

Table 1. Oklahoma Beef, Inc. bull test rations

	Angus, Brangus, Charolais	Hereford, Polled Hereford
Ingredient	%	%
Crimped corn	36	33
Crimped oats	30	30
Molasses	7	5
Dehydrated alfalfa	5	3
Cottonseed hulls	10	17
Soybean oil meal	10	5
Mineral mix	2	2
Cottonseed oil meal	—	5

Hereford bulls were bunk-line fed while the Polled Herefords were self-fed. The Angus, Brangus and Charolais were also fed the same ration; but the Angus were self-fed with 10 bulls per pen, Charolais were self-fed with 25 bulls per pen and Brangus were bunkline fed twice per day.

Measurements of weight, hip height and scrotal circumference were obtained prior to the start and upon completion of the official 140-day test. In addition, fat thickness and rib-eye area were estimated with a scanogram upon completion of the test. Average daily gain, weight per day of age, hip height growth rate and scrotal circumference growth rate were calculated.

Results and Discussion

Table 2 presents means for all on-test and off-test performance and testicular traits.

Table 2. Breed least squares means for performance traits of tested bulls

	Breed				
	Hereford	Polled Hereford	Angus	Brangus	Charolais
On-test performance data					
Number	119	120	141	90	27
HH (in)	$43.5 \pm .13^{c}$	43.2 ± 15^{cd}	$43.1 \pm .13^{d}$	$44.5 \pm .1^{b}$	$45.8 \pm .25^{a}$
SC (cm)	$25.7 \pm .25^{c}$	$25.6 \pm .30^{c}$	$27.7 \pm .25^{a}$	$26.6 \pm .38^{b}$	$26.0 \pm .51^{bc}$
Wt (lb)	605 ± 7^{b}	562 ± 9^{c}	620 ± 7^{b}	602 ± 11^{b}	722 ± 14^{a}
Wt/day (lb)	$2.51 \pm .03^{bc}$	$2.31 \pm .03^{d}$	$2.58 \pm .03^{b}$	$2.45 \pm .04^{c}$	$3.11 \pm .06^{a}$
Off-test performance data					
Number	116	118	135	90	26
HH (in)	$48.2 \pm .13^{c}$	$47.6 \pm .15^{d}$	$48.0 \pm .13^{c}$	$49.2 \pm .19^{b}$	$50.8 \pm .26^{a}$
HGR (in/day)	$.0322 \pm .0006^{a}$	$.0318 \pm .0007^{a}$	$.0339 \pm .0006^{a}$	$.0332 \pm .0009^{a}$	$.0335 \pm .0012^{a}$
SC (cm)	$33.6 \pm .21^{b}$	$33.1 \pm .26^{b}$	$35.2 \pm .21^{a}$	$35.6 \pm .31^{a}$	$34.9 \pm .43^{a}$
SCGR (cm/day)	$.054 \pm .002^{bc}$	$.054 \pm .002^{bc}$	$.052 \pm .002^{c}$	$.062 \pm .003^{a}$	$.059 \pm .003^{ab}$
Wt (lb)	1073 ± 9^{cd}	1047 ± 11^{d}	1118 ± 9^{b}	1082 ± 13^{c}	1251 ± 18^{a}
ADG (lb/day)	$3.18 \pm .04^{c}$	$3.47 \pm .04^{ab}$	$3.45 \pm .04^{ab}$	$3.37 \pm .06^{b}$	$3.58 \pm .09^{a}$
Wt/day (lb)	$2.77 \pm .02^{c}$	$2.72 \pm .03^{c}$	$2.89 \pm .02^{b}$	$2.79 \pm .03^{c}$	$3.27 \pm .05^{a}$
Fat (in)	$.38 \pm .01^{b}$	$.44 \pm .01^{a}$	$.45 \pm .01^{a}$	$.42 \pm .02^{ab}$	$.21 \pm .02^{c}$
REA (sq in)	$13.0 \pm .09^{c}$	$12.5 \pm .01^{d}$	$13.5 \pm .09^{b}$	$12.6 \pm .13^{d}$	$15.1 \pm .18^{a}$

^{a,b,c,d} Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

Body weight

Charolais bulls were heavier on-test, heavier off-test, gained more and had more weight per day of age than the other breed groups. Since different rations were fed to different breed groups (Table 1), interpretation of off-test weight and average daily gain differences among breeds is difficult. Average daily gains were similar for Charolais, Polled Hereford, Angus and Brangus, ranging from 3.58 lb per day for Charolais to 3.37 lb per day for Brangus. Although Polled Hereford bulls gained well (3.47 lb per day), they were lowest in off-test weight and weight per day of age due to a low on-test weight. Hereford bulls had the lowest average daily gain on test (3.18 lb per day) but were bunk-line fed the lowest energy diet.

Hip height

Breed rankings for on-test and off-test hip height were very similar. Charolais bulls were tallest, followed by Brangus. Polled Hereford, Hereford and Angus bulls were smaller framed. Differences in skeletal height both on and off-test represent differences in mature size of the breeds. Hip height growth rate from on-test to off-test were similar regardless of the mature size of the breed, ranging from .0318 to .0339 in. per day or approximately 1 in. per month.

Scrotal circumference

The on-test scrotal circumference was larger for Angus bulls than the other breed groups. Off-test scrotal circumference measurements were similar for Brangus, Angus and Charolais bulls, while Hereford and Polled Hereford bulls were smaller in their average circumference by approximately 2 cm or .8 in. However, all breed averages for yearling scrotal circumference were in the acceptable range.

The scrotal circumference growth rate between the on-test measurement and off-test measurement, representing basically a weaning to yearling period, was greatest for the Brangus bulls (9 cm), followed by the Charolais (8.9 cm), Hereford (7.9 cm), Angus (7.5 cm) and Polled Hereford (7.5 cm). Differences in scrotal growth rate between breeds may be due to: first, Brangus and Charolais are larger, later-maturing breeds that mature sexually later in their growth curve, and secondly, Hereford, Polled Hereford and Angus bulls are smaller, earlier-maturing breeds that possibly reach sexual maturity sooner.

Fat thickness

Upon completion of the 140-day test, Charolais bulls were leaner than the other breed groups. This advantage in leaness is associated with a later physiological maturity pattern and a larger mature size. Cattle sired by Charolais bulls should be leaner and have higher cutability than cattle sired by the other breed groups. Hereford bulls tended to be leaner than Polled Hereford, Angus and Brangus bulls. However, energy density of the ration is confounded with breed; therefore, interpretation of the differences are difficult.

Rib eye area

Rib eye area, as measured between the 12th and 13th rib by scanogram procedures, was used as an indicator of muscle. Charolais bulls were more heavily muscled, followed by Angus, Hereford, Brangus and Polled Herefords, respectively. Cattle sired by Charolais bulls should have higher muscle-to-bone ratios than cattle sired by the other breed groups.

Conclusions

Definite breed differences exist among Charolais, Brangus, Hereford, Polled Hereford and Angus bulls for on-test weight, off-test weight, hip height, scrotal circumference, average daily gain on test, fat thickness and muscling. Differences among breeds tended to parallel differences in breed physiological and sexual maturity patterns. Charolais bulls were taller, heavier, faster gaining and trimmer and possessed larger rib eye areas than the other breeds.

All breeds tended to grow in height at the same rate during the test period or from weaning to yearling; however, Charolais and Brangus were generally taller at the completion of test due to their large mature size.

Growth Rates of Hip Height, Scrotal Circumference and Weight for Purebred Hereford and Angus Bulls

J. H. Baker, J. R. Kropp,
E. J. Turman and R. L. Hintz

Story in Brief

Seasonal differences and growth rates were studied on 60 Hereford and Angus bulls born in the spring and fall calving seasons at Oklahoma State University. Hip height, scrotal circumference and weight measurements were taken over the two 10-month experiments.

Season of birth had no influence on scrotal circumference for either Hereford or Angus bulls. Season of birth in Angus bulls did not show a difference in hip height, scrotal circumference, or weight between spring and fall-born bulls.

Hip height and scrotal circumference growth rate, along with average daily gain, showed a linear decline from 6 to 17 months of age in both Hereford and Angus bulls. Hip height growth rate from 180 to 365 days of age averaged .0325 and .0321 in./day for Hereford and Angus bulls, respectively. In addition, hip height growth rate from 365 to 510 days of age averaged .0222 and .0207 in./day for Hereford and Angus bulls, respectively. Scrotal circumference growth rate from 180 to 510 days of age ranged from .0790 to .0000 cm/day for Herefords and .0843 to .0040 cm/day for Angus. Adjustment factors for scrotal circumference at 6 and 12 months of age were .08 and .04 cm/ day, respectively. Average daily gain was faster for Angus bulls at the start of the test than for Herefords, but declined much faster later in the test period. Average daily gain of Angus bulls from 180 to 510 days of age averaged 2.51 lb/day. Hereford bulls averaged 2.42 lb/day.

Introduction

In today's marketing and production systems it would be beneficial to have fast growing, rapidly gaining cattle that reach sexual maturity as young as possible. The desire to increase frame size and growth rate in cattle has generated considerable interest in hip height growth rates. Many studies have looked at hip height growth rate up to 12 months of age, but little has been reported on bulls after a year of age. In addition, some concern exists in the beef industry relative to the effect of increasing frame size and growth rates on scrotal circumference and sexual development. Relatively little is known about scrotal circumference growth rates in young bulls of different breeds. Although many studies have looked at the effect of age on scrotal circumference, few have reported actual growth rates that may be important for scrotal circumference adjustment factors at different ages.

The purpose of this study was to examine growth rates for hip height, scrotal circumference and body weight. In addition, a major objective was to evaluate the effect of breed, season and ambient temperature on scrotal circumference measurements in young beef bulls.

Materials and Methods

The data used in this study were the performance traits and scrotal measurements on Hereford and Angus bulls in the Oklahoma State University purebred herd. Data was collected from 20 Hereford and 12 Angus bulls born between January 1 and May 30, 1979, and these bulls were classified as spring-born. An additional 12 Hereford and 12 Angus bulls born between September 1 and December 10, 1979, were classified as fall-born. The Hereford bulls were mainly out of D4 Mischief dams and sired by seven different L1 Domino sires. The Angus bulls were straight-bred Emulous with four different sires represented.

Bulls used in this study were weaned at an average age of 6 months and placed on a warm-up period for 14 days prior to the start of this study. All bulls were fed the same ration (Table 1), grouped by season of birth and penned together on Bermuda grass pasture during the entire study. Hip height, scrotal circumference and weight were obtained every 30 days until the bulls reached approximately 17 months of age

Table 1. O.S.U. purebred bull ration

Ingredients	Percent of ration
Alfalfa hay (ground or pellet)	30.0
Rolled corn	32.0
Soybean meal	12.5
Cotton seed hulls	10.0
Rolled oats	10.0
Molasses	5.0
Trace mineral salt	.5

Results and Discussion

Hip height and scrotal circumference data were measured by two different technicians, and repeatabilities of .99 and .97 were recorded, respectively. These highly-significant values are mainly due to great care being taken in each measurement as well as the bulls' becoming extremely gentle and accustomed to the handling procedures during the two 10-month studies.

There was a difference ($P<.05$) between spring and fall-born Angus calves for hip height and weight from 6 to 17 months of age. Angus bulls born in the spring averaged 1.26 in. taller and 66.4 lb heavier from 6 to 17 months of age than Angus bulls born in the fall (Table 2). Season of birth had little influence on hip height and weight of Hereford bulls from 6 to 17 months of age.

The desire to increase frame size and growth rate in cattle has generated considerable interest in hip height growth rate from weaning to yearling and beyond. In addition, some concern exists in the beef industry relative to the effect of increasing frame size and growth rate on sexual development.

Figures 1, 2 and 3 depict the effect of age on hip growth, scrotal circumference growth and average daily gain. These traits decrease linearly in growth rate as

Table 2. Season of birth means for hip height, scrotal circumference and body weight from 6 to 17 months of age

Season	Hip height (in)	Scrotal circumference (cm)	Weight (lb)
Hereford			
Spring	47.8 ± .03[a]	32.1 ± 10[a]	955.8 ± 3.0[a]
Fall	47.7 ± .03[a]	32.3 ± .09[a]	967.9 ± 2.6[a]
Angus			
Spring	49.2 ± .04[a]	34.4 ± .10[a]	1081.5 ± 3.2[a]
Fall	47.9 ± .03[b]	33.5 ± .06[a]	1015.1 ± 1.8[b]

[a,b]Means in the same row that do not show at least one superscript are significantly different by LSD test ($P<.05$).

days in age increases. Hip height growth rate from 180 to 365 days of age ranged from .0373 to .0277 in./day (average = .0325) in Hereford bulls and from .0373 to .0270 in./day (average = .0321) in Angus bulls (Figure 1). These results are in agreement with the .03 in./day adjustment factor for height recommended by the Beef Improvement Federation Guidelines. Hip height growth rate from 365 to 510 days of age ranged from .0267 to .0183 in./day (average = .0222) in Hereford bulls and from .0247 to .0163 in./day (average = .0207) in Angus bulls.

Scrotal circumference growth rates also declined linearly at a rapid rate with increasing age (Figure 2). The increase in scrotal circumference as age increased ranged from .0790 to .0000 cm/day from 180 to 510 days of age for Hereford bulls and from .0843 to .0040 cm/day for Angus bulls. Very rapid growth in scrotal circumference was observed up to 13 months of age with a gradual decline in rate of growth until the end of the test. The average scrotal circumference growth rates from 180 to 390 days of age in Hereford and Angus bulls were .0543 and .0602 cm/day. Therefore, between weaning and yearling weigh periods, the Hereford and Angus bulls in this study tended to increase in scrotal circumference by approximately 12 cm or 4.7 in. Because of the very rapid decline in growth rate of scrotal circumference with increasing age, adjustment factors for scrotal circumference measurements for each month are recommended (Table 3).

Table 3. Scrotal circumference adjustment factors for Hereford and Angus bulls

Months of age	Scrotal circumference growth rate (cm/day)
6-7	.080
7-8	.070
8-9	.060
9-10	.055
10-11	.050
11-12	.040
12-13	.030
13-14	.025
14-15	.015
15-16	.010
16-17	.000

Average daily gain was faster for Angus initially but decreased at a faster rate as age increased (Figure 3). Average daily gain from 180 to 510 days of age in Hereford bulls ranged from 2.97 to 1.83 lb/day (average = 2.42) while the Angus bulls ranged from 3.23 to 1.80 lb/day (average = 2.51). Feed intakes were adjusted every 28 days so that the average daily gain for all bulls would be 2.5 lb/day for the entire study. Even though feed intakes were controlled, a definite separation in average daily gains occurred.

In general, performance traits and scrotal circumference tend to differ between breeds and between different frame sizes. Further study is necessary on the influence of season, preweaning effects of dam and nutrition on skeletal size and growth rates prior to weaning and after 365 days of age.

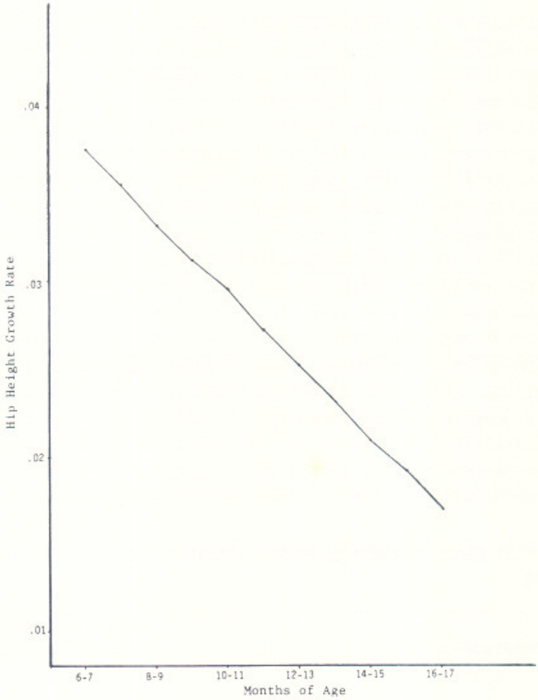

Figure 1. Predicted effect of age on hip height growth rates (in/day in Hereford and Angus bulls

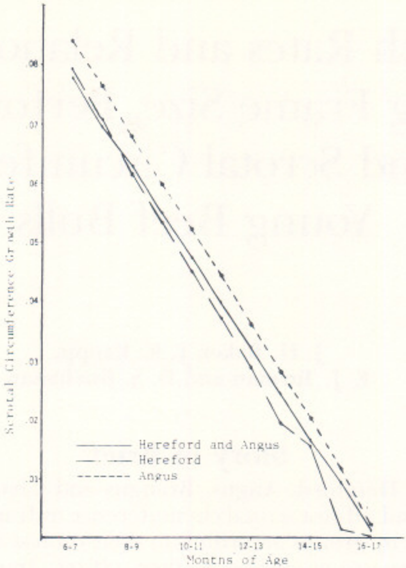

Figure 2. Predicted effect of age on scrotal circumference growth rate (cm/day) in Hereford and Angus bulls

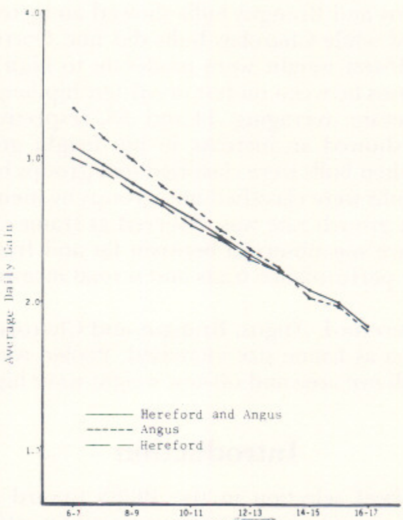

Figure 3. Predicted effect of age on average daily gain (lb/day) in Hereford and Angus bulls

Growth Rates and Relationships Among Frame Size, Performance Traits and Scrotal Circumference in Young Beef Bulls

J. H. Baker, J. R. Kropp, E. J. Turman and D. S. Buchanan

Story in Brief

Hereford, Polled Hereford, Angus, Brangus and Charolais bulls showed an increase in on-test and off-test scrotal circumference as frame size increased when bulls were classified by groups according to their on-test frame size. When bulls were classified by groups according to their off-test frame size, no significant relationship between on-test or off-test scrotal circumference and frame size was observed although scrotal circumferences tended to increase as frame size increased. However, when weight was held constant, the relationship between hip height and scrotal circumference was near zero.

All breeds showed an increase in weight as frame size increased. Hereford, Polled Hereford, Angus and Brangus bulls showed an increase in off-test weight as frame size increased while Charolais bulls did not. Correlations between off-test hip height and off-test weight were moderate to high (average .56) for all breeds, while correlations between on-test or off-test hip height and average daily gain were low to moderate, averaging .14 and .33, respectively.

Overall, all breeds showed an increase in hip height growth rate as off-test frame size increased when bulls were classified into groups by their off-test frame size. However, when bulls were classified into groups by their on-test frame size, a decrease in hip height growth rate was observed as frame size increased.

Overall, no difference was observed between fat and frame size. Correlations between fat and other performance traits and scrotal measurements were generally low.

Hereford, Polled Hereford, Angus, Brangus and Charolais bulls all showed an increase in rib eye area as frame size increased. Pooled within class, correlation coefficients between rib eye area and off-test weight were high, averaging .73 for all breeds.

Introduction

With the trend in beef selection in the 1980's toward larger-framed, later-maturing bulls, many concerns have been expressed by cattlemen relative to the effect of increased size and body growth on the reproductive development and performance of the bull. Although extensive data exists on the relationship between body size and testicular growth, especially in dairy bulls, few results have been published concerning the relationship between reproductive development and skeletal size.

The purpose of this study was to evaluate the relationships between skeletal size as measured by hip height in young beef bulls and scrotal circumference, body weight, average daily gain, fat thickness and rib eye area.

Materials and Methods

This study utilized performance data and testicular measurements from Hereford, Polled Hereford, Angus, Brangus and Charolais bulls on test at Okahoma Beef, Incorporated, as outlined in the previous paper (Baker et al., 1982).

The hip height measurement was used as the basis for classifying each bull into a skeletal frame size group. The frame size classification used was based on adjusted hip height calculated as the number of days to the closest month of age multiplied by .03 in./day plus or minus the actual hip height depending on whether the actual hip height was nearer to the younger or older month of age (Hubbard, 1981). The actual classifications used in this study are presented in Table 1 and were developed from data collected on bulls (Prosser, 1978). Skeletal frame size is a classification system based on hip height at a certain age in months. In this study, hip height measurements were obtained and classified into a frame size. Data were separately analyzed for on-test and off-test frame size because some bulls changed frame size during the test period. Bulls were classified in a frame size when they went on test and remained in this group even though their frame size changed during the test. In addition, these same bulls were classified for off-test frame size and, for the purpose of analysis, were considered to be in the same off-test frame size regardless of what their actual on-test frame score was.

Table 1. Hip height measurement in inches to determine various frame sizes at different ages

Age in Months	Frame Size 1	Frame Size 2	Frame Size 3	Frame Size 4	Frame Size 5	Frame Size 6
6	35	37	39	41	43	45
7	36	38	40	42	44	46
8	37	39	41	43	45	47
9	38	40	42	44	46	48
10	39	41	43	45	47	49
11	40	42	44	46	48	50
12	41	43	45	47	49	51
13	41.5	43.5	45.5	47.5	49.5	51.5

Results and Discussion

Scrotal circumference and scrotal growth rates

When bulls were classified into groups on the basis of on-test frame size, there was an increase in on-test scrotal circumference in Hereford, Angus and Brangus bulls as frame size increased. Similar trends were observed in Polled Hereford and Charolais bulls (Table 2).

Similar trends were observed in off-test scrotal circumference of bulls based on their on-test frame size classification. Hereford and Brangus bulls showed an increase in off-test scrotal circumference as on-test frame size increased. Angus,

Table 2. Scrotal circumference least square means classified by on-test frame scores

Frame Score	2	3	4	5	6
Breed			**On-test**		
Hereford	$22.9 \pm .97^{d}$	$25.0 \pm .34^{c}$	$26.0 \pm .29^{b}$	$27.8 \pm .55^{a}$	
Polled Hereford	$24.4 \pm .94^{a}$	$25.3 \pm .40^{a}$	$26.1 \pm .41^{a}$	$25.7 \pm .72^{a}$	
Angus	$27.0 \pm .87^{bc}$	$26.7 \pm .33^{c}$	$28.3 \pm .28^{ab}$	$29.4 \pm .76^{a}$	
Brangus		$26.2 \pm .72^{c}$	$28.0 \pm .56^{b}$	$28.7 \pm .74^{ab}$	29.5 ± 2.2^{a}
Charolais			24.2 ± 1.07^{a}	$25.1 \pm .55^{a}$	$26.3 \pm .77^{a}$
			Off-test		
Hereford	$31.7 \pm .78^{c}$	$33.3 \pm .28^{b}$	$33.4 \pm .25^{b}$	$35.5 \pm .46^{a}$	
Polled Hereford	$32.2 \pm .81^{a}$	$32.7 \pm .36^{a}$	$33.3 \pm .36^{a}$	$33.3 \pm .61^{a}$	
Angus	$33.6 \pm .93^{a}$	$34.7 \pm .34^{a}$	$35.5 \pm .29^{a}$	$36.4 \pm .87^{a}$	
Brangus		$34.6 \pm .59^{ac}$	$36.2 \pm .40^{ab}$	$36.3 \pm .55^{ab}$	37.8 ± 1.6^{a}
Charolais			$33.4 \pm .97^{a}$	$34.7 \pm .53^{a}$	$35.0 \pm .71^{a}$

[a,b,c] Means in the same row that do not share at least one superscript are significantly different by LSD test (P<.05).

Polled Hereford and Charolais bulls showed similar increasing trends in scrotal circumference as on-test frame size increased although these relationships were small (Table 2).

When bulls were classified into frame size groups on the basis of their off-test hip height, differences between scrotal circumference and frame size were generally not observed (Table 3). Thus, when bulls finished their 140-day test at approximately 12 months of age, there was little basic relationship between frame size and either on-test or off-test scrotal circumference. However, when bulls were classified into frame size groups on the basis of their on-test hip height, there was a tendency for larger-framed bulls to have larger on-test and off-test scrotal circumferences.

Table 3. Scrotal circumference least square means classified by off-test frame scores

Frame Score	2	3	4	5	6
Breed			**On-test**		
Hereford	25.6 ± 1.11^{a}	$25.1 \pm .46^{a}$	$25.8 \pm .34^{a}$	$26.5 \pm .49^{a}$	
Polled Hereford		$25.1 \pm .40^{a}$	$26.3 \pm .40^{a}$	$25.0 \pm .76^{a}$	
Angus		$27.0 \pm .42^{b}$	$27.4 \pm .29^{b}$	$29.6 \pm .56^{a}$	
Brangus		$27.5 \pm .80^{a}$	$27.2 \pm .54^{a}$	$29.2 \pm .54^{a}$	26.3 ± 2.29^{a}
Charolais			24.8 ± 1.55^{a}	$25.6 \pm .58^{a}$	$25.2 \pm .82^{a}$
			Off-test		
Hereford	$32.8 \pm .86^{a}$	$32.9 \pm .35^{a}$	$33.8 \pm .26^{a}$	$34.3 \pm .38^{a}$	
Polled Hereford		$32.5 \pm .34^{a}$	$33.4 \pm .35^{a}$	$33.5 \pm .65^{a}$	
Angus		$34.5 \pm .41^{a}$	$35.1 \pm .28^{a}$	$36.4 \pm .52^{a}$	
Brangus		$35.0 \pm .60^{a}$	$35.8 \pm .39^{a}$	$36.6 \pm .56^{a}$	35.5 ± 1.70^{a}
Charolais			34.4 ± 1.23^{a}	$33.9 \pm .46^{b}$	$35.9 \pm .64^{a}$

[a,b] Means in the same row that do not share at least one superscript are significantly different by LSD test (P<.05).

Correlations between on-test hip height and on-test scrotal circumference were .43, .49, .32, .35 and .56 while correlations between off-test hip height and off-test scrotal circumference were .25, .33, .28, .23 and .12 for Hereford, Polled Hereford, Angus, Brangus and Charolais bulls, respectively. When pooled within class, correlations were calculated with weight held constant, and the correlations between hip height and scrotal circumference were near zero for all breeds. This indicates that weight, and not height, is responsible for the relationship between hip height and scrotal circumference.

The pooled-within-class correlation coefficient between scrotal circumference and on-test weight, averaged among breeds, was .62 while the correlation between off-test scrotal circumference and off-test weight, averaged among breeds, was .38. These results suggest a higher relationship between scrotal circumference and weight at 7 months of age than at 12 months of age.

Correlations between on-test scrotal circumference and scrotal circumference growth rate were highly negative, averaging -.66, suggesting that bulls with larger scrotal circumference at 7 months of age had slower scrotal growth until 12 months of age. However, correlations between off-test scrotal circumference and scrotal circumference growth rate were positive, averaging .39, suggesting that bulls with larger testicles off-test had a faster scrotal growth rate during the testing period. Therefore, measurement of scrotal circumference at yearling time may be a better indication of scrotal growth than a weaning measurement.

Body weight and performance traits

The larger framed, taller bulls were also the heaviest bulls on-test, regardless of breed (Table 4). Hereford, Polled Hereford and Angus bulls showed an increase in on-test weight of 222, 139 and 167 lb, respectively, as frame size increased from 2 to 5. Brangus bulls showed a similar increase of 208 lb as frame size increased from 3 to 6, and Charolais bulls increased 127 lb as frame size increased from 4 to 6. Correlations between on-test hip height and on-test weight averaged .67 for all breeds.

The larger framed, taller bulls on-test also tended to be the heavier bulls off-test, regardless of breed. Hereford, Polled Hereford, Angus and Brangus bulls showed an increase in off-test weight of 132, 118, 176 and 131 lb, respectively, as frame score increased from 3 to 6. Little difference was noted for yearling

Table 4. Body weight least square means classified by on-test frame scores

Frame Score	2	3	4	5	6
Breed			**On-test**		
Hereford	474 ± 25^d	546 ± 9^c	633 ± 7^b	696 ± 14^a	
Polled Hereford	491 ± 23^c	535 ± 10^c	578 ± 10^b	630 ± 18^a	
Angus	550 ± 21^c	586 ± 8^c	652 ± 7^b	717 ± 19^a	
Brangus		587 ± 14^d	637 ± 6^c	676 ± 14^b	795 ± 43^a
Charolais			634 ± 37^b	692 ± 19^b	761 ± 27^a
			Off-test		
Hereford	927 ± 32^d	1013 ± 13^c	1079 ± 10^b	1145 ± 14^a	
Polled Hereford		999 ± 12^b	1077 ± 12^a	1117 ± 23^a	
Angus		1054 ± 15^c	1118 ± 10^b	1218 ± 19^a	
Brangus		1066 ± 21^c	1080 ± 14^c	1197 ± 20^{ab}	1231 ± 60^a
Charolais			1253 ± 71^a	1204 ± 26^a	1287 ± 37^a

[a,b,c,d] Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

weights of Charolais bulls of different frame size.

Pooled-within-class correlation coefficients between on-test hip height and average daily gain for Hereford, Polled Hereford, Angus, Brangus and Charolais bulls were .00, .36, .25, .21 and -.10, respectively, suggesting little relationship exists between initial frame size and average daily gain on test. Correlations between off-test hip height and average daily gain were somewhat higher, averaging .33, but still low in terms of relationship.

When bulls were classified into groups on the basis of on-test frame size, there were no significant differences in average daily gain as on-test frame size increased, regardless of breed. However, when bulls were classified into groups by their off-test frame size, average daily gain increased as frame size increased from 3 to 6 for Polled Hereford, Angus and Brangus bulls, but not for Hereford or Charolais bulls. Hereford and Charolais bulls possibly would have shown the same relationship if these bulls had been taken to an older end point because the smaller framed bulls would be physiologically older. Thus, they would be more mature in their growth curve and gaining less weight.

Hip height growth rate

Hip height growth rate was similar for all breeds from approximately 7 to 12 months of age (.0328 in./day) (Table 5).

Table 5. Hip height growth rate least square means classified by on-test and off-test frame scores

Frame	2	3	4	5	6
Breed			**On-test**		
Hereford	$.0359 \pm .002^{a}$	$.0337 \pm .001^{ab}$	$.0322 \pm .001^{ab}$	$.0288 \pm .001^{c}$	
Polled Hereford	$.0365 \pm .002^{a}$	$.0331 \pm .001^{ab}$	$.0299 \pm .001^{abc}$	$.0309 \pm .002^{c}$	
Angus	$.0389 \pm .002^{a}$	$.0368 \pm .001^{ab}$	$.0322 \pm .001^{c}$	$.0305 \pm .002^{c}$	
Brangus		$.0344 \pm .002^{a}$	$.0319 \pm .001^{a}$	$.0303 \pm .002^{a}$	$.0295 \pm .005^{a}$
Charolais			$.0383 \pm .003^{a}$	$.0342 \pm .002^{a}$	$.0310 \pm .002^{a}$
			Off-test		
Hereford	$.0292 \pm .002^{b}$	$.0310 \pm .001^{b}$	$.0315 \pm .001^{b}$	$.0351 \pm .001^{a}$	
Polled Hereford		$.0310 \pm .001^{a}$	$.0318 \pm .001^{a}$	$.0358 \pm .002^{a}$	
Angus		$.0303 \pm .001^{b}$	$.0351 \pm .001^{a}$	$.0368 \pm .001^{a}$	
Brangus		$.0282 \pm .002^{ac}$	$.0324 \pm .001^{ab}$	$.0350 \pm .002^{ab}$	$.0380 \pm .005^{a}$
Charolais			$.0309 \pm .004^{a}$	$.0324 \pm .002^{a}$	$.0374 \pm .002^{a}$

[a,b,c] Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

When bulls were classified into groups on the basis of their on-test hip height, there was a constant decline in hip height growth rate as frame size increased from 2 to 6. Larger framed bulls at the beginning of the test period grew more slowly in hip height than did smaller framed bulls to the completion of the 140-day test or approximately 12 months of age.

When bulls were classified into groups on the basis of their off-test hip height, all breeds showed an increase in hip height growth rate as frame size increased. Thus, bulls of larger frame size at 12 months tended to grow faster in hip height from 7 to 12 months of age than did bulls of smaller frame size, denoting differences in the physiological maturity and growth pattern of the bulls.

Differences in hip height growth rate between bulls classified by on-test and off-test frame size may possibly be explained by three points. First, the bulls went on test in varying degrees of condition, and there was no way to accurately measure preweaning effects of the dam, environmental conditions and (or) management of the bulls prior to arrival at the test station. Thus, bull calves that were on a higher plane of nutrition prior to arrival were possibly larger in their skeletal development due to preweaning influences but did not grow in height as rapidly as smaller framed calves in poorer body condition on arrival. Secondly, the physiological ages of the calves were different; thus, some bulls were simply earlier maturing in their growth pattern than others. Finally, there were no means of confirming the true birth date of all bulls.

These results suggest that a 12-month yearling hip height measurement is the best future indicator of hip height growth since maternal preweaning influences should have less drastic effects on frame size.

Fat thickness and rib eye area

There were no significant differences in fat thickness as frame size increased in any breed (Table 6). Correlations between fat thickness and all traits measured were generally low and not significant. All bulls in this study were fed similar high-energy rations and were of a fairly constant age on completion of test; therefore, little difference in fat deposition at the 12th rib would be anticipated at different frame sizes.

Table 6. Fat thickness and rib eye area least square means classified by off-test frame scores

Fat thickness					
Frame score	2	3	4	5	6
Breed			On-test		
Hereford	$.31\pm.05^a$	$.39\pm.02^a$	$.39\pm.02^a$	$.39\pm.02^a$	
Polled Hereford		$.45\pm.02^a$	$.44\pm.02^a$	$.37\pm.04^a$	
Angus		$.45\pm.02^a$	$.45\pm.02^a$	$.45\pm.03^a$	
Brangus		$.44\pm.04^a$	$.40\pm.02^a$	$.45\pm.03^a$	$.45\pm.10^a$
Charolais			$.20\pm.05^a$	$.20\pm.02^a$	$.23\pm.03^a$
Rib eye area					
Hereford	$12.1\pm.4^c$	$12.5\pm.2^c$	$13.0\pm.1^b$	$13.7\pm.2^a$	
Polled Hereford		$11.9\pm.1^b$	$12.8\pm.1^b$	$13.5\pm.3^a$	
Angus		$12.9\pm.1^c$	$13.5\pm.1^b$	$14.4\pm.2^a$	
Brangus		$12.6\pm.2^c$	$12.6\pm.1^c$	$13.4\pm.2^{ab}$	14.3 ± 1.5^a
Charolais			15.1 ± 1.6^a	$14.9\pm.3^a$	$15.3\pm.4^a$

[a,b,c] Means in the same row that do not share at least one superscript are significantly different by LSD test ($P<.05$).

When bulls were classified by off-test frame size, rib eye area increased as frame size increased in Hereford, Polled Hereford, Angus and Brangus bulls, but not in Charolais bulls. Correlations between off-test weight and rib eye area averaged .74 for all breeds, while correlations between off-test height and rib eye area averaged .47. However, when weight was held constant, the correlations between off-test hip weight and rib eye area were generally very low. Therefore, most of the relationship between hip height and rib area is probably due to weight.

Conclusions

Weaning and yearling frame size, as denoted by on-test and off-test hip heights, have marked influence on scrotal circumference, on-test weight, final weight, average daily gain, and rib eye area.

Hip height growth rates were similar for all breeds from weaning to yearling. However, a yearling hip height measurement is probably a more accurate growth indicator since maternal preweaning influences should have less drastic effects on frame size.

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Factors Related to Ram Fertility During May and June

J.V. Whiteman, K.A. Ringwall and R.P. Wettemann

Story in Brief

A flock of 160 Rambouillet ewes was purchased to combine with existing ewes to create 10 test groups to be used to measure the breeding effectiveness (aggressiveness and fertility) of rams. Two rams that showed little response in testicular circumference to the season of the year and two rams that responded strongly were tested to determine if this measurement was related to ram effectiveness in May and June. Three pairs of twin rams were used to determine if subjecting rams to reduced light for about 2 months before the breeding season would affect breeding effectiveness. One ram of each pair was subjected to reduced light, and one received normal light prior to the May-June breeding season. The rams selected to be more fertile on the basis of testicular size made considerably more matings and therefore sired more lambs than those thought to be less fertile, but so few rams were tested that cautious optimism prevails about the possibilities of using this procedure. The rams that were subjected to only 8 hours of light daily before breeding produced slightly higher conception rates than rams exposed to normal light, but the evidence that this was due to restricted light is inconclusive.

Introduction

Successful fall lambing is the result of an effective late spring (May-June) breeding season. Many sheepmen who attempt to lamb their ewes during the fall do not experience a high level of success as judged by the percent of the ewes that lamb (fertility) or the number of lambs born per ewe lambing (prolificacy), suggesting that the breeding season the previous spring was not very effective.

An effective breeding season results when fertile and aggressive rams are exposed to ewes, all of which are cycling regularly. Since ewes of only a few breeds or breedcrosses of sheep (Dorsets, Rambouillets, Dorset × Rambouillet crosses) cycle reasonably well during the spring, it is common to blame the ewes when breeding failures occur. Mating records have been maintained routinely on the experimental sheep flock at the Southwest Livestock and Forage Research Station near El Reno since 1955. These records indicate large differences in breeding effectiveness of different rams when exposed to the same kind of ewes. They also indicate that most rams are much more effective during the fall than during the spring. Similar observations have been noted by sheep producers and by scientists at other research locations.

The use of light control to reduce the amount of light to which sheep (ewes or rams) are exposed has been shown by several scientists to cause seasonally infertile (or less fertile) ewes and rams to become more fertile. If the more fertile rams could be detected, or if a practical system of light control would make rams generally more effective under spring breeding conditions, it should result in more effective spring breeding followed by more successful fall lambing.

The purpose of this report is to give some preliminary results obtained from research designed to estimate the improved breeding performance of rams subjected to light control and the differences in performance of untreated rams selected on the basis of testicular measurements to be *more* vs *less* fertile.

Experimental Procedure

The most accurate method of measuring a ram's fertility is to expose him to enough ewes to measure the speed with which he mates with them and the percent of pregnancies resulting from the matings. One hundred sixty Rambouillet ewes were purchased to combine with the existing flock so that mating groups could be created to test 10 rams per year. The flock ewes that were placed with the Rambouillets included F_2 Dorset × Finn crossbreeds, Dorset × Rambouillet ewe lambs and old Dorset × Rambouillet ewes. The 10 mating groups were balanced to contain the same proportion of ewes of each breed cross and age group.

The rams to be tested involved two kinds of tests. One test concerned the ability to select *more* vs *less* fertile rams on the basis of testicular size measurements. The second was concerned with whether reduced light prior to the breeding season would increase the breeding effectiveness of Dorset × Finn F_2 rams.

The possibility of selecting rams for fertility based on testicular size (scrotal circumference) is based on the idea that testicular size follows a rhythm during the year with a larger size prior to and during the regular breeding season and smaller size prior to and during the period when rams are infertile or less fertile (the period when seasonally anestrous ewes will not breed). The period of lowest fertility varies with different animals and different breeds but is some time between late winter and late summer. Since some rams are much more fertile and sexually aggressive during this period than others, the question arises, "Do these rams show the usual reduction in testicular size during this period?" To test this idea a group of Dorset × Finn yearling rams were measured monthly for a year to characterize their individual testicular size changes prior to the May-June 1981 breeding season. From this group two rams were selected as showing the least response to season in testicular size, and two were selected as showing the most response. Each of these four rams was placed with one of the test groups of ewes for breeding.

To test for the effect of reduced light on breeding effectiveness, seven Dorset × Finn yearling rams were placed on a schedule of 8 hours of light and 16 hours of dark for the last 10 weeks prior to the 1981 May-June breeding season. An equal group of the same kind of rams was maintained under normal light conditions for the same period of time. The 14 rams included three pairs of twins with one ram of each pair in each group. These six rams were tested for fertility by mating each with a test group of ewes.

The breeding season was from May 5 to June 30. Each group of ewes with the ram to be tested was in a different pasture containing similar grazing opportunities. The rams were fitted with marking harnesses to monitor mating activity. The ewe groups were observed daily or on alternate days, and the rump marks (indicating possible matings) were recorded. One of the rams in the groups that received normal light prior to the breeding season would not mate and was replaced 10 days after the breeding season began in order to get the ewes bred.

Results

These results must be considered very preliminary because only a few rams have been tested in one year. The data show promise at this point, and we are encouraged.

The performance of the rams whose fertility was predicted from testicular size changes is shown in Table 1. The percent mated column is a measure of the aggressiveness of the rams. It is obvious that the two rams predicted to be more fertile were more aggressive. They not only found and marked a higher percentage of their ewes; they also made about 40 percent more total matings

Table 1. Measures of breeding effectiveness of rams selected to be *more* or *less* fertile based upon testicular size changes

Predicted fertility	No. ewes	% mated	Conc.[a] rate (%)	Lambing[b] rate	Lambs/ewe exposed
More fertile					
1	29	100	66	1.26	.83
2	29	93	81	1.32	1.00
Less fertile					
1	27	78	67	1.29	.67
2	28	71	60	1.25	.54

[a] Percent of mated ewes that conceived.
[b] Lambs born per ewe lambing.

(not shown) as indicated by recorded rump marks. The rams predicted to be more fertile were especially more effective in finding and mating with the less sexually active ewes—the Dorset × Finn and the Dorset × Rambouillet ewe lambs.

The conception rate is the percent of the mated ewes that lambed and shows only a slight advantage for the rams predicted to be more fertile. The lambing rate is the number of lambs born per ewe lambing and shows no important trend. The lambs per ewe exposed favors the rams predicted to be more fertile and results largely from their aggressiveness in mating with a higher percent of their ewes. These data suggest that the rams whose testicular size changes showed the least seasonal effect were more effective because they were more aggressive in finding and mating with the ewes in their flock.

The breeding effectiveness of the rams on the light control test is presented in Table 2. A study of this table suggests that the results are quite inconclusive. Two of the pairs of rams (1s and 2s) responded similarly whether they were subjected to normal light or were exposed to light restriction. The two number 3 rams were twins also. The one on light control certainly performed better than his twin on normal light, but there is no way to prove that the light control caused the difference. If the two number 3 rams are ignored, the other rams performed similarly except that a higher percent of the ewes that were mated to twins on light control became pregnant. This test needs to be and will be repeated.

Table 2. Measures of breeding effectiveness of rams subjected to 8 hours of light vs normal day length prior to the May-June breeding season

Light treatment	No. ewes	% mated	Con.[a] rate (%)	Lambing[b] rate	Lambs/ewe exposed
8 hr light					
1[c]	29	97	75	1.14	.83
2	27	100	74	1.30	.96
3	28	82	65	1.40	.75
Normal light					
1[c]	29	97	68	1.42	.93
2	28	96	67	1.33	.88
3[d]	27	15	25	1.00	.04

[a] Percent of mated ewes that lambed.
[b] Lambs born per ewe lambing.
[c] The two rams with the same number were twins.
[d] This ram replaced after 10 days because of failure to make enough matings.

Induced Lactation of Infertile Dairy Cows

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Story in Brief

A trial was conducted to determine the lacteal response and subsequent fertility in non-lactating dairy cows that had failed to conceive. This was replicated in 1980 and 1981.

Seven of eight cows that were induced to lactation by hormone treatment produced in excess of 35 lb of milk per day. Two of three cows in the first replicate conceived, had normal gestations and calved normally. The second replicate is in progress, and conception data are not available yet.

Introduction

During any year, most dairymen have one or more of their genetically superior cows that fail to conceive by the end of lactation. Many times milk production of these cows decreases to a very low level, and it is not feasible to continue milking them. If lactation could be induced at a profitable level, efforts to get them bred could be continued. In addition, injection of the steroid hormones to induce lactation may alter the reproductive endocrine system of the cow and increase reproductive efficiency (Collier et al., 1975). The purpose of this study was to evaluate this treatment regime for the induction of lactation and to determine rebreeding performance of "problem breeders."

Material and Methods

Seven cows and one heifer in the University herd that were scheduled to be culled because of reproductive failure were used. These cows had all been dry at least 40 days. The animals ranged in age from a 30-mo-old heifer that had never calved to a 14-yr-old cow that had completed 10 lactations. All animals were given subcutaneous injections of estradiol (.1 mg/kg per day) and progesterone (.25 mg/kg per day) for 7 days. These materials were dissolved in ethanol with one half of the daily dose given at 12-hr intervals. Reserpine (5 mg/day) was given IM in the hip region. The injection schedule in 1980 was on days 1, 6, 11, 16 and 21. The injection schedule in 1981 was on days 8, 10, 12 and 14. Dexamethasone (20 mg/day) was injected IM on days 18, 19 and 20 in 1981. Dexamethasone was not used in 1980.

Milking of the cows was initiated when the teats became engorged or on day 21. The earliest milking was initiated on day 14.

Results and Discussion

The history and lactation performance of the seven cows and one heifer induced to lactate are presented in Table 1. Milk production varied from 4 lb to 57 lb per cow per day. Seven of the eight cows produced over 35 lb of milk per day.

Table 1. History and lactation performance of cows hormonally induced into lactation

Animal	Breed[a]	Previous lactations	Induced lactation: Peak milk yield, lb/day	305-day[b] yield	% fat
		1980			
1	H	10	57	12340	4.3
2	H	3	39	9600	4.2
3	H	0	35	8480	4.4
4	J	2	4	—	—
		1981			
5	H	2	52	—	4.5
6	H	1	49	—	4.2
7	H	7	45	—	3.9
8	H	2	44	—	3.5

[a]H = Holstein, J = Jersey.
[b]305 day production is not complete for 1981 animals.

This level of production is comparable to that reported by Collier et al. (1977). Fat test was higher in the induced lactation than in the previous normal lactation of the induced cows.

Two of the four cows treated in 1980 conceived, after two and four services. One cow did not milk and was not bred. The 14-yr-old cow became cystic and cycled irregularly after she was treated. She was bred four times but did not conceive. The two cows that conceived have calved and are milking normally this lactation. Conception information is not complete for the cows induced in 1981.

Previous research indicates that the hormones necessary for development of the mammary gland (similar to late pregnancy) and the initiation of lactation are estrogen, progesterone, glucocorticoids and prolactin. In this experiment the natural hormones estrodiol and progesterone were given, followed by injection of the reserpine and dexamethasone. Reserpine is a tranquilizer and hypotensive agent and also causes release of prolactin from the pituitary gland of the cow. The cows in this study showed various degrees of sedation after reserpine treatment. Reserpine injection was stopped after the third dose on one cow because of nasal congestion and labored breathing. After the fourth injection, one cow was sedated to the point she would not get on her feet for 24 hr. Both cows later returned to a normal healthy condition.

In this trial it was demonstrated that lactation can be induced in dairy cattle, and the hormonal treatment may enhance rebreeding. Although the level of production was below what one could expect following calving, it was high enough to offset the expense of keeping the cows in the herd for additional attempts at rebreeding.

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NUTRITION—
COW-CALF AND STOCKER

Energy vs Protein Supplementation of Steers Grazing Native Range in Late Summer and Early Fall

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Story in Brief

Forty-seven Hereford steers and 36 Angus × Hereford crossbred yearling steers weighing about 575 lb were grazed on native range from July 16 to October 20, 1981. Steers were divided into four groups and fed no supplement (control), .8 or 1.5 lb/day of protein supplements, or 3.0 lb/day of a 10 percent protein corn-based supplement. Soybean meal was the protein source. Supplements were fed on Monday, Wednesday and Friday. Average daily gains for the 96-day period were 1.44, 1.88, 1.97 and 1.78 pounds, respectively. Pounds of supplement per pound of added gain were 1.8, 2.8 and 8.8 for the .8, 1.5, and 3.0 lb/day supplements. A small amount of supplemental protein apparently increased forage intake and digestibility. Feeding supplemental energy was not efficient in increasing gains in steers grazing native range.

Introduction

Feeding small amounts of high protein meals to ruminants consuming low quality roughages has been shown to increase forage digestibility and intake. Increased weight gains from feeding high protein meals to cattle fed low quality roughages have generally been more efficient than increased gains from feeding energy supplements. Native grass is relatively low in protein from mid-summer to the end of the growing season. If efficient increases in weight gains could be accomplished with small amounts of soybean meal-based supplements, the cost of gain for summer grazing could be reduced. The objective of this research was to compare gains and efficiency of gains of yearling steers grazing native range from mid-summer to early fall and being fed two levels of high protein supplement and a high energy supplement.

Experimental Procedures

Forty-seven Hereford steers and 36 Angus × Hereford crossbred steers, approximately 16 months old, were allotted by breed to four treatments. Treatments were (1) control, no supplement, (2) .8 lb per day of a 39 percent protein supplement, (3) 1.5 lb per day of a 43 percent protein supplement and (4) 3.0 lb per day of a 10 percent protein supplement. Composition of the supplements is shown in Table 1. Treatments 2 and 4 provided the same amount of supplemental protein, but treatment 4 provided additional supplemental energy. Treatment 3 provided twice the amount of supplemental protein as treatments 2 and 4. Each supplement provided approximately 9 g of calcium, phosphorus and potassium per day. The additional mineral in a small amount of supplement necessitated the feeding of .8 lb of supplement 2 in order to provide the desired amount of soybean meal. All supplements were fed on Monday, Wednesday and Friday with supplement amounts prorated to give the prescribed daily amount.

The trial was conducted at the Lake Carl Blackwell Range 10 miles west of Stillwater in North Central Oklahoma. Each group of steers was grazed on 160 acres of native range and group-fed from July 16, 1981, to October 20, 1981. Weights of the steers were taken after the steers were held off pasture and water overnight. Prior to the start of the study, all steers were implanted with 36 mg of Ralgro, wormed with TBZ paste and vaccinated for IBR, PI-3, Lepto and BVD. Salt and minerals were provided free-choice for control steers.

Table 1. Supplement composition (as-fed)

	Treatment		
	2 .8 lb/day 39% protein	3 1.5 lb/day 43% protein	4 3.0 lb/day 10% protein
Ingredients, %			
Soybean meal	87.5	95.0	4.0
Corn	—	—	92.85
Limestone	1.5	2.0	.6
Dicalcium phosphate	10.0	3.0	1.8
Potassium chloride	1.0	—	.75
Composition, %			
Crude protein	39.0	42.6	10.0
TDN	62.0	68.0	72.0
Calcium	2.3	1.5	.6
Phosphorus	2.2	1.1	.6
Potassium	2.1	1.9	.7
Supplied/day in supplement			
Crude protein, lb	.31	.64	.30
TDN, lb	.50	1.0	2.2
Calcium, grams	8.3	10.5	8.2
Phosphorus, grams	8.0	7.8	8.2
Potassium, grams	7.9	12.6	9.3

Results and Discussion

Gains of steers and pounds of supplement required per pound of added gain are shown in Table 2. Steers fed no supplement gained 1.44 lb/day. Feeding .8 lb/day of protein supplement increased daily gains over the 96-day period by .44 lb/day (1.88 vs 1.44) with a conversion of 1.8 lb supplement per pound of added

Table 2. Weight gains of steers grazed on native range and fed protein or energy supplements

	Treatments[a]			
	Control no suppl.	.8 lb 39% protein	1.5 lb 43% protein	3.0 lb 10% protein
No. steers/treatment	21	21	21	20
Initial wt., 7/16/81	578	576	578	590
Intermediate wt., 9/4/81	666	673	692	680
Final wt., 10/20/81	717	757	764	760
Wt. gains, lb/day				
96 days, 7/16-10/20	1.44^{b}	1.88^{c}	1.97^{d}	1.78^{c} ($P<.001$)
1st period, 7/16-9/4	1.76^{b}	1.94^{b}	2.40^{d}	1.81^{b} ($P<.05$)
last period, 9/4-10/20	1.09^{b}	1.83^{d}	1.50^{c}	1.71^{cd} ($P<.001$)
Lb supp./lb added gain (96 days)	—	1.8	2.8	8.8

	Hereford	Hereford X Angus
No steers/treatment	47	36
ADG (96 days)	1.68	1.90 ($P<.005$)

[a] Supplements fed 3 days/week (Monday, Wednesday and Friday).
[b,c,d] Means with different superscript letters are significantly different ($P<.05$).

gain. Feeding 1.5 lb of protein supplement improved gains by .53 lb/day (1.97 vs 1.44) with a conversion of 2.8 lb supplement per pound of added gain. Gains of steers fed 3.0 lb of the high energy (corn-based) supplement were greater than control steers but less than steers fed protein supplements. The conversion of pounds of supplement to pounds of added gain for the corn-based supplement was 8.8:1, roughly three times the conversion rate of the high level of protein and five times the conversion rate for the low level of protein supplement.

Daily gains are also shown by period in Table 2. Steers fed 1.5 lb of protein supplement made the fastest gains during the first 50 days of the study (July 16-September 4). Steers fed .8 lb of protein supplement and 3.0 lb energy supplement gained at similar rates. All supplemented cattle gained faster than control steers during the first period.

Supplemented steers gained faster than control steers during the last 46 days of the study (September 4-October 20). Highest gains for the second period were made by the group fed .8 lb of protein supplement (1.83 lb/day) followed by steers fed 3.0 lb of energy supplement (1.71 lb/day) and those fed 1.5 lb of protein supplement (1.50 lb/day). The lower gains of steers fed 1.5 lb of supplement compared with the .8 and 3.0 lb groups may have been due to the rapid gains of the 1.5 lb group during the first period and their higher degree of condition going into the second period.

Forage samples, hand plucked to estimate forage selected by steers in all four pastures, averaged 9.0 percent crude protein on a dry matter basis and 52.3 percent dry matter on September 4. The protein level may seem high compared to typical levels for mid-summer native range but probably reflects the difference between forage the steers were consuming and whole-plant forage values. The trial period was unusually cool for the July-October period and marked by frequent rainfall.

Abundant forage was available in all pastures and along with the mild temperatures accounted for the very good steer gains even when no supplement was fed.

The dramatic response in gain to a small amount of supplemental protein was likely the result of increased fiber digestibility and increased forage intake. It is obvious that the protein or energy in the supplement alone could not account for an extra pound of gain for each 1.8 lb of supplement fed to the group receiving .8 lb of protein supplement. The fact that the conversion of pounds of supplement to extra gain for steers fed 1.5 lb of protein supplement per day was poorer (2.8:1) suggests that the smaller level of soybean meal probably was producing most of the possible improvement in forage digestibility and intake.

The poor conversion of supplement to added gain for the energy supplement indicates that the high grain supplement did not improve forage digestibility or intake and may have reduced both. Feeding starch has been shown to reduce rumen pH and inhibit fiber digestion. The conversion value of 8.8:1 is typical of many grain-on-grass experiments.

The effect of crossbreeding is dramatically illustrated in Table 2. Hereford x Angus calves gained .22 lb/day faster than straight Hereford steers. All steers were from the same Hereford cow herd.

If supplements used in this study were priced at \$245/ton, \$240/ton and \$135/ton for supplements fed at .8, 1.5 and 3.0 lb/day, respectively, feed costs for each pound of added gain would have been 20.8¢, 36.0¢ and 60.0¢ for the .8 and 1.5 lb/day protein supplements and the 3.0 lb/day energy supplement, respectively.

Condensed Molasses Solubles and Corn Steep Liquor As Protein Supplements for Range Cows

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Story in Brief

Corn steep liquor (CSL) and condensed molasses solubles (CMS) were compared in two trials to cottonseed meal as protein supplements for wintering dry, pregnant Hereford cows on native range. In trial 1, 48 cows were assigned to four protein treatments: negative control, positive control, CMS and CSL that furnished .30, .64, .57 and .66 lb supplemental crude protein per head per day, respectively. Cows were group-fed 6 days per week. Weight losses for 112 days were greatest for negative control and CMS and least for positive control and CSL. Rumen ammonia-N levels at 1-and 4-hr postfeeding were higher ($P<.05$) for CMS and CSL than for either control. In trial 2, 60 cows were individually fed 6 days each week four protein supplements: negative control, positive control, CSM and CSL to provide .18, .51, .40 and .51 lb crude protein per day for 84 days, respectively. Weight losses after 56 and 84 days of supplementation and condition losses after 84 days were lower ($P<.01$) for cows fed the positive control and CSL than for the negative control and CMS. Weight losses for the negative control, positive control, CMS and CSL were 44.0, 11.0, 44.0 and 14.0 lb after 56 days and 57.0, 11.0, 51.0 and 22.0 lb after 84 days, respectively. Condition losses were .96, .33, .90 and .28, respectively, after 84 days. Rumen ammonia levels were higher at 1-and 4-hr postfeeding for cows fed both liquid supplements than for controls. The CSL supplement contained 72 percent of the crude protein as amino acids compared to 39 percent for CSL. Tungstic acid precipitable protein was much higher in CSL (35 percent) than in CMS (12 percent). Corn steep liquor appeared to be about equal to cottonseed meal for wintering dry, pregnant cows on native range.

Introduction

Liquid supplements contain a variety of ingredients, many of which are by-products from the manufacture of foods, alcoholic beverages, glutamic acid and other products. The increased use of liquid by-products as feed ingredients has been caused by several factors, among which are the high cost of molasses, poor results with urea-molasses for cattle consuming low quality roughage and environmental regulations prohibiting the dumping of wastes.

Little is known about the composition of many liquid feed ingredients or their usefulness as protein sources to ruminants fed low quality roughage. If these ingredients have nitrogenous fractions that are mostly ammonia, urea or ammonium compounds, they will likely perform no better than urea-molasses mixes. However, if their nitrogen fractions are high in amino acids, peptides and proteins of plant or microbial origin, some by-products could be acceptable protein sources for ruminants.

Two of the most common by-products in liquid supplements are condensed fermented corn extractives, commonly referred to as corn steep liquor (CSL) and condensed molasses solubles (CMS). Corn steep liquor is obtained during the wet milling of corn and contains most of the soluble proteins of corn. Condensed molasses solubles is the residue from molasses that has been used in various fermentations to produce glutamic acid, citric acid, ethanol and other products.

The objective of this research was to evaluate CSL and CMS as protein sources for beef cows grazing dormant native range.

Materials and Methods

Trial 1.

Forty-eight dry, pregnant Hereford cows were allotted by weight to four supplemental protein treatments (Table 1). Treatments were: negative control, .30 lb crude protein (CP) per day; positive control, .62 lb CP per day; CMS, .62 lb CP per day; and CSL, .62 lb per day. Each treatment was replicated twice with each replicate grazing a pasture of about 80 acres. Forage consisted of native tallgrass with little bluestem, big bluestem, switchgrass and Indiangrass. All supplements were calculated to be approximately isocaloric and to provide equal amounts of phosphorus and potassium.

Initially cows were offered liquid supplements ad libitum in lick tanks filled twice weekly. However, it was apparent after 1 week that the liquid supplements were very palatable and that all supplement was consumed within a few hours after the tanks were filled. Thereafter, supplements were fed 6 days per week with dry supplements fed in metal troughs and liquid supplements fed in lick feeders made from metal drums.

Table 1. Percent composition of supplements fed in trial 1

	Treatments			
Ingredient	Negative control	Positive control	Condensed molasses solubles (CMS)	Corn steep liquor (CSL)
Cottonseed meal	7.2	40.8		
Corn, ground	82.5	51.3		
Dicalcium phosphate	6.9	5.0		
Salt	2.2	2.2		
Potassium chloride	1.0	.5		
Trace mineral premix	.1	.1	.1	.1
Vitamin A (30,000 IU/g)	.1	.1	.3	.3
Cane molasses			39.1	41.6
CMS			55.0	
CSL				55.0
Ammonium polyphosphate			3.5	3.0
Phosphoric acid			2.0	
Analysis (as fed)				
Dry matter, %	90.1	90.0	66.0	61.0
Crude protein, %	10.1	20.2	14.5	16.2

Liquid supplements were mixed at a commercial facility and stored in 55 gal steel drums until feeding. Dry supplements were manufactured at the Oklahoma State University feedmill.

Cows were weighed after overnight withdrawal from feed and water at the beginning of the study and at 28-day intervals thereafter. The trial was conducted for 112 days, from November 22, 1978, to March 3, 1979. One animal from each CSL replicate refused to eat supplement and was removed from the study; both cows were extremely timid and refused to approach the feeders with others present. One cow was removed from the positive control because she aborted, and one cow was removed from the negative control because she calved during the study.

In mid-January cows from one replicate of each treatment were fed their supplements individually. Rumen fluid samples were withdrawn via stomach tube at 1 hour and 4 hours after feeding for rumen ammonia analyses. Microbial action was stopped in rumen fluid by adding 5 g of meta-phosphoric acid per 50 ml of rumen fluid. Samples were then frozen for subsequent rumen ammonia analysis.

Trial 2

Sixty dry, pregnant Hereford cows were allotted by weight to four supplemental protein treatments (Table 2). Treatments were: negative control (8 percent CP), positive control (24 percent CP), CMS (16 percent CP) and CSL (18 percent CP). Liquid supplements were again mixed at a commercial facility but were delivered and stored in bulk rather than drums as in trial 1.

Table 2. Percent composition of supplements fed in trial 2

	Treatments			
Ingredient	Negative control	Positive control	Condensed molasses solubles (CMS)	Corn steep liquor (CSL)
Cottonseed meal		48.0		
Corn, ground	89.0	44.0		
Dicalcium phosphate	6.8	4.8		
Salt	2.0	2.0		
Potassium chloride	2.0	1.0		
Trace mineral mix	.1	.1	.1	.1
Vitamin A (30,000 IU/g)	.1	.1	.1	.1
CMS			71.1	
CSL				71.1
Water			7.1	.7
Cane molasses			17.2	25.5
Sulfuric acid			.5	.5
Phosphoric acid			3.9	2.0
Analysis (as-fed)				
Dry matter, %	90.3	91.2	59.2	54.4
Crude protein, %	8.4	23.0	15.9	17.9
pH			4.1	4.1

Cows were gathered at 8 a.m., 6 days each week and fed their supplements individually. Cows on all treatments grazed a common pasture with ample standing tallgrass forage as described in trial 1. The trial lasted 84 days, from December 7, 1979, to February 29, 1980. Large round bales of wheat straw were offered free choice on days when snow or ice covered the grass.

During the first 56 days of the study, the positive control, CMS and CSL supplements were fed in isonitrogenous amounts based on bi-weekly analysis of supplements. The negative control was fed to provide one-third the CP of the positive control. At these levels of consumption, all supplements were formulated to provide equal amounts of supplemental energy. During the last 28 days of the study, supplement levels were increased to maintain weight of the positive control cows. However, CMS was less palatable than the other supplements, so cows fed CMS were allowed to consume all they would in 45 minutes.

Weights were taken, and rumen fluid was sampled from 10 cows on each treatment as described in trial 1. Cows were visually scored for condition at the beginning and end of the trial based on a rank of 1 = very thin to 10 = very fat. Supplements were sampled weekly for analysis.

Results and Discussion

Trial 1.

Supplements were readily consumed by all cows (Table 3) except two that refused to approach the lick feeders and thus were removed from the study. The liquid supplements were palatable, evidenced by the fact that during the first week of

Table 3. Weights, weight changes and rumen ammonia levels for cows in trial 1

	Treatments			
Item	Negative control	Positive control	CMS	CSL
Number of cows				
Replication 1	6	5	6	5
Replication 2	5	6	6	5
Initial cow wt				
Replication 1	922	891	919	930
Replication 2	946	922	942	917
Wt change, 112 days				
Replication 1	16.0	− 7.0	−38.1	5.1
Replication 2	−83.8	−35.9	−41.0	14.9
Supp consumption, kg/day	1.41	1.41	1.82	1.82
Crude protein intake	.30	.64	.57	.66
Rumen Ammonia-N mg/dl				
1 hr postfeeding	1.78[c]	1.48[c]	22.90[a]	13.70[b]
4 hr postfeeding	.46[b]	2.28[b]	8.84[a]	8.88[a]

[a,b,c]Means with different superscript letters differ significantly ($P<.05$).

the study cows on CSL and CMS consumed a 3-day allowance (over 12 lb per head) within 4 hours. Apparently, ammonia toxicity is not a major problem with CSL- or CMS- based supplements. A similar intake of a urea-molasses supplement with 90 percent of the crude protein equivalent from urea would have provided about .30 grams/lb body weight of urea to a 950-lb cow and probably would have been toxic.

Cows fed CSL gained weight during the 112-day trial, and their performance slightly exceeded that of positive control cows. Positive control cows tended to lose less weight than negative control cows. Weight losses of CMS cows tended to be between the positive and negative controls.

Rumen ammonia-N levels at 1-hour postfeeding were highest ($P<.05$) for the liquid supplements and lowest for control supplements. CSM produced higher ($P<.05$) levels than did CSL. Ammonia-N concentrations at 4-hour postfeeding were similar for CMS and CSL, with both liquid supplements producing more rumen ammonia ($P<.05$) than the control supplements.

Trial 2.

Cows grazing a single pasture were individually fed to measure supplement intake of each animal and to eliminate the pasture effects encountered in trial 1. Sulfuric acid, a common intake limiter, was added to both liquid supplements (Table 2) at the manufacturing plant; and as a result, they were not as palatable as in trial 1. Three cows refused to eat the CMS supplement and were switched with two cows from the positive control and one cow from the negative control that would readily consume CMS. All CSL supplement and most of the CMS was readily consumed at the levels offered for the first 56 days of the trial (Table 4). When the supplement levels were increased during the final 28 days of the trial to maintain weight of the positive control cows, all but one cow on CSL consumed the increased supplement. Several cows fed CMS refused to consume a level that was isonitrogenous to the positive control. In addition to the presence of sulfuric acid, reduced supplement intake in trial 2 compared to trial 1 could be attributed to the absence of feeding competition and to the lower molasses content of the liquid supplements.

The negative controls lost more ($P<.01$) weight than the positive controls after 56 and 84 days. Cows fed CSL lost 8.0 lb during the final 28 days compared to no weight loss for the positive controls; however, one-half the weight loss in the CSL group occurred in one cow that consumed only 65 percent of her supplement during the last 28 days. Weight losses for the negative control and CMS groups were almost identical throughout the study. Condition score changes followed weight change patterns, with negative control and CMS cows losing more ($P<.01$) condition during the trial than positive control or CSL cows.

Rumen ammonia-N concentrations for CMS and CSL were similar at 1-hour postfeeding but were higher ($P<.05$) for CSL than CMS at 4 hours. Both liquid supplements produced higher ($P<.05$) rumen ammonia-N levels than the control supplements at both sampling times.

Weight changes for cows fed CSL were similar to those of cows fed the cottonseed meal-based positive control supplements in both trials, indicating CSL is an effective protein source for cows on dormant range grass. Conversely, the performance of cows on CMS was about equal to that of cows fed the negative control supplements in both trials, suggesting CMS is a poorly utilized protein source for cows on low quality forage.

A detailed analysis of the nitrogen fractions in the CMS and CSL supplements fed in trial 2 is shown in Table 5 and provides some explanation for the perform-

Table 4. Mean weights, weight changes and rumen ammonia levels for cows in trial 2

Item	Negative control	Positive control	Condensed molasses solubles (CMS)	Corn steep liquor (CSL)
Number of cows	15	15	15	15
Initial cow wt	895	895	915	920
Wt change, 56 days	-44.0^b	-11.0^a	-44.0^b	-14.0^a
Last 28 days	−13.0	0.0	−11.0	− 7.9
Total, 84 days	-57.0^b	-11.0^a	-55.0^b	-22.0^a
Condition score, initial	5.47	5.95	5.78	5.64
Condition score change, 84 days	$-.96^b$	$-.33^a$	$-.90^b$	$-.28^a$
Supplement consumption, lb/day				
First 56 days	1.7	1.7	2.2	2.4
Last 28 days	2.2	2.2	2.5	2.8
Total 84 days	1.9	1.9	2.3	2.6
Crude protein intake, lb/day				
First 56 days	.13	.40	.35	.44
Last 28 days	.18	.51	.40	.51
Total 84 days	.15	.44	.37	.46
Rumen Ammonia-N, mg/dl				
1 hr postfeeding	6.13^b	6.79^b	21.63^a	22.68^a
4 hr postfeeding	3.89^c	5.11^c	9.13^b	14.64^a

[a,b,c]Means with different superscript letters differ significantly ($P<.05$).

ance differences. Although the analyses are of the complete supplements rather than of CSL and CMS alone, they should represent these ingredients since the CP of molasses is low, and molasses made up small and similar proportions (17.2 and 25.5 percent) of the CMS and CSL supplements, respectively. Amino acid analysis of unhydrolyzed samples of each supplement indicate the concentrations of free amino acids, while analysis after hydrolysis indicates total amino acids including those in peptides and proteins.

Corn steep liquor contained 72.5 percent of the CP as amino acids compared to 39.3 percent for CMS. Subtracting free amino acids (unhydrolyzed) from total amino acids (hydrolyzed) shows that CSL contained about twice the level of amino acids in the form of peptides and proteins as CMS. Tungstic acid precipitable protein was much higher in CSL (35 percent) than in CMS (12 percent). Ammonia-N contributed 35.3 percent of the CP in CMS compared to 6.3 percent of the CP in CSL.

Table 5. Analysis of liquid supplements fed in trial 2

Item	CMS Hydrolyzed	CMS Unhydrolyzed	CSL Hydrolyzed	CSL Unhydrolyzed
Amino acids, % of dry matter				
Aspartic acid	.64	.02	1.74	.47
Thereonine	.17	.08	.91	.29
Serine	.22	—	.99	.51
Glutamic acid	5.65	2.12	4.28	.57
Proline	.17	—	3.00	1.10
Glycine	.47	.06	1.72	.32
Alanine	.88	.49	1.67	.87
Cystine	.16	—	.64	—
Valine	.35	.08	1.23	.51
Methionine	.17	.01	.34	.25
Isoleucine	.21	.02	.74	.29
Leucine	.28	.03	2.85	1.14
Tyrosine	.21	.10	.43	—
Phenylalanine	.10	.05	.80	.56
Histidine	.06	—	.88	.18
Lysine	.14	.02	.80	.41
Arginine	.12	—	.52	—
Total amino acids, % of dry matter	10.00	3.08	23.54	7.79
Crude protein, % of dry matter		25.4		32.5
Composition (%) of crude protein,				
Ammonia-N		35.3		6.3
Free amino acids[a]		12.1		24.0
Peptide and protein amino acids[b]		27.2		48.5
Tungstic acid precipitable protein		12.0		35.0

[a]Calculated from unhydrolyzed sample.
[b]Calculated from hydrolyzed sample.

Other research has shown that amino acids are utilized by rumen bacteria and that rumen microbial protein yield can be increased by adding amino acids to a diet containing urea as the sole nitrogen source. Amino acids are also converted to volatile fatty acids by rumen bacteria and have been shown to stimulate rumen cellulolytic activity. An Ohio study showed that corn steep liquor significantly increased crude fiber, cellulose and dry matter digestibilities in lambs when added to a 50 percent roughage ration.

Results of this research indicate tht liquid supplement ingredients must be evaluated for type as well as amount of NPN.

Corn Steep Liquor and Fermented Ammoniated Condensed Whey as Protein Sources for Lactating Cows and Yearling Heifers Grazing Winter Native Range

J. J. Wagner, K. S. Lusby, G. W. Horn and M. J. Dvorak

Story in Brief

Corn steep liquor (CSL) and fermented ammoniated condensed whey (FACW) were compared to cottonseed meal (CSM) as protein sources for wintering 61 lactating first-calf Hereford heifers and 32 yearling Hereford heifers on native range. Cattle were allotted by weight and individually fed 6 days per week for 12 weeks one of four protein treatments: negative control (NC), positive control (PC), CSL and FACW to provide .7, 1.5, 1.5 and 1.5 lb crude protein (CP) per day, respectively, to the lacating heifers and .2, .4, .4 and .4 lb CP per day, respectively, to the yearling heifers. CSM was supplied in the CSL and FACW treatments at the same level as in the negative control. Lactating heifers fed the NC lost more ($P<.005$) weight and body condition (120 lb and 1.6 units) than those fed the PC (45.8 lb and .9 units). Weight and condition losses were similar ($P>.05$) for lactating heifers fed PC, CSL and FACW. Yearling heifers fed the NC lost more ($P<.005$) weight than those fed the PC (49.4 vs 10.6 lb). Yearling heifers fed CSL and FACW gained more ($P<.005$) weight than those fed the PC (17.6 and 9.3 vs − 10.6 lb). Feeding CSL resulted in significantly lower rumen pH, lower ruminal acetate and higher ruminal butyrate, isovalerate and caproate levels than did feeding either control. Supplementing with FACW produced significantly lower rumen pH, higher rumen ammonia and soluble carbohydrate levels, lower ruminal acetate, and higher ruminal propionate and butyrate concentrations than did either control supplement. In vitro ammonia concentrations for FACW were similar at 1, 2, 4 and 8 hours incubation and were higher ($P < .05$) than the CSL ammonia concentrations. Ammonia nitrogen, amino acid nitrogen and long chain polypeptide and protein nitrogen accounted for 13.3, 17.0 and 29.6 percent of total nitrogen, respectively, in CSL and 60.0, 7.0 and 13.2 percent of total nitrogen, respectively, in FACW. Corn steep liquor and FACW appear to be effective protein sources for cows and heifers grazing winter native range.

Introduction

Modern liquid supplements contain a variety of by-product ingredients from the sugar, paper or fermentation industries. Corn steep liquor (CSL) is obtained during the wet milling of corn and contains most of the soluble proteins of corn. Fermented ammoniated condensed whey (FACW) is manufactured from liquid whey, a by-product of the cheese industry, and contains ammonium lactate as its primary nitrogen source.

Data comparing CSL and FACW-based liquid supplements to dry, processed oil meal protein supplements for cattle consuming low quality roughages is limited although previous research has shown that CSL and FACW are effective sources of crude protein for feedlot cattle fed corn silage-based rations. The objective of this study was to compare CSL and FACW to cottonseed meal as protein sources for lactating first-calf heifers and yearling heifers grazing winter native range.

Materials and Methods

Sixty-one lactating first-calf Hereford heifers and 32 yearling Hereford heifers were allotted by weight to four supplemental protein treatments. During the 84-day trial lasting from mid-November to mid-February all cattle grazed together in two pastures (220 acres) of native tallgrass range in north central Oklahoma. The predominant forage species were little bluestem, switchgrass, big bluestem and Indian grass.

Cattle were gathered from the pastures at 8:00 a.m. six days each week and fed their supplements individually in covered stalls. Supplement treatments were: negative control (NC), positive control (PC), CSL and FACW to supply .7, 1.5, 1.5 and 1.5 lb CP per day, respectively, to the lactating heifers and .2, .4, .4 and .4 lb CP per day, respectively, to the yearling heifers. Cattle fed the liquid supplements received cottonseed meal to supply equal CP as the negative control. Corn steep liquor or FACW was then fed to make up the difference between the NC and PC. All supplements were formulated to be approximately isocaloric and to provide equal amounts of calcium, phosphorus and potassium. The composition of each supplement is shown in Table 1.

Cattle were weighed after an overnight shrink (16 hr) at 28-day intervals and visually scored for body condition (1 = very thin, 9 = very fat) at the beginning and end of the trial.

Table 1. Percent composition of protein supplements fed to lactating first-calf heifers and yearling heifers

Ingredient	Treatment			
	NC	PC	CSL	FACW
Cottonseed meal	11.5	66.7		
Corn, ground	41.8	30.6		
Sorghum, grain	41.8			
Dicalcium phosphate	3.2	.6		
Limestone	.7	2.2		
Potassium chloride	1.2			
Vitamin A (30,000 Iu/g)	.1	.1	.3	.3
Trace mineral premix[a]	.1	.1	.1	.1
CSL			69.9	
FACW				37.2
Cane molasses			27.4	60.3
Sulfuric acid			1.1	1.0
Analysis (as-fed)				
Dry matter, %	89.8	91.0	53.7	69.0
Crude protein, %	12.9	29.0	16.8	16.0
Total digestible nutrient, %	72.0	72.6	55.0	62.0
pH			4.2	5.0

[a]Ingredients in trace mineral premix, %: Zn, 16.0; Fe, 12.0; Mg, 3.0; Mn, 6.0; Cu, 1.0; Co, .3; I, .6; K, 1.0.

Rumen liquor samples were obtained at 1 and 4 hours postfeeding via stomach tubes on day 49 of the trial from 10 randomly selected first-calf heifers from each treatment. Rumen pH was determined immediately at sampling time. Ruminal fluid was analyzed for ammonia, soluble carbohydrate and volatile fatty acid (VFA) concentrations.

Fermentation in vitro was used to compare the rate of ammonia release from CSL and FACW to the rate of ammonia release from soybean meal (SBM), urea and ammonium lactate (AL).

Corn steep liquor and FACW were analyzed for total nitrogen, ammonia nitrogen, amino acid nitrogen and long chain polypeptide and protein nitrogen. Dry matter and lactic acid concentrations were also determined.

Results and Discussion

The performance of lactating first-calf heifers is shown in Table 2. Heifers fed the NC supplement lost more ($P < .005$) weight and body condition (120 lb and 1.6 units) than those fed the PC (45.8 lb and .9 units). Differences in weight and condition losses between heifers fed the PC, CSL (55.1 lb and .8 units) and FACW (49.6 lb and .7 units) were not significant. Calves of the NC supplemented cattle tended to gain less weight than calves whose dams received PC, CSL or FACW. Differences in conception rates between treatments were not significant. Poorer conception rates for the positive control cattle in both trials were probably a function of low animal numbers per treatment.

Table 2. Performance of lactating first-calf heifers and their calves

Item	Treatment			
	NC	PC	CSL	FACW
Number of pairs	15	15	15	16
Initial cow weight, lb	890.6	884.2	884.2	889.5
Cow weight change, lb	–120.0[a]	–45.8[b]	–55.1[b]	–49.6[b]
Initial body condition	6.5	6.4	6.4	6.4
Body condition change	–1.6[a]	–.9[b]	–.8[b]	–.7[b]
Initial calf weight, lb	110.2	110.2	118.8	126.7
Calf weight gain, lb	69.9	83.1	76.9	79.3
Conception rate, %	86	60	80	81

[ab]Means with different superscript letters differ ($P < .05$).

The performance of yearling heifers is shown in Table 3. Yearling heifers receiving the NC supplement lost more ($P < .005$) weight than those consuming the PC (49.4 vs 10.6 lb). Weight gains by yearling heifers supplemented with CSL and FACW were similar (17.6 and 9.3 lb, respectively) and greater ($P < .005$) than weight gains of heifers fed the PC (– 10.6 lb). Differences in body condition and conception rates between treatments were not statistically significant.

Lower ruminal pH was observed in cattle fed CSL and FACW than in cattle fed NC and PC (Table 4). Rumen ammonia and soluble carbohydrate levels are also presented in Table 4. At 1 and 4 hours postfeeding, rumen ammonia and soluble carbohydrate levels were highest ($P < .05$) in FACW fed cattle. Rumen ammonia

Table 3. Performance of yearling heifers

Item	Treatment			
	NC	PC	CSL	FACW
Number	8	8	8	8
Initial weight,lb	779.3	768.1	768.3	770.5
Weight change, lb	-49.4^{a}	-10.6^{b}	$+17.6^{c}$	$+9.3^{c}$
Initial body condition	7.2	7.0	7.2	7.1
Body condition change	−.9	−.7	−.7	−.8
Conception rate, %	83	67	100	100

[abc]Means with different superscript letters differ (P< .05).

Table 4. Ruminal pH and the concentration of ammonia and soluble carbohydrate in rumen fluid collected 1 and 4 hours postfeeding

Item	Treatment			
	NC	PC	CSL	FACW
Number	10	10	10	10
Rumen pH				
1 hr postfeeding	7.07^{a}	7.24^{a}	6.73^{b}	6.79^{b}
4 hr postfeeding	6.83^{b}	7.06^{a}	6.89^{b}	6.79^{b}
Rumen ammonia, mg/d1				
1 hr postfeeding	8.4^{c}	10.5^{c}	18.9^{b}	26.2^{a}
4 hr postfeeding	3.8^{c}	11.3^{b}	14.8^{b}	23.1^{a}
Rumen soluble				
Carbohydrates, u moles/1				
1 hr postfeeding	1865.6^{b}	2268.9^{b}	5016.1^{b}	17271.1^{a}
4 hr postfeeding	2144.4^{b}	1705.0^{b}	2169.9^{b}	3703.9^{a}

[abc]Means in same row with different superscripts differ (P < .05).

concentrations were higher (P < .05) in CSL supplemented cattle than in the NC or PC cattle at 1 hour postfeeding and similar (P > .05) to the ammonia level in the PC cattle at 4 hours postfeeding.

Ruminal VFA concentrations are shown in Table 5. Total VFA concentrations were similar (P > .05) for cattle fed NC, PC, CSL and FACW. Feeding FACW resulted in a lower (P < .05) acetate to propionate ratio than feeding NC, PC or CSL. Rumen fluid from FACW supplemented cattle contained lower (P < .05) acetate and higher (P < .05) propionate and butyrate levels than rumen fluid from NC or PC supplemented cattle. Feeding CSL resulted in higher (P < .05) butyrate and lower (P < .05) acetate levels than did feeding NC and PC. The molar concentrations of isovalerate and coproate were higher (P < .05) in rumen fluid from the CSL treatment.

Table 5. Volatile fatty acid concentration in rumen fluid collected at 1 and 4 hours postfeeding[a]

Item	Treatments			
	NC	PC	CSL	FACW
One hour postfeeding				
Total VFA, u moles/ml	92.42	95.53	93.60	93.88
Acetate	71.90[b]	71.48[b]	69.87[bc]	68.77[c]
Propionate	16.06[c]	16.21[c]	16.76[c]	19.83[b]
Isobutyrate	1.07[b]	1.19[b]	1.13[b]	.28[c]
Butyrate	9.24[c]	8.78[c]	10.74[b]	10.71[b]
Isovalerate	1.07[b]	1.99[b]	1.32[b]	.39[c]
Valerate	.59[b]	.72[b]	.68[b]	.44[c]
Caproate	.08	.07	.05	.02
Acetate/propionate	4.53[b]	4.32[b]	4.38[b]	3.62[c]
Four hours postfeeding				
Total VFA, u moles/ml	93.37	73.63	92.92	83.33
Acetate	71.13[b]	71.76[b]	65.90[c]	61.05[d]
Propionate	15.15[c]	15.85[c]	15.31[c]	17.93[b]
Isobutyrate	1.12[b]	1.23[b]	1.12[b]	.56[c]
Butyrate	10.26[d]	9.36[d]	14.42[c]	18.80[b]
Isovalerate	1.06[c]	.83[c]	1.52[b]	.42[d]
Valerate	1.02	.85	1.34	1.15
Caproate	.26[bc]	.12[cd]	.39[b]	.10[d]
Acetate/propionate	4.74[b]	4.65[b]	4.33[b]	3.54[c]

[a]Molar %.
[bcd]Means in same row with different superscripts differ ($P < .05$).

The in vitro ammonia concentrations are presented in Table 6. Ammonia was released gradually in vitro from SBM and CSL, presumably due to digestion by microbial proteases and the subsequent deamination of amino acids. The concentration of ammonia in the urea system was initially low but rapidly increased due to the hydrolysis of urea to ammonia. The ammonia in AL and FACW apparently established an immediate equilibrium between the disassociated free ammonium ion and the closely associated ammonium salt form.

Table 6. In vitro ammonia concentratiion from nitrogen sources[a]

Nitrogen source	Time of incubation (hr)			
	1	2	4	8
	mg NH_3 — N/dl			
SBM	13.83[b]	15.33[bc]	19.89[bc]	36.83[d]
CSL	23.58[c]	23.23[c]	22.71[bc]	36.00[d]
FACW	42.59[de]	44.51[def]	50.13[ef]	43.86[def]
AL	71.11[g]	71.47[g]	69.16[g]	62.92[g]
Urea	24.38[c]	53.00[f]	71.82[g]	85.33[h]

[a]Nitrogen source by incubation time interaction ($P < .005$).
[bcdefgh]Means with different superscripts differ ($P < .05$).

The percentage of dry matter, lactic acid, crude protein and the composition of crude protein in CSL and FACW is presented in Table 7. The CSL supplement contained 53.74 percent dry matter, 5.6 percent lactic acid and 16.85 percent CP (N^{x}6.25). The nitrogen in CSL was composed of 13.3 percent ammonia nitrogen, 29.6 percent long chain polypeptide and protein nitrogen, and 17.0 percent amino acid nitrogen. The FACW supplement contained 68.95 percent dry matter, 10.2 percent lactic acid and 16.0 percent CP (N 6.25). The nitrogen in FACW was composed of 60.0 percent ammonia nitrogen, 13.2 percent long chain polypeptide and protein nitrogen and 7.0 percent amino acid nitrogen.

Table 7. Dry matter, lactic acid and crude protein composition of CSL and FACW

	Supplement	
Item	CSL	FACW
Dry matter[a]	53.74	68.95
Lactic acid[a]		
L(+) lactate	1.49	3.64
D(−) lactate	4.11	6.56
Total lactate	5.60	10.20
Crude protein (Nx6.25)[a]	16.85	16.00
Protein fractionation[b]		
NH_3 - N	13.3	60.0
Long chain polypeptide and protein N	29.6	13.2
Amino acid N	17.0	7.0
Undetermined N	40.1	20.0

[a]Percent composition, as fed basis.
[b]Percent of total nitrogen.

Greater weight and body condition losses by cattle fed the NC supplement indicated that a protein deficiency was established in the NC cattle. Improved performance by yearling heifers fed either liquid and similar weight and condition losses by lactating heifers fed the PC, CSL and FACW suggest that CSL and FACW are effective protein sources for cattle wintered on native range. Corn steep liquor appears to be a good source of amino acids and natural proteins. The high non-protein nitrogen (NPN) content of FACW is apparently well utilized by cattle grazing low quality forage.

The Influence of Postpartum Nutrition and Weaning Age of Calves on Cow Body Condition, Estrus, Conception Rate and Calf Performance of Fall-Calving Beef Cows

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Story in Brief

One hundred one fall-calving Angus X Hereford cows ranging in age from 3 to 6 years were assigned to either a Moderate (maintain post-calving weight) or Low (lose 10 percent of post-calving weight) level of supplementation from calving to the start of the breeding season. From the start of the 67-day breeding season until warm season grasses began to grow, all cows were fed the Moderate level of supplementation.

Moderate level cows exhibited postpartum estrus an average of 21.7 days sooner (54.1 vs 75.8 days) and had a higher conception rate (96 vs 82.3 percent) than Low level cows. Adjusted weaning weight of the calves was not significantly affected by the dam's level of supplementation prior to breeding but was affected by breed of sire and month of birth. Calves weaned at 285 days were 73.5 and 93.5 lb heavier for the Moderate and Low levels, respectively, than calves weaned at 210 days and grazed on native pasture for 75 days. Charolais-sired calves were approximately 75 lb heavier at 285 days than Hereford-sired calves, regardless of weaning method.

Introduction

Approximately 30 to 40 percent of the beef cows in Oklahoma calve in the fall (September-December). Fall-calving cows vary considerably in body condition at calving due to differences in forage availability and level of protein supplementation. Many producers wean fall-born calves late (9-10 months of age) to take advantage of summer grasses and thus wean heavier calves. However, late weaning may have an adverse effect on cow condition.

Research with spring-calving cows indicates that cows on an adequate plane of nutrition prior to calving and in moderate flesh at calving have short postpartum intervals to first estrus and high conception rates. Fall-calving cows are typically in better condition going into the calving season than spring calving cows; however, little is known about the combined effects of condition at calving and postpartum level of nutrition on the reproductive performance of fall-calving cows, especially when the availability and quality of forage is decreased. While it may be possible to increase the pay weight of the calves by extending the weaning period to 9-10 months, the effect on cow condition and reproductive performance is unknown.

The purpose of this study was to determine the influence of postpartum nutrition and weaning age of calves on cow body condition, postpartum interval to first estrus, conception rate and calf performance of fall-calving beef cows.

Experimental Procedure

One hundred thirty-five fall-calving Angus X Hereford cows ranging in age from 3 to 6 years and bred to Charolais and Hereford bulls were assembled at the Southwestern Livestock and Forage Research Station in the summer of 1980. The range on the Research Station, classified in excellent condition, is little bluestem (*Andropogon scorparius*) predominantly and has a carrying capacity of approximately 7 acres per cow-calf unit on a year-long basis. The range forage is normally dormant from early November (first frost) to late April.

At calving (September 1, 1980, to November 5, 1980) each female was assigned to a level of postpartum nutrition on the basis of calving date and age of dam to equalize these effects within treatment. The Moderate level of nutrition consisted of that amount of supplemental feed necessary for fall-calving cows to maintain their post-calving weight from calving to the start of the breeding season. To achieve this level of postpartum nutrition, the cows were maintained on abundant forage and fed 7 lb of cottonseed cake (41 percent CP) per head per day from calving to the start of the breeding season. The Low level of nutrition consisted of that amount of supplemental feed necessary for fall-calving cows to lose 10 percent of their post-calving weight from calving to the start of the breeding season. To achieve this level of postpartum nutrition, the cows were maintained on abundant forage and fed ½ lb of cottonseed cake (41 percent CP) per head per day until November 25 and 3½ lb per day to December 15, 1980.

At the start of the breeding season (December 15), all cows were fed 5 lb of cottonseed cake daily to March 30, 1981, and 2 lb daily until April 20, 1981. Throughout the study, all cows were fed three times per week (daily allowance × 7 ÷ 3). After April 20, 1981, all cows grazed common pasture through weaning.

Individual cow weights and body condition scores were taken after a 12-hour shrink biweekly from September 1, 1980, to February 20, 1981 (end of breeding season), and monthly from February 20, 1981, to September 1, 1981. The condition scores were based on a scale of 1 (very thin) to 9 (very fat) (Table 1).

All calves were weighed and identified by ear tag within 24 hours after birth. The calves remained with their dams on native pasture until weaning and did not receive creep feed. Calf weights were obtained after a 6-hour shrink biweekly until the end of the breeding season and monthly thereafter. To determine the effect of weaning age on calf performance as well as to create a 1.0 to 1.5 unit difference in cow body condition going into the subsequent calving season, calves were weaned from their dams at 210 or 285 days of age, ±7 days, by weaning biweekly from March 30, 1981, to August 17, 1981. Assignments to weaning age within postpartum nutrition level were made on the basis of calving date to equalize the effect within treatment groups. The age-corrected weaning weights were adjusted for age of dam by Beef Improvement Federation Guidelines, and all heifer calves were corrected to a steer equivalent by multiplying by 1.05. Calves weaned at 210 days were fed a high roughage weaning ration (ad-libitum) for two weeks to reduce weight loss associated with the stress of weaning. After the 2-week period, the weaned calves were placed on native pasture similar to that grazed by the nursing calves and received no additional feed. All calves were implanted with Ralgro in February and reimplanted in June.

Table 1. System of body condition scoring (BCS) for beef cattle

Group	BCS	Description
Thin Condition	1	EMACIATED — Cow is extremely emaciated with no detectable fat over spinous processes, transverse processes, hip bones or ribs. Tail-head and ribs project quite prominently.
	2	POOR — Cow still appears somewhat emaciated but tail-head and ribs are less prominent. Individual spinous processes are still rather sharp to the touch but some tissue cover exists along spine.
	3	THIN — Ribs are still individually identifiable but not quite as sharp to the touch. There is obvious palpable fat along spine and over tail-head with some tissue cover over dorsal portion of ribs.
Borderline Condition	4	BORDERLINE — Individual ribs are no longer visually obvious. The spinous processes can be identified individually on palpation but feel rounded rather than sharp. Some fat cover over ribs, transverse processes and hip bones.
Optimum Moderate Condition	5	MODERATE — Cow has generally good overall appearance. Upon palpation, fat cover over ribs feels spongy and areas on either side of tail-head now have palpable fat cover.
	6	HIGH MODERATE — Firm pressure now needs to be applied to feel spinous processes. A high degree of fat cover is palpable over ribs and around tail-head.
	7	GOOD — Cow appears fleshy and obviously carries considerable fat. Very spongy fat cover over ribs and over and around tailhead. In fact "rounds" or "pones" beginning to be obvious. Some fat around vulva and in crotch.
Fat Condition	8	FAT — Cow very fleshy and over conditioned. Spinous processes almost impossible to palpate. Cow has large fat deposits over ribs, around tail-head and below vulva. "Rounds" or "pones" are obvious
	9	EXTREMELY FAT — Cow obviously extremely wasty and patchy and looks blocky. Tail head and hips buried in fatty tissue and "rounds" or "pones" of fat are protruding. Bone structure no longer visable and barely palpable. Animal's mobility may even be impaired by large fatty deposits.

From calving to the start of the breeding season, teaser bulls, equipped with chin-ball markers, were placed with the cows. Teaser bull activity and visual observation twice daily were used for detection of estrus. During the breeding season (December 15, 1980, to February 20, 1981), the cows were divided into four breeding groups on the basis of postpartum nutrition level and weaning age of the calf. All cows were exposed to fertile Beefmaster bulls, which were rotated biweekly among pastures during the breeding season. Cows were observed for breeding activity twice daily, and herd bulls were equipped with chin-ball markers to assist in determination of breeding dates.

Results and Discussion

Cow weight and condition

Up to the start of the breeding season, the Moderate cows were able to maintain their post-calving weight and condition with 7 lb of cottonseed cake daily (Table 2). The cows were in moderate flesh (5.5 condition score). However, the Low level cows, fed ½ lb of cottonseed cake daily from calving until November 25 and 3½ lb daily from November 26 to December 15, 1980, lost a full condition score but only 3.8 percent of their post-calving weight. The use of 5 lb of cottonseed cake daily from the start of the breeding season (December 15) to the end of the breeding season (February 20) was not adequate to maintain the weight of either treatment group. However, the additional supplement fed the Low level cows during the breeding season tended to improve their body condition, possibly a factor of increased forage intake and digestibility. The drop in condition of the Moderate level cows was attributed to increased milk production; however, at weaning, no differences in body condition between treatments were noted.

With the advent of warm season grass growth in early April, 1981, all cows were able to regain considerable weight to weaning.

Table 2. Weights, weight change and condition score data

	Moderate	Low
No. of cows	50	51
Initial wt, postcalving	959	949
Wt, start of breeding season	952	913
Wt, end of breeding season	873	853
Wt, at weaning		
Calf weaned at 210 days	924	907
Calf weaned at 285 days	1075	1089
Wt change, %		
Initial to start of breeding	−.69	−3.70
Initial to end of breeding	−8.8	−9.9
End of breeding to weaning		
Calf weaned at 210 days	+5.84	+6.33
Calf weaned at 285 days	+23.14	+27.67
Initial to weaning		
Calf weaned at 210 days	−3.65	−4.42
Calf weaned at 285 days	+12.10	+14.75
Condition score		
Initial	5.7	5.4
State of breeding	5.5	4.6
End of breeding	5.15	4.9
Weaning		
Calf weaned at 210 days	5.49	5.4
Calf weaned at 285 days	6.0	5.98

Reproductive performance

The reproductive performance of fall-calving cows appears to be affected by level of postpartum nutrition (Table 3). Cows on the Moderate level of nutrition postpartum returned to normal estrus activity 21.7 days sooner than cows fed the Low level. As a result of the long postpartum interval to first estrus for the Low level cows and only a 67-day breeding season, 12 percent fewer cows conceived as compared to the Moderate level. In addition, the Moderate level cows were in much better body condition going into the breeding season (5.4 vs 4.6 condition score).

Table 3. Reproductive performance data

	Moderate	Low
No. of cows	50	51
No. exhibiting estrus	42	38
Days postpartum to 1st estrus	54.1	75.8
Days postpartum to apparent conception	96.3	95.4
No. of females bred	48	42

Calving data

The mean birth weights and adjusted weaning weights are presented in Table 4. The level of postpartum nutrition had little effect on the weaning performance of the calves. However, breed of sire and age at weaning exhibited marked influences on calf performance.

Charolais-sired calves were heavier at birth (approximately 4 lb) and were an average of 75 lb heavier at weaning than the Hereford-sired calves. This difference in birth weight and weaning weight is largely due to the increased mature size and growth potential of the Charolais breed.

Delaying the weaning of fall-born calves to 9-10 months to take advantage of summer forage appears to be a major improvement regardless of level of

Table 4. Calving data

	Moderate		Low	
	Charolais	Hereford	Charolais	Hereford
No. of calves	31	19	24	22
Males	14	10	14	12
Females	17	9	15	10
Avg birth wt				
Males	81.8	70.1	81.4	80.6
Females	77.4	75.8	73.1	69.8
Adj 210 day wt				
WNGRP 1*	451	357	426	348
WNGRP 2	456	375	450	375
Adj 285 day wt				
WNGRP 1	578	492	540	468
WNGRP 2*	641	576	636	559

*Adjusted weaning weight for respective weaning groups.

postpartum nutrition of the cow. Calves weaned at 285 days were 73.5 and 93.5 lb heavier for the Moderate and Low levels, respectively, than calves weaned at 210 days and grazed on native pasture for 75 days and fed a high roughage ration during the initial 14 days of the grazing period. The 20-lb advantage to the Low level group is unclear.

Effect of Yeast Culture[1] on Nitrate Toxicity of Lambs and Steers Fed High-Nitrate Sorghum-Sudan Hay

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Story in Brief

Lambs and steers were fed low-nitrate hay and supplements that supplied 0 or .1 lb (lambs) or .25 lb (steers) of Yeast Culture per head per day for 14 and 12 days, respectively, before being fed high-nitrate sorghum-sudan hay. The effect of Yeast Culture on blood methemoglobin concentrations was evaluated. Nitrate consumption by lambs 6 hr after being fed the high-nitrate hay was similar among treatments and ranged from about .3 to .5 g/kg body weight during 3 challenge days. Similar rates of nitrate consumption were observed for steers. Blood methemoglobin concentrations of lambs and steers fed Yeast Culture were not lower than those of control animals. Results of the study do not indicate that Yeast Culture will decrease the toxicity of high-nitrate forages consumed by sheep or cattle.

Introduction

In previous studies conducted at the University of Missouri by Grebing (1974 and 1976), the feeding of about 0.1 pound per day of Diamond V Yeast Culture markedly decreased death losses of lambs that received a ruminal drench of potassium nitrate and sodium nitrate. In these studies the nitrate dosage was about 0.8 g nitrate per kg of lamb body weight. In the 1976 study lambs were fed a cottonseed hull, cracked corn, soybean meal based ration that contained 24.5 percent corn.

Sapiro et al. (1949) reported that very severe blood methemoglobin concentrations were produced in sheep fed a poor quality grass hay and dosed with 0.4 g

[1]Diamond V Yeast Culture, Diamond V Mills, Inc., Cedar Rapids, Iowa.

nitrate per kg of body weight. One of four sheep died. In the studies of Lewis (1951), 0.3 g nitrate per kg of body weight resulted in methemoglobin concentrations of 60 percent in wethers fed meadow hay.

Nitrate toxicity remains a very significant animal health problem. Feed ingredients that would reduce the incidence of nitrate toxicity in ruminants fed and(or) grazing forages which tend to accumulate nitrates would be welcomed aids.

Diamond V Yeast Culture is very palatable and, when mixed with a self-fed mineral mixture at levels of 33 and 50 percent, increased consumption of the mineral mixture from .08 to .14 and .24 lb per head per day, respectively, by stocker cattle on wheat pasture (Streeter et al., 1981). The effect of Yeast Culture on blood methemoglobin concentrations of lambs and steers challenged with a high-nitrate hay was evaluated in this study.

Experimental Procedure

Lamb Trial

The trial consisted of a 14-day preliminary period and a 5-day experimental period. Twenty-four (24) yearling wethers that weighed 78.0 ± 7.8 lb were housed in individual pens and randomly allotted to two treatment groups. The lambs were fed .5 lb of supplement per head per day that supplied .1 lb of wheat middlings (control) or Yeast Culture (Table 1). Time was allowed for complete consumption of the supplements before hay was fed. During the preliminary period, all lambs had free choice access for 1 ½ hours each day to 2 lb of a control (i.e., low-nitrate) sorghum-sudan hay. Hay that was not consumed during the 1 ½ hour period of each day was removed in an attempt to encourage rapid hay consumption. Mean hay consumption of all lambs during the last 6 days of the preliminary period was 1.7 percent of body weight. If the hay had contained 29,300 ppm nitrate, it would have supplied .50 g nitrate per kg of body weight, which was the desired nitrate dosage.

Table 1. Composition of supplements fed to lambs[a]

Item	Control	Yeast culture
Dehydrated alfalfa meal, %	74.7	74.7
Wheat middlings, %	20.0	—
Diamond V Yeast Culture, %	—	20.0
Dicalcium phosphate, %	4.4	4.4
Trace-mineralized salt, %	.9	.9
Vitamin A*	+	+
Vitamin D*	+	+

[a] Supplements fed at level of .5 lb/head/day to supply .10 lb of yeast culture/head/day.
* Vitamin A and D added to furnish 2000 and 250 IU per head per day.

On day 1 of the 5-day experimental period, all lambs were fed a high-nitrate (i.e., 29,300 ppm nitrate) sorghum-sudan hay in place of the control hay. Because of previous difficulties with rate of consumption of the high-nitrate hay, the lambs were not fed any hay for 43 hours prior to feeding the high-nitrate hay. Supplements were fed daily during the 43-hour period. The lambs had ad libitum access to the high-nitrate hay during the 5-day experimental period. Blood samples were collected from the jugular vein for methemoglobin analysis at 6 hr after feeding the high-nitrate hay on days 1, 2 and 5 of the experimental period. Blood methomoglobin analyses were conducted by a modification of the procedure of

Table 2. Composition of supplements fed to steers[a]

Item	Control	Yeast culture
Soybean meal, %	81.4	81.4
Wheat middlings, %	12.5	—
Yeast culture, %	—	12.5
Molasses, %	2.6	2.6
Dicalcium phosphate, %	1.75	1.75
Trace-mineralized salt, %	1.75	1.75
Vitamin A, IU/lb	11,918	11,918

[a] Supplements fed at level of 2 lb/head/day to supply 0.25 lb yeast culture/head/day.

Table 3. Composition of hays fed in lamb and steer trials

Trial	Crude protein (% of DM)	IVDMD, %	Nitrate (% as-fed)
Lamb			
Control sorghum-sudan[a]	7.8	52.7	<1,000
High-nitrate sorghum-sudan	14.7	58.0	29,300
Steer			
Period I			
Prairie hay[a]	5.6	41.9	NA[b]
High-nitrate sorghum-sudan	13.7	59.0	32,000
Period II			
Control sorghum-sudan[a]	6.4	55.7	1,330
High-nitrate sorghum-sudan	15.4	56.8	29,900

[a] Fed during preliminary period only.
[b] Not analyzed.

Leahy et al., 1960. Number of lambs that were bled per treatment are shown in Table 4.

Hay fed during the preliminary and challenge periods of both the lamb and steer trials was ground in a hammermill through a ¾ inch screen to minimize sorting by the animals. Because of bale-to-bale variation in nitrate concentration, the high-nitrate hay was mixed in an Oswalt mixer-feeder wagon before feedings of individual animals were weighed out. The hay was sampled during mixing for crude protein, in vitro dry matter digestibility (IVDMD) and nitrate analyses. Results of these analyses are shown in Table 3.

Steer Trial

Ten yearling Hereford steers that weighed 561 ± 82 lb were paired by weight, placed in individual pens and randomly assigned within pairs to two treatments. A crossover design that consisted of two 14-day periods was used. Periods consisted of a 12-day preliminary period and a 2-day challenge period during which high-nitrate hay was fed. During the first 10 days of the preliminary periods, steers were fed prairie hay (Period I) and a control (i.e., low-nitrate) sorghum-sudan hay (Period II) at a level of about 2.2 percent of body weight and 2 lb of supplement per head per day that contained 0.25 lb of wheat middlings (control) or Yeast Culture. Composition of the supplements is shown in Table 2. On days 11 and 12 of the preliminary periods, steers were fed prairie hay at a level of 1

Table 4. Effect of yeast culture on blood methemoglobin concentrations of sheep

Item	Control	Yeast culture	Observed significance level
Number of wethers	11	12	
Weight, lb	76.8	79.1	
Day 1 (6 hr post-feeding)			
Number of wethers	6	6	
Hay intake, % of body wt	1.73	1.95	.09
Nitrate intake, g/kg body wt	.51	.57	.09
Methemoglobin, %	28.7	29.2	.98
Day 2 (6 hr post-feeding)			
Number of wethers	11	12	
Hay intake, % of body wt	.95	1.08	.33
Nitrate intake, g/kg body wt	.28	.32	.33
Methemoglobin, %	6.4	8.2	.55
Day 3 (24 hr post-feeding)			
Number of wethers	11	12	
Hay intake, % of body wt	2.87	2.71	.33
Nitrate intake, g/kg body wt	.84	.79	.33
Day 4 (24 hr post-feeding)			
Number of wethers	11	12	
Hay intake, % of body wt	2.74	2.77	.77
Nitrate intake, g/kg body wt	.80	.81	.77
Day 5 (6 hr post-feeding)			
Number of wethers	8	7	
Hay intake, % of body wt	1.52	1.80	.20
Nitrate intake, g/kg body wt	.44	.53	.20
Methemoglobin, %	6.4	14.4	.20

percent of body weight (Period I) and 2 lb per head per day of the control sorghum-sudan hay (Period II). Supplements were fed as usual.

A high-nitrate sorghum-sudan hay was fed at levels to supply 0.5 g nitrate per kg of body weight on each of the 2 days of the challenge period. Blood samples were obtained from jugular vein catheters, by crowding the steers into a corner of the pens at various times after feeding the high-nitrate hay, for methemoglobin analysis. The times in which blood samples were taken are shown in Tables 5 and 6.

Results and Discussion

Lamb Trial

Intake of hay (percent of body wt) and nitrate (g/kg body wt) by the lambs during the 5-day period in which high-nitrate hay was fed is shown in Table 4. The lambs did not consume the high-nitrate hay as rapidly as hoped. Nitrate intake of six lambs per treatment, which had consumed the most hay at 6 hours post-feeding on day 1, was .51 and .57 g/kg body weight, respectively, for lambs fed the control and Yeast Culture supplements. Blood methemoglobin concentra-

Table 5. Hay and nitrate intake and blood methemoglobin concentrations of steers fed high-nitrate sorghum-sudan hay (period I)[a]

Item		Supplement					
		Control			Yeast Culture		
		Hay intake (% of body wt)	Nitrate intake (g/kg body wt)	Methemoglobin (%)	Hay intake (% of body wt)	Nitrate intake (g/kg body wt)	Methemoglobin (%)
Challenge day	Hr post-feeding						
1	0	—	—	0	—	—	0
1	4	0.78	0.25	—	0.76	0.24	—
1	6	0.92	0.29	13.1	0.93	0.30	25.8***
1	12	1.55	0.50	—	1.57	0.50	—
1	24	—	—	2.5	—	—	0.7
2	4	0.83	0.27	26.1	0.65	0.21	40.1*
2	7	1.28	0.41	19.3	1.07	0.34	31.9*
2	12	1.55	0.50	5.5	1.57	0.50	18.2*
2	24	—	—	0.6	—	—	0.6

[a]Four and five steers (561 ± 82 lb) fed control and yeast culture supplements, respectively. Sorghum-sudan hay contained 32,000 ppm nitrate.
Significantly greater (***P<.01, *P<.10) than methemoglobin concentrations of control steers.

Table 6. Hay and nitrate intake and blood methemoglobin concentrations of steers fed high-nitrate sorghum-sudan hay (period II)[a]

Item		Supplement					
		Control			Yeast culture		
		Hay intake (% of body wt)	Nitrate intake (g/kg body wt)	Methemoglobin (%)	Hay intake (% of body wt)	Nitrate intake (g/kg body wt)	Methemoglobin (%)
Challenge Day	Hr post-feeding						
1	4	0.93	0.28	14.1	1.01	0.30	21.8
1	7	1.17	0.35	52.3	1.11	0.33	34.4
1	12	1.49	0.45	29.7	1.69	0.50	23.3
2	4	0.81	0.24	22.1	0.82	0.25	38.7
2	7	1.34	0.40	27.0	1.32	0.39	37.1
2	12	1.67	0.50	14.4	1.69	0.50	19.7
2	24	—	—	0.7	—	—	1.1

[a] Five steers (551 ± 87 lb) per treatment. Sorghum-sudan hay contained 29,900 ppm nitrate.

tions of lambs on the two treatments were very similar (i.e., 28.7 vs 29.2 percent) at this time. Nitrate intake of all lambs by 6 hours post-feeding on day 2 was .28 and .32 g/kg body weight for the two treatments and was less than that of day 1. Data of one control lamb was deleted because he pulled large amounts of hay out of the feeder, and accurate measurements of hay consumption were not possible. Blood methemoglobin concentrations were low at 6 hours post-feeding on day 2 and were not significantly different between treatments.

By day 5 there was enough high-nitrate hay remaining for only 15 lambs. Nitrate intake of lambs fed the control and Yeast Culture supplements was .44 and .53 g/kg body weight, respectively, at 6 hours post-feeding. Mean blood methemoglobin concentrations were 6.4 and 14.4 percent, respectively, and were not significantly different.

Steer Trial

Intake of high-nitrate hay (percent of body weight), nitrate intake (g/kg of body weight) and blood methemoglobin concentrations of steers during Periods I and II are shown in Tables 5 and 6, respectively. Data of one control steer during period I was deleted because of low hay intake. Blood methemoglobin concentrations are also shown graphically in Figures 1 and 2. Nitrate intakes of steers fed the control and Yeast Culture supplements were similar at the various time intervals after feeding of both Periods I and II. The steers consumed enough hay during the first 4 hours post-feeding to supply about .25 g nitrate/kg body weight. The remainder of the high-nitrate hay was generally consumed by 12 hours post-feeding.

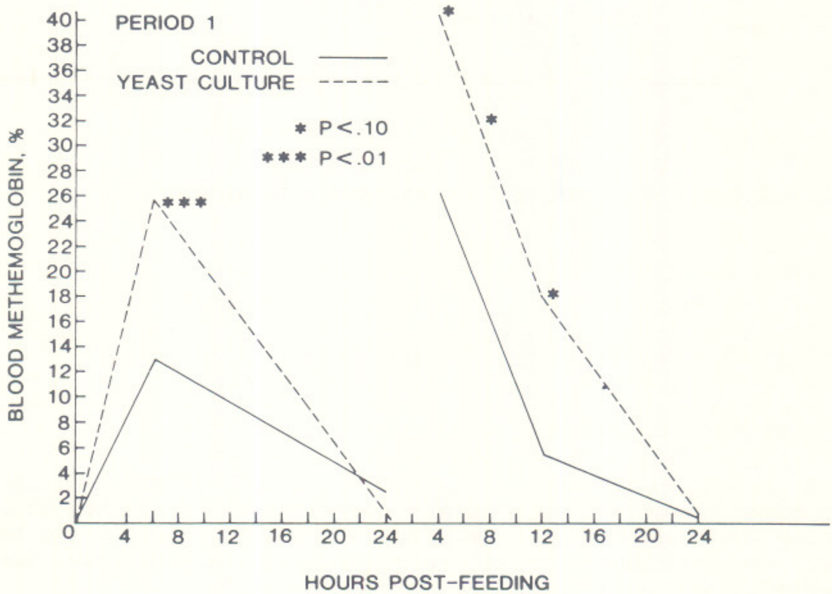

Figure 1. Blood methemoglobin concentration of steers (Period 1)

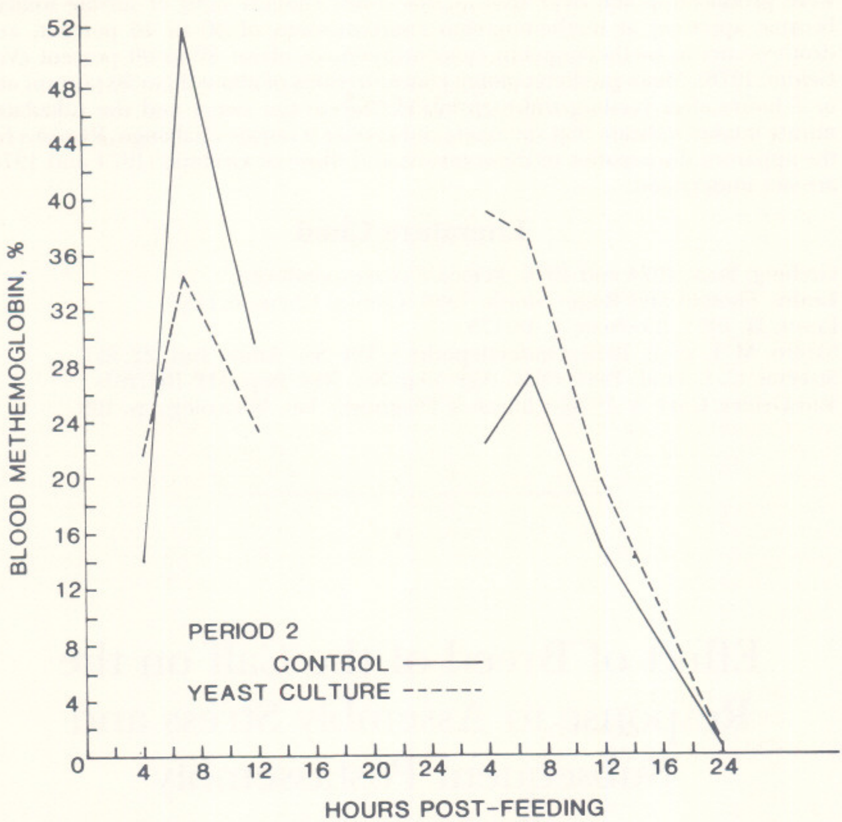

Figure 2. Blood methemoglobin concentration of steers (Period 2)

Blood methemoglobin concentrations at 6 hours post-feeding on day 1 (Period I) were 13.1 and 25.8 percent (P<.01), respectively, for steers fed the control and Yeast Culture supplements. Blood methmoglobin concentrations at 4, 7 and 12 hours post-feeding on day 2 (Period I) were higher (P<.10) for steers fed the Yeast Culture supplement.

None of the differences among blood methemoglobin concentrations of steers fed the control or Yeast Culture supplements during Period II were significant (P>.10). Methemoglobin concentrations of control steers were, however, higher at 7 and 12 hours post-feeding on day 1. Definite clinical signs of nitrate toxicity (i.e., depression, cyanosis and staggering) were observed in one steer of each treatment at 7 hours post-feeding of day 1 (Period II). At 12 hours post-feeding, the steers were much more alert and were not staggering. A pinkish color had returned to the nose and skin around the eyes of the steers.

Results of this study do not indicate that Yeast Culture will decrease the toxicity of high-nitrate forages. While the nitrate challenge was not nearly as acute as in the studies of Grebing (1974 and 1976), definite clinical signs of nitrate toxicity were produced in the steer trial of this study. Clinical signs of nitrate toxicity become apparent at methemoglobin concentrations of 30 to 40 percent, and death occurs at methemoglobin concentrations of about 80 to 90 percent (Van Gelder, 1976). Mean methemoglobin concentrations of about 20 to 50 percent at 4 to 7 hours after feeding the high-nitrate hay to the steers and the calculated nitrate intakes indicate that the steers did receive a nitrate challenge. Reasons for the apparent discrepancy in these results and those of Grebing (1974 and 1976) are not understood.

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Effect of Breed of the Calf on the Response to Assembly Stress and Subsequent Postassembly Performance

W. A. Phillips and R. R. Frahm

Story in Brief

Steer calves representing four crossbred groups were used to determine the effect of calf breed on the amount of weight lost during assembly and the subsequent postassembly performance. All breed groups were raised under the same environmental and managerial conditions and subjected to two periods of fasting and one period of refeeding to simulate the stress of assembly and transit. Calf breed had no effect on the amount of weight lost during the first period of fasting in the assembly process. There were differences among breeds in the amount of weight regained during a refeeding period following the first fast and in the amount of weight lost during the second period of fasting, which simulated

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the transit phase. Postassembly feed consumption and rate of gain was not significantly affected by calf breed, but the cost of a pound of gain over the weaning weight increased as the percentage of Brahman breeding increased. Thus, it appears that calf breed can affect the amount of weight lost during assembly as well as the cost of gain during the early feeding period.

Introduction

During the past 5 years the USDA in cooperation with various state experiment stations has been conducting research to reduce the losses in beef calves due to the stresses imposed at the points of assembly and as the result of transit. The farm of origin from which the calves were purchased has consistently had a significant impact on the performance and health of stocker calves after they have been exposed to the stressors found in the assembly and transit system, which moves beef calves from the cow-calf farms to the next production point. It is logical to anticipate that the farm of origin would be important because it is a broad classification taking in the breed and age of the calf, prior nutrition level and parasite exposure, just to list a few. Of all these components, the genetic variation (breed) could be one of the most important factors. To date, no observations have been reported on calves of different definable breeds born and raised at the same farm of origin.

It is important to identify factors which influence how much weight is lost during assembly and how quickly the weight can be regained. The arrival weight of the calf at the final destination is much less (4-10 percent) than the amount purchased. This loss is due to periods of fasting and refeeding associated with assembly and transit. Until the calf regains the lost weight, it is not a productive unit. Thus, the amount of weight lost should be reduced, or the recovery time for the lost weight should be shortened. The objective of this experiment was to determine the effect of calf breed on feed consumption and weight changes during and after exposure to the stressors associated with assembly and transit.

Materials and Methods

Ninety-two crossbred steer calves, representing five different definable breed groups, were born and raised under the same management and environmental conditions at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma. The breed groups consisted of either 0, 25 or 50 percent Brahman breeding. Hereford and Angus dams served as the foundation herd. The various percentages of Brahman breeding were incorporated through the use of purebred and crossbred Brahman sires. The resulting calves were classified as ½ Hereford ½ Angus (HA), ¼ Brahman ¼ Hereford ½ Angus (BA), ¼ Brahman ¼ Angus ½ Hereford (BH), ½ Brahman ½ Hereford or ½ Brahman ½ Angus. Due to the small number of calves in the last two groups, these calves were combined to form a 50 percent Brahman breed group (B). Thus, there were only four breed groups.

Calves were weaned and weighed at an average age of 205 days. All calves were commingled in a 12 ft by 112 ft pen without feed or water for the first 24 hr to simulate the stress which would be associated with the auction barn phase of the normal assembly process. After the initial fast the calves were weighed, moved to a larger pen (200 x 225 ft) and allowed access to medium quality hay and water for the next 72 hr to simulate the order-buyer barn phase of the assembly process. This phase was followed by weighing each calf and crowding them into a 12 ft x 112 ft pen without feed and water for 24 hr to simulate the fasting and restraint associated with transit. On the following day the calves were moved a short distance and placed in 25 ft x 50 ft dirt-surface pens. Six calves from the same breed were allotted to each pen based on weaning weight. Four pens, each containing one breed group, were used per replicate. Animal numbers were not equal, so only three full replicates could be constructed. The remaining calves formed an incomplete replicate. There were 22 HA, 34 BA, 17 BH and 19 B calves.

The same ration was fed daily to all calves for 28 days and contained 53.7 percent corn, 35.2 percent cottonseed hulls, 7.9 percent soybean meal, .9 percent dry molasses, .3 percent urea, .6 percent calcium sulfate, .1 percent calcium carbonate and 1.3 percent potassium chloride. The ration allowance for the first day was 5 lb per head. That amount was increased at the rate of 2 lb per head per day until refusals were noted. Body weights were determined at weekly intervals just prior to the morning feeding. Feed consumption was also determined weekly for each pen. Each calf was observed daily for clinical symptoms of respiratory disease or other clinical problems. Sick calves were treated with antibiotics and then returned to the original pen. At the termination of the study, the calves were fasted for 18 hr then weighed.

The data from the three complete replications were analyzed as a randomized block design. No differences due to replication were noted, so the complete data was then analyzed as a one-factor experiment to determine differences among the four crossbred groups.

Results and Discussion

The weight at weaning and the changes in body weight during the assembly process are shown in Table 1. The average weaning weight was 505 lb, with the B calves being the heaviest and the BH calves being the lightest at weaning. Calves lost an average of 43.2 lb (8.7 percent) during the initial 24-hr fast. There was no difference in the amount of weight lost during this period due to the breed of the

Table 1. The effect of calf breed on weight changes during fasting and refeeding

Weight and weight changes at each assembly point	Breed of calf[a]				
	HA	BA	BH	B	Mean
Weaning weight, lb	486	515	468	542	503
After 24-hr fast; lb lost	41.2	43.6	40.6	47.0	43.2
% of wwt[b]	91.4	91.5	91.0	91.3	91.3
After 72-hr refeed; lb gained	31.0[c]	29.3[c]	21.2[d]	29.8[c]	28.1
% of wwt	98.1[c]	97.2[cd]	95.72[d]	96.8[cd]	97.0
After 2nd fast; lb lost	28.0	27.2	25.11	30.4	27.6
% of wwt	92.2[c]	91.9[c]	90.2[d]	91.2[cd]	91.5

[a] HA = 1/2 Hereford 1/2 Angus, BA = 1/4 Brahman 1/4 Hereford 1/2 Angus. BH = 1/4 Brahman 1/4 Angus 1/2 Hereford, and B = 1/2 Brahman 1/2 Hereford or 1/2 Brahman and 1/2 Angus.

[b] wwt = weaning weight.

[c,d]Means in the same row with different superscripts differ ($P<.05$).

calf when expressed as pounds lost or as a percentage of the weaning weight. There was, however, a significant difference in the amount of weight gained during the subsequent 72-hr refeeding period. Calves within the HA, BA and B groups gained 29.9 lb during this period, which was 68 percent of the 44 lb of weight lost during the previous 24-hr fast. After the refeeding period these calves weighed 97.4 percent of their weaning weight. BA calves gained only 21.2 lb during the refeeding period, which was 8.7 lb less than the other three groups. Although the calves and dams were reared in a research environment, the weaning procedure seemed stressful as judged by observations of the calves postweaning. The calves walked around the perimeter of the pens during both fasting and refeeding phases, which is characteristic of the stress of separation from the dam. It was approximately 48 hr after hay and water were afforded during refeeding before the majority of calves began to eat hay. The difference in the amount of weight gained during the refeeding period probably reflects a difference in the amount of hay and water consumed or the time at which the calves began to consume hay.

The importance of regaining as much of the weaning weight as possible during the refeeding period is illustrated in Table 1. After the refeeding period a second period of fasting was imposed to simulate the transit phase. The HA, BA and B groups gained more weight during the refeeding period but lost more weight during the second fasting period. The amount of weight lost by the calves in these three groups was 28 lb, which was 1.7 lb less than the amount previously gained. Thus, these calves entered the conditioning lot at 91.8 percent of their weaning weight. Although the BH calves lost less weight during the second fasting period, they had already lost 8.7 lb more than the other calves. After regaining 21.2 lb during the refeeding period, they lost 25.1 lb during the second fast; thus, an additional 3.9 lb were lost over and above the amount regained. As a result, these calves entered the conditioning lot at 90.2 percent of their weaning weight. The BH calves tended to be slower in regaining previously lost weight during the refeeding phase. Although the calves were not actually transported, the average amount of weight lost during this period was 5.6 percent of the prefast body weight, which was comparable to previous observations of calves transported 850 miles by a commercial carrier (Phillips et al., 1981). No differences were noted in ration consumption among the different breed groups (Table 2). The calves readily consumed the ration provided. As described previously, the initial

Table 2. The effect of the calf breed on the amount of ration consumed during each week

	Breed of calf[a]				
Time period	HA	BA	BH	B	Mean
Week 1	9.50[b]	9.50	9.48	9.48	9.50
Week 2	13.24	13.86	13.64	13.29	13.56
Week 3	17.26	18.02	17.90	19.60	18.10
Week 4	20.41	20.60	20.66	22.70	20.96
Mean	15.10	15.49	15.42	16.27	15.52

[a] HA = 1/2 Hereford 1/2 Angus, BA = 1/4 Brahman 1/4 Hereford 1/2 Angus, BH = 1/4 Brahman 1/4 Angus 1/2 Hereford and B = 1/2 Brahman 1/2 Hereford and 1/2 Brahman 1/2 Angus.

[b] Pounds of 90% dry matter ration per head per day.

allotment of ration was 5 lb per calf on day 1. The amount was then increased at 2 lb increments each day if no refusal was noted. In order to prevent digestive problems, the calves were held at 12 lb of ration per head for 2 days (days 5 and 6) before increasing the amounts provided. As a result, there were no refusals during the first week, and intakes were the same for all pens. As noted in Table 2, ration consumption increased weekly from 9.6 lb per head per day during week 1 to 21.0 lb per head per day during week 4. The average daily ration consumption for the 28-day long experimental period was 15.9 lb per head per day. This level of feed consumption was approximately 1 lb more per day than previously noted for Angus calves, which had been transported 850 miles (Phillips et al., 1981).

The BH calves were the lightest group at weaning and lost more weight during the assembly process (Table 1) than the other three groups, but they consumed as much feed during the 28-day postassembly period as the other three breed groups. Thus, the BH calves consumed more ration as a percentage of their body weight than the other three groups, but this was only significantly greater during weeks 1 and 2. By the fourth week of the postassembly period, ration consumption was 3.9 percent of body weight and similar for all four breed groups.

During the assembly period, the calves appeared to be distressed over the change in surroundings and the absence of the dams. The amount of weight lost during the various phases of fasting was similar to previously observed values when calves were moved through the normal industry channels. Thus it was felt that the stresses found in the normal channels were accurately simulated, but recently published data by Galyean et al. (1981) indicates that the physiological response to fasting alone is different from transit. Transit can have a negative effect on rumen function, which would influence posttransit ration consumption. Subsequent experiments to study these breed groups will employ an actual transit phase.

The amount of weight gained each week and the accumulative weight gain for the 28-day period are shown in Table 3. There were no differences in the amount of weight gained due to the breed of the calf, but large increases were noted during weeks 1 and 2 because the initial weight was a shrunk weight taken at the end of the last assembly fast. The subsequent weights taken 7 and 14 days later

Table 3. The effect of the calf breed on the amount of weight gained each week after assembly

	Breed of calf[a]				
Time period	HA	BA	BH	B	Mean
Week 1	25.3	29.0	32.8	34.5	29.9
Week 2	32.8	33.2	26.3	26.2	30.4
Week 3	20.2	16.8	23.7	22.4	20.1
Week 4	12.2	10.2	10.1	9.9	10.6
Total	90.5	89.2	92.9	93.0	91.0
Adj. weight[b] gain	59.4	54.6	69.1	54.9	58.8

[a] HA = 1/2 Hereford 1/2 Angus, BA = 1/4 Brahman 1/4 Hereford 1/2 Angus, BH = 1/4 Brahman 1/4 Angus 1/2 Hereford and B = 1/2 Brahman 1/2 Hereford or 1/2 Brahman 1/2 Angus.

[b] Adjusted weight gain was corrected for gut fill by fasting the calves overnight before weighing.

were full weight. Thus a large part of these weight gains are due to replacing the gut fill. Approximately 30 lb were gained each week for the first 2 weeks, then 20 and 10 lb per head per week for the last 2 weeks. The average increase in weight for the 28-day period was 91 lb. Using data from Table 1, the net amount of weight lost after weaning can be calculated. Subtracting this from the weight gained after assembly yielded a net gain of 48.5 lb over weaning weight or 1.73 lb of additional gain per day.

Adjusted weight gains are also shown in Table 3. These gains are the difference between the initial postassembly weight and a shrunk weight taken at the end of the 28-day period. This should account for any gut fill differences and be a more accurate reflection of body mass changes during the 28-day experiment. HA, BA, and B groups have similar adjusted weight gains. Although the BH appeared to have gained more body mass during the 28-day postassembly period, it was not significantly greater than the other three groups. The BH group had already lost almost 9 lb more than the other three groups during assembly. So the net gain over weaning was similar for all groups.

Calculated from the weight change data in Tables 1 and 3 and the feed consumption data from Table 2, the net gain over weaning weight and the cost per pound of this gain are presented for each breed group in Table 4. A price of $135 per ton was established as the cost of the postassembly ration, and the total feed cost is presented in Table 4. The cost of the feed consumed during the 28-day period was charged against the net weight gain (gain above weaning weight). The HA calves had a cost of gain of 54.57¢ per lb of gain over weaning weight, which was 6.79¢ to 13.14¢ less than the other groups. This difference was due to a slightly greater rate of net gain and lower feed consumption. These differences were not statistically significant, but the number of observations was small. Additional collection of data on these breed groups over the next 3 years will increase

Table 4. The effect of the calf breed on net weight gain and cost of gain

Item	Breed of calf[a]			
	HA	BA	BH	B
Total amount of feed consumed, lb	423	434	432	455
Feed cost at $135 ton[b]	$28.54	$29.27	$29.15	$30.74
Gain for 28 day, lb	90.5	89.2	92.9	93.0
Total weight lost during assembly, lb	38.2	41.5	44.5	47.6
Net gain over weaning weight, lb	52.3	47.7	48.4	45.4
Cost per lb of gain over weaning weight	54.57¢	61.36¢	64.21¢	67.71¢

[a] HA = 1/2 Hereford 1/2 Angus, BA = 1/4 Brahman 1/4 Hereford 1/2 Angus, BH = 1/4 Brahman 1/4 Angus 1/2 Hereford and B = 1/2 Brahman 1/2 Hereford or 1/2 Brahman 1/2 Angus.

[b] Cost of feed was calculated from ingredient prices at the time of the trial (Oct. 1981) and includes a 15% markup.

the number of observations and help to determine if the trends noted in this report are consistent over years.

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Adaptation of Stocker Calves to NPN as the Result of Consuming Wheat Forage

W. A. Phillips

Story in Brief

Twenty-four heifer calves were divided into two groups. A control group was fed wheat straw, soybean meal and corn, and another group was fed wheat forage. Consumption of wheat forage resulted in significantly higher ruminal ammonia and nonprotein nitrogen (NPN) concentrations than found in the control group. A change in the ruminal metabolism of the forage nitrogen was noted 30 days after consumption of forage began. Concentrations of ammonia and NPN in the rumen decreased, and plasma protein concentration increased. Although the wheat forage group appeared to be going through an adaptation phase to NPN while grazing, the utilization of a urea supplement fed to both groups following the grazing phase was not different from that of the unadapted control group. The consumption of wheat forage during March and April did not increase the utilization of urea following the grazing period, but there may be another form of NPN to which adaptation had occurred.

Introduction

Wheat pasture has been used extensively in the southern plains area as a high quality forage for young ruminants from November to March and even as late as May if a grain crop is not harvested. The protein content of wheat forage will vary within the grazing period and between different years. The protein content as a percentage of the dry matter has been reported to range from 25 to 32 percent,

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and the nonprotein/nitrogen (NPN) content can represent 12 to 28 percent of the total protein content (Johnson et al., 1973). NPN sources are not efficiently utilized by the ruminant immediately upon addition to the diet, and an adaptation period of 20 to 40 days is required before they can be effective as nitrogen sources for growth of young ruminants. Once adaptation has been achieved, it is not permanent and can be lost with removal of the NPN from the diet for a few days. Thus, another period of adaptation is required when NPN is again reintroduced in the diet. It would appear that young ruminants, such as stocker calves, should be adapted to NPN after 40 days of grazing winter wheat pasture. This information would facilitate the formulation of protein-efficient rations for feeding calves prior to grazing wheat pasture, during periods of no wheat forage availability and during the subsequent finishing period. The objective of this experiment was to determine if ruminants are adapted to NPN after grazing winter wheat pasture.

Materials and Methods

Hereford-Angus crossbred heifer calves weighing an average of 455 lb were assigned to two groups of 12 heifers each. During Phase I of the experiment, group 1 grazed wheat pasture for 45 days from March 3 to April 16, 1980, and the other 12 heifers were confined in drylot and fed 6.8 lb of a 15 percent plant protein supplement (Table 1). The combination of supplement and straw fed to heifers of group 2 was calculated to promote the same rate of gain as heifers of group 1.

At the end of phase 1, all heifers were confined in a drylot and individually fed 8.1 lb per head per day of the supplement which contained urea (phase 2); see Table 1. Each heifer was individually fed the supplement in two equal portions at 0830 and 1530 each day. Approximately 30 minutes were needed at each feeding for all heifers to consume the supplement. When not in individual stalls, the heifers were maintained as a group in drylot. Wheat straw was fed once each day after the afternoon feeding of the supplement.

Rumen and blood samples were collected at 15-day intervals during phase 1 and at 10-day intervals during phase 2. Rumen samples were collected 2 hours after feeding and blood samples 6 hours after feeding during both phases. Rumen ammonia concentration was determined by an ion specific electrode; NPN concentration was determined by extracting the soluble nitrogen with buffer and precipitating the protein with tungstic acid. Plasma protein was determined by biuret reaction. The data were analyzed within each phase as a one-way classification over time.

Results

The changes in the concentration of ammonia in the rumen fluid during phase 1 for the two experimental groups are shown in Table 1. The initial concentration of ammonia (day 0) was equal for the two groups because both groups had been receiving the same diet, indicating that there was no built-in bias. Group 1 had a significant increase in the rumen ammonia concentration from the initial value of 18.5 mg/100 ml to 75.4 mg/100 ml after grazing wheat forage for 15 days. This increase was due to an increase in the dietary nitrogen level. On day 30 the ammonia concentration declined to 57.3 mg/100 ml and did not significantly change for the remainder of phase 1. The crude protein content of the wheat forage initially and at the subsequent three 15-day intervals was 24, 28, 25 and 23 percent of forage dry matter. Thus, the decline in rumen ammonia concentration at day 30 was not due to a drastic drop in forage crude protein content. The decline was probably due to either a change to a more efficient utilization of the forage protein by the animal in terms of assimilating more of the ammonia into microbial protein or a change in the composition of the protein fractions in the forage. As anticipated, the rumen ammonia concentration of group 2 was lower than group 1 and remained lower throughout phase 1. The combination of supplement and straw was adequate for a moderate rate of gain (.6 lb/day) but did not contain the excess protein level that was found in wheat forage.

The pattern of change in ruminal NPN concentration for the two experimental groups was the same as noted for ruminal ammonia concentration. Consumption of the wheat forage resulted in an elevation of the NPN concentration at day 15, but that concentration significantly declined at day 30. No differences were noted between day 30 and day 45. Group 2 had a lower ruminal NPN concentration than group 1. Since ruminal ammonia is a large part of the ruminal NPN fraction, the factors which were previously discussed as affecting ruminal ammonia concentration would also have an influence on ruminal NPN. Previous research in the area of NPN adaptation has indicated that NPN concentration in the rumen decreased as adaptation occurred over a 30 to 40-day period of time (Ludwick et at., 1972). Thus, it would appear that group 1 was utilizing the protein in the wheat forage more efficiently with time.

As previously noted, there appeared to be a change in the ruminal metabolism of forage protein in wheat by day 30. A significant increase in total plasma protein concentration was also noted by day 30 in group 1 (Table 1).

Table 1. Composition of supplements[a]

	Group	
	1	2
Phase I		
Corn, ground	--	76.5
Soybean meal	--	17.1
Molasses	--	4.2
Dical	--	2.2
Phase II		
Corn, ground	88.2	88.2
Soybean meal	2.8	2.8
Urea	2.1	2.1
Molasses	5.0	5.0
Dical	1.9	1.9

[a]Percent of dry matter.

Although the heifers in group 1 appeared to be undergoing some metabolic changes which had the same characteristics as those experienced by ruminants adapting to NPN, the real test of adaptation was during phase 2 of this experiment. On day 45 both groups of heifers were individually fed a urea supplement. The subsequent changes in ruminal ammonia, NPN concentrations and plasma protein concentrations at 10-day intervals after initiation of phase 2 are shown in Table 2.

Ten days after introduction of the urea diet, the rumen ammonia concentration of group 2 had increased four-fold, but no change was noted in group 1. There was, however, a significant increase in NPN concentration in the rumen fluid for

Table 2. Concentration of ruminal and plasma nitrogen components during phase 1

Concentration of nitrogen components	Sampling period, days			
	0	15	30	45
Rumen ammonia, mg/100 ml				
Group 1	18.5[a]	75.4[b]	57.3[c]	52.4[c]
Group 2	18.3[a]	14.8[b]	12.8[b]	13.8[b]
1 vs 2[d]	NS	.01	.01	.01
Rumen non-protein nitrogen, mg/100 ml				
Group 1	32.6[a]	92.6[b]	73.3[c]	85.5[b,c]
Group 2	31.8[a]	28.4[a,b]	24.6[b]	22.3[b]
1 vs 2	NS	.01	.01	.01
Plasma protein g/100 ml				
Group 1	6.46[a]	6.60[a]	6.85[b]	6.82[a,b]
Group 2	6.61[a]	6.60[a]	6.49[a,b]	6.36[b]
1 vs 2	NS	NS	.05	.05

[a,b,c]Means in the same row with different superscripts are different (P<.01).
[d]Comparison of the two groups within each sampling period: NS = nonsignificant, .05 = P<.05, and .01 = P<.01.

both groups 1 and 2. For the remainder of the trial, significant differences were noted between groups 1 and 2 for any of the measurements except the NPN concentration at day 40. Ruminal ammonia and NPN concentrations decreased to significantly lower levels at day 20. Another significant decline was noted on day 40. Plasma protein concentration is inversely related to rumen ammonia and NPN concentration when nitrogen intake is held constant. When these two ruminal measurements increase, plasma protein concentration usually decreases because less nitrogen is being incorporated into microbial protein for later diges-

Table 3. Concentration of ruminal and plasma nitrogen components during phase 2

Concentration of nitrogen components	Sampling period, days					
	0	10	20	30	40	50
Rumen ammonia, mg/100 ml						
Group 1	52.4[a]	57.5[a]	28.5[b]	30.1[b]	21.4[c]	23.0[c]
Group 2	13.8[a]	51.6[b]	29.7[c]	29.7[c]	23.2[d]	22.5[d]
1 vs 2[e]	.01	NS	NS	NS	NS	NS
Rumen non-protein nitrogen, mg/100 ml						
Group 1	85.5[a]	124.4[b]	51.0[c]	40.4[c,d]	26.4[d]	30.2[c,d]
Group 2	22.3[a]	112.5[b]	61.3[c]	36.2[a]	30.4[a]	31.4[a]
1 vs 2	.01	NS	NS	NS	.05	NS
Plasma protein g/100 ml						
Group 1	6.82[a]	6.40[b]	6.96[a]	6.98[a]	6.85[a]	6.61[a,b]
Group 2	6.36[a]	6.34[a]	6.89[b]	6.89[b]	6.92[b]	6.73[b]
1 vs 2	.05	NS	NS	NS	NS	NS

[a,b,c,d]Means in the same row with different superscripts are different (P<.01).
[e]Comparison of the two groups within each sampling period: NS = nonsignificant, .05 = P<.05, and .01 = P<.01.

tion and absorption. As the ruminal metabolism of NPN improved with time, indicated by lower ammonia and NPN concentrations, plasma protein concentration also increased, with the exception of days 40 and 50. On day 40 another significant decrease in rumen ammonia and NPN concentration was observed although the plasma protein concentration was only slightly lower than on day 30.

The anticipated response of heifers in group 1 was not observed. Had these heifers been better prepared to utilize NPN in the form of urea as a result of consuming wheat forage, the changes in ruminal nitrogen components would have been lower in amplitude than they were in group 2, which were considered to be unadapted animals.

It is concluded that the consumption of wheat forage during March and April did not increase the utilization of a urea supplement following the grazing phase. The change in ruminal nitrogen metabolism during phase 1 for group 1 warrant further investigation. There may be another form of NPN to which the animals are adapting during the forage period.

Literature Cited

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Corn Gluten Meal Plus Urea For

W. A. Phillips

Story in Brief

Steer calves lost more weight than heifer calves during assembly and processing. Substituting corn gluten meal plus urea for soybean meal resulted in lower feed intake and weight gain initially, but during the second 28-day period, performance of the steer calves fed the corn gluten meal plus urea diet was slightly superior to those fed the soybean meal diet. When urea provided 10 percent of the total dietary nitrogen, and corn gluten meal was the supplemental protein source, calves ate less feed but gained as much weight as calves consuming a higher level of urea or no urea.

Introduction

During assembly and transportation of stocker calves from the farm of origin to the next production point, periods of starvation and refeeding are encountered. During these periods, the stressed calf will mobilize body reserves of protein and energy to meet metabolic needs. At the same time, rumen function may cease due to infrequent feeding, stress, and diet changes. Since the ruminant depends upon the microorganisms of the rumen for conversion of various nitrogen sources into protein, protein supply is reduced, forcing the calf to draw upon body reserves further. Diets rich in energy and protein are needed following the stress of assembly and transit both to meet current needs and to replace body reserves quickly and efficiently. When protein needs of the calf are high, and microbial protein production is low, special supplementation may prove helpful. To increase the amount and type of protein reaching the intestinal tract for absorption, protein which bypasses ruminal fermentation can be fed. Some nitrogen available to the ruminal microorganism also must be provided so that rumen function is not depressed. The objective of this experiment was to measure the effect which the composition of the protein supplement in the receiving diet of stressed calves has on feed intake, health and performance.

Materials and Methods

Seventy-two crossbred calves (33 heifers and 39 steers) were weighed, weaned from their dams and subjected to a 24-hr fast without feed and water to simulate the first phase of assembly (movement from the farm of origin and through the auction barn). Next, the calves were moved several miles by trailer to another assembly point and provided hay and water for the next 24 hr. A second period of fasting was then imposed for 24 hr to simulate the transit. Calves were then divided into six pens. One pen of steers and one pen of heifers were fed each of the diets shown in Table 1.

USDA, Agricultural Research Service, Southern Region in Cooperation with the Oklahoma Agricultural Experiment Station.

Table 1. Composition of receiving rations[a]

Ingredients	Diets		
	Control	U-10	U-20
Corn, ground	55.0	61.0	62.6
Cottonseed hulls	25.9	23.4	24.1
Soybean meal	11.1	—	—
Corn gluten meal	—	6.6	4.0
Molasses	5.0	5.0	5.0
Urea	—	.45	.9
Minerals	3.0	3.6	3.4
Nutrient composition[a]			
Crude protein	12.5	12.5	12.5
Net energy-Maint., Mcal	.84	.85	.85
Net energy-Gain, Mcal	.49	.50	.50

[a]Percent of dry matter.
[b]Net energy as Mcal per pound of dry matter.

Diets differed only in the source of the supplemental protein. The control diet (C) contained soybean meal as the supplemental protein source while the other two diets contained corn gluten meal plus urea. Urea provided either 10 percent (U-10) or 20 percent (U-20) of the total dietary nitrogen in these two rations. Corn gluten meal, a by-product of the corn milling industry, has a crude protein content of 60 percent. Much of this protein source supposedly bypasses ruminal digestion and is digested and absorbed postruminally. Urea provides a readily available nitrogen for rumen microorganisms.

All diets provided equal amounts of crude protein and energy, and calves had free access to diets for 56 days. Feed consumption and body weight changes were measured each week. Body weights were taken prior to the morning feeding and after a 16-hr period without water in order to reduce gut fill. Data were analyzed statistically as a randomized block design. The sex of the calf was the block, and the stress diets were the treatments within each block.

Results

The average weight of the calves at weaning was 357 lb with steer calves weighing more than the heifer calves (Table 2). During the first 24-hr fast, the

Table 2. The effect of sex of the calf on weight changes during assembly, fasting and refeeding

	Heifer	Steer	Mean
No. of calves	33	39	
Weaning weight, lb	334.3	376.1	356.9
First fast weight, lb	299.3	335.1	318.7
Weight lost, lb	35.0	41.0	38.2
Weight lost[a], %	10.5	10.9	10.7
Refed weight, lb	320.8	364.1	344.3
Refed weight, %	95.9	96.8	96.4
Second fast weight	302.7	339.2	322.5

[a]Percentage of weaning weight.

steer calves lost 41 lb, and heifer calves lost 35 lb. Expressed as a percentage of the weaning weight, weight losses were 10.5 vs 10.9 percent for steers and heifers. During the subsequent refeeding period, both groups were visibly distressed but regained over 60 percent of their weight loss. Steer calves regained 29 lb and weighed 96.8 percent of their weaning weight while the heifer calves regained 22 lb to weigh 95.9 percent of their weaning weight. During the second fasting period, steer calves again lost more weight than heifer calves. When all losses and gains over the assembly period (fast-refeed-fast) had been totaled, the steer calves had lost 37 lb and weighed 90.2 percent of their weaning weight while heifer calves had lost 32 lb and weighed 90.5 percent of weaning weight. Although steer calves changed weight more rapidly, both groups entered at the feedlot with the same percentage of the original weaning weight.

Few health problems were encountered, and no calves were treated for bovine respiratory disease. No comparison of the effects of diet on health were possible. The steer calves gained more weight than the heifer calves; both groups responded similarly to the three diets (Table 3).

During the first 28 days of the trial, the corn gluten meal and urea rations produced slower rates of gain than the soybean meal ration. The opposite effect was noted during the second 28-day period with greater gain with the U-10. Overall, rates of gain during the 56-day feeding period for calves fed the three different rations were not significantly different.

No difference in feed consumption attributable to diet or sex of the calves was apparent, but slightly less of the U-10 and U-20 diets was consumed, especially during the first 28 days. Lower intake may explain the poor performance noted for both steer and heifer calves during the initial 28-day period. For the 56-day feeding period, intake of the U-10 diet was 10.3 percent less than the soybean diet. Since animal gains were equal, feed efficiency data favored the U-10 diet.

Table 3. The effect of diet on the average daily gain and feed consumption

	Heifers			Steers		
Items	**C**	**U-10**	**U-20**	**C**	**U-10**	**U-20**
Average daily gain[a], lb						
0-28 days	2.15[c]	1.75[cd]	1.72[d]	2.71[c]	2.08[d]	2.31[cd]
29-56 days	2.52[c]	3.04[d]	2.58[cd]	2.66[c]	3.05[d]	2.92[cd]
0-56 days	2.34	2.39	2.15	2.68	2.57	2.62
Feed consumption[b]						
0-28 days	11.76	9.56	10.05	12.64	11.07	12.05
29-56 days	17.33	16.40	16.92	18.68	17.09	18.09
0-56 days	14.54	12.98[c]	13.49[cd]	15.64[c]	14.08[d]	15.06[c]
Feed efficiency						
0-28 days	5.47	5.46	5.84	4.66	5.32	5.22
29-56 days	6.88[c]	5.39[d]	6.56[cd]	7.02[c]	5.60[d]	6.20[cd]
0-56 days	6.21	5.43	6.27	5.84	5.48	5.75
Crude protein intake						
0-28 days	1.61	1.43	1.45	1.69	1.47	1.54
29-56 days	1.87	2.33	1.94	1.96[c]	2.42[d]	2.07[c]
0-56 days	1.74	1.87	1.69	1.83	1.96	1.78

[a]Pounds/head/day.
[b]Pounds of 90% dry matter feed consumed per head per day.
[c,d]Means in the same row within one sex with different superscripts are different ($P<.05$).

Analysis of the weekly feed samples revealed that diets were similar in protein content during the first 4 weeks of the experiment. On week 6 for reasons unknown, the protein content of the U-10 was 16.6 percent (dry matter basis) whereas the other two diets remained at 12.5 percent. Protein intake of calves tended to be lower for diets containing corn gluten meal plus urea during the first 28-day period, but during the second 28-day period, crude protein intake of the U-10 diet increased dramatically due to the increased protein content of the diet. Whether the gain response to U-10 during the second 28-day period was due to protein source or the protein intake is uncertain. Additional research is needed concerning the source and concentration of protein needed for stressed calves.

Corn gluten meal is used primarily in the poultry industry, and the supply and price can fluctuate, depending upon local demand. At the time of this experiment, the costs of protein from corn gluten meal and soybean meal were similar. Cost per ton of ration was slightly less for the corn gluten meal and urea diets than for the soybean meal diet. Cost of gain for the 56-day trial was 8 cents per pound lower for calves receiving the U-10 diet than calves fed the soybean meal diet. Net gain over weaning weight was lower for the U-10 and U-20 rations during the first 28-day period and resulted in a higher cost per pound of gain than for the C ration. During the second 28-day period the calves receiving the corn gluten meal and urea rations ate slightly less feed than the calves receiving the C ration but gained more weight. This resulted in a lower cost of gain especially for those calves receiving the U-10 ration. Results suggest that corn gluten meal plus urea is a useful protein source for stressed calves. Although initial intake and gain may be reduced, later performance should compensate and decrease the cost of gain. Further study of long-term and health effects of rations containing high bypass protein is needed.

Table 4. Weight changes and cost of gain of steer and heifer calves fed three different diets

	Heifers			Steers		
Items	C	U-10	U-20	C	U-10	U-20
Feed cost, $[a]						
0-28 days	26.60	21.02	21.48	28.23	24.33	25.76
29-56 days	38.71	36.06	36.16	41.72	37.58	38.67
0-56 days	64.97	57.08	57.64	69.95	61.91	64.43
Gain over weaning[b]						
0-28 days	27.4	19.1	15.7	36.2	22.8	28.3
29-56 days	70.7	85.1	72.3	74.5	84.6	76.6
0-56 days	98.1	104.2	88.0	110.7	107.4	104.9
Cost per pound of gain over weaning[c] weight						
0-28 days	95.84	110.05	136.82	77.98	106.71	91.02
29-56 days	54.75	42.37	50.00	56.00	44.42	50.48
0-56 days	66.23	54.78	65.50	63.19	57.64	61.42

[a]Cost 1 ton C = $159.53, U-10 = $157.05 and U-20 = $152.67.

[b]Total pounds of gain that period.

[c]Cost as cents per pound of gain over weaning weight.

Protein vs Energy in Receiving Diets for Stocker Cattle

E. J. Richey, D. R. Gill
F. N. Owens and K. S. Lusby

Story in Brief

One hundred eighty head, one load of calves and one load of yearlings, were fed 2 lb of pellets containing 40 percent protein or 6 lb of a 13 percent protein-energy feed daily.

Daily gains averaged 1.47 lb per day for the cattle receiving the high protein feed and 1.55 lb per day for the animals fed the high energy feed. Free-choice hay intake averaged 9.0 lb per day for the protein cattle and 7.7 for the energy cattle. Total feed fed was 10.5 and 13.1 lb per day for the cattle fed protein and energy, respectively, for the 28 or 29-day receiving period. Response of calves to supplemental energy was more favorable than response of yearlings.

Additional expense of feeding 6 lb of high energy feed in addition to grass hay did not improve weight gains or animal health. These cattle will be weighed again after being pastured on wheat and again out of a feedlot. Those results will be reported in the future.

Introduction

One receiving program for stressed, shipped cattle has evolved at the Pawhuska Research Station. The diet has consisted of a high quality, locally produced native grass hay fed free choice supplemented with 2 lb of a 40 percent protein pellet fed once daily. This program has resulted in an excellent recovery of health and is considered economical by local ranchers, who pay for the feed. They produce the hay, and their only added expense is for protein pellets. In the past all loads of cattle have received 2 lb of pellets for at least the first week, after which the rate has been reduced to 1 lb per day if the cattle appear strong.

Results of Lofgreen at Clayton, New Mexico, suggest that much more rapid gains can be achieved with a 72 percent concentrate program. His data shows consistently higher rates of gain with a higher concentrate receiving program, and this advantage is maintained in subsequent grazing or feeding periods. However, rations fed at Clayton are usually complete milled rations rather than concentrate pellets added to loose-fed long grass hay as used in the Osage.

The objective of this research was to determine if there is an economic response to providing additional energy in receiving diets based on long grass hay fed free-choice.

Experimental Procedure

Two truckloads of steers were purchased on successive days on the Oklahoma City market and delivered to the OSU research facility at Pawhuska, Oklahoma. On arrival the cattle were handled as outlined in OSU Fact Sheets 9102 and 9103 and OSU RP-9104. Cattle were processed on 2 successive days, and each load was divided into four pens. The loads were kept in separate pens except when sick cattle went to one of two sick pens. One sick pen was maintained for each nutritional treatment. Two pens of cattle from each load were assigned to diets consisting of free choice grass hay plus either 2 lb of 40 percent protein pellets or 6 lb of 13 percent protein high energy pellets (Table 1).

Table 1. Composition of experimental supplements

Ingredients, %	Supplement type Energy	Protein
Soybean meal	13.00	90.80
Corn	84.96	0.00
Dicalcium phosphate	1.00	2.75
Salt	1.00	3.00
Vitamin A-30000 I.U./G	0.036	0.11
Cottonseed hulls		1.75
Calcium carbonate		1.50
Trace mineral		0.10
Protein, %	13.	40.

Hay was kept in feeders at all times, and concentrate pellets were fed twice daily in feed bunks. All animals in a pen had an equal opportunity to eat pellets. It took several days before the animals receiving the high energy pellet would consume 6 lb each day. Initial weights were determined as cattle were unloaded from trucks. Final weights were taken after 12 hours without feed or water. These cattle will continue on test on wheat pasture and will be followed through the feedlot.

Results and Discussion

There appeared to be a difference in the age of the cattle in the two loads received. One load was designated as calves and the other as yearlings. Performance differed with age (Table 2).

Response to additional grain feeding was very poor. Concentrate intake with the high energy supplement was 40 percent of total intake. As in other trials (Gill, et al., 1982; Lusby, et al., 1982) grain had an unfavorable negative associative effect on forage intake and/or digestibility.

Table 2. Animal performance

	Calves		Yearlings	
Feed	2#-40% CP	6#-13% CP	2#-40% CP	6#-13% CP
Days	29	29	28	28
Number of animals	49	46	42	43
Initial weight, lb	456	455	448	460
Final weight, lb	489	494	503	512
Average daily gain, lb	1.11	1.31	1.89	1.81
Average daily hay, lb	8.52	7.27	9.54	8.24
Average daily conc., lb	1.91	5.26	1.93	5.41
Total daily feed, lb	10.43	12.53	11.47	13.65
Feed per lb gain	9.40	9.56	6.07	7.24
Percent sick once	55.10	51.10	38.10	51.16
Percent sick twice	14.29	4.26	0.00	9.30
Percent dead	2.13	0.00	0.00	0.00

Probably starch in the energy feed reduced the digestibility of the hay to an extent that intake of digestible energy was not increased, and value of added energy was not realized. Some of the advantage of feeding more grain also may have been lost due to greater fill of forage-fed steers.

Typical of many stressed cattle, about half the cattle on both treatments were sick but responded well to treatments outlined in OSU RP-9104. It is possible that calves and yearlings differ in their health response to protein or energy supplementation. With the yearlings there was less sickness with the high protein diet, consistent with other observations. The response of these cattle in subsequent periods of grazing on wheat pasture and finishing in a feedlot is being followed.

Literature Cited

Gill, D. et al. 1982. OSU MP-112
Lusby, K. et al. 1982. OSU MP-112

The Effect of Low Level Energy vs Protein on Just-Received Stocker Steers

**D. R. Gill, F. N. Owens,
K. S. Lusby, and E. J. Richey**

Story in Brief

Ninety-nine yearling steers were fed 2 lb of a 40 percent supplement for 10 days, then either 1 lb of a 40 percent protein pellet or 3 lb of 13 percent protein energy feed. Average daily gain averaged 1.24 lb per day for the high protein treatment and 1.18 lb per day for those changed to 3 lb of energy feed. While supplemental protein intake of both groups of cattle was held constant, the energy group received 3 vs 1 lb of supplement per day but did not gain as well. Intake of free-choice hay averaged 8.50 lb per day for the high protein cattle and 8.27 lb per day for those which got the 3 lb of energy feed. The extra feed fed in the energy treatment saved 0.23 lb of hay per day and resulted in the total feed conversion of 8.08 for protein and 9.32 for energy.

If 3 lb of high energy, 13 percent protein feed had cost more than one-third the cost of 1 lb of 40 percent protein feed, however, it would not have been economical.

Introduction

A constant program for evaluating rations for just-received cattle is a part of the nutrition and health program at the Pawhuska Research Station. There is some question as to the possible benefits of feeding more energy in receiving rations to increase gains and thus reduce both feed and overhead costs. See "Protein vs Energy in Receiving Diets for Stocker Cattle" also found in this publication.

Experimental Procedure

Ninety-nine yearling steers averaging 475 lb were assembled on the Oklahoma City market and shipped to Pawhaska on September 10, 1981. The cattle were divided into two nutritional treatments. Both groups were started on free-choice native grass hay plus 2 lb per day of a 40 percent protein pellet. After 10 days one group had the 40 percent protein pellet reduced to 1 lb per day, and the other group was changed to receive 3 lb per day of a 13 percent protein energy pellet. Pellets were fed twice daily, and cattle had access to grass hay at all times. The pellet composition is given in Table 1.

On arrival the cattle were handled as outlined in OSU Fact Sheets 9102 and 9103 and OSU RP-9104. After 25 days on test, the cattle were weighed after 12 hours without feed or water.

Table 1. Composition of experimental supplements

	Supplement type	
	Protein	Energy
Ingredients, %		
Soybean meal	90.80	13.00
Corn	0.00	84.96
Dicalcium phosphate	2.75	1.00
Salt	3.00	1.00
Vitamin A-30000 I.U./G	0.11	0.036
Cottonseed hulls	1.75	
Calcium carbonate	1.50	
Trace mineral	.10	
Protein, %	40.00	13.00

Table 2. Animal performance

	Daily supplement	
Feed	2# 40% ——> 1# 40%	2# 40% ——> 3# 13%
Days	25	25
Number of animals	50	49
Initial weight, lb	473	476
Final weight, lb	504	505
Average daily gain, lb	1.24	1.18
Average daily hay, lb	8.50	8.27
Average daily concentrate, lb	1.40	2.60
Total daily feed, lb	9.90	10.87
Feed per lb gain	7.98	9.21
Percent sick once	60.00	54.00
Percent sick twice	2.00	4.00
Percent dead	0.00	2.00

Results and Discussion

Daily gains were not improved by adding extra energy feed during the last 18 days of the receiving period. This is somewhat surprising because it is usually presumed that cattle respond in gain to extra energy (Table 2).

Since most of the sick cattle (95 percent) were detected as sick at first processing, this problem could not be attributed to nutritional treatment. The cattle responded well to the treatment procedures listed in OSU-RP-9104. The poor response of calves to extra energy added to a grass hay diet was similiar to responses in other reports.

Effect of Lasalocid on Weight Gains of Stocker Steers

D. R. Gill, E. J. Richey,
F. N. Owens, and K. S. Lusby

Story in Brief

Seventy-one yearling steers (399 lb) were fed fed 2 pounds per day of a 10 percent protein pellet containing 0 or 50 mg of lasalocid per pound. Cattle were grazed on native pasture for the grazing season. Daily gain was greater for steers fed lasalocid (2.17 vs 2.34 lb) for a 7.8 percent response from the drug. No coccidiosis problems were observed in this trial.

Introduction

Lasalocid is a polyether ionophore antibiotic related to monensin which may help control coccidiosis and acidosis in cattle. In previous tests with stocker cattle at this station, benefits to coccidiostats have been observed in some studies (Rust et al., 1981). In feedlot cattle, lasalocid appears to improve efficiency while not depressing feed intake to the extent observed with monensin (Davis, 1978). Little information is available on dose level for this drug. The level selected for this test should be adequate for coccidia control with lightweight cattle.

Experimental Procedures

Seventy-one 399-pound yearling steers were assembled at the Oklahoma City market and shipped to Pawhuska in April, 1981. Processing procedures were as outlined in OSU Extension Fact Sheets 9102, 9103 and 9104. The cattle were placed in eight drylot pens for about a week before being asigned to one of two pasture groups. Four lots were assigned as controls and four lots as the lasalocid group. Cattle received 2 pounds per day of a 10 percent protein pellet (Table 1).

Table 1. Composition of experimental supplement

Ingredient	Percent
Soybean meal	5.00
Salt	3.00
Ground milo	47.00
Dicalcium phosphate	1.50
Vitamin A-30000/G	0.10
Ground corn	43.40
Lasalocid premix	(a)

(a) control = none; treatment = 50 miligrams per lb.

The cattle were rotated among pastures to remove pasture effects. The cattle were pastured for 97 days and weighed following a 12-hour period without feed or water.

Results and Discussion

Lasalocid increased weight gains of these lightweight yearlings by 7.8 percent. These differences in weight gain (Table 2) were significant ($P<.05$).

Table 2. Pasture weight gain

Treatment	Control	Lasalocid
Days	97	97
Number of steers	35	36
Initial weight, lb	401	397
Final weight, lb	608	628
Average gain, lb	211	227
Average daily gain, lb	2.17	2.34

All of the cattle in this experiment were in good health when allocated to treatment, and no differences in sickness were observed. No signs of coccidiosis were seen in any of the animals. The response to lasalosid, 7.8 percent, is similiar to that reported with monensin on similar cattle. All animals consumed their feed containing lasalocid readily from the start of the trial. The lack of feed rejection with 50 milligrams of lasalocid per pound is encouraging.

Literature Cited

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Compudose — A Long-Lasting Implant for Pastured and Feedlot Steers

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Story in Brief

Compudose implants, new long-lasting growth stimulants, were administered to steers in two trials. Implants were solid or coated with the active ingredient estradiol; coated implants ranged from .25 to 1.5 in. in length. The first trial had three periods—suckling (140 days), grazing (120 days) and feedlot (139 days). Implants were administered at the start of the suckling phase. Gains were not significantly increased during the first two periods, but during the feedlot period, gains were increased 11.7 percent, and feed efficiency was improved a mean of 7.4 percent with 1-in. coated Compudose implants. The second trial was divided into two periods—grazing (104 days) and feedlot (84 days). Implants were administered at the start of the grazing period. Pasture gains were not significantly increased during the grazing period. On the average, implants increased rate (3.6 percent) and efficiency (5.7 percent) of gain during the feedlot period. Combining trials, Compudose implants increased rate and efficiency of gains during the feedlot period of steers implanted 104 to 260 days earlier. Coated implants with a length of 1 in. gave the greatest response. These data indicate that the implants worked very well. This new concept shows promise of improving the efficiency of beef production.

Introduction

Commercially available growth promoting implants effectively increase rate and efficiency of gain in cattle. Responses in weight gain are restricted to the period of release of drug from the implant, usually 75 to 100 days. To maintain beneficial effect of implants beyond 100 days, reimplantation is necessary.

A new implant (to be marketed under the trade name COMPUDOSE by Elanco Products Division of Eli Lilly Company) has been developed. This implant has several advantages: 1) release of compound from the surface is controlled to prevent any burst effect and to reduce the chance of side effects due to implant crushing, and 2) the active hormone is estradiol 17-beta, a naturally-occurring estrogen.

Compudose is an implant with greater longevity. The hormone is released uniformly for up to 400 days. To test these implants, calves were implanted in two trials, and gain and efficiency were measured during subsequent grazing and feeding periods.

Experimental Procedures

Experimental implants were constructed by mixing a nonpolymerized silicone rubber with microcrystalline estradiol 17-beta, adding catalyst and molding in long cylinders 4.7 mm in diameter. Implants were then cut to the desired length.

Implants were prepared in both solid and coated forms. The coated implant had the same outside dimension as the solid implant; however, the core of the coated implant was composed of nonmedicated silicone rubber (Dow Corning MDX-4210). The coating was .500 mm thick and had the same composition as the solid implant. Coating reduced the amount of drug which was needed in the implant. The active drug, estradiol, migrates through the silicone rubber at a constant rate. Release of compound is proportional to the drug concentration on the surface of the implant which contacts animal tissue.

The release pattern of hormone from the implant appeared to be relatively constant throughout the 399 days of this test.

Suckling phase: Trial 1

Sixty crossbred steer calves from the Kerr Foundation herd at Poteau, Oklahoma, ranging in age from 60 to 138 days, were divided on the basis of sire into one of six experimental groups. Table 1 shows the experimental treatments.

Table 1. Experimental design

Length of implant	Type	Number of steers
1.00 in.	control	10
1.00 in.	solid	10
0.25 in.	coated	10
0.50 in.	coated	10
1.00 in.	coated	10
1.50 in.	coated	10

The control implant was made of non-medicated silicone rubber (Dow Corning MDX-4210).

The calves were implanted on February 24, 1976. The cows and calves were placed on tall fescue winter pastures. Treatments were divided into two replications. One replication grazed pasture not previously grazed while the other grazed a pasture which had been grazed. Both pastures provided adequate forage. After 56 days, the cows and calves were moved to pastures containing both fescue and ladino clover. Calves were run with the cows for 140 days before weaning.

Growing phase: Trial 1

Following weaning, the cattle in trial 1 were pastured as a group for 120 days on pastures consisting of dormant fescue, fescue and ladino clover, or hybrid sudan. Pasture conditions were unfavorable due to extreme drought.

Feedlot phase: Trial 1

The cattle were trucked to Stillwater and fed in 14 pens at the Beef Cattle Center with two replicate pens per implant treatment. The diet consisted of whole shelled corn and supplement with cottonseed hulls for roughage. Rumensin was included at 30 grams per ton. The animals were fed 139 days on test, at which time the cattle were weighed after an overnight stand without feed or water. The implants were removed, and the cattle were fed for 35 additional days.

Growing phase: Trial 2

Ninety-six yearling three-way-cross (H x A) x Charolais steers were divided into six treatment groups as listed in Table 1 with 16 steers per treatment. Steers grazed native range near Arnett, Oklahoma, for 104 days.

Finishing phase: Trial 2

Steers were trucked to Goodwell, Oklahoma, and fed in 12 pens for 84 days and an additional 42 days after removal of implants. The diet was the same as used in trial 1.

Results and Discussion

The results from trial 1 are shown in Table 2.

Table 2. The effect of Compudose implants of various lengths on weight gains, trial 1

Implant length	Type	Suckling 140 days	Growing 120 days	Finishing 139 days
1.00	Control	1.94	.88	2.40
1.00	Solid	2.10	1.05	2.41
0.25	Coated	2.01	.99	2.30
0.50	Coated	1.94	.86	2.69
1.00	Coated	2.00	1.03	2.68
1.50	Coated	2.04	.97	2.48

The improvement in gain due to the implants was most pronounced in the feedlot phase. This was probably because gains during the suckling and stocker periods were restricted by drought conditions and poor pastures.

The effect of the implants on both gain and feed efficiency were measured during the feedlot phase (Table 3). Because of the long withdrawal period, weight gains are expressed as a shrunk basis, not a carcass basis as they usually are. No differences in carcass traits were apparent. Blood samples were taken 288 days after implanting and plasma estradiol 17-b levels determined using 10 control steers, 10 steers with 1.00-in. solid, and 10 steers with 1.00-in. coated implants. The results of these assays are shown in Table 4.

Table 3. The effect of various dose levels of Compudose on feedlot and gain efficiency, trial 1

Implant length	Type	Initial weight	ADG lb	ADF lb	F/G
1.00	Control	596	2.40	14.97	6.24
1.00	Solid	630	2.41	15.63	6.47
0.25	Coated	596	2.30	14.48	6.30
0.50	Coated	571	2.69	15.26	5.68
1.00	Coated	618	2.68	15.44	5.78
1.50	Coated	609	2.48	15.65	6.31

Results of the pasture and finishing periods of trial 2 are presented in Table 5. Gains were not significantly increased during either period with implants although gain and efficiency were improved by 3.6 and 5.7 percent, respectively, by implants.

Table 4. Plasma estradiol of steers, trial 1

Implant length	Type	Number of animals	Plasma pg/ml	E_2[b] SE
1.00	Control	10	1.5	0.8
1.00	Solid	10	6.8	4.4
1.00	Coated	10	4.3	1.8

Table 5. Performance of cattle, trial 2

Implant length	Type	Pasture gain, lb	Feedlot gain, lb	Total gain	Feed to gain ratio
1.00	Control	2.00	3.30	2.58	6.04
1.00	Solid	2.15	3.62	2.81	5.91
0.25	Coated	1.99	3.62	2.72	5.72
0.50	Coated	1.97	3.33	2.58	5.62
1.00	Coated	2.06	3.73	2.48	5.61
1.50	Coated	1.98	3.74	2.77	5.54

Results from these two trials have been combined for comparison in Table 6. Greatest rates of gain were for steers which received 1-in. solid or coated implants, with an average increase of 9 percent over the control implanted steers. Coated implants appeared as effective as solid implants. Efficiency of feed use was best for steers with the 1-in. coated implants. Shorter implants had less effect on performance. Increased rates of gain are usually observed with implants for pastured steers. Failure to see a response in these two trials may be attributed to the lack of available grass.

Table 6. Combined results, trials 1 & 2

Implant length	Type	Pasture gain, lb	Feedlot gain, lb	Total gain, lb	Feed to gain ratio
1.00	Control	1.72	2.85	2.02	6.13
1.00	Solid	1.88	3.02	2.19	6.09
0.25	Coated	1.77	2.96	2.10	5.92
0.50	Coated	1.71	3.01	2.06	5.79
1.00	Coated	1.80	3.21	2.21	5.70
1.50	Coated	1.88	3.11	2.14	5.97

NUTRITION— FORAGE EVALUATION

Ammoniated Wheat Straw for Wintering Beef Cows

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Story in Brief

Effects of ammoniation of wheat straw on performance and straw intake of non-pregnant, non-lactating cows in drylot were studied. Forty-eight mature Hereford cows (812 lb) grazed dormant native range pasture (treatment 1) or had ad libitum access in drylot to either untreated (treatment 2) or ammoniated (treatment 3) wheat straw. All cows were individually fed 2.1 lb/day of a cottonseed meal-based supplement that supplied .70 lb of crude protein. Ammoniation increased crude protein content and in vitro dry matter digestibility (IVDMD) of straw from 4.2 to 8.7 percent and from 40.9 to 53.9 percent, respectively. Cows on native range gained .52 lb/day and improved in body condition by about .5 units (9 point scale). Cows fed untreated straw maintained body weight and condition. Gains of cows fed ammoniated wheat straw (.40 lb/day) were similar to those of cows that grazed native range, but the cows did not improve in condition as much as cows grazing native range. Ammoniation increased intake of straw about 20 percent. Ammoniated wheat straw would be an alternative feed for wintering cows when amounts of dormant native range are inadequate.

Introduction

Large amounts of wheat straw are available as a feedstuff each year in Oklahoma. The digestibility and crude protein content of wheat straw are both low. Treatment of crop residues with chemicals can increase digestibility, voluntary feed intake and animal performance. When ammonia is the chemical used for treatment, it (1) can reduce the chemical cost of treatment, (2) can increase the crude protein content of treated residues and (3) does not pollute the environment. Effects of ammoniation of wheat straw on body weight and condition changes of cows in drylot were examined in this study.

Experimental Procedure

The trial was conducted from December 2, 1980, to January 29, 1981 (58 days), at the Range Cow Research Center, Stillwater, Oklahoma. Forty-eight (48) non-pregnant, nonlactating Hereford cows that were 5 years old and weighed 812 ± 52 lb were stratified by weight and randomly assigned to three treatments with two replications per treatment. The cows grazed dormant native range pasture (treatment 1) or had ad libitum access in drylot to either untreated wheat straw (treatment 2) or ammoniated wheat straw (treatment 3).

The wheat straw was ammoniated by the "stack method" similar to that described by Sundstφl et al. (1978). Two separate stacks of 28 large round bales per stack were ammoniated. The bales of straw (2 rows of 14 bales placed end-to-end per row) were placed on one edge of a 40 × 100 foot sheet of black plastic (.20 mm thick). The free portion of the plastic sheet was pulled over the bales, and the edges were rolled together and sealed. The ends of the stack were tied closed with nylon cord after a 0.5 inch (O.D.) black pipe had been placed in the stack. The end of the black pipe entered an empty oil drum in the middle of the stack. Anhydrous ammonia (3.7 percent w/w of straw DM) was injected into the sealed stack through the pipe. Straw was ammoniated during cool weather of the fall, and the stack remained sealed for 30 days after injection of ammonia. Untreated and ammoniated bales of straw were sampled with a forage probe immediately prior to feeding in panel-type feeders. Samples were stored in double plastic bags in a freezer until analyses were completed.

All cows were individually fed 2.1 lb/day of a supplement that contained 34 percent crude protein. Ingredient composition of the supplement is shown in Table 1. The cows were weighed after being held off feed and water for 24 h on days 0, 16, 46 and 58 of the trial and assigned a body condition score of 1 to 9 (1 = very thin, 9 = very fat) on days 0 and 58.

Table 1. Composition[a] of supplement fed to cows

Ingredient	% as-fed
Cottonseed meal	90.5
Molasses	3.1
Calcium carbonate	2.7
Dicalcium phosphate	1.2
Trace mineralized salt	2.5

[a]Vitamin A added (11,917 IU/lb of supplement).

Voluntary consumption of wheat straw by the cows in drylot was measured during days 28 through 42 of the trial. Cows were fed 11.6 g chromic oxide in their daily allotment of supplement during 10-day preliminary and 5-day fecal collection periods. Fecal samples were collected each time the cows were fed supplement and were composited across days, within cows, on an equal wet weight basis for drying at 60 C and subsequent analyses. Fecal outputs were estimated by dilution of the chromium. Yearling Hereford steers, fitted with fecal collection bags and harnesses, were used to adjust for incomplete or cyclic recovery of chromium. At the start of the preliminary period, three steers were placed in one pen of each group of cows fed untreated or ammoniated straw and were fed the same amount of chromic oxide containing supplement as the cows. Acid-insoluble ash (AIA) was used as an internal marker, and the AIA content of feces, straw, and supplement was used to calculate straw intake. Fecal AIA concentrations were corrected for fecal recovery of AIA (94.2 percent) obtained in a previous straw feeding trials with lambs. The 2**N** HCL procedure (Van Keulan and Young, 1977) was used for analysis of AIA.

Results and Discussion

Crude protein content and in vitro dry mater digestibility (IVDMD) of untreated and ammoniated straw are shown in Table 2. Crude protein content of straw DM was increased from 4.2 to 8.7 percent by ammoniation. Calculated recovery of ammonia injected into the two stacks was only 23.4 ± 3.7 percent. This is lower than the 33 percent reported by Sundstφl et al. (1978). Ammonia may have been lost through small punctures in the plastic. Punctures in plastic are an important practical problem with ammoniation by the stack method. Recovery of ammonia might be greater if lower levels of ammonia were used. The IVDMD of wheat straw was increased about 32 percent (Table 2) by ammoniation.

Table 2. Composition of untreated and ammoniated wheat straw fed to cows

Item	Untreated	Ammoniated[a]
Crude protein, % of DM	4.2	8.7
NH_3-N recovery[b], %		23.4 ± 3.7% (N = 2)
IVDMD[c], %	40.9	53.9

[a]3.7% NH_3 w/w of straw DM.

[b] $\frac{\text{Increased N content of straw in stack}}{\text{Amount of } NH_3\text{-N added}} \times 100.$

[c]In vitro dry matter digestibility.

Body weight gains and condition score changes of the cows are shown in Table 3. Cows on native range gained .52 lb/day and improved in body condition by about .5 units. Cows fed untreated wheat straw maintained body weight and condition. Rate of gain of cows fed ammoniated wheat straw in drylot was similar to that of cows that grazed native range, but the cows fed ammoniated straw did not improve in condition as much as cows grazing native range. Part of the improved condition of the range cows may have been due to the consumption of cool-season annual grasses that remained green during the extremely mild winter weather.

Digestibility and intake of wheat straw DM, calculated using AIA as an internal marker, were increased, respectively, from 65.4 to 72.8 percent and 2.48 to 2.92 percent of cow body weight by ammoniation (Table 4). These unrealistically high values are probably due to sorting of straw by the cows and consumption of straw

Table 3. Mean body weight gains and condition score changes of cows

		Drylot	
	Native range	Untreated straw	Ammoniated straw
No. of cows	16	16	16
Average daily gain, lb	.52[a]	.09[b]	.40[a]
Condition score[c]			
Initial	4.94	4.97	5.00
Final	5.42	5.02	5.12
Change	+.48	+.05	+.12

[ab]Means with a common superscript are not different (P>.05).

[c]1 to 9 scale; 1 = very thin, 9 = very fat.

Table 4. Effect of ammoniation on intake and digestibility of wheat straw by cows in drylot

	Untreated Straw	Ammoniated Straw
No. of cows[a]	15	16
Method of estimating in vivo digestibility (and/or intake of straw)		
AIA[b]		
Straw DM digestibility, %	65.4	72.8**
Straw DM intake		
lb/day	19.9	24.4**
% of body wt	2.48	2.92*
IVDMD[c]		
Straw DM digestibility[d], %	47.0	56.6
Straw DM intake		
lb/day[e]	12.3	15.1**
% of body wt	1.50	1.81**

[a]Data of 1 and 2 cows fed untreated and ammoniated straw, respectively, were deleted because of extremely high fecal AIA concentrations.

[b]Straw intake, lb DM/day = $\frac{\text{Acid—insoluble ash (AIA) in feces from straw, lb}}{\text{AIA content of straw, \% of DM}}$

[c]In vitro dry matter digestibility.

[d]Calculated from regression equation of Oh et al. (1966): In vivo DMD, % = 16.7 + .74 (IVDMD).

[e]Straw intake, lb/day = $\frac{\text{Fecal output (lb) corrected for Cr recovery and indigestibility of supplement}}{\text{1-(in vivo DMD/100)}}$

**P<.01.
*P<.05.

containing less AIA than the samples of straw obtained with the forage probe. Failure to account for AIA content of refused feed has been identified (Block et al., 1981) as a problem where AIA is used as a marker. This was not possible in the present study where cows had ad libitum access to large round bales of straw in panel-type feeders.

Intakes of straw, calculated from in vivo DMD estimates from IVDMD values, were 1.50 and 1.81 percent of body weight (Table 4). Irrespective of which procedure was used to estimate straw intake, ammoniation increased intake of straw (percent of body wt) about 20 percent. This value agrees with other studies (Horton and Steacy, 1979; Saenger et al., 1981) with ammoniated crop residues.

Results indicate that ammoniated wheat straw is an alternative feed for wintering cows when amounts of dormant native range are inadequate.

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Effect of Source of Supplemental Crude Protein on Intake and Digestibility of Wheat Straw by Lambs

D. W. Pace, G. W. Horn and C. L. Streeter

Story in Brief

Thirty lambs with a mean initial weight of 85 lb were housed in individual pens and fed untreated chopped wheat straw free choice and either soybean meal (SBM), dehydrated alfalfa pellets (DEHY) or harvested wheat forage in amounts to supply .13 lb of supplemental crude protein per day. Straw dry matter (DM) intake was greatest for lambs supplemented with SBM (1.26 percent of body weight). Intake of straw by lambs fed DEHY (1.12 percent of body weight) was slightly lower than lambs fed SBM. Supplementation with wheat forage decreased ($P<.05$) straw consumption as compared with lambs supplemented with SBM and DEHY. Total feed intake was highest for lambs supplemented with DEHY. Dry matter digestibility of wheat straw was 37.2, 36.4 and 49.2 percent, respectively, for lambs supplemented with SBM, DEHY and wheat forage. The decreased straw consumption of lambs supplemented with wheat forage would be of concern in situations where an abundant supply of straw or other low-quality roughage was to serve as the base of the feeding program. In these situations, supplemental protein should enhance intake and utilization of the low-quality roughage.

Introduction

Effects of protein supplementation in increasing consumption and digestibility of low-quality roughages by ruminants are well known. While oil seed meals such as cottonseed and soybean meal are commonly used as sources of supplemental protein, high-protein forages may also be used. Wheat forage commonly contains 25 to 30 percent crude protein (DM basis). Utilization of wheat forage to supplement low-quality roughages would be particularly appropriate since large amounts of wheat pasture are grown on the southern Great Plains. The objective of this study was to determine the effect of three sources of supplemental crude protein (soybean meal, dehydrated alfalfa and wheat forage) on intake and dry matter digestibility of wheat straw by lambs.

Experimental Procedure

Thirty wether and ewe lambs with a mean initial weight of 85 lb were randomly assigned, within sex, to three treatments. The lambs were housed in individual pens and had free-choice access to chopped wheat straw. Supplements of either soybean meal (SBM), dehydrated alfalfa pellets (DEHY) or wheat forage were fed to supply .13 lb crude protein per day. Amounts of wheat forage that were fed were adjusted daily according to dry matter and crude protein analyses of the forage. The wheat straw contained 4.3 percent crude protein and had an in vitro dry matter digestibility of 37.4 percent. Dicalcium phosphate, limestone, trace mineralized salt and vitamins A and D were added to the supplements to fulfill daily requirements. Wheat forage was harvested in early April with a small pull-type flail harvester. After harvesting, the forage was placed in large plastic bags (about 25 lb/bag), excess air was removed and the bags were sealed. The bagged forage was stored in a walk-in freezer at -2° C and fed as needed during the trial.

Samples of wheat straw and the three sources of supplemental protein were collected daily and composited over 5-day intervals during the trial for chemical analysis. The trial included a 10-day preliminary period for the lambs to adapt to the diets and a 13-day period in which straw consumption was measured. Total fecal excretion of five lambs per treatment was measured during the last 5 days of the trial by use of fecal collection bags.

Dry matter (DM) digestion coefficients of wheat forage and dehydrated alfalfa were obtained by feeding an additional five lambs per supplement for a period of 10 days with total fecal output collected the last 4 days. The supplements were fed at a level of 1.6 percent of body weight. The TDN value of 81 percent (NRC) was used as the DM digestion coefficient of SBM. Straw dry matter digestibility was calculated by "difference" (Schneider and Flatt, 1975).

The data were analyzed by analysis of variance procedures. Duncan's multiple range test was used to test differences among treatment means for significance.

Results and Discussion

Dry matter and crude protein content and dry matter digestibility of the three supplements are shown in Table 1. The wheat forage was harvested at the three-joint, pre-boot stage of maturity. Its crude protein content and digestibility were therefore lower than that of wheat forage grazed during the "normal" November 15 to March 15 grazing period.

Table 1. Dry matter and crude protein content and DM digestibility of supplements

	Source of supplemental crude protein		
	Soybean meal	Dehydrated alfalfa pellets	Wheat forage
Dry matter, %	88.1	91.4	23.6
Crude protein, % of DM	47.7	16.9	20.7
Dry matter digestibility, %	81.0[a]	60.1[b]	64.5[b]

[a]From TDN value of SBM of 81% (NRC).
[b]From lamb digestion trial.

Total DM intake expressed as a percentage of body weight is presented in Figure 1. Dry matter consumption from supplements was greatest for lambs fed DEHY (.89 percent of body weight) followed closely by wheat forage (.74 percent of body weight). Soybean meal DM intake was only .32 percent of body weight. Straw DM intake (Table 2) was greatest (1.26 percent of body weight) for lambs fed soybean meal. Intake of straw by lambs fed DEHY (1.12 percent of body weight) was slightly lower than lambs fed SBM. Supplementation with wheat forage decreased ($P<.05$) straw consumption as compared with lambs supplemented with SBM and DEHY. Total feed intake was highest for lambs supplemented with DEHY.

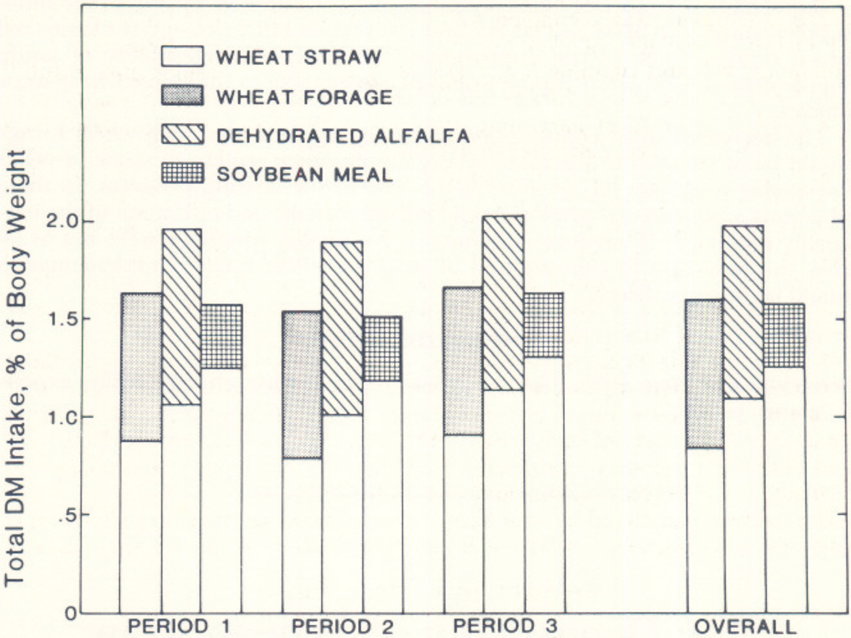

Figure 1. Total DM intake. Period 1, 2 and 3 relate to days 11-15, 16-20 and 21-23 of the 23-day trial. Overall is days 11-23.

Table 2. Feed dry matter (DM) intake and DM digestibility of wheat straw

	Source of supplemental crude protein		
	Soybean meal	Dehydrated alfalfa pellets	Wheat forage
Supplemental crude protein, lb/head/day	.13	.13	.13
Lamb weights, lb			
Initial	85.9	86.3	84.1
Final	83.5	85.2	83.3
Feed DM intake			
Supplement, lb/day	.27	.76	.62
Wheat straw			
lb/day	1.06[a]	.96[a]	.70[b]
% of body wt	1.26[a]	1.12[a]	.84[b]
Supplement plus wheat straw, % of body wt	1.58[a]	2.02[b]	1.59[a]
Straw DM digestibility, %	37.2[a]	36.4[a]	49.2[b]

[ab]Means in the same row with different superscripts are different ($P<.05$).

Digestibility of straw DM (Table 2) was similar (37.2 and 36.4 percent) for lambs supplemented with SBM and DEHY and was highest (49.2 percent) for lambs fed wheat forage. Some of the improvement in straw DM digestibility of lambs supplemented with wheat forage would be attributable to the lower wheat straw intakes.

The decreased straw consumption of lambs supplemented with wheat forage would be of concern in situations where an abundant supply of straw or other low-quality roughage was to serve as the base of the feeding program. In these situations, supplemental protein should enhance intake and utilization of the low-quality roughage. If adequate amounts of low-quality roughage were not available, the reduction in consumption of straw by wheat forage supplementation would be of less concern.

Literature Cited

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The Digestibility of Wheat Straw After Being Ensiled with Alfalfa or Wheat Forage

W. A. Phillips and L. C. Pendlum

Story in Brief

The addition of wheat straw to wheat forage prior to ensiling increased the initial dry matter content and the amount of dry matter lost during storage. Even though the silage made of wheat forage and straw (DCS) lost more dry matter during storage, there was still more dry matter present in the silo at the time of feeding than with direct cut silage (DC). DCS silage was less digestible than DC silage. Wilting wheat forage to 43 percent dry matter before ensiling decreased dry matter digestibility (DMD). The amount of dry matter lost during ensiling and the DMD were greater for alfalfa silages than for wheat forage silages. Wilting alfalfa forage or adding wheat straw prior to ensiling decreased DMD of the silage. Wheat straw DMD was significantly decreased when added to alfalfa forage but was increased when added to wheat forage.

Introduction

There is good probability that less grain will be fed to beef cattle in the future as a result of increased demand for corn and sorghum for other purposes and higher prices for these grains. It will be necessary to provide increased amounts of digestible energy for beef production from forages to replace the grains presently used. The southwestern U.S. is fortunate to be able to utilize small grain forages as pasture during the fall and winter months to grow stocker calves. At the end of the wheat pasture stockering phase, perennial grass species adapted to this area are available to continue an adequate rate of gain, but as the amount of rainfall decreases during the summer months and the maturity of the species increases, daily gains will decline. In order to continue an adequate rate of gain, high quality harvested forages are necessary. These harvested forages can be employed at the beginning of the stockering season before adequate supplies of wheat forage are available or during periods of snow cover when wheat forage is unavailable. They can also be used to continue growth if the grain option is selected in March.

Harvesting available forages as a silage affords the producer the opportunity to completely mechanize the harvesting, storage and feeding system; to decrease the probability of the loss of the forage due to climatic conditions; and to store the forage in a very stable form. Some forages have too high a moisture content to be ensiled as direct cut silage at the time of cutting and must be field wilted prior to ensiling. This allows the plant to continue to respire and consume the most desirable plant components. An alternative means of increasing the dry matter content without increasing the time period from cutting to ensiling would be beneficial. The objective of this study was to determine what effect the addition of wheat straw to direct cut silage as a means of increasing the dry matter would have on dry matter digestibility and ensiling losses.

Materials and Methods

Wheat forage in the soft dough stage of maturity and alfalfa forage at .1 bloom were harvested on separate dates and ensiled in 55-gallon containers that were lined with plastic bags. Approximately one third of the forage was ensiled immediately after harvesting and designated as direct cut silage (DC). Another third was allowed to wilt (W) before ensiling while the remaining forage was blended with chopped wheat straw before ensiling (DCS). Thus, two methods of increasing the dry matter content of the forage were used. The dry matter content of DC forage was anticipated to be approximately 30 percent. The W silage was allowed to wilt and the DCS contained enough straw to increase the dry matter content to 40 percent. Actual dry matter percentages are shown in Table 2. Wheat straw made up 21 and 22 percent of the total silage dry matter for wheat and alfalfa silages, respectively.

Twelve crossbred steers weighing 517 lb were used in six digestion trials to determine the digestibility of each of the different silages. Two digestion trials were used to establish the digestibility of the concentrate supplement fed with the silages and of the wheat straw which was used to formulate the DCS treatment. Only three silages from the same forage source were fed within a trial, and two trials were conducted for each forage source. Total dry matter consumption was limited to 1.5 percent of body weight. The silage and concentrate supplement were fed in a 2:1 ratio twice daily. The composition of supplements used for wheat and alfalfa-based silages is presented in Table 1. The digestion trials consisted of a 2-day transition, a 7-day preliminary period and a 5-day collection period. Animals were blocked according to weight, and treatments were randomly assigned for each trial with the restriction that no animal would receive the same treatment twice. Data were analyzed as a randomized block design within each trial.

Table 1. Composition of concentrate supplements

Ingredients	Forage source	
	Wheat	Alfalfa
Corn	71.0[a]	76.2
Soybean meal	8.6	——
Molasses	14.0	16.9
Mineral[b]	6.4	6.9

[a]Percentage of dry matter.
[b]Minerals mix was 25% dicalcuim phosphate and 75% trace mineralized salt.

Results and Discussion

The initial and final dry matter content of the six silages used in this study are presented in Table 2. They were determined by drying a sample of each silage at 150 F for 72 hours. The initial dry matter content of DC forages was higher than anticipated and was within an acceptable range (35-45 percent) for ensiling; thus, after wilting or having wheat straw added, the W and DCS silages were drier than planned. The dry matter percentage of the wheat forage after either wilting or adding wheat straw was 4.2 and 7 percentage units greater than DC. A more drastic shift in the dry matter percentage was noted for the alfalfa silages. Again the DC forage was drier than anticipated, and the addition of wheat straw increased the dry matter percentage by 7.3 units, similar to the DCS wheat forage. The wilted silage (W) was much drier than calculated.

Table 2. The dry matter and crude protein content of the different silages and the amount of dry matter lost during ensiling

Item	Forage source					
	Wheat			Alfalfa		
	DC	DCS	W	DC	DCS	W
Dry matter, % ;[a]						
Initial	38.7	45.7	42.9	34.5	41.8	51.4
Final	35.0	42.4	39.1	27.8	31.4	41.3
Dry matter lost, %[a]	6.8[b]	11.6[c]	10.3[c]	20.3[b]	26.0[c]	21.1[bc]
Crude protein content, %[a]	9.4	8.4	9.0	17.9	15.1	18.6

[a]Expressed as a percentage of the dry matter.
[b,c]Means in the same row and forage source with different superscripts are different (P<.05).

The final dry matter content was determined at the time of feeding, which was 18 months after ensiling. This was an unusually long storage period, but harvested forages used in a stocker program may be harvested one year and not fed until one to two years later, depending on the needs of the system. There was a significant decline in dry matter content during the ensiling and storage period as organic acid, water and carbon dioxide were produced by the microorganism metabolizing the plant components. Each silo was weighed at the time of ensiling and at the time of feeding. By multiplying the weight of the silage by the dry matter percentage, the amount of dry matter in the silo initially and after the 18-months storage period was determined. As anticipated, the amount of dry matter in the silo at the time of feeding was less than at the time of ensiling. These losses are expressed as a percentage of the initial dry matter present at the time of ensiling and are presented in Table 2.

Wilting the wheat forage or adding wheat straw prior to ensiling significantly increased the amount of dry matter lost during ensiling and storage. Alfalfa forage silage lost more dry matter than wheat forage silage. The addition of wheat straw increased the amount of dry matter lost, but wilting was not significantly different from DC or DCS silage. Differences in the amount of dry matter lost are a reflection of fermentable substrates if it is assumed that the initial population of microorganisms was the same within a forage source (Edwards et al., 1978). Wilting of the forage reduced the amount of soluble carbohydrates through plant respiration while adding wheat straw diluted the soluble carbohydrate source. Crude protein content was similar among treatments and lowest for the DCS silages.

The dry matter digestibility (DMD) of the total ration of wheat straw forage plus the concentrate supplement was significantly reduced when wheat straw was added or the forage was wilted prior to ensiling (Table 3). The DMD of the concentrate supplement was determined in a separate trial using corn silage as the forage source and was used to calculate the silage DMD presented in Table 3. Wilting the wheat forage from 38.7 percent dry matter to 42.9 percent prior to ensiling decreased the DMD of the forage. It was anticipated that the addition of wheat straw would result in a lower DMD since the wheat straw used in these trials had a DMD of 48.5 percent prior to its addition to the wheat or alfalfa forage. Assuming that the wheat forage in the DCS silage was as digestible as W silage, the digestibility of the wheat straw fraction of the DCS silage was 56 percent. This was a 15.4 percent improvement in the DMD of the wheat straw as a result of being ensiled with DC wheat forage.

Table 3. Digestibility of the total ration and the silage component

		Replication					
		1			2		
Forage	Digestibility	DC	DCS	W	DC	DCS	W
Wheat	Ration dry matter	66.60^{a}	61.16^{c}	64.02^{b}	66.19^{a}	62.18^{b}	63.10^{b}
	Silage dry matter	69.63^{a}	60.61^{b}	65.29^{ab}	69.02^{a}	62.27^{b}	63.79^{b}
Alfalfa	Ration dry matter	68.78^{a}	62.66^{b}	67.07^{a}	68.01^{a}	62.8^{b}	67.05^{ab}
	Silage dry matter	74.92^{a}	64.60^{c}	71.85^{b}	74.13^{a}	64.26^{c}	72.34^{b}

a,b,c Means in the same row and replication with different superscripts are different ($P<.05$).

Wilting of alfalfa forage prior to ensiling did not significantly decrease the DMD of the ration, but the addition of wheat straw did. The DMD of the supplement fed with the alfalfa based rations was also determined in a separate trial using corn silage as the forage source. After accounting for the DMD contributed by the supplement, both W and DCS silages had a lower DMD than DC silage. The DMD of the wheat straw component of the DCS silage was calculated to be 37 percent. This was a decrease in DMD of 23 percent. The addition of wheat straw to alfalfa forage resulted in a lower DMD of the wheat straw component than when it was added to wheat forage. The combination of a highly digestible dietary component with one of low digestibility will decrease the digestibility of the latter. Given a limited amount of time for digestion of fibrous material by the rumen microorganisms, the priority by which digestion occurs is based on susceptibility. Since alfalfa DC silage is more digestible than wheat DC silage, it is more susceptible. Thus, less time was alloted for digestion of the wheat straw.

From these data it would appear that ensiling wheat or alfalfa forage as direct cut silage at 39 and 34 percent dry matter, respectively, will result in a silage that is more digestible than when the forage is wilted prior to ensiling. The addition of wheat straw to wheat forage prior to ensiling increased the DMD of the wheat straw by 15 percent, but a decrease of 23 percent was noted when alfalfa forage was used. If silage storage space does not limit how much wheat forage is harvested as silage, then it would be advantageous to add wheat straw at the time of ensiling to increase the DMD of the wheat straw. If storage space is limited, more digestible dry matter would be realized if the straw is mixed with wheat silage at the time of feeding.

Literature Cited

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Calibration of a Near Infrared Reflectance Spectrometer for Prediction of Forage Quality

S. W. Coleman, F. E. Barton, II
and R. D. Meyer

Story in Brief

In order for near infrared (NIR) reflectance spectroscopy to be used to estimate forage quality, the instrument must first be calibrated using a set of samples of known chemical composition. Regression analysis is used to develop a relationship (calibration equations) between one or more of the wavelengths and the chemical or quality component in question. Seventy-six "Old World" Bluestem samples, collected in 1974-75, were used to calibrate the instrument. Chemical data determined near the time the samples were collected could not be used for calibration purposes after the samples had aged either because of changes in composition or erroneous laboratory determinations. Coefficients of determination were increased when the samples were reanalyzed chemically within a few weeks of the time the spectral data were collected. Those with significant differences between "actual" determination and that "predicted" by NIR were reanalyzed a third time and the new data entered into the calibration file. This procedure

improved the agreement between NIR spectra and chemical analysis. Another study indicated that the width of the derivative segment of the spectral data may influence calibration for some constituents. Further, 40 samples selected at random do not appear to be enough to calibrate the instrument. Calibration equations derived from small sample sets tend to be dependent on the sample set and do not have general applicability.

Introduction

Near infrared (NIR) reflectance spectroscopy has been suggested as a method that will decrease the time for laboratory analyses of chemical components of forages used as quality indices (Barton and Coleman, 1981). Ultimately the technique may be capable of predicting the animal performance potential of forages. Previous research suggests that calibration data must be obtained from forages similar in taxonomy, age, location grown, environment, etc., to those being predicted, rather than using data from one kind of forage to develop a general prediction equation which would work for all kinds of feeds and forages. Several variables appear to influence the suitability of calibration data and the resulting equations used to predict quality. Some of these are age of samples, number of samples, accuracy of chemical analysis, derivative segment width of the NIR spectral data and the number of wavelengths (λ) chosen. The purpose of these experiments was to characterize the effects of certain variables on the calibration of NIR spectrometers.

Experimental Procedures

Samples of 5 "Old World" Bluestem (OWBS) varieties (Plains, Caucasian, B,L, and T blends) were collected over two growing seasons (1974 and 75). The samples were oven dried and ground in a Wiley Mill[1] to pass through a 1 mm screen. Between the years 1976-78 the samples were analyzed for dry matter (DM), ash, crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), permanganate lignin (PML), and in vitro dry matter disappearance (IVDMD) by a modified Tilly and Terry procedure.

In 1981, a random subset of the samples was reground with a Udy[1] cyclone grinder fitted with a 1 mm screen and packed into sample cups approximately 5 cm in diameter by 1 cm thick and sealed with foam-filled poster board backing. Seventy-six of the samples were scanned with a NIR spectrometer through a range of wavelengths from 1100-2500 nm. Reflectance spectra containing 700 data points were smoothed and derivatized (2nd derivative). Chemical analyses, conducted from 1976-78, were regressed on to the spectral data using stepwise linear multiple regression procedures. Statistical comparisons between actual and predicted values were conducted.

Chemical components of the samples were routinely determined a second time, and the new chemical data were subjected to statistical analysis with the original spectra. Chemical components were "predicted" using the spectral data, and samples with "predicted" values deviating by more than two standard deviations from chemical determination were reanalyzed a third time. A third data set, identical to the second data set except for replacement of aberrant chemical values by the new chemical values, was reanalyzed statistically.

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[1]Mention of trade name, proprietary product of specific equipment does not imply its approval to the exclusion of other products that may also be suitable.

The 76-sample subset plus 24 other samples from the same large data set were randomly divided into two subsets of 40 and 60 samples each. Prediction equations were derived from each set, and the reciprocal set was used as a "blind" comparison to test effect of samples' set size and the derivative segment width on calibration equations derived from regression analysis and their relative usefulness for predicting the chemical components in question.

Results and Discussion

The NIR spectrum as log(1/reflected energy) for two diverse samples is presented in Figure 1. Note obvious differences in the absorbance of the two samples from 1100-1300 nm (lignin), 1500 nm (fiber). 1940 nm (water), 2150 nm (protein), 2200 nm (fiber) and 2350 nm (carbohydrates). However, several physical factors, such as fineness of grind may shift the entire spectrum vertically, thus precluding its usefulness as a predictor. To overcome these nonchemical problems, the spectrum may be normalized by derivative spectroscopy. The first derivative depicts the slope of the various peaks, and the second derivative (Figure 2) depicts the rate of change of the slope of the peak. Compound peaks

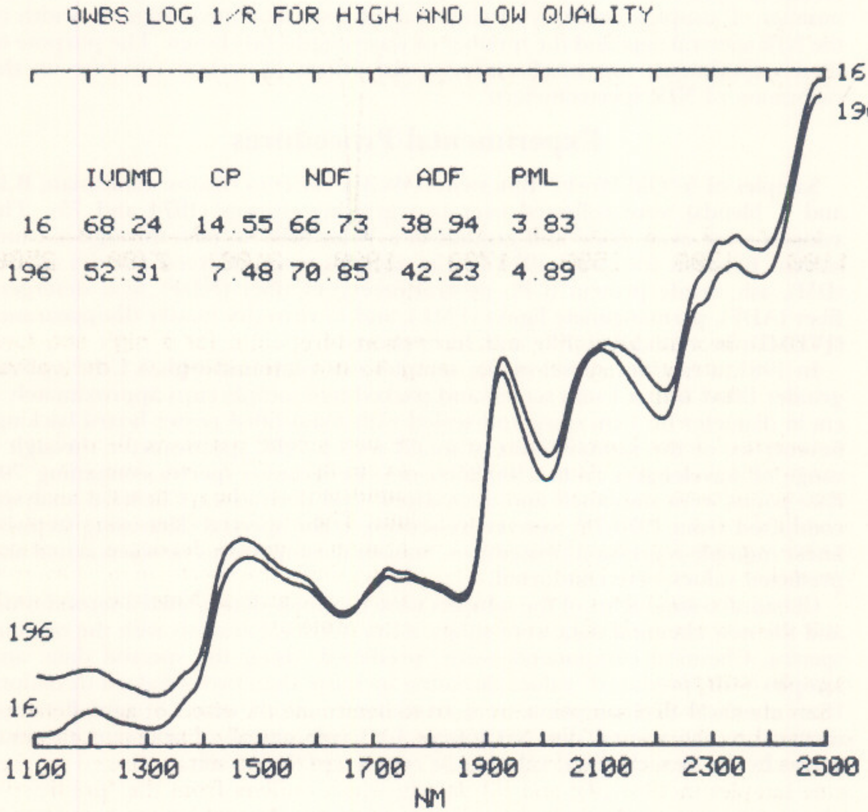

Figure 1. Log (1/Reflectance) spectra for a high and low quanity forage sample

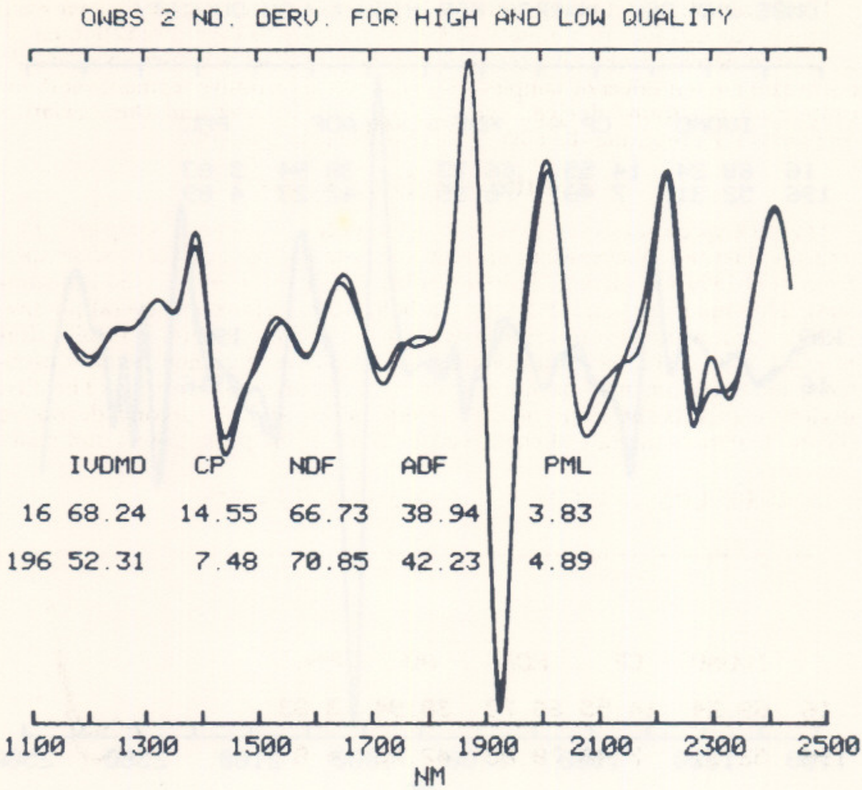

Figure 2. Second derivative transformation of spectra for a high and low quality forage sample using 36 nm smoothing and derivative function

comprised of several overlapping peaks require second derivative treatment to deconvolute the peak. The spectrum is made up of 700 data points at 2nm intervals. To overcome "noise" which is accumulated with the spectra, the curve is smoothed using a running average technique. The number of data points taken in each segment for smoothing and derivatization influences the degree to which the peaks are resolved. Figure 3 shows a second derivative spectrum in which the derivative segments were half as wide as those in Figure 2. Note the increased number of peaks in the 2100-2200 nm range (protein).

Age of sample

Seventy-six OWBS samples were used to determine the effect of age of chemical data on calibration of the NIR (Table 1.) Three sets of calibration data were obtained: (1) chemical data collected 3-5 years ago (I); (2) data collected on the same samples in 1981 (R); and (3) data in which outliers from the "predicted" value were two standard deviation units from the "actual," were reanalyzed chemically and were then added to the calibration data file (C). Only the "actual" means of crude protein and ADF were not changed appreciably by one or more

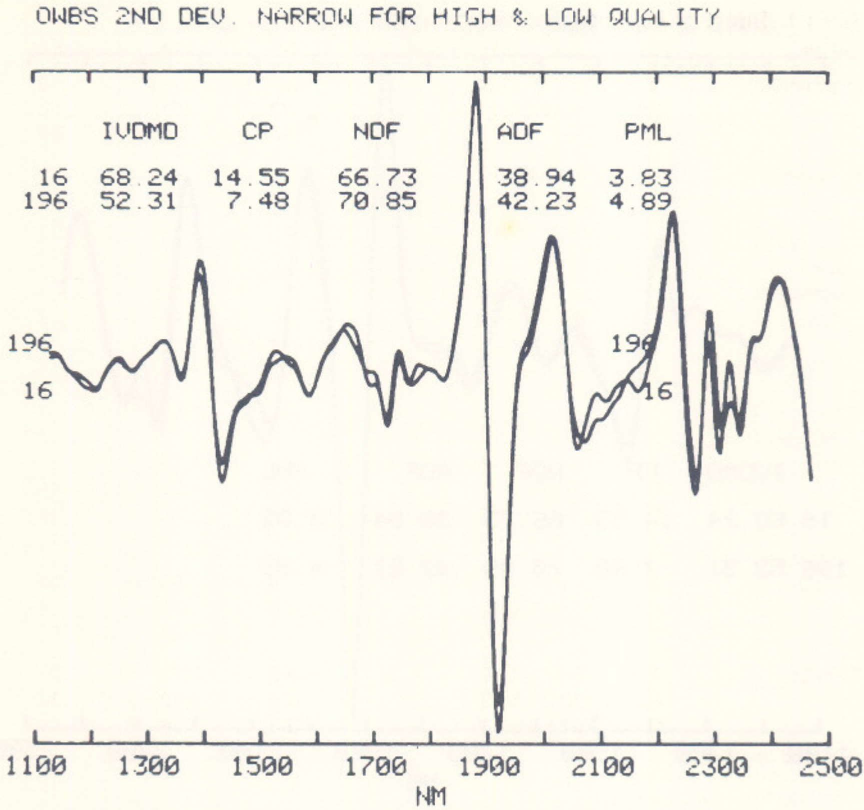

Figure 3. Second derivative transformation of spectra for a high and low quality forage sample using narrow (18 nm) smoothing and derivative function

of the reanalyses. In all cases except IVDMD, R^2 was higher and standard error of calibration lower in data sets R and C compared to 1. It appears from these data that some chemical constituents change with time, but location and reanalysis of probable "error" samples resulted in more consistent improvement in calibration. Further, NIR may be used to detect inaccurate chemical data in a sample set. In every case where predicted vs actual values did not agree, the reanalysis proved the NIR to be more correct. The final equations (C) appear to be satisfactory to predict quality components of OWBS. However, they must be tested against a "blind" set to see if the equation will predict the chemical constituents of samples not included in the calibration data set.

Effect of sample set size and derivative segment width

Results for calibrating the NIR for dry matter (100-moisture) produced mixed results (Table 2). Unpublished results from our lab showed that variations in moisture of 1-2 percentage units occurred due to variations in time the samples spent in the dessicator after oven drying. In our estimate, oven drying samples is

Table 1. Effect of lab data on calibration

Analysis	Run	Mean ± SD[a]	#λ's[b]	R^{2c}	SEC[d]	Repeat[e]
Dry matter	I[f]	93.3±1.82	3	.63	1.11	.03
	R[g]	95.3±1.16		.73	.61	.06
	C[h]	94.7±1.06		.84	.43	.02
Protein	I	12.2±1.96	3	.84	.80	.03
	R	12.4±2.00		.87	.71	.04
	C	12.3±2.01		.94	.49	.05
Neutral detergent fiber	I	67.7±3.12	5	.65	1.86	.16
	R	68.2±2.91		.73	1.52	.08
	C	67.6±2.71		.82	1.15	.27
Acid detergent fiber	I	38.8±2.55	3	.63	1.55	.10
	R	38.6±2.95		.81	1.27	.25
	C	38.8±2.90		.87	1.04	.09
Permanganate lignin	I	4.9±1.14	3	.38	.90	.05
	R	3.7±1.23		.66	.71	.01
	C	3.7± .87		.61	.54	.01
IVDMD	I	60.4±4.10	3	.68	2.33	.21
	R	60.2±5.78		.65	3.40	.33
	C	62.5±3.34		.83	1.36	.11

[a]Standard deviation.
[b]Number of wavelengths used in equation.
[c]R^2 = Coefficient of determination.
[d]SEC = Standard error of calibration.
[e]Repeat = Repeatability error.
[f]I = File data several years old.
[g]R = Samples were all reanalyzed routinely.
[h]C = Samples from R which were statistical outliers were reanalyzed and the new data were incorporated into the file.

not sufficiently accurate to calibrate the NIR for dry matter. For this reason, the Karl Fisher method is being investigated by the national USDA-NIR project.

Calibration and prediction data for crude protein is presented in Table 3. The best prediction equation was obtained with the 60 samples and 36 nm (wide) derivative segment. A slight bias (.18 percent) did occur when the predicted values of the 40 samples were compared to the actual wet chemistry values. It might be noted that agreement between actual and predicted values was better for crude protein than the fiber components or IVDMD. The reason is that crude protein measures a distinct chemical entity whereas fiber and IVDMD are not chemically defined. The lowest bias was found with the narrow (18 nm) derivative segment though the standard error of prediction (.65) was higher, and the coefficient of determination (R^2 = .88) was lower than that for the wide derivative segment. The standard errors are similar to those for multiple runs of the same samples in the laboratory.

Table 2. Effect of sample number and derivative width on calibration and prediction of dry matter

File	Function	#λ's[a]	Bias[b]	SE[c]	R^{2d}	Repeat[e]
OWBS60W[f]	Calibrate	3	—	.61	.74	.04
OWBS40	Predict		.79	1.05	.84	—
OWBS60N[g]	Calibrate	3	—	.58	.76	.14
OWBS40	Predict		.15	.70	.81	—
OWBS40W	Calibrate	2	—	.45	.88	.01
OWBS60	Predict		−.58	1.16	.32	—
OWBS40N	Calibrate	2	—	.44	.89	.05
OWBS60	Predict		−.38	1.18	.24	—
OWBS100W	Calibrate	3	—	.64	.74	.04
OWBS100N	Calibrate	2	—	.70	.69	.10

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

Table 3. Effect of sample number and derivative width on calibration and prediction of crude protein

File	Function	#λ's[a]	Bias[b]	SE[c]	R^{2d}	Repeat[c]
OWBS60W[f]	Calibrate	3	—	.46	.97	.04
OWBS40	Predict		.18	.57	.96	—
OWBS60N[g]	Calibrate	2	—	.52	.96	.10
OWBS40	Predict		−.05	.65	.88	—
OWBS40W	Calibrate	3	—	.53	.93	.04
OWBS60	Predict		.33	.71	.94	—
OWBS40N	Calibrate	3	—	.51	.92	.09
OWBS60	Predict		−.09	.62	.95	—
OWBS100W	Calibrate	3	—	.49	.96	.04
OWBS100N	Calibrate	2	—	.57	.95	.10

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

Neutral detergent fiber (NDF) (Table 4) is one of the more difficult parameters for which to calibrate the NIR because it is not a single chemical entity but represents both the hydrolyzable and non-hydrolyzable cell wall components. As such, the NIR attempts to predict total cell wall components including carbohydrate (pentose and hexose chains), lignin and residual protein, most of which we cannot measure chemically with any degree of accuracy. Bias was approximately half as large using 60 samples to calibrate and 40 to predict than when the reverse was used. Both 18 and 36 nm derivative width gave similar results. Five wavelengths significantly contributed to the calibration equation for the 60-sample set, but may result in "overfitting" the data.

Table 4. Effect of sample number derivative width on calibration and prediction of neutral detergent fiber

File	Function	#λ's[a]	Bias[b]	SE[c]	R^2[d]	Repeat[e]
OWBS60W[f]	Calibrate	5	—	1.06	.89	.19
OWBS40	Predict		.57	1.67	.60	—
OWBS60N[g]	Calibrate	5	—	1.10	.88	.26
OWBS40	Predict		.65	1.44	.67	—
OWBS40W	Calibrate	3	—	1.13	.75	.16
OWBS60	Predict		−1.04	2.21	.64	—
OWBS40N	Calibrate	3	—	1.09	.77	.19
OWBS60	Predict		−1.47	2.44	.63	—
OWBS100W	Calibrate	3	—	1.38	.77	.22
OWBS100N	Calibrate	4	—	1.19	.83	.24

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

The best calibration equation to predict ADF (Table 5) was from 40 samples using the wide derivative segment. ADF appears easier to calibrate for than NDF. Further, the range of ADF in the 40 samples may be more representative of the 100-sample population than the 60 samples. No differences were observed in calibration errors with the wide and narrow derivative segments, but predictions were better when the wide derivative segment was used. This would suggest that broad, smooth peaks, including some combinations, may be best for parameters which are not well defined chemically.

Permanganate lignin (Table 6) contained little variation from which to predict; therefore, R^2 was quite low. Bias and standard errors were also low. However, general observation of individual predicted vs actual values would suggest the prediction may be about as good as the chemical determination.

Although IVDMD (Table 7) is not a chemical component, several chemical components have a bearing on its magnitude. Therefore, with a combination of wavelengths, it is possible to predict IVDMD. The R^2 value was not as high as with other constituents, and it appears that the narrow derivative segment might be more beneficial than the wide. Bias was high, but the IVDMD procedure itself

Table 5. Effect of sample number and derivative width on calibration and prediction of acid detergent fiber

File	Function	#λ's[a]	Bias[b]	SE[c]	R^2[d]	Repeat[e]
OWBS60W[f]	Calibrate	3	—	.94	.90	.06
OWBS40	Predict		1.00	2.00	.72	—
OWBS60N[g]	Calibrate	3	—	.96	.90	.14
OWBS40	Predict		.37	1.64	.59	—
OWBS40W	Calibrate	4	—	.73	.91	.07
OWBS60	Predict		.04	1.32	.81	—
OWBS40N	Calibrate	4	—	.74	.91	.15
OWBS60	Predict		−1.15	2.07	.77	—
OWBS100W	Calibrate	5	—	.87	.91	.09
OWBS100N	Calibrate	4	—	.98	.88	.15

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

Table 6. Effect of sample number derivative width on calibration and prediction of permanganate lignin

File	Function	#λ's[a]	Bias[b]	SE[c]	R^2[d]	Repeat[e]
OWBS60W[f]	Calibrate	3	—	.49	.73	.03
OWBS40	Predict		.04	.67	.63	—
OWBS60N[g]	Calibrate	3	—	.46	.75	.08
OWBS40	Predict		−.06	.67	.38	—
OWBS40W	Calibrate	4	—	.49	.68	.06
OWBS60	Predict		.15	.70	.56	—
OWBS40N	Calibrate	4	—	.49	.68	.14
OWBS60	Predict		.51	.97	.42	—
OWBS100W	Calibrate	3	—	.55	.66	.04
OWBS100N	Calibrate	5	—	.51	.71	.09

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

Table 7. Effect of sample number and derivative width on calibration and prediction of in vitro dry matter disappearance

File	Function	#λ's[a]	Bias[b]	SE[c]	R^{2d}	Repeat[e]
OWBS60W[f]	Calibrate	3	—	1.53	.86	.07
OWBS40	Predict		−1.94	2.75	.76	—
OWBS60N[g]	Calibrate	3	—	1.73	.82	.16
OWBS40	Predict		−.80	1.58	.78	—
OWBS40W	Calibrate	3	—	1.02	.88	.16
OWBS60	Predict		.63	2.32	.73	—
OWBS40N	Calibrate	4	—	1.08	.86	.29
OWBS60	Predict		−1.81	2.98	.67	—
OWBS100W	Calibrate	3	—	1.45	.85	.20
OWBS100N	Calibrate	5	—	1.38	.87	.43

[a]Number of wavelengths used in the equation.
[b]Difference in mean of "actual" and "predicted" values.
[c]SE = Standard error of calibration for calibrate; standard error of the difference of actual vs predicted for predict.
[d]R^2 = Coefficient of determination.
[e]Repeat = Repeatability error.
[f]W = Wide derivative segment — 36 nm.
[g]N = Narrow derivative segment — 18 nm.

can only be used for ranking taxonomically similar plant samples and not for widespread comparisons across sample types and plant ecotypes.

These data would suggest that different smoothing and derivative segment widths are desirable for predicting different plant constituents. The classical method for selecting derivative width is to take the interval width of a peak at half its height. Computer programs for instruments in the national NIR project are presently being written to arrive at the proper width for each constituent.

The number of samples required for calibration appears to be greater than 40 for most chemical constituents. Even when the set of 40 gave the best equation, the equation may be sample set dependent and may not be of general value for predicting other OWBS data sets. Samples used for calibration should be scanned with the NIR instrument as soon as possible after the chemical laboratory analysis is obtained. These data indicate that changes in the samples may take place over a period of time which affect the relationship between NIR spectra and laboratory chemical data.

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Brassica and Beet Crops as Potential Livestock Feedstuffs

U. G. Bokhari and F. P. Horn

Story in Brief

A number of Brassica crops such as kale, turnips, rape, swede and beets were studied in 6 × 9 m plots during the 1979 and 1980 growing seasons to evaluate their forage potentials and nutritive values. Dry matter yield varied from a minimum of 2321 lb/A to a maximum of 8661 lb/A. Average protein concentration ranged from 17 to 22 percent in leaves and from 8 to 19 percent in roots while dry matter digestibility ranged from 71 to 82 percent in the leaves and from 47 to 91 percent in the roots.

Introduction

In many European countries, Brassica crops are an important and integral component of the grazing system, especially for sheep grazing (Greenhalgh et al., 1977). These crops can provide abundant forages for livestock during periods when most of the warm or cool season grasses are not available. Brassica and beet crops are low in dry matter but high in protein and carbohydrate contents, with highly digestible dry matter. When blended with grain crops or grasses, these crops can fill in some of the gaps in the grazing system in Oklahoma and other adjacent states.

This study was undertaken to study the forage production potentials, nutritive characteritics and growth habits of Brassica crops under central Oklahoma conditions.

Materials and Methods

Seeds of kale, rape, turnips, swede and beets were planted in 6 × 9m plots during the 1979 and 1980 growing seasons in replicated and completely randomized plots. The soil at this site at the USDA-Research Station in El Reno is classified as Dale fine silty, mixed, thermic, pachic haplustolls with a pH of approximately 6.6. At the time of each planting, 35.7 lb N/A and 71.4 lb P/A was applied as a top dressing. Samples for dry matter, crude protein, total nonstructural carbohydrates (TNC), in vitro dry matter digestibility (IVDMD) and neutral detergent fiber (NDF) determination were taken at frequent time intervals during each of the two growing seasons. Samples were taken from a 2-foot row in the center of each plot. Plants were separated into roots and shoots except the first samplings which had not yet developed a sizable root system. Samples were weighed, dried at 70 C for 72 hr and reweighed.

Crude protein was determined by Kjeldahl N × 6.25. In vitro dry matter digestibility was determined by the two-stage technique of Tilley and Terry (1963) as modified by Monson et al. (1969). Total nonstructural carbohydrate was determined by the method described by Smith (1969).

Results and Discussion

Brassica crops produced dry matter yield ranging from 2321 lb/A to 8861 lb/A during the 1979 and 1980 growing seasons (Tables 1, 2). Contribution to the total dry matter yield was over 50 percent by leaves and 37 to 45 percent by roots. All the Brassica crops were very low in dry matter content, ranging from 8 to 13 percent in leaves and from 15 to 23 percent in the roots. However, the roots and leaves of these crops were very high in TNC and protein contents, respectively (Tables 3, 4). In pure stands, Brassica crops may not be able to provide sufficient dry matter for growing animals. Blending grain crops or grasses with Brassica or beet crops could compensate for their low dry matter contents, and the latter will compensate for the low concentration of protein and carbohydrates in grasses.

Both leaves and roots were quite high in IVDMD (Table 5). In leaves IVDMD ranged from 71 to 82 percent and in roots from 47 to 91 percent. At the same time, the roots of these crops contained higher amounts of TNC (Table 3) than their corresponding leaves. Except for polyeura beets, the leaves of the rest of Brassica crops contained relatively higher amounts of NDF than the roots (Table 6). In leaves NDF ranged from 18 to 25 percent and in roots from 18 to 28 percent.

Many of the Brassica crops were found to be less tolerant to the drought condition during the 1980 growing season. Mako and Marco turnips and Perko and Fora rape were relatively more drought tolerant than the rest of the crops. One of the major problems, especially during hot summer months in Oklahoma, appears to be susceptibility of these crops to hosts of insects and other parasitic diseases.

During 1981, we established three pastures of equal size (0.95 hectare) of three types of turnips (purple top, Sirius and Marco) and allowed pregnant cows to graze these under a 12-hr observation period for about 3 weeks. At the beginning, for about 1 week cows preferred to graze pig weed and then began to graze

Table 1. Dry matter yield (lb/acre) of different types of Brassica and beet crops during 1979 growing season

Type	Date	Roots	Leaves	Leaves & roots
Fora rape	July 2	—	—	3790
	July 20	2314	3610	5920
	Aug. 15	2058	3415	5473
Perko rape	July 2	—	—	3238
	July 20	2063	3334	5396
	Aug. 15	1878	2263	4136
Marco stubble turnip	July 2	—	—	3611
	July 20	2111	2975	5086
	Aug. 15	1906	2339	4246
Rova turnip	July 2	—	—	5074
	July 20	2046	3406	5453
	Aug. 15	1906	2415	4321
Polyeura beet	July 2	—	—	3660
	July 20	2303	2866	5170
	Aug. 15	832	2638	3471
	Sept. 17	3778	1427	5205

Table 2. Dry matter yield (lb/acre) of different types of Brassica crops during 1980 growing season

Type	Date	Roots	Leaves	Leaves & roots
Grummer kale	May 27	—	—	2690
	June 26	301	2870	3171
	July 10	2280	1447	3728
Mako turnip	May 27	—	—	5509
	June 26	2658	6008	8667
	July 10	2613	2729	5342
Marco stubble turnip	May 27	—	—	6887
	June 26	2011	6246	8257
	July 10	2946	3153	6099
Texi summer turnip	May 27	—	—	6165
	June 28	339	7796	8136
	July 10	2896	2190	5330
Sirius turnip	May 27	—	—	8055
	June 26	255	2351	2606
	July 10	1401	1563	2959
Perko rape	May 27	—	—	6542
	June 26	294	7168	7463
	July 10	1691	896	2588
Silona rape	May 27	—	—	8162
	June 26	698	6669	7367
	July 10	—	—	—
Marrow stem kale	May 27	—	—	4355
	June 26	1921	5432	7354
	July 10	—	—	—
Fora rape	May 27	—	—	6662
	June 26	455	5426	5879
	July 10	—	—	—
New Zealand sensitive swede	May 27	—	—	4708
	June 26	230	2133	2363
	July 10	—	—	—
Doom Major swede	May 27	—	—	7896
	June 26	339	3459	3798
	July 10	—	—	—
Mako summer turnip	May 27	—	—	6854
	June 26	614	7380	7994
	July 10	—	—	7994

turnips. Our observations indicated that cows would pull out the whole plants, discard the leaves and utilize the root system more efficiently. At the time cows were allowed to graze these crops the leaves had become very brittle and full of tiny epidermal hairs. At an earlier stage, leaves were not as brittle and were more palatable. We have been able to establish Brassica crops during spring and late fall. These two periods appear to be more critical in the grazing system in much

Table 3. Total nonstructural carbohydrates (TNC) in Brassica and beet crops during 1980 growing season

	%	
Type	Roots	Leaves
Fora rape	30.86	8.58
Perko rape	30.35	12.93
Marco turnip	32.0	9.56
Mako turnip	32.13	12.37
Polyeura beet	39.05	8.73

Table 4. Crude protein percent in the roots and leaves of Brassica and beet crops during 1979 and 1980 growing season

	1979		1980	
Type	Roots	Leaves	Roots	Leaves
Fora rape	8.18	17.06	11.12	22.32
Perko rape	7.88	17.41	10.55	20.15
Marco turnip	12.85	18.18	18.75	20.87
Rova turnip	13.67	18.11	—	—
Mako turnip	—	—	16.38	22.35
Polyeura beet	9.93	18.14	—	—

Table 5. In vitro dry matter digestibility of Brassica and beet crops from 1979 growing season

Type	Roots	Leaves	Leaves & roots
Fora rape	46.9	81.8	64.9
Perko rape	70.5	74.2	69.0
Marco turnip	74.5	71.2	71.2
Rova turnip	75.6	82.2	82.6
Polyeura beet	90.8	79.5	90.1

Table 6. Neutral detergent fiber (NDF) in Brassica and beet crops (percent dry weight) during 1980 growing season

Type	Roots	Leaves
Fora rape	19.07	20.44
Perko rape	20.56	25.08
Marco turnip	18.70	25.00
Mako turnip	17.94	18.40
Polyeura beet	27.81	22.62

of Oklahoma when warm season or cool season grasses are not available. Brassica crops can fill in these two gaps if properly managed and blended with grain crops, especially in the fall.

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Forage Potentials of Legume-Interseeded Pastures

U. G. Bokhari

Story in Brief

Old World Bluestems (Bothriochloa sp.) pastures of five cultivars were overseeded with lespedeza and alfalfa during the 1979 and 1980 growing season. There was a significant increase in dry matter production of lespedeza overseeded pastures as compared to the control treatment during 1979, but in 1980, due to severe drought, the legume contribution was relatively insignificant. All the Old World Bluestems cultivars were found to be very poor utilizers of photosynthetically active radiation.

Introduction

Old World Bluestems (Bothriochloa sp.) or "Asiatic Bluestems" are very productive and nutritionally acceptable grasses in much of Oklahoma and the adjacent states. Two varieties of Old World Bluestems, "Plains" and "Caucasian," and a number of experimental blends have been found to be very high yielding, relatively drought tolerant and winter hardy (Ahring et al., 1978). These grasses respond to high fertility levels and can tolerate both acid and alkaline soils. As a result of increasing cost of fertilizer materials, it is imperative to search for alternative sources of nutrients, especially nitrogen. Legumes that are otherwise compatible with these grasses need to be studied to evaluate their contribution to the nitrogen economy of a grass legume system. This study was untertaken to understand the interactions between Old World Bluestems and legumes in terms of compatibility and the effect of legumes on productivity under dry land conditions.

Materials and Methods

Ten replicated pastures containing two replicates each of "Plains" (B. Ischaemum L. Keng.), "Caucasian" (B. caucasica C. E. Hubb.) and three blends, experimentally designated as "B," "L," "T" (B. intermedia var. indica), were divided into three subpastures of equal size. One of the subpastures under each variety or blend was overseeded with lespedeza (lespedeza stipulacea. Maxim.) in March, the second was fetilized at a rate of 67 pounds N/ha and the third was the untreated control. The same procedure was followed during the 1980 growing season with the exception that the untreated control of 1979 was overseeded with alfalfa (Medicago sativa L.) variety "Cody."

Samples for dry matter determination were taken from at least five 0.25 M^2 quadrates from each subpasture. Aboveground plant materials from each quadrate were separated into grass and legume species, dried at 70 C for 48 hr and weighed.

Photosynthetic conversion efficiency of Old World Bluestems was determined by first converting the dry matter biomass into Kcal/ha on the basis of 4.7 K cal/g·dr·wt, and then dividing this by incoming solar irradiance. The latter was measured with Lamda Corporation Quantum Sensor, Model LI-188.

Results and Discussion

All cultivars produced more aboveground dry matter under fetilization or lespedeza overseeding, as compared to the untreated control, during the 1979 growing season (Table 1). The fertilized and lespedeza overseeded pastures of "Plains" produced significantly higher yield than the rest of the cultivars. The two

Table 1. Old World Bluestem production (pounds/A) during 1979 growing season

		Varieties/Blends				
Date harvest	Treatment	Plains	Caucasian	"B"	"L"	"T"
June	Control	2291	2971	3441	3388	2609
	Fertilized	4873	4478	3767	4012	2198
	Lespedeza overseeded	5052	4149	2300	3582	2428
August	Control	2130	3251	2222	3559	2928
	Fertilized	4767	5584	4175	5502	4205
	Lespedeza overseeded	5093	3486	2797	2675	3389
Season total production	Control	4497	6222	5664	6947	5538
	Fertilized	9640	10062	7942	9513	6404
	Lespedeza overseeded	10145	7903	5097	6257	5817

Table 2. Percent contribution by lespedeza and fertilization to the total forage production during 1979

Treatment	Plains	Caucasian	"B"	"L"	"T"
Control					
Fertilized	53	38	28	27	13
Lespedeza overseeded	55	18	−11	−11	4

blends, "B" and "L," produced less dry matter from the lespedeza overseeded pasture than that of the untreated control. The increase in dry matter production from the lespedeza overseeded pasture is not due to increase in the dry matter productivity of Old World Bluestems but is merely a result of additional plant biomass of the legume community. Legumes contributed 55, 18 and 4 percent to the total dry matter production of "Plains," "Caucasian" and "T" blend respectively (Table 3). There was no evidence of direct transfer of symbiotically fixed nitrogen from the legumes to the companion plants of the grass species. Legumes' contribution to nitrogen economy of plant communities could be made through decomposition of legume residues as well as through below ground root and nodule biomass. When some of the lespedeza plants were brought from the field to the laboratory for determination of their N_2-fixation potentials, it was found that most plants were able to fix about 53 to 70 pounds N/ha·year. Partial analysis of samples for protein determination indicated increase in crude protein from 12 percent in the untreated control pasture to 15 percent in the lespedeza overseeded pastures.

Fertilized pastures produced 53, 38, 28, 27 and 13 percent more dry matter from the "Plains," "Caucasian," "B," "L" and "T" pastures than the untreated control, respectively (Table 2). In this case the increase in dry matter could be attributed directly to nitrogen fertilization. The data from the 1980 growing season are not conclusive as a result of very droughty conditions (Table 2), which

Table 3. Old World Bluestems production (pounds/A) during 1980 growing season

		Varieties/Blends				
Date harvest	Treatment	Plains	Caucasian	"B"	"L"	"T"
June	Fertilized	3024	3522	2158	2757	2430
	Lespedeza overseeded	1951	2648	1917	2053	2057
	Alfalfa overseeded	1672	2741	2134	2778	2110
July	Fertilized	3977	5965	3854	3479	2875
	Lespedeza overseeded	2733	4098	2385	3321	2462
	Alfalfa overseeded	3316	3689	2802	3369	2438
August	Fertilized	3646	4718	3195	6063	3713
	Lespedeza overseeded	3182	4661	2130	2599	2482
	Alfalfa overseeded	3236	4544	2571	3213	3017
Season total production	Fertilized	10638	14205	9208	12298	9018
	Lespedeza overseeded	7867	11407	6429	7973	7001
	Alfalfa overseeded	8224	10974	7503	9361	7564

affected legumes more adversely than the grasses. Like many other warm season grasses, Old World Bluestem cultivars were found to be very poor utilizers of solar energy (Table 4). Peak solar energy conversion efficiency was exhibited during July and August, which also coincided with the peak aboveground biomass. More work should be done on genetic manipulation of these grasses to increase their photosynthetic efficiency.

Table 4. Solar energy conversion-efficiency (%) of Old World Bluestems

	Species/blends					
Time	Plains	Caucasian	"B"	"L"	"T"	Avg.
May-June	0.48	0.48	0.34	0.53	0.28	0.42
July-August	1.52	1.50	1.12	1.33	1.22	1.33
Sept.-Oct.	0.13	0.23	0.16	0.16	0.25	0.18
Average	0.71	0.73	0.54	0.67	0.58	0.64

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Evaluation of Legumes in Micro Plot Studies

U. G. Bokhari

Story in Brief

Different types of legumes planted in 20 x 30 ft micro plots indicated that they can be integrated into local grazing systems which will provide adequate dry matter during spring, summer and fall. Dry matter digestibility was high at early growth stages but in some cases declined towards the end of the growing season.

Introduction

Certain types of legumes adapted to particular soil and climatic conditions will benefit farmers in a number of ways depending upon the specific purpose for which the legumes, are included in any farming operation. Generally, almost all types of legumes, if interseeded into an otherwise compatible grass pasture, will improve forage quality, extend grazing period and improve gain of livestock on a per animal or per acre basis. Compatability of legumes with companion plants, persistence of legumes under grazing and N_2-fixation in a sward are some of the problems associated with a grass-legume system. This study was undertaken to study adaptation, growth and some nutritive characteristics of a number of legumes under field conditions in micro plots.

Materials and Methods

Seeds of the following legumes were planted in March-April in 20 x 30 ft plots at 1-ft row spacing. All the seeds were inoculated with appropriate rhizobia before planting.

- Alfalfa (Medicago Sativa L.): varieties, "Cody" and Spreador II (Spreador II was supplied by Northrop King Seed Co.)
- White clover (Trifolium repens L.): variety, "Louisiana S-1"
- Hairy vetch (Vicia villosa (RELL.) HERMANN)
- Korean lespedeza (lespedeza stipulacea Maxim.)
- Sericea lespedeza (lespedeza cuneata (DUMONT) G. DON)
- Birdsfoot Trefoil (lotus corniculatus L.)
- Arrowleaf (Trifolium vesiculosum L.)

Each type was replicated three times in a completely randomized block design. The soil at this site is classified as Dale Fine Silty, mixed, thermic, pachic haplustolls with a pH of approximately 6.6. Urea fertilizer at the rate of 26.8 lb/acre was applied as top dressing before planting and again in October at the same rate. The soil at this site contained less than 4.5 lb of nitrate nitrogen per acre. Average monthly temperature (C°) and precipitation (CM) data are given in Table 3.

Samples for dry matter and IVDMD determination were taken from a 2-ft row in the center of each plot at monthly intervals from April to November. At the same time, soil cores containing whole plants were taken from each plot and brought to the laboratory for acetylene reduction using Perkin Elmer gas chromatograph 990.

Results and Discussion

Dry matter productivity of different types of legumes is given in Table 1. Except for lespedeza, B. F. Trefoil and Arrowleaf, all the other legumes exhibited peak productivity during July. Both types of lespedeza had two distinct peaks during July, September and November. Among the different types of legumes which were planted at the same time, lespedeza (Korean type), B. F. Trefoil and Arrowleaf continued producing new growth in December and may do so during the subsequent months.

Except for hairy vetch, none of the roots of the rest of the legumes were nodulated in June. The slow growth during the initial stage could be attributed to poor nodulation and almost negligible N_2-fixation. However, almost all the legumes were found nodulated during their subsequent growth, which resulted in increasing productivity during the late growth period.

Preliminary analysis of N_2-fixation potentials indicated that about 53 to 160 lb N/acre was fixed by these legumes.

There was a gradual decrease in IVDMD of all the legumes towards the end of the growing season (Table 2) except for white clover and Arrowleaf. Both types of lespedeza had lower IVDMD throughout the growing season than the rest of the legumes tested. Among all the legumes, maximum IVDMD of 78 percent was recorded for white clover and 70 percent for Arrowleaf in September. Minimum digestibility of 30 percent was recorded for Sericia lespedeza in October. Both

Table 1. Dry matter production (pounds/acre) of legumes during 1981 growing season

Species/variety	Date harvest					
	June	July	Aug.	Sep.	Oct.	Nov.
Alfalfa, Cody	2565	3092	1719	1783	1918	609
Alfalfa, Spreader II	3371	3223	2136	1967	2246	572
White clover, Lousiana S-1	697	3030	1983	3313	1501	3290
Hairy vetch	5464	5581	3425	3679	2929	—
Lespedeza (Korean)	1468	6762	6131	16478	—	—
Lespedeza (Sericia)	413	4710	3830	8809	6905	—
B. F. Trefoil	1643	4480	4255	4253	4289	12180
Arrowleaf, Yuchi	2108	7619	4584	7149	9485	19826

Table 2. In vitro dry matter digestibility of legumes during 1981 growing season

Species/variety	Date harvest				
	June	July	Aug.	Sep.	Oct.
Alfalfa, Cody	61.02	59.53	54.50	54.32	47.58
Alfalfa Spreader II	64.48	54.02	58.39	56.49	46.19
White clover, Lousiana S-1	60.66	72.55	63.08	78.68	74.82
Hairy vetch	57.66	68.32	50.92	69.73	51.68
Lespedza (Korean)	55.27	52.12	51.31	49.39	—
Lespedza (Sericia)	44.11	40.41	46.62	35.30	30.06
B. F. Trefoil	64.46	60.36	51.27	60.52	46.42
Arrowfeaf, Yuchi	63.86	69.77	64.00	70.05	58.34

types of alfalfa were high in IVDMD during June and low during October. Samples were not taken during the early growth from April to June due to slow and inconsistent growth of these legumes. Digestibility may be somewhat higher at earlier growth periods.

This preliminary data indicated that legumes of different species planted even at the same time will provide adequate green materials throughout the summer and early fall, and maybe during late fall, if planted at different times during early spring or late fall. There is a great potential for these legumes in our local grazing system if integrated with other small grains and grasses. Spacing planting dates according to types of legumes will also help extend the grazing season through much of the winter, spring and summer.

Most of these legumes except lespedeza are usually planted in September-October, depending on the moisture situation, and will provide adequate materials for grazing during winter and spring.

Table 3. Average monthly precipitation (cm) and temperature (C°) during 1981 growing season

	J	F	M	A	M	J
Temperature (C)	3.3	5.8	11.4	19.7	19.1	26.6
Precipitation (cm)	0.36	2.24	6.78	4.37	10.69	16.41
	J	**A**	**S**	**O**	**N**	**D**
Temperature (C)	29.5	26.1	23.5	15.1	10.2	5.1
Precipitation (cm)	6.71	11.25	7.21	17.12	2.62	0.56

Digestibility of Hays from Improved Selections of Old World Bluestems

I. Londoño, L. J. Bush,
D. G. Wagner and P. L. Sims

Story in Brief

The digestibility of various nutrient components of hay from four selections of Old World bluestems was compared in a feeding trial with lambs. Digestibilities of all four varieties, WW-506, WW-573 (WW Spar), WW-474 and WW-517, were similar and relatively high considering that the hays were obtained after seed had been harvested from the grasses.

Introduction

Development of improved types of grasses that are well adapted to the climatic conditions and soils of this area is very important to the economy of Oklahoma. From a collection of over 750 accessions of Old World bluestems mainly by Harlan et al. (1958, 1961), several varieties have been developed that have potential as productive pasture grasses in the semi-arid regions of the Southern Great Plains. With proper management, these can be used to renovate deteriorated native range and marginal cropland areas.

Characteristics considered in selection of ecotypes for potential use include adaptability to soil type, drouth resistance, winter hardiness, disease and pest resistance, ease of establishment, yield and quality of forage produced. Horn and Taliaferro (1979) made an assessment of the seasonal changes in the nutritive value of five selected varieties of Old World bluestems, including "Plains" and "Caucasian." There was a downward trend in in vitro dry matter digestibility as the season progressed, but not as great as is seen in most grasses. Crude protein declined with season, yet was high enough that protein supplementation of grazing cattle would rarely be needed during the growing season. Digestibilities of dry matter in hays made from the same varieties were similar, although differences among cuts during the growing season were sizeable (Horn and Jackson, 1979). All the hays were relatively high-quality forages.

During the last few years, information has been obtained at the Southern Plains Range Research Station at Woodward, Oklahoma, indicating considerable potential for some selections of Old World bluestems which are being considered for release to seed producers. Included in the comparisons on yield, voluntary consumption by cattle and weight gains by grazing cattle are "Caucasian" and WW Spar bluestem, a selection within the group of accessions used to develop "Plains" bluestem (Dewald et al., 1981). Weight gains of steers grazing WW Spar were equal or higher than those of steers grazing other varieties being tested. Gains of steers fed hay from stands harvested for seed were higher than for other varieties, indicating forage of relatively high nutritive value. However, the nutritional characteristics of such forage have not been studied extensively, especially with respect to relatively mature forage from which seed has been harvested.

In cooperation with Southern Plains Range Research Station, Woodward, OK.

Old World bluestem seed is in great demand; therefore, one can expect that considerable forage residue or hay made after seed harvest will be available. Little is known about the nutritional characteristics of such material and the differences that might exist among genetic lines of these forages. Therefore, the objective of this study was to evaluate the in vivo digestibility of four varieties of Old World bluestem hay baled after seed had been harvested, using lambs as test animals.

Materials and Methods

Mature hay was made from four varieties of Old World bluestem after seed was harvested in July of 1980 at the Southern Plains Range Research Station at Woodward, Oklahoma. The varieties compared in a digestibility trial using young lambs were:

Variety	Scientific name
WW-506	Bothriochloa ischaemum var. sengarica
WW-573 (WW Spar)	Bothriochloa ischaemum var. ischaemum
WW-477	Bothriochloa ischaemum var. sangarica
WW-517	Bothriochloa intermedia var. indica

Each hay was chopped and fed to each of 16 lambs in sequences of a replicated 4X4 Latin Square design. Experimental periods were 2 weeks, with 8 days for adjustment to rations and 6 days for collection. Hay was fed twice daily in sufficient quantity to allow some feed refusal in most instances. Soybean meal (75g per head per day) was added to assure adequate protein intake for maintenance. A mineral supplement containing 13-15 percent calcium, 7 percent phosphorus, and 30-36 percent salt was fed(10g per head per day) to assure adequate intake of these minerals. In addition, a trace mineral supplement was available for ad libitum consumption.

Feed refusals and total feces collections were made once daily. Representative samples of all feed, feed refusals and feces were analyzed for dry matter, crude protein, acid detergent fiber (ADF) and neutral detergent fiber (NDF).

Results and Discussion

As expected, the crude protein content of the hays was somewhat low because they were harvested after seed harvest (Table 1). In comparison, protein content of hays harvested three times during the growing season from Old World bluestem plots at the Southwestern Livestock and Forage Research Station (SLAFRS) at El Reno, Oklahoma, was substantially higher in most instances (Horn and Jackson, 1979). Nevertheless, cows fed hay with a crude protein content of 6.1 to

Table 1. Chemical composition of Old World bluestem hays[a]

Variety	Crude protein	Acid detergent fiber	Neutral detergent fiber
	(%)		
WW-506	6.7	45.6	74.0
WW-573[b]	6.6	44.0	72.8
WW-474	7.0	43.6	70.8
WW-517	6.1	44.3	73.4

[a]Dry matter basis.
[b]This variety released as WW Spar Old World bluestem.

7.0 percent, as observed in this study, would not require as much protein supplementation as those consuming some other types of dry forage available during the wintering period in Oklahoma.

Intake of the hays by the sheep was relatively low, being less than the amount needed to meet their energy requirements of maintenance (Table 2). During the 8-wk trial, average weight loss was 1.5 lb per lamb. Intake of dry matter averaged only 1.75 percent of body weight, probably due to its advanced stage of maturity. This was reflected in ADF values ranging from 44.0 to 45.6 percent.

Since the most likely use for hay of this type would be as an energy source under conditions where a protein supplement would be provided, digestibility of the hays was determined under similar conditions. Thus, sufficient protein, as SBM, was provided to complete protein requirements of the lambs for maintenance. This must be taken into account in interpretation of the values obtained since it has been demonstrated in other trials that supplemental protein does enhance both intake and digestibility of relatively low quality forage by ruminant animals.

Table 2. Intake by sheep during digestion trial

Variety	Dry matter	Crude protein[a]
	(g/day)	
WW-506	585	66.3
WW-573[b]	612	66.1
WW-474	601	68.4
WW-517	600	63.5

[a]Values include about 34 g/day from soybean meal supplement.
[b]Released as WW Spar Old World bluestem.

Digestibility values (Table 3) of various components of the Old World bluestem hays ranged from 59.0 to 61.4 percent for dry matter, 68.7 to 71.4 percent for crude protein, 50.9 to 54.6 percent for ADF and 58.4 to 61.0 percent for NDF. In general, all four varieties of hay were similar and relatively high in digestibility of the various nutrient components, considering the stage of maturity at harvest. The somewhat higher values for digestibility of dry matter than previously observed by scientists at the SLAFRS may be attributed to the associative effect of

Table 3. Digestibility of various components of Old World bluestem hays

Variety	Dry matter	Crude protein[a]	Neutral detergent fiber	Acid detergent fiber
		(%)		
WW-506	61.1	70.2	61.0	54.6
WW-573[b]	60.7	69.6	60.3	53.5
WW-474	61.4	71.4	60.3	52.0
WW-517[c]	59.0	68.7	58.4	50.9

[a]Values reflect high digestibility of SBM supplement; see text.
[b]Released as WW Spar Old World bluestem.
[c]Digestibility of WW-506, WW-573 and WW-474 *vs* WW-517 significantly different ($P<.002$ for DM, $< .01$ for protein and $< .02$ for ADF and NDF).

adding supplemental protein as noted above and to the fact that sheep rather than steers were used as test animals. Digestibility of Variety WW-517 was slightly and consistently lower than that of the other three varieties; however, the differences were probably not of sufficient magnitude to be of practical significance.

The high digestibility of protein (Table 3) reflects the fact that approximately one-half of the daily crude protein intake by the sheep was from soybean meal. Assuming a digestibility coefficient of 80 percent for SBM, it can be calculated that 27g of the digestible protein in the daily ration was derived from this source. Total intake of digestible protein minus that from SBM gives an estimate of 19g as the average amount of digestible protein from the hay. Thus, digestibility of protein in the forage could be estimated to be approximately 59 percent. Since SBM contributed only a small proportion of the other nutrient components in the diet, its effect on overall digestibility of those components, if any, would probably be via an associative effect.

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Gains of Stocker Cattle on Midland and Hardie Bermudagrass Pastures: A 5-Year Summary

W. E. McMurphy, G. W. Horn
and J. P. O'Connor

Story in Brief

Hardie and Midland bermudagrass have been evaluated in a 5-year grazing trial with steers. Average daily gain was 1.80 lb for Hardie and 1.61 lb for Midland. Stocking rates were adjusted to utilize available forage and averaged 2.4 steers per acre for Hardie and 2.3 steers per acre for Midland. Total beef production per acre was 636 lb for Hardie and 492 lb for Midland. These results reveal that Hardie bermudagrass produced higher daily steer gains, had a greater carrying capacity and produced more beef per acre.

Introduction

The selection and release of two new bermudagrass varieties, Hardie and Oklan, were based upon laboratory tests for forage quality. The purpose of this study was to compare these grasses with Midland bermudagrass in regard to animal performance. This report includes results of steer grazing trials conducted in 1981, plus a 5-year summary of results for 1977 through 1981.

Experimental Procedure

The trials were conducted at the Agronomy Research Station, Perkins, Oklahoma. Two blocks of pastures, containing one pasture each of the hybrid bermudagrass varieties Midland, Hardie, Oklan and SS-16 (an unreleased experimental strain), were used in a randomized complete block design. The soils were the Dougherty, Konowa and Teller fine sandy loams (Arenic Haplustafs, Ultic Haplustafs and Udic Argiustolls). Soil tests revealed that the pH was 5.7 to 6.5, and soil phosphorus and potassium were very high. Soil moisture measurements have been taken at several dates each season with a neutron moisture probe for the 1978 through 1981 seasons.

The pastures were sprigged in 1975, and grazing trials began in 1977. Each of the pastures was about 3 acres in area and was subdivided with electric fences into three paddocks to facilitate rotational grazing during the grazing trials. The rotational grazing objective was 1-week grazing of the pastures followed by a 2-week deferment. Thus, throughout most of the bermudagrass growing season, the forage was 2, and never over 3, weeks of age.

In early June of each year, when steers were rotated, each paddock was mowed to remove cool season annuals. The pastures were fertilized with 150 lb of actual nitrogen in three equal applications in early April, late June and early August.

Hereford and Hereford × Angus steers for the 1980 trial were purchased at a livestock auction in March and grazed on small grain with limited forage until the trial began. Average daily gain during this pretrial period was about 0.8 lb. Details of the steers and their management in the earlier years were reported by Horn and McMurphy (1981). The steers were assigned to treatment groups on the basis of source, breed and weight. These were the tester steers which remained on the pasture all season. Stocking rates were adjusted to utilize available forage using additional steers, put-and-take animals.

Daily gains were calculated from weight gains of steers that remained in the pastures throughout each grazing trial (tester steers). Average initial weight (mean ± SEM) of all tester steers in 1977 was 518 ± 8.4 lb; in 1978, 520 ± 6.3 lb; in 1979, 486 ± 10.9 lb; 1980, 453 ± 9.1 lb; and in 1981, 499 ± 10.1 lb.

Stocking rates on the pastures were adjusted according to the amount of available forage throughout the grazing trials by use of put-and-take steers. For calculation of total steer gain, put-and-take steers were assigned daily gains of tester steers during each period. Steer weights were measured after about a 16-hour overnight shrink without feed or water.

All 1980 and 1981 steers were implanted with Ralgro at the beginning of each trial. In previous years the steers were implanted with diethylstilbestrol. Tramisol (levamisole phosphate) was given for internal parasite control in April. Excellent fly control was achieved during each trial by spraying the steers on each weigh date, except July 1 when a pour-on insecticide for grub control was applied, and by keeping dust bags in the pastures. Steers in all pastures had access to trees or constructed shades. A commercial mineral supplement that contained 12 percent calcium and 12 percent phosphorus was fed free-choice during the trials.

Results and Discussion

Rainfall recorded at the station during the first 9 months of each year is compared with the long-term average in Table 1. This 9-month total has varied from 73 to 106 percent of the long-term average. The driest season was in 1978, and the greatest total precipitation was in 1980 although distribution of rainfall in 1980 was very poor. The 1981 season began very dry. Soil moisture was adequate only in the surface three feet, and the subsoil moisture in the fourth and fifth feet of the soil profile remained dry throughout 1981. In normal seasons it is the moisture from the lower soil profile that supports growth during short dry spells. Production in 1981 was very much dependent upon the timely precipitation which occurred. The bermudagrass did stop growth twice, once in May and again

Table 1. Seasonal precipitation (inches) for Agronomy Research Station, Perkins

Month	1977	1978	1979	1980	1981	Long-term average
January	0.22	0.92	2.11	2.14	0.05	1.53
February	1.16	2.63	0.25	0.86	1.02	1.46
March	2.50	1.46	3.80	2.39	1.66	2.20
April	2.23	1.85	3.42	4.07	1.05	3.16
May	8.46	7.28	6.83	7.57	6.92	5.09
June	1.90	4.59	3.01	8.78	4.52	4.58
July	3.15	0.90	0.42	0.05	4.89	3.45
August	2.88	0.53	1.62	1.56	5.06	3.19
September	1.77	0.49	1.94	2.88	1.93	3.81
Total	24.27	20.65	23.40	30.30	27.10	28.47

in July, and exhibited signs of severe moisture stress. Thus, while the overall grazing production results for 1981 were excellent, we were on the brink of disaster twice.

The rotation grazing was discontinued by September 5. With the slower regrowth rate in September, steers were given free access to all three paddocks in each pasture.

Details of the results for 1977 through 1980 seasons were published by Horn and McMurphy (1979, 1980, 1981). The original study included Oklan and SS-16 bermudagrass; however, these two varieties suffered enough winterkilling damage in the winter of 1978-79 that they were dropped from the test.

Average daily gains (Table 2) were highest in May and lowest in July. The differences between Hardie and Midland have not been statistically significant. The 1981 season average daily gains were 1.89 lb for Hardie and 1.54 lb for Midland. This was close to the 5-year average of 1.80 lb and 1.61 lb ($P<.05$) for Hardie and Midland, respectively.

Table 2. Average daily gains (ADG) of steers, total steer grazing days per acre, and total gain per acre for intervals in 1981 with 5 years of seasonal averages and the 5-year average

Grazing interval	Number of days	ADG, lb		Total steer days/acre[a]		Total gain/acre, lb	
		Midland	Hardie	Midland	Hardie	Midland	Hardie
4-28 to 6-2	35	2.64	3.10	76	103	199	317
6-2 to 7-2	30	1.64	1.97	88	65	144	128
7-2 to 8-4	36	0.69	1.04	122	122	85	127
8-4 to 9-2	29	1.03	1.47	72	72	75	105
9-2 to 10-7	35	1.64	1.83	65	87	106	159
1981 Season	165	1.54	1.89	422	448	609	837
1980 Season	111	1.39	1.57	245	265	351	454
1979 Season	147	1.83	1.99	381	406	658*	861
1978 Season	114	1.82	1.84	242*	259	419	487
1977 Season	153	1.45	1.73	281	313	416*	552
5-year Average	138	1.61*	1.80	315*	337	492*	636

*Indicates a significant difference ($P< 0.05$) between Midland and Hardie.

[a]Steers/acre = $\frac{\text{Steer days/acre}}{\text{No. of days in grazing interval}}$.

The average gains are a product of environment plus good animal and pasture management practices. The animal management includes selection of good steers, implantation with growth hormones, excellent internal and external parasite control, shade and mineral supplement. Pasture practices of nitrogen fertilization, proper stocking rates and rotation to provide young forage between 2 and 3 weeks of age are also factors favorable to good steer gains.

Stocking rates are expressed as steer days per acre. Dividing steer days per acre by the number of days in that interval gives a quotient of steers/acre for that interval. Thus, Hardie bermudagrass for the entire 1981 season had an average stocking rate of 2.7 steers per acre (448/165).

Producers do not have the option to adjust stocking rates as freely as in our research. The only way most producers can use this program and keep the available forage young will be with rotation grazing and hay removal at peak growth periods. Therefore, the lowest stocking rate at any grazing interval becomes an important value to a producer. A producer must not run out of forage. The lowest stocking rate for a grazing interval was 2.2 steers per acre for Hardie in June and 1.9 steers per acre for Midland in September. Thus, the base stocking rate at which a producer should attempt to operate has been about 2 steers per acre.

Total gain per acre for 1981 was 837 lb of beef for Hardie and 609 for Midland. The total gain per acre as well as the carrying capacity has fluctuated widely over the 5 years. The high production figures for 1979 and 1981 are a result of the late summer drought of the preceding years. The August fertilizer application of 50 lb of nitrogen per acre in 1978 and 1980 never received the precipitation to make it effective for production. The increased production of 1979 and 1981 may well reflect use of residual soil nitrogen from the previous years.

These results reveal excellent average daily gains in some years. The 5-year averages reveal distinct differences between Hardie and Midland bermudagrass, with Hardie being superior in total gain per acre and carrying capacity. Much of the advantage to Hardie was produced during May when Hardie had a higher carrying capacity due to its earlier and faster growth rate at that time.

The results emphasize the importance of a complete program for both steer and pasture management to provide and maintain high quality young forage for maximum animal production. There will be great fluctuations in total forage production from year to year as measured in steer days per acre. However, the minimum stocking rate of about 1.8 to 2.0 steers per acre appears to be consistent with hay removal at peak growth periods. The program is vulnerable to late summer drought in that grazing was terminated in early September in 2 of the 5 years when bermudagrass growth ceased.

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NUTRITION—FEEDLOT

Salinomycin Levels for Feedlot Steers

F. N. Owens and D. R. Gill

Story in Brief

A new feed additive, salinomycin, was fed to 140 finishing steers (initial weight of 788 lb) for 110 days. Salinomycin was fed at 0, 5, 10, 15 and 30 g per ton of an 89 percent whole shelled corn, 5 percent cottonseed hull diet. Averaged across salinomycin levels, gain was increased 9.4 percent, and efficiency of feed use was increased 7.8 percent. Feed intake was increased 1 percent by salinomycin. At the optimum drug level in this trial, 10 g per ton of feed, gain and feed efficiency were increased by 12.9 and 9.5 percent. Feces tended to be drier and contain more starch when the drug was fed. Carcass measurements were not changed by salinomycin feeding. This drug shows excellent promise for improving efficiency and rate of gain of feedlot steers.

Introduction

Feed additives of a class called ionophores have proven to increase efficiency of feed use by feedlot cattle. Monensin, lasalocid and salinomycin are three ionophores. Monensin is fed widely today, and approval for lasalocid is expected shortly. Salinomycin has been evaluated previously in one study in Virginia. In that trial, gain and efficiency increases of 21 percent for beef steers fed a 20 percent roughage diet were reported. In this trial, salinomycin was fed at five levels to finishing steers to examine its effect on rate and efficiency of gain.

Materials and Methods

Steers of mixed breeding which had commonly grazed pasture in Purcell, Oklahoma were sorted, vaccinated for bovine rhinotracheitis, leptospirapomona, bovine virus diarrhea, parainfluenza 3, blackleg and malignant edema and trucked to Stillwater. On arrival, steers were held on pasture for 3 weeks and were then divided into four weight groups. Steers within each weight group were randomly allocated to one of five pens and the five levels of salinomycin, 0, 5, 10, 15 and 30 g/ton of feed, and were randomly assigned to pens within each weight group. Cottonseed hulls and corn comprised 94 percent of the ration, with the percentage hulls in the ration sequentially decreasing from 40 to 30 to 20 to 12.5 and 5 percent at 3-day intervals at the start of the trial until the final ration (Table 1) was being fed. Steers had access to feed from self-feeders throughout the 124-day trial. Steers were weighed following withdrawal of feed and water at the start of the trial and on day 110. Other weights were taken full. Three steers were removed from the experiment due to sudden death and chronic health problems.

Table 1. Feed and pellet compositions, dry matter basis[a]

Ingredient	Percent	Pellet ingredient[b]	Percent
Corn, whole shelled	89.0	Soybean meal	57.0
Cottonseed hulls	5.0	Limestone	16.0
Pelleted supplement	6.0	Urea	7.75
		KC1	6.25
		Salt	4.75
		Alfalfa meal	4.50
		Dicalcium phosphate	3.50
		Trace minerals	0.25
		Vitamin A-30	0.18

[a]Average analysis: 90.2% dry matter, 11.8% protein, ME = 2.80 on as fed basis.
[b]0, 83, 167, 333 or 500 g active drug added per ton of pelleted supplement.

Table 2. Performance data

	Salinomycin level, g/ton					
Item	0	5	10	20	30	SE
Weight, lb						
Initial[a]	779	786	795	786	792	8.7
28 days[b]	912	907	924	922	922	12.0
56 days[b]	1002	1018	1040	1020	1021	12.0
84 days[b]	1084	1108	1128	1110	1107	14.5
110 days[a]	1121[b]	1158[ab]	1180[a]	1155[ab]	1158[ab]	14.4
124 days[b]	1177[b]	1214[ab]	1231[a]	1209[ab]	1208[ab]	14.1
125 days[c]	1169	1205	1215	1204	1190	13.9
Daily gains, lb						
0-56 days	3.08	3.23	3.44	3.27	3.18	.15
57-110 days	3.13[b]	3.54[a]	3.56[a]	3.45[ab]	3.49[a]	.11
0-110 days	3.10[b]	3.38[ab]	3.50[a]	3.36[ab]	3.33[ab]	.10
0-125 days	3.14	3.38	3.39	3.37	3.20	.07
Feed/Intake, lb/day, dry matter						
0-56 days	20.4	20.9	21.2	20.9	19.4	.55
57-110 days	20.1	20.3	20.2	19.7	20.6	.40
0-110 days	20.2	20.6	20.7	20.3	20.0	.44
0-124 days	19.9	20.3	20.3	20.2	20.2	.50
Feed/gain, dry matter						
0-56	6.68	6.49	6.17	6.39	6.14	.22
57-110 days	6.42[a]	5.76[b]	5.71[b]	5.71[b]	5.97[ab]	.17
0-110 days	6.53[a]	6.09[b]	5.91[b]	6.05[b]	6.05[b]	.14
0-125 days	6.34	6.02	5.99	6.03	6.27	.13
Metabolizable energy[d], mcal/kg	2.81[b]	2.93[ab]	3.01[a]	2.95[a]	2.98[a]	1.2

[a]Shrunk weights.
[b]Full weights x .95.
[c]Carcass weight /.62.
[d]Calculated from gain and feed intake, as fed basis.

On day 106, fecal samples were obtained for analysis. Salinomycin was withdrawn from the pelleted supplement on day 110 and on day 124, and steers were trucked to Booker, Texas, for slaughter and carcass evaluation.

Results

Daily gain and feed intake were increased with salinomycin added to the diet (Table 2). Efficiency of feed and energy use was maximized when intake was maximum with 10 g per ton salinomycin. With this diet, gain and feed efficiency were improved by 12.9 and 9.5 percent. Higher salinomycin levels gave slightly less response.

Feces of steers fed the 10 g per ton salinomycin diet were drier and contained more starch than feces of steers fed the control diet (Table 3). Carcass characteristics, obtained 15 days after withdrawal of the drug, were unchanged with salinomycin supplementation (Table 4) although the incidence of liver abscesses tended to increase with this drug. Increased incidence of liver abscesses has occasionally been reported when monensin has been supplemented as well. Though performance and efficiency responses were less than observed in the trial reported from Virginia, comparison with other ionophores (Table 5) suggests that this compound has promise as a feed additive for feedlot steers. Responses to drugs differ with ration composition, environment and feeding conditions so reponses from experiment stations will differ. The summary indicates that for feed savings, feeding an ionophore to feedlot cattle is consistently beneficial.

Table 3. Feces composition

	Salinomycin, g/ton					
Item	0	5	10	20	30	SE
Dry matter, %	23.9[b]	24.9[b]	30.7[a]	23.2[b]	28.4[a]	1.0
Starch, % of DM	17.0[c]	24.5[ab]	27.2[a]	17.9[bc]	21.9[abc]	2.3
pH	5.95	5.95	5.94	5.95	5.92	0.22

[abc]Means in a row with different superscripts differ significantly (P<.05).

Table 4. Carcass characteristics

	Salinomycin, g/ton					
Item	0	5	10	20	30	SE
Carcass weight, lb	724	747	753	746	738	8.6
Dressing percent	64.2	64.1	63.8	64.3	63.7	.37
Liver conditions						
Abscesses						
Incidence, %	29	43	36	43	41	8.3
Severity	1.9	1.9	1.8	1.6	1.5	0.3
Flukes, %	3.6	0	7.1	0	5.0	3.3
Rib eye area						
sq. in.	12.9	13.4	13.1	12.9	13.0	.33
sq. in./cut carcass	1.78	1.80	1.73	1.74	1.77	.002
Fat thickness, in.	.54	.58	.54	.59	.59	.033
KHP, %	2.69	2.75	2.84	2.79	2.63	.090
Marbling score	13.7	13.5	13.6	14.5	13.7	.41
Federal grade	12.8	12.8	12.9	13.1	12.9	.11
Cutability	49.8	49.7	49.5	49.3	49.3	.43
Percent choice	61	71	64	68	64	9.1

Table 5. Ionophore comparisons from feedlot trials at Oklahoma State

Ionophore	Cattle fed	Trials	Daily gain Control	Daily gain Drug	Response	Feed efficiency Control	Feed efficiency Drug	Response
			lb	lb	%	lb	%	
Monensin	800	7	3.33	3.33	0.0	5.82	5.53	5.0
Lasalocid	84	1	3.38	3.40	0.6	5.75	5.31	7.7
Salinomycin	140	1	3.10	3.39	9.4	6.53	6.02	7.8

Lasalocid for Feedlot Steers

F. N. Owens and D. R. Gill

Story in Brief

Lasalocid and monensin were supplemented at 0, 20 or 30 grams per ton with a shelled corn diet and fed to 140 steers (initial weight 679 lb) for 119 days. Rate of gain tended to be greater with the higher level of lasalocid than the higher level of monensin addition to the feed. Feed intake was reduced by 4.1 percent with lasalocid and 2.0 percent with monensin. Efficiency of gain was improved by 5.9 percent with addition of either drug and was slightly greater (7.6 percent vs 4.3 percent) with lasalocid than monensin. Calculated metabolizable energy was increased with either drug (3.8 percent) and greater with lasalocid than monensin (5.1 vs 2.4 percent). Fecal starch tended to be lower with lasalocid than with monensin feeding. Fat thickness tended to be lower with drug feeding, and percent of carcasses graded choice was significantly greater for steers fed lasalocid than those fed monensin due to slightly higher marbling score. Results indicate that lasalocid increases efficiency of feed use by feedlot steers to a level equal to or greater than monensin. The lower feeding level (22 ppm) proved as effective as the higher level of either drug. When legally cleared for feedlot cattle, lasalocid should be a useful feed additive.

Introduction

Monensin is fed widely to feedlot cattle to improve efficiency of feed use. A summary of six trials in Oklahoma (Witt et al., 1980) indicated that at 33 ppm, monensin depressed rate of gain very slightly but reduced feed intake (19.2 vs 18.2 lb/day) and improved feed efficiency by 4.8 percent. Monensin is cleared for feeding in the range of 5 to 30 grams per ton. In one previous trial (Gill et al., 1978), monensin was fed to steers at 15 or 30 grams per ton with a high-moisture corn diet. Gains and feed efficiencies with the 0, 15 or 30 grams per ton monensin diets were 3.22, 3.20 and 3.17 lb/day and 5.51, 5.36 and 5.33 lb feed/lb gain.

Thornton and Owens (1976) reviewed the available literature and concluded that though monensin reduces feed cost most when fed at 30 grams per ton of feed, lower levels are more economically advantageous when yardage and interest costs are high relative to feed costs. Lasalocid functions in a manner similar to monensin. The objective of this experiment was to determine the effect of feeding monensin or lasalocid at 20 or 30 grams per ton on performance and carcass characteristics of feedlot steers.

Materials and Methods

Steers of mixed breeding which had been pastured together for several months near Purcell, Oklahoma, were sorted, and 140 steers were trucked to Stillwater, Oklahoma, on January 23, 1981. Steers had an average shrunk weight of 679 pounds following arrival. Steers were blocked into two weight groups averaging 640 and 719 pounds and randomly allocated within group to pens. Treatments were randomly allotted to pens within a weight group. Within each weight group, half of the pens received a starting ration diluted with cottonseed hulls while for the other half, the ration was diluted with dehydrated alfalfa meal. Steers were ear tagged and vaccinated for IBR-BVD-P13 and blackleg (5-way) on arrival. The ration (Table 1) was diluted with roughage to a level of 40 percent roughage for 3 days, 30 percent roughage for 3 days, 20 percent roughage for 2 days and 12.5 percent roughage for 2 days. On days 28, 55 and 90 of the trial, steers were weighed full. Samples of feces from three steers per pen were obtained on day 20 and day 115 of the trial for pH, dry matter and starch analysis. On day 119 of the trial, steers were weighed after 18 hours without feed and water. Steers were then re-fed and trucked to Booker, Texas, for slaughter the following morning. Slaughter and carcass data were obtained, and livers of steers fed lasalocid were discarded.

Table 1. Ration composition (dry matter basis)

	Ration roughage level (%)				
Ingredient	40	30	20	12.5	5[a]
Whole shelled corn	53.87	63.87	73.87	81.37	88.87
Cottonseed hulls	25	15	10	5	5
Alfalfa meal or cottonseed hulls	15	15	10	7.5	0
Pelleted supplement[b]	6.13	6.13	6.13	6.13	6.13

[a]Calculated composition (dry matter basis) is 3.15 mcal ME/kg; 12.08% protein; .65% K; .47% Ca; .37% phosphorus. Analyzed between 89 and 91% dry matter.

[b]Contained, as a percent of the total ration, soybean meal, 3.4; limestone, 1.03; urea, .50; KC1, .40; salt, .30; dehy, .27; dicalcium phosphate, .23. Vitamin A at 30,000 IU/g, .01; and monensin (60 g/lb) at 0, .016 or .025 or lasalocid (20%) at .011 or 0.16.

Results and Discussion

Rate of weight gain was influenced little by drug source or level (Table 2). Gains were slightly faster with the low than with the high monensin level when calculated on a shrunk or a carcass weight basis. Daily feed intake was reduced by 0.9 lb per head daily (4.1 percent) with lasalocid and 0.5 lb (2.0 percent) with monensin. Efficiency of gain was 5.9 percent greater with addition of either ionophore and tended to be greater (7.6 vs 4.3 percent) with lasalocid than monensin. Metabolizable energy content of the ration was calculated from weight

Table 2. Steer performance and intakes

	Drug level, g/ton				
Lasalocid	0	20	30	0	0
Monensin	0	0	0	20	30
Weights, lb					
Initial	680	684	675	677	676
55 days	919	928	922	922	915
119 days					
Live	1090	1103	1109	1100	1094
Carcass[a]	1085	1089	1085	1080	1083
Daily gain, lb					
0-55	3.53	3.59	3.65	3.61	3.52
56-119	3.38	3.46	3.64	3.50	3.50
0-119 live	3.45	3.52	3.64	3.55	3.51
0-119 carcass[a]	3.38	3.37	3.42	3.36	3.39
Daily feed, lb dry matter					
0-55	19.3	18.8	18.4	18.4	18.4
56-119	20.2	18.8	19.8	20.1	20.5
0-119	19.8	18.8	19.2	19.3	19.5
Feed/gain					
0-55	5.50	5.26	5.07	5.11	5.26
56-119	5.98[b]	5.44[c]	5.45[c]	5.72[bc]	5.86[b]
0-119 live	5.75[b]	5.35[cd]	5.27[c]	5.43[cd]	5.58[bc]
0-119 carcass[a]	5.86	5.86	5.63	5.71	5.79
ME carcass[e]	2.91[d]	3.05[b]	3.07[a]	3.01[bc]	2.95[cd]

aCalculated as hot carcass weight/.62.
[bcd]Means in a row with different superscripts differ significantly ($P<.05$).
[e]Calculated from feed intake and rate of gain.

gain, rate of gain and net energy equations. Metabolizable energy was increased 3.8 percent by ionophore addition, with lasalocid being superior (5.1 vs 2.4 percent) to monensin.

Fecal dry matter, pH and starch (Table 3) were all increased with ionophore addition. Fecal pH tended to be greater and starch content tended to be lower from steers receiving lasalocid than those receiving monensin.

Carcass characteristics are presented in Table 4. Dressing percentage tended to be lower with feeding of either ionophore. While only three steers had liver

Table 3. Feces compositon

	Drug level, g/ton				
Lasalocid	0	20	30	0	0
Monensin	0	0	0	20	30
Dry matter, %	19.9[b]	24.7[a]	21.6[ab]	25.1[a]	23.4[ab]
pH	5.94[ab]	6.13[a]	6.24[a]	5.61[b]	6.02[ab]
Starch, % of DM	13.6[b]	17.9[ab]	15.0[b]	25.8[a]	20.1[ab]
Whole kernels,					
% of samples	17	29	21	50	37

[ab]Means in a row with different superscripts differ significantly ($P<.05$).

Table 4. Carcass characteristics

	Drug level, g/ton				
Lasalocid	0	20	30	0	0
Monensin	0	0	0	20	30
Carcass weight, lb	673	675	673	670	671
Dressing percent	61.8	61.2	60.7	60.9	61.4
Liver abscesses					
Incidence, %	36	36	59	32	39
Severity[a]	2.0	1.8	1.9	1.5	1.8
Fluke incidence, %	3.6	0	4.2	0	3.6
Rib eye area					
Square in.	12.0	12.2	12.2	12.1	11.9
$In.^2$/cwt	1.79	1.82	1.82	1.82	1.78
Fat thickness, in.	.44[d]	.34[e]	.39[de]	.39[de]	.39[de]
KHP, %	2.3	2.3	2.3	2.3	2.3
Marbling score[b]	13.0	13.1	12.6	12.4	12.7
Federal grade[c]	12.7	12.6	12.6	12.4	12.4
Percent choice	67.9[d]	60.7[de]	56.7[de]	39.3[e]	40.0[e]
Cutability, %	50.4	51.1	50.8	50.8	50.6
Yield grade	2.90	2.70	2.84	2.82	2.73
Carcass value, $/cwt	61.40	61.82	60.56	61.54	61.78

[a]Scored from 1 = a single small abscess to 3 = several severe or active abscesses.
[b]Slight plus = 12; small minus = 13.
[c]Good plus = 12; choice minus = 13.
[de]Means in a row with different superscripts differ significantly ($P<.05$).

flukes, over 40 percent had liver abscesses. Abscesses were of moderate severity. Rib eye area was smaller than in most previous trials but was not affected by treatment. Fat thickness over the 12th rib was lower with addition of either drug. Marbling score and federal grade tended to be lower with drug addition. Percent of carcasses graded choice was greater for steers fed lasalocid than for those fed monensin. Cutability and yield grades were not altered with drugs.

Literature Cited

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Alfalfa vs Cottonseed Hulls for Starting Cattle on High Concentrate Rations

D. R. Gill and F. N. Owens

Story in Brief

Rations for starting feedlot steers were diluted with cottonseed hulls or a mixture of cottonseed hulls plus alfalfa meal and fed for the first 24 days of a 119-day feeding period for 140 steers weighing 678 lb at the start of the trial. Compared with steers receiving cottonseed hulls in their starting rations, steers fed alfalfa meal consumed 1.4 percent more feed and gained about 2.5 percent more rapidly for a slight improvement (1.7 percent) in feed efficiency. Results suggest that with these starting rations, a protein content as low as 11 percent for 700-lb feedlot cattle had no marked adverse effect on subsequent feedlot performance. Though dehydrated alfalfa meal produced no significant performance or carcass benefit, economics in this trial justified including a low level of alfalfa meal in the starting ration.

Introduction

Rations for starting feedlot cattle on feed generally contain moderate amounts of roughage to prevent overeating and acidosis. Intake of many essential nutrients, such as protein and potassium, may be considerably below animal requirements because intake of newly received cattle is often low, and chemical composition of roughages differ markedly. Dehydrated alfalfa meal (62 percent TDN, 19 percent protein) and cottonseed hulls (41 percent TDN, 4.3 percent protein) are two roughages which are used to start cattle on feed. Unidentified growth factors also have been ascribed to alfalfa meal, and it is included in many rations designed for starting cattle on feed. The objective of this trial was to compare performance of feedlot steers fed starting rations with roughage provided 1) by cottonseed hulls alone or 2) by a mixture of alfalfa meal and cottonseed hulls to maintain protein content.

Material and Methods

Ration composition is presented in Table 1. From 40 to 70 percent of the roughage was provided from dehydrated alfalfa meal in the starting rations to maintain protein content near 13 percent (Table 1) compared with 10.3 to 11.9 percent protein for the cottonseed hull rations. Potassium levels for the two roughages and thereby for the rations were similar, but phosphorus and calcium were lower with the cottonseed hull rations. Steers had access to feed at all times in self-feeders. Steers received approximately 80 lb of each ration consecutively so that all steers were on each ration for 4 to 7 days and reached the top ration by day 24 of the experiment. During this period, each alfalfa-fed steer received a mean of 40 lb of dehydrated alfalfa. Other procedures were as described in "Lasalocid for Feedlot Steers" found elsewhere in this publication.

Table 1. Ration composition (dry matter basis)[a]

Ingredient	Ration roughage level (%)				
	40	30	20	12.5	5[b]
Whole shelled corn	53.87	63.87	73.87	81.37	88.87
Cottonseed hulls	25	15	10	5	5
Alfalfa meal or cottonseed hulls	15	15	10	7.5	0
Pelleted supplement[c]	6.13	6.13	6.13	6.13	6.13

[a] Protein content of the starting rations with alfalfa meal present were 12.5, 13.1, 12.9 and 13.0% of dry matter compared with 10.3, 10.9, 11.4 and 11.9% with cottonseed hulls as the only roughage present.

[b] Calculated composition (dry matter basis) is 3.15 mcal ME/kg; 12.08% protein; .65% K; .47% Ca; .37% phosphorus. Analyzed between 89 and 91% dry matter.

[c] Contained, as a percent of the total ration, soybean meal, 3.4; limestone, 1.03; urea, .50; KCl, .40; salt, .30; dehy, .27; dicalcium phosphate, .23. Vitamin A at 30,000 IU/g, .01; and monensin (60 g/lb) at 0, 0.16 or .025 or lasalocid (20%) at .011 or 0.16.

Table 2. Steer performance and intake

Item	Alfalfa	Hulls
Steers, number	70	70
Weights, lb		
Initial	677	679
55 days	924	919
119 days		
Live	1103	1095
Carcass	1090	1079
Daily gain, lb		
0-55	3.63	3.52
56-119	3.52	3.46
0-119 live	3.57	3.49
0-119 carcass	3.43	3.33
Daily feed, lb		
0-28	19.3	19.2
0-55	21.0	20.6
56-119	22.2	22.0
0-119	21.6	21.3
Feed/gain		
0-55	5.78	5.87
56-119	6.31	6.34
0-119 live	6.06	6.12
0-119 carcass	6.30	6.41
Metabolizable energy,[a] Mcal/kg	3.00	2.99

[a] Calculated from gain and feed intake.

Results and Discussion

Performance information is presented in Table 2. No significant differences in performance were detected. Steers receiving alfalfa in their starting ration consumed an average of 1.4 percent more feed, which increased gain by 2 to 3 percent and improved feed efficiency by 1.7 percent. Energy availability of the ration was unchanged. Based on the averages, replacing 40 lb of cottonseed hulls with dehydrated alfalfa meal during the starting period saved 44 lb of feed over the 119-day trial.

Carcass characteristics (Table 3) were not significantly altered by composition of the starting ration though fat thickness, KHP, marbling score and cutability all indicate that carcasses were slightly fatter for steers which received dehydrated alfalfa meal.

Table 3. Carcass characteristics

	Starting roughage	
Item	Alfalfa	Hulls
Carcass weight	676	669
Dressing percent	61.3	61.1
Liver abscesses		
Incidence, %	45	36
Severity	1.78	1.84
Rib eye area		
Square inches	12.1	12.1
In. ^{2}/cwt	1.79	1.82
Fat thickness, in.	.41	.37
KHP, %	2.33	2.24
Marbling score	12.9	12.6
Federal grade	12.5	12.5
Percent choice	55	51
Cutability, %	50.5	50.9
Carcass value, $/cwt	61.34	61.50

Table 4. Composition of feces

Day of trial	Component	Starting ration	
		Alfalfa	CSH
20	pH	6.36	6.37
	Dry matter, %	21.8	22.4
	Starch, % of DM	17.7	16.5
	Samples with whole kernels, %	27	17
115	pH	5.63	5.60
	Dry matter, %	23.1	24.5
	Starch, % of DM	17.3	22.5
	Samples with whole kernels, %	23	57

Feces samples were obtained on day 20 when steers were fed receiving diets containing cottonseed hulls (12.5 percent) or a mixture of cottonseed hulls (5 percent) plus alfalfa meal (7.5 percent) as a source of roughage. No marked effect of roughage source at this time or later in the feeding period was apparent (Table 4). The dry matter, starch and whole kernel percentages were higher later in the feeding trial, and pH was lower. Whether this difference is due to a reduced digestibility with age and time on feed or a ration composition difference is under study.

Influence of Starting Weight and Breed on Performance of Feedlot Steers

F. N. Owens and D. R. Gill

Story in Brief

Steers were grouped by initial weight and fed high concentrate rations in two finishing trials. Feed intake was greater for heavier steers but, expressed as a fraction of body weight, declined from 2.5 to 2.2 percent per day as mean steer weight increased from 850 to 1137 lb. Efficiency of feed use has generally been lower for heavier cattle, but energetic efficiency, calculated from net energy equations, is consistently higher for heavier cattle. Fat cover and marbling have generally increased with starting weight and carcass weight. Comparison of breeds in these trials revealed lower rates of grain for Angus steers, especially late in the finishing period; lower dressing percentages for Hereford steers than other types; and high rates of gain and carcass cutability for exotic crossbred steers.

Introduction

Effect of starting weight on feedlot performance has been studied previously with 500 and 600-lb steers (Gill et al., 1980). Intakes and gains were greater for heavier steers, but heavier steers had less desirable feed efficiencies. These effects need examination with heavier steers.

Feedlot performance and carcass characteristics among common cattle breeds have been reviewed (Owens et al., 1979; Gill et al., 1981). Total feedlot gain for Angus-Hereford crossbred steers has exceeded the mean of Angus and Hereford steers by 6 to 8 percent. Marbling score and percent of carcasses grading choice have consistently favored the Angus steers. Carcass traits of Angus-Hereford crossbred steers appears intermediate in all measurements. In these trials, performance and carcass traits of 280 steers of mixed breeding were examined.

Materials and Methods

Steers used in both trials had been assembled in Purcell, Oklahoma, and pastured together for several months prior to transport to Stillwater for finishing. Steers used in the "Lasalocid for Feedlot Steers" trial reported elsewhere in this publication were subdivided into two groups based on initial weight (640 vs 714 lb). Steers in the "Salinomycin for Feedlot Steers" trial were divided into four weight groups based on initial weight. Steers were classified into four breed types by appearance in both trials and assigned randomly to pens. Therefore, no feed intake or efficiency data are available for steers by breed type.

Results and Discussion

Animal performance information by weight group is presented in Tables 1 and 2. Feed intake was greater for the heavier set of steers in both trials (4.3 and 5.6 percent for every increase of 100 lb in the two trials), especially early in the feeding study when intake was 5.9 and 6.8 percent greater per hundred pounds. These differences are less than the 10 percent observed with steers averaging 100 lb heavier in a previous trial. Overall, feed intake was equal to 1.33 times weight to the .41 power. Subdividing feed intake by periods reveals that feed intake

Table 1. Steer performance by initial weights

Item	Weight group	
	Light	Heavy
Steers, no.	70	70
Pens	10	10
Weights, lb		
Initial	640[b]	717[a]
55 days	881[b]	962[a]
119 days	1061[b]	1137[a]
Daily gain, lb		
0-55 days	3.59	3.57
56-119 days	3.50	3.49
0-119 days	3.54	3.53
Daily feed, lb		
0-55 days	19.8[b]	21.7[a]
56-119 days	22.3	21.9
0-119 days	21.1	21.8
% of body weight	2.48	2.35
Feed/gain		
0-55 days	5.55[b]	6.09[a]
56-119 days	6.37	6.28
0-119 days	5.98[b]	6.19[a]
Metabolizable energy, mcal/kg	2.97	3.02

[ab]Means in a row with different superscripts differ ($P<.05$).

Table 2. Steer performance by initial weights

	Weight group			
	1	2	3	4
Steers, number	35	35	35	35
Weight, lb	755[a]	768[a]	799[b]	828[c]
Initial				
56 days	984[a]	1003[ab]	1025[b]	1069[c]
120 days	1158[a]	1180[ab]	1202[b]	1247[c]
Daily gain, shrunk, lb				
0-56	3.18	3.29	3.12	3.35
57-110	3.57[a]	3.22[b]	3.44[ab]	3.50[ab]
0-120 carcass	3.38	3.25	3.28	3.42
Daily feed, lb				
0-56	22.2	22.8	22.9	23.3
57-110	21.5	22.5	23.0	22.7
0-120	22.0	22.3	22.5	22.9
% of body weight	2.30	2.28	2.25	2.20
Feed/gain				
0-55	6.97	7.02	7.34	6.99
57-110	6.06	6.99	6.69	6.53
0-120	6.80	6.74	6.96	6.77
Metabolizable energy, mcal/kg	2.98[a]	2.87[b]	2.90[ab]	3.01[a]

[abc]Means in a row with different superscripts differ ($P<.05$).
[d]Calculated from gain and feed intake.

increased proportionately to body weight the first 56 days on test (Intake = 5.66 + .019 weight). Intake was not influenced by body weight during the last half of the feeding study when average steer weight exceeded 950 lb.

Daily gain was not influenced by weight group at any period of this trial. This contrasts with an 8 percent increase in gain per hundred pounds initial weight in the previous trial. No explanation for this difference is apparent. Efficiency of feed use was 4.6 percent lower for every hundred pounds increase in initial weight in the first trial compared with 0.6 percent in the second trial and 3.1 percent in the previous trial. Efficiency of conversion of feed to gain is depressed when feed intake above maintenance is low or when tissue gain is higher in fat and lower in protein and water. Yet, availability of energy, estimated from net energy equations, indicated a superiority for heavier animals in both studies as was true in the previous trial. This increase may be due to minor errors inherent in the net energy equations used to calculate energy efficiency. Digestibility might be expected to decline with greater intake and weight. Carcass characteristics (Tables 3 and 4) indicate that heavier steers were depositing more fat both over the rib and in the rib eye than lighter steers. Rib eye area per hundred pounds of carcass declined as carcass weight increased as expected.

The influence of breed type on performance and carcass characteristics is presented in Tables 5 and 6. In these trials, rate of gain of Angus-Hereford crossbred steers was 98 and 103 percent of the average of Angus and Hereford steers, somewhat below previous values (106 and 108 percent). Other crosses including Brahman and Charolais type steers gained at rates 2 and 5 percent above the Angus-Hereford crossbred steers. Rate of gain of Angus steers was considerably less (6 and 3 percent) than for other breed types during the second half of the feeding trial as has been observed in previous trials (6 and 7 percent).

Table 3. Carcass characteristics of trial 1

	Initial weight	
	640	717
Carcass weight, lb	647[b]	698[a]
Dressing percent	61.0	61.4
Liver abscesses		
Incidence, %	38.6	41.9
Severity[c]	1.65	1.98
Rib eye area		
Square inches	11.9[b]	12.3[a]
In²/cwt	1.84[a]	1.77[b]
Fat thickness, in.	.36	.41
KHP, %	2.31	2.26
Marbling score	12.4[b]	13.1[a]
Federal grade	12.5	12.5
Percent choice	49.5	56.3
Cutability	51.0	50.5
Value	61.5	61.3

[ab]Means in a row with different superscripts differ ($P<.05$).
[c]Slight = 1; severe = 3.

Table 4. Carcass characteristics from trial 2

	Weight group			
	1	2	3	4
Carcass weight	718[a]	731[ab]	745[b]	773[a]
Dressing percent	63.1[a]	64.2[b]	64.2[b]	64.5[b]
Liver abscesses				
Incidence, %	41	43	32	37
Severity	1.73	1.62	2.00	1.55
Rib eye area				
Square inches	12.7	12.8	13.3	13.4
In²/cwt	1.78	1.75	1.79	1.75
Fat thickness, in.	.56	.51	.59	.60
KHP, %	2.74	2.68	2.75	2.80
Marbling score[c]	13.3	13.9	13.8	14.3
Federal grade[d]	12.8	13.0	12.9	13.0
Percent choice	70	60	64	69
Cutability	49.5	49.8	49.4	49.3

[ab]Means in a row with different superscripts differ ($P<.05$).
[c]Low choice = 13; average choice = 14.
[d]Slight plus = 12; small minus = 13.

Table 5. Breed effects on performance, trial 1

Item	Breed: Hereford	Angus	Black baldy	Crosses
Number	42	15	37	45
Weights				
Initial	662[c]	719[a]	688[b]	672[bc]
55 day	903[b]	958[a]	929[ab]	918[ab]
119 day	1064	1110	1095	1084
Daily gains				
0-55	3.55	3.47	3.54	3.65
56-119	3.51[ab]	3.22[b]	3.47[ab]	3.57[a]
0-119	3.35	3.26	3.39	3.45
Carcass hot weight	660	689	679	673
Dressing %	61.0	61.7	61.5	61.1
Rib eye area, in.^{2}	11.8	12.3	12.1	12.3
Rib eye area, in.^{2}/cwt	1.80	1.80	1.78	1.83
Fat over rib, in.	.40[a]	.48[a]	.43[a]	.32[b]
KHP, %	2.3	2.3	2.3	2.3
Marbling	12.7[ab]	13.6[a]	12.9[ab]	12.4[b]
Federal grade	12.5	12.6	12.6	12.4
Yield grade	2.8[ab]	3.0[a]	2.9[ab]	2.7[b]
Cutability	50.6[b]	50.3[b]	50.4[b]	51.3[a]
Choice, %	52	64	63	41

[abc]Means in a row with different superscripts differ significantly ($P<.05$).

Table 6. Breed effects on performance, trial 2

Item	Breed type: Hereford	Angus	Black baldy	Crosses
Number	13	8	33	78
Weights				
Initial	780	803	798	785
56 days	1014	1018	1019	1027
124 days	1206	1198	1207	1212
Daily gains				
0-56	3.27[ab]	2.94[b]	3.05[b]	3.41[a]
57-124	3.60	3.35	3.40	3.40
0-124	3.43	3.14	3.22	3.40
Carcass weight	737	738	743	746
Dressing %	63.7	64.2	64.2	64.1
Ribeye area				
sq. in.	12.6	12.7	13.2	13.1
sq. in./cwt	1.70	1.72	1.79	1.77
Fat over rib, in.	.58[ab]	.64[ab]	.65[a]	.53[b]
KHP, %	2.6	2.8	2.8	2.8
Marbling	12.8	14.6	14.0	13.8
Federal grade	12.6	13.1	12.9	12.9
Cutability	49.2	49.0	49.1	49.8
Choice, %	62	63	70	63

[ab]Means in a row with different superscripts differ significantly ($P<.05$).

This as well as the consistently increased marbling of the Angus steers and generally higher Federal grade suggests that the Angus steers are closer to mature size than other types tested and need to be marketed more promptly when finished than other breeds. Again, in these two studies dressing percent was lower for the Hereford than other breed types. Carcass value estimated from cutability favored the exotic crossbred steers. When sold on a live basis, exotic crosses are often discounted. Grade and yield marketing may improve the economic return on such cattle as these data suggest that carcasses were fully as valuable and cutability was higher than for other steers in these two trials.

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Propylene Glycol and Feed Intake by Steers

D. C. Weakley, F. N. Owens,
K. W. Milliner and
D. A. Phelps

Story in Brief

Propylene glycol (PG), a compound which supplies glucose for tissues and is used to prevent ketosis, was added to a high concentrate diet for 14 finishing steers. Feed intake over 3 weeks was reduced by 36 percent and gain by 93 percent with the addition of 5 percent PG. In another trial, PG and other glucose and non-glucose forming compounds were fed to nonruminant animals (rats) at levels up to 20 percent of their diet. Feeding propylene glycol, triacetin, tributyrin, glucose or corn oil for one week had little effect on feed intake. However, feeding 14 percent acetic acid, a compound not used to form glucose, increased intake by 37 percent. Intake has not been depressed at PG levels over 15 percent in diets of dairy cows and nonruminant animals. Results suggest that supply of glucose-producing compounds like propionate limit feed intake of steers fed high concentrate rations.

Introduction

For treatment of ketosis of dairy cows, it is common to feed propylene glycol (PG), a compound which, like propionate, is used by the liver to form glucose. Some work has suggested that PG fed to dairy cows at 6 percent of the concentrate ration helps in prevention of ketosis, and a level of 9 percent is not detrimental. This experiment was conducted to determine the effect of this glucose-forming compound on feed intake of rats and steers.

Materials and Methods

Fourteen steers (mean weight 864 lb) in individual pens were fed a diet containing 89 percent whole shelled corn, 5 percent cottonseed hulls and 6 percent pelleted supplement, primarily soybean meal, with or without addition of 5 percent PG (industrial grade) for 21 days. Feed was available at all times, and PG was added each day to the new feed. Treatments were rotated and feed intake again was measured for 21 days. Feed intake the final 10 days of each period was used for calculations to remove the time period of adaptation to the diet. Steers were weighed on 2 consecutive days at the start and end of each period to calculate gain.

In another experiment, 56 rats (mean weight 325 g) were fed the diets shown in Table 1 over two periods. In each period, eight rats were fed diets containing either tributyrin (TB), propylene glycol (PG), triacetin (TA), acetic acid (AA), glucose (G) or corn oil (CO) as supplementary energy sources. All diets were formulated to be of equal digestible energy content and contain glycerol in amounts equivalent to the control diet (C). Bomb calorimetry was performed on all diets to determine gross energy content. Daily dry matter consumptions,

Table 1. Rat trial diet composition

Item	Diet[a]						
	C	TB	PG	TA	AA	G	CO
	% of dry matter						
Tributyrin		22.8					
Propylene glycol			21.4				
Glucose						24.2	
Triacetin				16.9			
Acetic acid					15.6		
Glycerol	5.9		5.7		5.7	5.8	5.7
Corn oil							11.6
Ground corn and SBM mixture	86.7	57.8	59.9	72.9	72.9	68.3	66.6
Polyethylene	5.7	17.8	11.4	8.5	4.1		14.5
Gross energy, kcal/g	4.1	3.9	3.6	4.5	4.0	4.2	4.2

[a]Diets included .6% vitamin mix and 1.1% mineral mix.

expressed as a percentage of each rat's average weight, were measured the final 5 days of each 14-day period.

Results and Discussion

Feed intake of these feedlot steers was decreased by 36 percent, and gain was decreased by 93 percent with addition of 5 percent PG to the diet. Dairy cows have been fed rations with 9 percent of the concentrate portion of their ration being PG. This was fed with oat silage so that 3.5 percent of dietary dry matter was PG. Intake was reduced by only 8 percent (Fisher et al., 1973). Levels up to 16 percent PG have not depressed intake of dairy cows (Emery, 1964). Propionate production in the rumen may be lower with the higher roughage diets normally fed to dairy cows than high concentrate diets usually fed to feedlot steers. The rat trial responses (Table 3) indicate no effect on intake of supplementary ketone-forming triglycerides (TB, TA) or corn oil. Even though the intake of the PG-fed rats was elevated 12 percent above the C-fed rats, the gross energy content of the PG diet was 12 percent less than the control diet, suggesting little effect by PG on energy intake. Glucose, as well, had little effect on feed intake. A 37 percent increase in intake was noted for rats fed acetic acid, a compound used for fat synthesis. However, a portion of this response may be due to slow evaporation of acetic acid from the diet in the feeders. An increase in intake with acetic acid is impressive considering its odor. This change might be expected if synthesis of fat from glucose is related to mechanisms which control feed intake.

Table 2. Intake and gain by steers

Item	Propylene glycol, %	
	0	5
Dry matter intake, lb	18.5[a]	11.7[b]
Daily gain, lb	4.45[a]	.29[b]

[ab]Means in a row with different superscripts differ statistically ($P<.05$).

Table 3. Rat trial dry matter consumption

Diet	Added energy source	Daily dry matter consumed as % of average rat wt
C	Glycerol	4.88[c]
TB	Tributyrin	4.60[c]
PG	Propylene glycol	5.47[b]
TA	Triacetin	4.92[bc]
AA	Acetic acid	6.56[a]
G	Glucose	4.84[c]
CO	Corn oil	4.40[c]

[abc]Means with different superscripts differ statistically ($P<.05$).

Species and diet differences suggest that supply of glucose-producing compounds may control intake of feedlot steers. Methods are under study to decrease propionate production and increase rate of metabolism of propionate in order to increase energy intake of feedlot steers.

Literature Cited

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Roughage Source in Feedlot Diets

S. R. Rust and F. N. Owens

Story in Brief

The influence of roughage source on digestion of a high grain diet was measured with 24 Hereford-Angus steers. The six roughages tested were cottonseed hulls, prairie hay, alfalfa hay, sorghum plant silage and two varieties of corn plant silage. The diet consisted of 82 percent whole shelled corn, 10 percent roughage and 8 percent supplement. Daily feed intake was restricted to 2 percent of body weight. Digestion of organic matter, starch, ADF and nitrogen were not significantly different for the diets containing the six roughages. Total diet organic matter and starch digestibilities tended to be higher for cottonseed hulls and prairie hay diets than the diets containing silage. The more completely digested roughages were not necessarily associated with the more digestible grain diets. Results indicate that cattle feeders may ignore forage digestibility and energy content in selection of roughages for whole corn finishing diets and be more concerned with roughage availability, palatability, ration handling characteristics and cost. Traditional roughages such as corn silage and alfalfa hay, which are often preferred by cattle feeders, appeared to have little advantage in this study.

Introduction

Corn is usually processed to increase its energy availability. Feeding corn in the whole shelled form eliminates one processing step and some costs. Cattlemen often prefer alfalfa hay or corn silage as a roughage source in feedlot diets. One possible reason for this preference may be the presence of unidentified growth factors. The purpose of this research was to examine the influence different types of forages have on digestion of whole shelled corn in typical feedlot finishing diets.

Experimental Procedures

Twenty-four Hereford-Angus steers (800 lb) were utilized to examine the effects of six different roughage sources on digestion of a high concentrate diet. The six roughages (Table 1) were cottonseed hulls (CSH), prairie hay (PH), alfalfa (AH), sorghum plant silage (SS) and two corn plant silages (FCS = forage corn silage and GCS = grain corn silage). Four steers were randomly allocated to each of the six roughages. Animals were housed in individual pens on slatted concrete floors. Steers were fed the assigned diets for 21 days. The last 5 days of this period, fecal grab samples were collected at 0600 hr, pH was determined and samples were frozen for laboratory analysis. Chromic oxide was added at .2 percent of the diet as an indigestible marker to calculate digestibility. Steers were fed twice daily. Diets contained whole shelled corn (WSC) plus supplement and roughage (Table 2). Supplement composition is shown in Table 3. Protein was added to obtain a minimum protein level of 10.5 percent with some of the rations being above this level. Feed and fecal samples were analyzed to determine the digestibility of organic matter, nitrogen, starch and fiber. Fiber content was

Table 1. Ingredient analysis (%)

Item	DM	Dry matter basis		
		Starch	ADF	Protein
Cottonseed hulls	88.5	3.9	64.2	7.5
Prairie hay	91.2	3.8	46.2	5.9
Alfalfa hay	90.6	2.0	40.1	18.2
Sorghum silage	27.9	18.5	37.3	7.7
Corn silage (grain)	33.8	21.1	31.3	8.4
Corn silage (forage)	32.8	23.2	30.0	7.6
Whole shelled corn	88.4	73.8	2.4	9.9

Table 2. Diet composition (DM basis)

Ingredient	%
Whole shelled corn	82
Forage	10
Supplement	8

Table 3. Supplement composition[a] (DM basis)

Ingredients	CSH & PH %	AH %	Silages %
SBM	72.3	0	45.3
Ground corn	5.1	50.4	4.9
Dicalcium phosphate	10.7	13.1	13.1
Limestone	2.7	15.1	15.1
Potassium chloride	0	5.6	5.6
Salt	1.6	3.1	3.1
Urea	3.8	7.5	7.5
Sodium sulfate	2.4	2.4	2.4
Trace mineral mix	.2	.3	.3
Chromic oxide	1.3	2.5	2.5

[a]Vitamin A and D were added to supply NRC requirements.

estimated by analyzing the samples for acid detergent fiber (ADF). Rumen samples were obtained using a stomach tube on the final day of the study and analyzed for pH, ammonia concentration and volatile fatty acid concentrations.

Results and Discussions

Total tract digestibility estimates for organic matter, starch, nitrogen and ADF for the six diets are shown in Table 4. At low levels in the diet, source and digestibility of roughage appear less important than in diets composed entirely of roughage. In comparison of predicted vs determined digestibilities, alfalfa and two of the three corn silage diets appeared considerably below expected values. Starch digestion of these diets was also lower with those three roughages. This

Table 4. Effects of forage source on nutrient digestibility

Item	CSH	PH	AH	SS	GCS	FCS
Digestibility, %						
Organic matter						
Determined	73.8	77.1	65.2	69.6	67.8	74.1
Calculated[a]	74.4	75.5	74.5	74.4	75.8	75.8
Starch	90.8	89.2	77.4	79.7	77.4	84.8
ADF	27.1	37.2	25.0	34.2	44.8	47.0
Nitrogen	62.3	66.1	51.6	63.8	55.5	68.3

[a]Calculated from TDN of ingredients listed in NRC for dairy cattle.

suggests that the influence of roughage on corn digestibility in diets containing high levels of whole shelled corn is an important factor when considering value of a roughage. Using roughages which are available and palatable and do not reduce starch digestion may have economic advantages in high-grain diets.

The effect of roughage source on fecal parameters is shown in Table 5. Fecal pH and fecal starch tended to be higher when silages were fed. Fecal fiber was highest and fecal ash lowest with CSH. Fiber digestibility tended to increase as fecal pH increased. This suggests low pH in the large intestine may have reduced fiber digestion with these rations. If fiber digestion in the rumen decreases as grain intake increases, much of the fiber digestion with feedlot diets may be dependent upon fermentation in the large intestine and cecum. Rumen ammonia tended to be higher with the silage diets, and ruminal pH tended to be higher with alfalfa and prairie hay (Table 6). Ruminal volatile fatty acids were similar except for isobutyrate and isovalerate, which are branch chain fatty acids derived primarily from protein degradation. With the low protein roughages, low levels of these acids might be expected.

Although roughage source at 10 percent of the diet did not greatly influence digestion of high concentrate diets in the total digestive tract, the site of digestion may have been altered, which could influence starch digestion. Since forage contributes little energy to the total dietary energy concentration, the energy value or digestibility of a roughage would appear to be of secondary importance to palatability, availability and cost in whole corn finishing diets. Though alfalfa and corn silage are often preferred by cattlemen, no special characteristics or advantages of these roughages could be detected. In fact, the less digestible roughages, cottonseed hulls and prairie hay, seem preferable to improve digestibility of starch in the ration.

Table 5. Effects of forage source on fecal parameters

Item	CSH	PH	AH	SS	GCS	FCS
Fecal						
pH	5.68[d]	5.75[d]	5.86[de]	5.88[de]	6.12[e]	6.07[e]
Dry matter, %	28.2	26.0	29.0	28.9	31.4	28.7
Starch[a]	20.6	26.6	35.2	36.7	37.4	34.2
Nitrogen[a]	2.83	2.76	2.76	2.36	2.61	2.39
ADF[a]	24.7[c]	18.2[bc]	14.3[b]	12.7[b]	10.5[b]	11.2[b]
Ash[a]	7.7[e]	10.8[d]	8.2[de]	11.3[d]	11.7[d]	11.5[d]

[a]Percentage of fecal dry matter.
[bc]Means in a row with different superscripts differ statistically ($P<.01$).
[de]Means in a row with different superscripts differ statistically ($P<.05$).

Table 6. Effect of forage source on rumen pH, ammonia and volatile fatty acid concentration

Item	CSH	PH	AH	SS	GCS	FCS
Ruminal						
pH	5.98	6.20	6.22	5.94	5.91	5.83
Ammonia, mg/dl	4.98[c]	8.77[cd]	9.97[cde]	16.65[e]	15.05[de]	10.65[cde]
Volatile fatty acid, moles/100 moles						
Acetate	59.72	57.03	56.18	57.32	55.89	59.5
Propionate	28.59	30.56	23.03	28.26	21.31	21.9
Butyrate	7.68	9.04	12.24	8.81	12.39	13.57
Isobutyrate	.16	.16	1.02	.48	1.77	.73
Valerate	1.62	1.39	3.55	1.57	3.44	1.69
Isovalerate	1.90[a]	1.82[a]	3.69[ab]	2.47[a]	4.96[b]	2.39[a]
Caproate	.33	0	.29	1.08	.24	.22
Total, μM/ml	81.29	79.36	69.07	110.55	71.80	102.50

[ab]Means in a row with different superscripts differ statistically ($P<.05$).
[cde]Means in a row with different superscripts differ statistically ($P<.01$).

Effect of Limestone on Digestibility of Feedlot Diets

S. R. Rust and F. N. Owens

Story in Brief

Two levels of limestone (.7 and 2.0 percent) were fed with two levels of chopped alfalfa hay (10 and 50 percent) to 22 Hereford steers (517 lb). The diet also contained whole shelled corn and supplement. Animals were fed individually at a level equal to 2.5 percent of body weight daily in two equal meals. Organic matter, fiber and nitrogen digestibility were increased with added limestone. Fiber and nitrogen digestibility also increased as alfalfa was added to the diet. Beneficial effects of additional limestone involved increased fiber and nitrogen digestibility primarily, not increased starch digestibility. If increased fiber digestion speeds clearance from the rumen, limestone supplementation beyond nutritional requirements may increase feed intake as well as digestibility of higher roughage diets.

Introduction

Several researchers have reported that limestone supplementation increases energy availability of high concentrate diets. Increased starch digestion has been suggested as one explanation. Limestone has been suggested to increase starch digestion by preventing ruminal and intestinal pH from falling so low as to inhibit starch digestion. However, Zinn and Owens (1982) reported limestone altered ruminal and intestinal pH very little. Fiber digestion may be more susceptible than starch digestion to low ruminal pH.

The purpose of this study was to determine the influence of additional limestone on starch and fiber digestion.

Experimental Procedure

Twenty-two Hereford steers (517 lb) were fed one of two levels of alfalfa (10 and 50 percent) with two levels of limestone (.7 and 2.0 percent). Steers were fed 2.5 percent of their body weight as feed dry matter in two equal meals each day.

Table 1. Diet composition (% of dry matter)

	Diet	
	High roughage	Low roughage
Whole shelled corn	42	82
Alfalfa	50	10
Supplement	8	8
Analysis (%)		
Protein	13.6	12.4
Starch	31.57	58.54
ADF	24.63	6.70
Ca, (calculated)	.97-1.65	.44-.87

The diet included whole shelled corn (42 or 82 percent), alfalfa (10 or 50 percent) and 8 percent supplement (Table 1). Steers were fed each diet for 21 days. The limestone was incorporated into a pelleted supplement (Table 2). Chromic oxide was included in the supplement as an indigestible marker to calculate digestibility. Animals were housed in individual pens with concrete slatted floors. Samples of feces were collected the last 5 days of each period. Samples were analyzed for pH, dry matter, ash, nitrogen, starch, ADF (a fiber estimate) and chromium. Rumen samples were collected with a stomach tube the last day of each period. Rumen samples were analyzed for pH and volatile fatty acid concentrations.

Table 2. Supplement composition (% of dry matter)

	Diet	
	Low limestone	High limestone
Dry rolled corn	67.7	51.0
Urea	6.0	6.0
Potassium chloride	10.3	10.3
Calcium carbonate	9.1	25.8
Dicalcium phosphate	2.2	2.2
Salt	2.5	2.5
Chromic oxide	2.0	2.0
Trace mineral	.3	.3
Vitamin A	+	+

Results and Discussion

Limestone addition increased digestibility of organic matter, nitrogen and fiber (Table 3). Starch digestion tended to be greater with limestone addition, but effect was much less than for fiber. Limestone addition had little effect on rumen pH (Table 4). This suggests that the positive influence of additional limestone in this study probably was not due to a ruminal pH effect. Other possible benefits of added limestone include altered ruminal outflow rates, increased salivation and rumination or an effect of the calcium on enzyme action or stability. Calcium concentration of the low calcium-low roughage diet was .44 percent, which meets the NRC requirement, while the higher limestone diet contained .87 percent calcium. Limestone had similar effects on digestibility with both roughage levels (Table 5). The response in starch digestibility to addition of limestone tended to be greater with the lower roughage level (2.6 percentage units) than the higher roughage level (1.6 percentage units).

Table 3. Influence of limestone on diet digestibility

	Limestone level, %	
	.7	2.0
Digestibility (%)		
Organic matter	68.8[a]	74.0[b]
Starch	90.3	92.3
Fiber	27.9[a]	35.6[b]
Nitrogen	62.1[a]	67.6[b]

[ab]Means in a row with different superscripts differ statistically ($P<.01$).

Table 4. Effect of limestone level on ruminal parameters

	Limestone (%)	
	.7	2.0
Rumen:		
pH	6.57	6.57
Volatile fatty acids[d]		
Total μmoles/ml	90.1	90.4
Acetate	56.9	56.2
Propionate	22.0	23.3
Butyrate	9.5	9.5
Isobutyrate	6.6	6.6
Valerate	2.1	1.9
Isovalerate	2.2	2.1
Caproate	0.7	0.5
C_2/C_3	3.1[b]	2.7[a]
NGR[c]	3.9[b]	3.4[a]

[ab]Means with different superscripts differ statistically (P<.05).
[c]Non-glucogenic ratio.
[d]Individual VFA in moles/100 moles.
Total VFA in μmoles/ML.

Table 5. Effect of limestone addition within two roughage levels

Roughage level	10		50	
Limestone level	.7	2.0	.7	2.0
Digestibility (%)				
Organic matter	72.4	77.4	65.7	71.2
Starch	88.8	91.4	91.5	93.1
Fiber	16.3	23.0	37.6	46.1
Nitrogen	60.9	68.9	63.2	68.2

Fiber digestion was significantly increased with added alfalfa (Table 5). Starch and nitrogen digestibility tended to increase with added roughage while organic matter digestibility was reduced. Since much of the protein in alfalfa is associated with fiber, increased fiber digestion should increase nitrogen digestibility. Though roughages in some trials have reduced starch digestibility, roughage addition to the diet also may increase rumination and digestion of the whole shelled corn. Studies with intestinally cannulated cattle and pigs suggests that with whole corn, the kernel surface limits digestion. With ground or processed corn, other factors may limit digestion.

Volatile fatty acid concentrations (Table 4) were similar; however, the ratio of acetate to propionate (C_2/C_3) was less with added calcium. This could decrease methane loss and increase energetic efficiency. Efficiency of energy utilization also has been related to the ratio of non-glucogenic to glucogenic fatty acids (NGR). Ratios from 2 to 3.5 appear to be utilized efficiently for growth while ratios above or below this range may be used less efficiently for growth. Limestone decreased the NGR from 3.9 to 3.4. Forage addition to the diet decreased concentrations of total volatile fatty acid, propionate, valerate, isovalerate and caproate (Table 7). Acetate levels increased greatly with additional roughage.

Table 6. Roughage level effect on diet digestibility

	Roughage level (%)	
	10	50
Digestibility (%)		
Organic matter	74.9[b]	68.4[a]
Starch	90.1	92.3
Fiber	19.7[a]	41.9[b]
Nitrogen	63.9	65.7

[ab]Means in a row with different superscripts differ statistically ($P<.01$).

Table 7. Effects of roughage level on ruminal parameters

	Roughage level (%)	
	10	50
Rumen:		
pH	6.35	6.77
Volatile fatty acids		
Total	94.3[f]	87.0[e]
Acetate	48.4[a]	63.0[b]
Propionate	29.0[b]	17.6[a]
Butyrate	9.8	9.2
Isobutyrate	6.8	6.4
Valerate	2.8[b]	1.4[a]
Isovalerate	2.5[b]	1.9[a]
Caproate	0.8[d]	0.4[c]
C_2C_3	1.9[a]	3.7[b]
NGR	2.5[a]	4.5[b]

[ab]Means in a row with different superscripts differ statistically ($P<.01$).
[cd]Means in a row with different superscripts differ statistically ($P<.05$).
[ef]Means in a row with different superscripts differ statistically ($P<.10$).
[g]Non-glucogenic ratio.

In summary, limestone addition to increase dietary calcium from .44 to .87 percent of diet dry matter increased digestibility of organic matter, nitrogen and fiber. With high roughage diets, the increased fiber digestibility due to added limestone may increase clearance of fiber from the rumen and thereby permit feed intake and gain to increase. Added calcium might be beneficial in a similar manner for stressed cattle. Benefits from added limestone in this trial were related primarily to increased fiber and nitrogen digestion rather than increased starch digestibility. Results would support feedlot trial findings elsewhere in this report that when added calcium increases feed intake, it will improve animal performance.

Literature Cited

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Limestone and Potassium for Feedlot Steers

R. A. Zinn, F. N. Owens,
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Story in Brief

A high moisture corn diet was supplemented with limestone to increase calcium content to 1 percent of dry matter in two trials and with potassium chloride to increase potassium to 1 percent of the ration in one trial with feedlot steers. In the first trial, calcium supplementation decreased feed intake by 10 percent and rate of gain by 13 percent. But in the second trial, gain was increased by 9 percent with addition of the same level of calcium from the same source, largely due to a 4 percent increase in feed intake. Results indicate that if calcium supplementation increases feed intake, it will increase animal performance and vice versa. Review of experiments from across the United States reveals that only one location has reported consistent benefit from calcium supplementation while little or no benefit has been reported from other locations. Potassium supplementation increased dry matter digestibility and live weight gain, but carcass gain was changed little.

Introduction

Calcium supplementation of feedlot rations has increased rate of gain and efficiency of feed use in some feedlot studies. Lack of response has been attributed by some workers to low solubility and large particle size of the limestone. Previous studies with cannulated steers have shown that digestion of starch and fiber may be increased with added limestone. Previous studies with cannulated steers have shown that digestion of starch and fiber may be increased with added limestone, but digestibility of starch in the small intestine has not increased (Zinn and Owens, 1980). Similarly, added potassium may increase digestion in the rumen due either to buffering properties or more frequent and smaller meals. The objectives of these studies were to determine the influence of supplemental calcium and potassium on performance of feedlot steers.

Materials and Methods

Ninety-six steers were allocated to 12 pens in each trial with four pens (32 steers) receiving each treatment. The first trial used 717 lb steers in a 121-day trial. In the second trial, steers weighed 613 lb initially and were fed for 147 days. Rations used in both trials were similar (Table 1), consisting of high moisture corn and corn silage. The first trial began in April. One source of calcium, obtained from Texas, was added to the diet to increase dietary calcium to 1 percent of dry matter. Potassium chloride was added in a second treatment to produce a dietary K level of 1 percent. The second trial started in November to double check results of the first trial. For the second trial, two sources of calcium — the same relatively low solubility limestone as used in trial 1 as well as a "high reactivity" form from Carthage, Missouri — were used.

Table 1. Ration composition

Ingredient	Percentage[a]
Corn, high moisture	81.0
Corn silage	8.0
Alfalfa, chopped	4.0
Soybean meal	2.4
Cottonseed meal	2.6
Limestone	.8 – 2.5
Urea	.35
Dicalcium phosphate	.20
KCl	.15 – 1.00
Salt	.30

[a]Vitamin A, Tylan and Rumensin also included.

Results and Discussion

Added limestone in the first trial reduced feed intake by 10 percent, gains by 13 percent and efficiency of feed use by 4 percent, calculated on a carcass weight basis (Table 2). These results indicate that extra calcium supplementation may depress feed intake and reduce gains of rapidly growing steers under some conditions. This suggests some type of toxicity of the added limestone. However, in the second trial, using identical diets, addition of limestone from the same source increased gains of steers that were gaining less rapidly. Limestone used in the second trial had smaller particle size than in the first study. Carcass measurements were not consistently changed by limestone (Table 3).

The "more reactive" limestone in the second trial produced performance equal to that of the less soluble limestone, suggesting that solubility or reactivity alone was not responsible for the difference. Results from these trials indicate that when the limestone reduced feed intake, it had a deleterious effect on steer performance, but when it increased feed intake, it improved performance. These effects are probably due to extent of ruminal fermentation, clearance of fiber from the rumen, or levels of specific acids produced in the rumen.

Potassium supplementation increased feed intake and live weight gain slightly. When corrected for the slight difference in dressing percentage, gains and efficiencies were influenced very little by added potassium. Potassium may have increased fluid intake and retention. Some of the benefit attributed to high potassium levels for newly received cattle may be due to increased intake and retention of fluids.

Response to supplemental calcium from trials in the literature is summarized in Table 4. Though overall, favorable effects are noted, consistently favorable responses come from one location only. Calcium supplementation has not consistently improved performance at other locations. Calculations from that location indicate that the unsupplemented corn-corn silage diet they have used has a

Table 2. Feeding trial results

	Trial 1			Trial 2		
Calcium level	0.46	1.00	0.46	0.46	1.00	1.00
Calcium source	—	TX	—	—	TX	MO
Potassium level	0.65	0.65	1.00	0.65	0.65	0.65
Weights						
Initial	715	716	720	608	606	626
57-62 days	991	970	1008	834	876	880
121-147 days	1148[a]	1093[b]	1161[a]	1014	1055	1068
Daily gain, lb						
Early	3.82[ab]	3.46[b]	4.00[a]	2.60	3.36	3.08
Late	2.75	2.52	2.90	2.86	2.86	2.96
Total	3.30[a]	3.00[b]	3.46[a]	2.76	3.05	3.01
Total[d]	3.58[a]	3.11[b]	3.65[a]	2.65	2.90	2.82
Daily feed, lb						
Early	19.9[a]	18.2[b]	20.4[a]	14.0	14.9	14.9
Late	19.4[ab]	17.8[b]	19.6[a]	17.4	18.1	17.8
Total	19.9[a]	18.0[b]	19.9[a]	16.1	16.9	16.7
Feed/gain						
Early	5.22	5.26	5.13	5.38[a]	4.45[c]	4.84[b]
Late	7.14	7.11	6.75	6.08[ab]	6.33[a]	6.02[b]
Total[a]	5.55	5.78	5.47	6.00	5.83	5.96
ME, mcal/kg	3.28	3.22	3.30	3.01	3.06	3.06
Fecal pH	5.6[ab]	5.8[a]	5.5[b]			
Digestibility, %						
Dry matter	73[b]	70[a]	74[b]			
Starch	92	91	91			
Nitrogen	61	57	60			

[abc]Means within a trial with different superscripts differ (P<.05).
[d]Based on carcass weights.

much lower net energy value than expected, and supplementation increased the value of their ration to a point equal to what would be expected from their ration. Though responses have been inconsistent, calcium does not increase energy value of feeds beyond table values. Some of the differences in response to limestone sources from trials may be due to toxic effects of some sources rather than unidentified benefits from the "better" limestone sources.

Table 3. Carcass measurements

	Trial 1			Trial 2		
Calcium level	0.46	1.00	0.46	0.46	1.00	1.00
Calcium source	—	TX	—	—	TX	MO
Potassium level	0.65	0.65	1.00	0.65	0.65	0.65
Carcass weight	712[a]	678[b]	720[a]	618	641	645
Dressing percent	61.3	60.3	60.7	60.9	60.7	60.4
Rib eye area						
Sq. inches	12.2	11.9	12.1	12.6	12.9	13.1
in.²/cwt	1.72	1.76	1.69	2.05	2.04	2.02
Fat thickness, in.	.54	.50	.60	.29	.31	.31
KHP, %	3.08[a]	2.75[b]	3.00[a]	2.36	2.52	2.33
Marbling score[c]	13.7	13.0	13.0	9.9	10.6	10.2
Federal grade[d]	12.9	12.6	12.6	11.7	12.0	11.9
Percent choice	81	62	67	—	—	—
Cutability, %	49.7[a]	49.2[ab]	48.8[b]	52.1	52.0	52.2
Cooler shrink, %	1.7	1.5	2.0	—	—	—

[ab]Means in a row within a trial with different superscripts differ significantly ($P<.05$).
[c]Slight minus=10; slight average=11.
[d]High good=12; low choice=13.

Table 4. Influence of calcium on feedlot performance — literature summary

		Change, percent for every 1% added Ca		
Location	Trials	Gain	Feed intake	Feed/gain
All	39	+3.1	− .1	+ 3.4
One	19	+7.5	−3.9	+12.3
Others	20	+ .5	+2.3	− 1.8

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Effect of Age, Size and Biological Type on Feedlot Performance of Steers Following Two Planes of Nutrition

S. W. Coleman and B. C. Evans

Story in Brief

The objective of this experiment was to determine the effect of two levels of nutrition for two durations during the growing phase on subsequent performance of steers during the finishing phase. Angus and Charolais weanling steers were fed either a moderate (control) or restricted growing ration for 306 days (older steers) or 95 days (younger steers). Steers were then switched onto a high energy finishing ration (80 percent concentrate).

Compensatory growth was observed in the older restricted steers when compared to the older control steers during the first part of the finishing phase for Charolais but not for Angus. Dry matter efficiency followed a similar trend in that the Charolais restricted steers were more efficient than their controls, but no differences were observed in the Angus steers. Growth rates for the growing and finishing phases combined were greater for the younger than the older steers. Further, the younger steers were more efficient in conversion of dry matter and metabolizable energy for live weight gain. From a practical viewpoint, holding steers on a growing ration for a long period of time offers no advantage in overall rate of gain or nutrient efficiency. When steers were held on a growing ration for a shorter period of time on either level of nutrition, no differences were seen in nutrient efficiency for live weight or carcass gain.

Introduction

During recent years, the need for more efficient and economical beef production has become increasingly apparent to the beef cattle industry. When cereal grain prices increase, the producer seeks alternative methods of feeding cattle and often looks toward higher roughage feeding programs. This means of reducing his costs must be weighed, however, against the increased inventory time necessary for the cattle to reach the final endpoint. In the post weaning segment of production it is believed that calves which enter the feedlot after being grown on a relatively low plane of nutrition will gain faster than calves reared on a high plane of nutrition, other factors being equal.

Data from many experiments support the phenomenon of compensatory growth. However, the physiological cause of the accelerated growth has not been

This work was a cooperative effort between USDA-ARS, Southern Region, Southwestern Livestock and Forage Research Station, El Reno, and OSU Animal Science Dept.

satisfactorily explained since the conditions under which the animal is subjected to the nutrient restriction (age, severity and duration of the restriction, genetic type, etc.) influence the animal's ability to compensate.

The objective of this study was to determine the effect of a low vs moderate growing diet on rate of gain and nutrient efficiency of steers during the subsequent finishing period. The design allowed for the evaluation of the effect of animal age and animal weight at the end of this period on successive performance. Steers entering the finishing phase were either of equal weight but different ages or of different weight but the same age. Further, two breeds were used to evaluate the effect of frame size (large frame, late maturing vs small frame, early maturing steers) in conjuction with age and size on steer performance.

Materials and Methods

A 2 x 2 x 2 factorial design which included age, resulting from the duration of the growing phase (older vs younger); biological type (large frame vs small frame); and plane of nutrition during the growing phase (control vs restricted) was used. Thirty-four spring-born weanling Angus steers and thirty-four Charolais steers purchased in November, 1978, represented the older steers. An equal number of fall-born steers of each breed were purchased from the same producers in June, 1979, and represented the younger steers. The Angus steers were representative of the small frame, early maturing biological type, and the Charolais steers were representative of the large frame, late maturing type. All steers were maintained in confinement pens (2 animals per pen) at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma.

Growing phase

Twelve older and 12 younger steers of each biological type were stratified based on weight, height at the withers and ultrasonic backfat thickness to one of three reps. Within each rep, the calves were randomly allotted to either the control or the restricted growing ration for a final distribution of six animals per treatment-type-age subgroup. Those calves on the control ration were fed pelleted dehydrated alfalfa ad libitum. Gains of approximately .75 kg per day were expected. The restricted steers were limit fed a ration which had a digestible energy content of 81.8 Mcal/kg. Adjustments were made in the amount of the ration fed until average daily gains of approximately .2 kg per day were attained. Ration composition, chemical analyses and nutrient values are described in Table 1.

The steers were weighed onto trial and at 28-day intervals following a 16-hour shrink without feed and water. The growing phase was terminated for each rep when the younger steers fed the control growing ration reached approximately the same weight as the older steers fed the restricted ration. At this point, half of the steers (six animals) of each treatment were slaughtered, and the remaining steers were switched to a high concentrate finishing ration (Table 2). A schematic drawing of the design of the experiment is in Figure 1.

Finishing phase

During the first, second and third weeks of the finishing phase, the steers were fed a 50:50, 60:40 and 70:30 concentrate:roughage ration, respectively. Beginning the fourth week and for the remainder of the experiment, all steers received a typical 80 percent concentrate ration (Table 1), fed ad libitum.

The final slaughter point was determined by ultrasonic measurement of backfat thickness. Angus steers were slaughtered at 12 mm backfat and Charolais steers at 8 mm backfat.

Table 1. Ingredients and chemical analysis of the rations

Item	IRN[a]	Growing Ration		Finishing ration[b]
		Control	Restricted	
Ingredients		(%)		
Alfalfa hay	1-00-059		13.0	10.0
Dehydrated alfalfa pellets	1-00-023	100.0		
Cracked shelled corn	4-02-931			70.3
Soybean meal	5-04-604		10.0	3.9
Cottonseed hulls	1-01-599		45.0	10.0
Mixed grass hay	1-02-244		19.0	
Wheat straw	1-05-175		13.0	
Molasses	4-04-696			5.0
Salt				0.6
Calcium carbonate				0.2
Proximate analysis[c]				
Dry matter, %		92.6	93.5	87.6
Organic matter, %		89.5	93.6	95.3
Crude protein, %		17.2	10.1	10.8
Neutral detergent fiber, %		50.5	75.4	30.1
Energy, Mcal/lb		2.2	1.8	2.0
Digestible protein, %		9.4	4.7	7.4
Digestible energy, Mcal/lb		1.2	.8	1.5
Metabolizable energy, Mcal/lb		1.0	.7	1.3

[a]International reference number.
[b]Finishing ration contains 250 mg monensin per ton.
[c]All components except % dry matter are expressed on a dry matter basis.

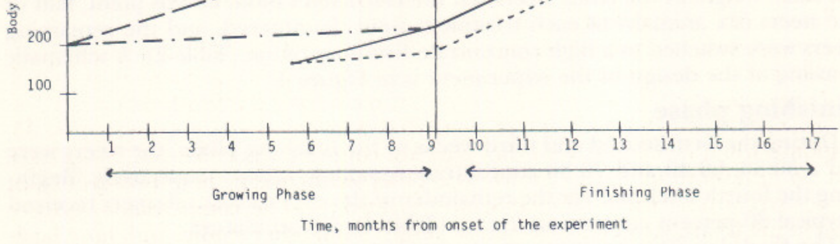

Figure 1. Basic design of the experiment with regard to nutrient level, animal age and duration of the growing and finishing phases

Results and Discussion

Growing phase

The objective of the growing phase was to create differences in body weight and/or composition due to breed, treatment and age in order to determine their effect on steer performance during the subsequent finishing phase. Average daily gains (ADG) during this period directly reflected the energy level of the diets as the control steers gained significantly faster than the restricted steers within their respective breed/age subgroup (Table 2). Final weight was greater ($P<.05$) for the older control steers within both breeds (Angus, 361.8; Charolais, 471.7 kg), but weight was similar for the older restricted and younger control steers ($P>.05$) as was predetermined in the design of the experiment. The younger restricted steers were the lightest groups within breed. On the average, Charolais steers remained in the growing phase longer than the Angus steers (215 vs 186 days), and the older steers were on trial longer than the younger steers (306 vs 95 days).

Finishing phase

Live weight performance of all steers during the finishing phase is presented in Table 3. At the onset of this phase, the older control steers were heavier ($P<.05$) than the other three sub-groups with both breeds, and the older restricted and younger controls were similar in weight. At the end of the finishing phase (12 mm backfat for Angus steers; 8 mm backfat for Charolais steers) the Charolais steers were heavier ($P<.05$) than the Angus steers, and the older steers within each breed were heavier ($P<.05$) than the younger steers. In addition, the older control steers required less time to reach the final endpoint ($P<.05$) than did the other sub-groups within a breed, as was expected due to their heavier weight at the beginning of the finishing phase.

Average daily gain (ADG) did not differ due to breed but was greater ($P<.05$) for the older steers than the younger steers (1.25 vs 1.10 kg). When comparing ADG among the groups of steers, however, one environmental factor must be considered. Just after the first group of steers reached the final endpoint and were slaughtered, several weeks of very cold and wet weather conditions prevailed, resulting in a period of maintenance for about 45 days. This resulted in a decrease in ADG of the remaining steers from that time until their respective time of slaughter. Therefore, it is necessary to compare ADG during the finishing phase in two periods: from the onset until the first group was slaughtered, and from that time until the remaining steers were slaughtered (Table 4). During the first period, the Angus and Charolais older restricted and younger control steers, which entered the finishing phase at similar weights within breed, showed no difference ($P>.05$) in ADG.

These results support those of Coleman et al. (1976) which indicated that feedlot gains were independent of animal age and of previous plane of nutrition and are closely related to animal weights upon entering the finishing phase. The older, restricted Charolais steers exhibited a compensatory growth ($P<.05$) response when compared with their control counterparts (1.54 vs 1.25 kg/day), but no difference in ADG ($P=.57$) was observed between these two groups of Angus steers (restricted 1.65; control, 1.59 kg/day). The compensatory growth seen in the Charolais steers is similar to results from other studies with both large frame steers (Drori et al., 1974) and with smaller frame steers (Fox et al., 1972) but is in contrast with results of Levy et al. (1971) where Israeli-Friesian bull calves (large frame) failed to show compensatory growth following a restricted period.

Table 2. Effect of breed, age and treatment on weight gain of steers during the growing phase

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial weight, lb	379	356	321	317	507	494	493	608	59
Final weight, lb	796	491	471	378	1038	690	696	617	36
Days on feed	314	330	108	108	291	289	82	83	8
Average daily gain, lb	1.36	.35	1.28	0.51	1.85	0.66	1.36	0.35	0.19

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.

Table 3. Effect of breed, age and treatment on weight gain of steers during the finishing phase[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Inital weight, lb	838	488	492	380	1043	660	649	636	
Final weight, lb	954^{d}	927^{d}	839^{e}	819^{e}	1468^{f}	1437^{f}	1303^{g}	1362^{g}	101
Number of days on feed	58^{d}	182^{e}	160^{e}	202^{e}	163^{f}	279^{g}	260^{g}	269^{g}	12
Average daily gain, lb	2.84^{d}	2.49^{d}	2.31^{e}	2.18^{e}	2.84^{d}	2.82^{d}	2.51^{e}	2.68^{e}	0.63

[a]Least square means; number of observations/mean = 6.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d,e,f,g]Means in the same row with different superscripts are different ($P<.05$).

Table 4. Effect of breed, age and treatment on weight gain of steers before and after the first group was slaughtered during the finishing phase[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Days to first slaughter	34[e]	61[f]	32[e]	84[f]	121[g]	154[h]	133[gh]	140[gh]	13
ADG to first slaughter lb/day	3.50[e]	3.63[e]	3.70[e]	2.57[f]	2.75[f]	3.39[e]	3.34[e]	3.28[e]	0.39
Days after first slaughter	....	121	128	118	89	124	126	130	13
ADG after first slaughter lb/day	....	1.91	1.82	1.85	1.80	1.94	1.56	1.94	0.92

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d]ADG = average daily gain.
[e,f,g,h]Means in the same row with different superscripts are different ($P<.05$).

The results of the Angus steers, however, conflict with those previously mentioned for smaller frame steers. A possible explanation is that the older control steers may have also been exhibiting compensatory growth following the growing phase, since they were not growing to their maximum potential on the pelleted alfalfa diet.

Reasons for the compensatory growth observed in the Charolais but not the Angus steers are not apparent. Periods of energy restriction in larger frame steers generally have not resulted in compensatory growth since the composition of the gain is unaltered (Levy et al., 1971); but in smaller frame steers, a restriction was associated with an increase in protein and water accumulation (Fox et al., 1972) and a resulting decrease in fat deposition during the subsequent refeeding period and thus increased ADG.

Table 5. Effect of breed, treatment on feed and energy efficiency of steers during the finishing phase[a]

	Angus		Charolais		
Item	C[b]	R[b]	C	R	SEM[c]
DMI[d], lb/day	18.1	16.1	20.4	17.8	3.4
DMI, % body weight	2.35	2.47	1.80	1.69	.22
DMI, lb/live weight gain, lb	7.04[fg]	7.09[f]	8.21[g]	6.61[g]	.47
MEI[e], Mcal/day	23.88	21.41	27.19	23.86	2.04
MEI, Mcal/live weight gain, lb	9.3[fg]	9.4[f]	10.9[g]	8.8[f]	0.28

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d]DMI = dry matter intake.
[e]MEI = metabolizable energy intake.
[f,g]Means in the same row with different superscripts are different ($P<.05$).

The older steers consumed more dry matter per day during the finishing phase ($P<.05$) than the younger steers of either breed (Table 6). However, most of the increase was the result of animal size. When intake was divided by metabolic body size, the differences were not significant ($P>.05$). The compensatory growth response observed in the older restricted Charolais steers was not, therefore, due to an increase in dry matter intake, but to an increase ($P<.05$) in utilization.

Dry matter efficiency for liveweight gain was greater for the younger steers of both breeds ($P<.05$) throughout the feedlot phase. Within the Angus steers, there was no difference in dry matter efficiency (Table 6) for any treatment group. In

Table 6. Effect of age on feed and energy efficiency of steers during the entire finishing phase[a]

Item	Older	Younger	SEM
DMI[c], lb/day	19.8[e]	16.4[f]	1.2
DMI, % body weight	2.07	2.07	.02
DMI, lb/live weight gain, lb	7.61[e]	6.86[f]	.16
MEI[d], Mcal/day	26.34[e]	21.83[f]	.70
MEI, Mcal/live weight gain, lb	10.1[e]	9.1[f]	.10

[a]Least square means; number of observations/mean = 12.
[b]SEM = standard error of the mean.
[c]DMI = dry matter intake.
[d]MEI = metabolizable energy intake.
[e,f]Means in the same row with different superscripts are different ($P<.05$).

contrast, the restricted Charolais steers were more efficient than their controls (P<.01), suggesting not only compensatory gain for the Charolais steers (during the early part of the finishing phase) but compensatory efficiency as well. Metabolizable energy (ME) efficiency for live weight gain followed the same trend as did dry matter efficiency during the finishing phase. The younger steers were more efficient (P<.05) than the older steers, and the restricted Charolais steers required less ME per unit of live weight gain than the control steers (P<.01). No differences occurred due to treatment for the Angus steers (P>.10). The younger steers had a lower average weight during the finishing period and, therefore, a lower maintenance requirement.

These results further indicate that efficiency was not affected by previous plane of nutrition in the small frame steers, which supports results of Coleman et al. (1976) with crossbred steers. Restricting the larger frame steers resulted in greater efficiency during the feedlot phase similar to work by Levy et al. (1971) and Fox et al. (1972).

Carcass parameters

Slaughter data for steers at the end of the finishing phase, adjusted to a constant backfat thickness, are presented in Table 7. Charolais steers were heavier than the Angus steers, and the control steers were heavier than the restricted steers. No differences (P>.05) were observed in hot dressing percent or rib eye area due to breed or treatment although the Charolais steers did tend to have larger rib eyes. In addition, quality grade was higher for older steers than for younger steers.

Table 7. Effect of breed and age on carcass characteristics of steers at the end of the finishing phase[a]

	Angus		Charolais		
Item	Older	Younger	Older	Younger	SEM[c]
Slaughter weight, lb	930[d]	819[e]	1353[f]	1276[g]	105
Hot carcass weight, lb	600[d]	541[e]	881[f]	833[g]	51
Hot dressing percent	64.38	65.78	65.18	65.37	1.14
Backfat thickness, in.	.61	.54	.31	.28	.03
Rib eye area, in.^{2}	1.89	1.74	2.39	2.37	.01
Quality grade[c]	13.5[d]	12.3[e]	12.4[d]	11.2[e]	0.6

[a]Least square means (backfat thickness is the actual measurement); number of observations/mean = 12.
[b]SEM = standard error of the mean.
[c]10 = average good; 13 = average choice; 16 = average prime.
[d,e,f]Means in the same row with different superscripts are different (P<.05).

Growing and finishing phases combined

The older restricted steers of both breeds had the lowest (P<.05) ADG of any age and treatment group for the growing and finishing phases combined. As a result, they were on the experiment longer (P<.05) than any other group. The time required from the onset of the study to final slaughter was similar for the younger control and restricted steers of both breeds. Within treatment, the older Angus steers, which had equal gains and energy efficiencies during the finishing phase, had lower ADG and a greater length of time on trial than the younger Angus steers. Similar results have been reported, both in studies where compensatory growth was observed (Fox et al., 1972) and not observed (Levy et al., 1971). No difference was observed in ADG for the Angus and Charolais steers within the control group. Within the restricted steers, daily gains of Angus were lower than those of Charolais steers. Therefore, while no difference due to breed occurred with control steers, small frame steers were more adversely affected by the restriction than were larger frame steers.

The results indicate that nutrient restriction for a short period of time may not affect overall steer performance, especially in the larger frame steers. Longer periods of restriction will lead to an increased inventory time which may more than offset any increased efficiency of steers exhibiting compensatory gain during the finishing period. Thus, even if compensatory gains can be expected, overall profitability of the production scheme is questionable. Producers may take advantage of the compensatory growth response when attempting to make more efficient utilization of forages or homegrown grains where availability is influenced by season, rainfall, temperature, etc. But, more commonly, the compensatory growth phenomenon is used when different owners are involved in the growing and finishing phases, and then by one at the expense of the other.

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Carcass Compositional Changes and Nutrient Efficiency of Steers as Affected by Size, Age or Biological Type

**S. W. Coleman, B. C. Evans
and J. J. Guenther**

Story in Brief

Angus and Charolais weanling steers were fed either a control or restricted growing ration for 306 days (older steers) or 95 days (younger steers). Steers were then switched to a high energy finishing ration (80 percent concentrate). Representative steers from each breed, treatment and age subgroup were slaughtered initially and at the end of the growing and finishing phases to determine carcass composition and nutrient efficiency data. The older control Angus steers yielded leaner carcasses when compared to other treatment groups at the end of the finishing period. Few differences were noted in Charolais carcasses due to age or treatment. Younger steers were more efficient in conversion of dry matter and metabolizable energy to live weight gain and in conversion of metabolizable energy to carcass energy. From a practical viewpoint, small-framed, fast maturing cattle should be used in a system for growing the cattle on a forage ration up to about 700-800 lb before placing them on a high concentrate ration. If placed in the feedlot at a light weight, either because of age or near-maintenance nutritional level, they fatten too quickly, and the final carcass composition could exceed 30 percent fat. Charolais cattle, on the other hand, should be placed in the feedlot as early as possible to facilitate finishing quality grade, but some trade-off in efficiency may be encountered.

Introduction

The physiological causes of compensatory growth and the composition of that growth have not been satisfactorily explained. It is generally accepted that the conditions under which the animal is subjected to nutrient restriction (age, severity and duration of restriction, genetic type, etc.) have a profound influence on the animal's ability to compensate. Further, it is now recognized that changes in carcass composition can be accomplished with nutrition as well as genetics and that the two may interact. The objectives of this study were to determine the influence of size, age and carcass composition on the rate and composition of gain of different biological types of cattle following a period of restricted feeding or adequate energy intake.

This work was a cooperative effort between USDA-ARS, Southern Region, Southwestern Livestock and Forage Research Station, El Reno, and OSU Animal Science Department.

Materials and Methods

The overall design was described by Coleman and Evans (1982). Slaughter groups were taken at the initation of the study (6 steers per breed-age), during the switch from the growing to finishing diets (6 steers per treatment-breed-age), and after the cattle finished (6 steers per treatment-breed-age). All steers were weighed (after a 16-hr shrink) and transported to the Oklahoma State University Meat Laboratory where they were penned overnight without feed and water and slaughtered the following morning. Each steer was weighed immediately prior to slaughter. Reticulo-rumen and omasum contents were weighed and subtracted from pre-slaughter live weight to determine empty body weight.

The right side of each carcass was physically separated into bone, soft tissue, and kidney and pelvic fat. After the soft tissue was ground and mixed, two 10-lb samples were removed. These samples were again ground and mixed. Four samples (.5 lb) were then taken, homogenized using a Sorvall Omnimixer, frozen and stored at -20 C while awaiting chemical analysis. Proximate analysis procedures (A.O.A.C., 1975) were used to determine percent moisture, protein, ether extract and ash of the carcass soft tissue. Gross energy was calculated using equations reported by Garrett and Hinman (1969).

Results and Discussion

Growing Phase

Weight changes and gains of various tissues are presented in Table 1. Daily protein gain, fat gain and, consequently, energy gain were greater for the control vs restricted steers within age groups of both breeds. Further, the older Charolais steers deposited more protein and less fat than the older Angus steers within treatment level. However, energy gain was not different ($P>.05$) among breed.

Control steers were more efficient in utilizing metabolizable energy for live-weight gain (Table 2) than the respective restricted groups within breed and age ($P<.05$). In addition, the younger Angus steers were more efficient than the older Angus steers. This can be attributed to the shorter duration of the growing phase. A reverse trend occurred in the Charolais steers. This difference is credited to the younger steers having lost weight early in the experiment and not to a true difference between the two breeds. The older control steers of both breeds and the Charolais younger control steers were more efficient than their restricted subgroups in converting metabolizable energy intake (MEI) to carcass energy gained. The younger Angus steers were similar in efficiency (10.7 Mcal MEI/Mcal gain) across treatments, which is probably associated with their shorter growing phase.

The Angus and Charolais steers differed in the efficiency of utilization of digestible protein intake (DPI). The younger Angus steers were more efficient than the older steers (4.1 vs 11.1g DPI/g protein gain), but no difference was observed for the Charolais steers (10.3 g DPI/g protein gain).

Finishing phase

Rate of daily energy gain ($P<.05$) and protein gain ($P=.10$) in the carcass was greater for the older steers than for the younger steers (Table 3). While no difference was observed in the Charolais steers ($P>.2$) due to treatment, the control Angus steers had an increased rate of protein gain ($P=.07$) when compared to the restricted Angus steers (122.7 vs 86.9 g protein/day, respectively) (Table 4). Fat deposition (g/day) was similar ($P>.1$) for all steers. There was a

Table 1. Effect of breed, treatment and age on weight gain and components of carcass gain of steers during the growing phase[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
Initial weight, lb (kg)	378 (172)	356 (162)	321 (146)	317 (144)	507 (231)	494 (225)	537 (244)	608 (276)	27 (12)
Final weight, lb (kg)	796 (362)	491 (223)	471 (214)	328 (172)	1038 (472)	690 (314)	696 (316)	617 (280)	16 (8)
Number of days on feed	314	330	108	208	291	289	82	83	8
Average daily gain, lb (kg)	1.36 (.62)	.35 (.16)	1.28 (.58)	.51 (.23)	1.85 (.84)	.66 (.30)	1.36 (.62)	.35 (.16)	.09 (.04)
Protein gain[d], g/day	57.4	24.0	87.7	42.5	94.8	32.8	68.7	3.8	4.64
Fat gain[d], g/day	132.1	15.9	62.5	32.4	110.4	10.2	78.9	18.4	2.79
Energy gain[d], Mcal/day	1.56	0.28	1.07	0.54	1.56	0.20	1.12	0.19	0.05

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d]Carcass compostitional changes are based on hot carcass weight.

Table 2. Effect of breed, treatment and age on feed, energy and protein efficiency of steers during the growing phase[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		
Item	C[b]	R[b]	C	R	C	R	C	R	SEM[c]
MEI[d], Mcal	17.71	9.45	11.71	5.86	20.18	12.54	16.15	8.19	.39
MEI, Mcal/live weight gain, kg	22.82	70.36	17.17	51.38	18.35	40.85	21.00	43.84	25.07
MEI, Mcal/carcass gain, gain, Mcal	10.01	33.74	11.26	10.14	11.54	48.79	13.29	49.41	14.77
DPI[e], g/day	795.2	223.3	525.5	173.4	905.8	292.7	725.2	235.3	15.15
DPI, g/carcass protein gain, g	12.83	9.33	4.96	3.28	8.68	9.36	10.04	13.20	2.58

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d]MEI = metabolizable energy intake.
[e]DPI = digestible protein intake.

trend, however, towards an increased fat deposition rate for the older steers vs the younger steers and for the older restricted steers vs the older control steers. These results support data of Byers and Rompala (1979) which indicated an increase in fat deposition with increased ADG but contrasts their observation of greater rates of protein gain with larger vs smaller-frame steers.

Metabolizable energy (ME) efficiency for liveweight gain was greater for the younger steers of both breeds ($P<.05$) (Table 3). The restricted Charolais steers required less ME per unit of live weight gain than Charolais control steers ($P<.01$) (Table 4). No differences occurred due to treatment for the Angus steers ($P>.1$). These results indicate that dry matter and energy utilization, as measured by live weight gains, are dependent on animal age and that younger steers are more efficient. Two factors need to be considered here: first, the younger steers had a lower average daily weight during the finishing period and, therefore, a lower maintenance requirement; second, the gain of the younger steers (especially the Angus) contained less energy. As a result, the difference in efficiency observed on the basis of live weight gain does not occur when efficiency is expressed on an

Table 3. Effect of age on components of carcass gain and energy efficiency of steers during the finishing phase[a]

Item	Older	Younger	SEM[b]
Protein gain[c], g/day	110.5	96.9	4.77
Fat gain[c], g/day	391.6	345.9	18.84
Energy gain[c], Mcal/day	4.287[e]	3.782[f]	0.161
MEI[d], Mcal/day	26.34	21.83	.70
MEI, Mcal/live weight gain, kg	22.25	20.11	.47
MEI, Mcal/carcass gain, Mcal	7.10	6.01	.44

[a]Least square means; number of observations/mean = 24.
[b]SEM = standard error of the mean.
[c]Changes based on hot carcass weight.
[d]MEI = metabolizable energy intake.
[ef]Means in the same row with different superscripts are different ($P<.05$).

Table 4. Effect of breed and treatment on feed and energy and protein efficiency of steers during the finishing phase[a]

	Angus		Charolais		
Item	C[b]	R[b]	C	R	SEM[c]
MEI[d], Mcal/day	23.88	21.41	27.19	23.86	2.04
MEI, Mcal/live weight gain, kg	20.45[fg]	20.76[f]	24.07[g]	19.44[f]	1.36
MEI, Mcal/carcass gain, Mcal	6.17	5.26	8.80	5.99	1.27
DPI[e], g/day	592.5	531.2	671.9	589.0	50.8
DPI, g/carcass protein gain, kg	5.17[f]	6.45[g]	6.69[fg]	6.50[fg]	0.52
Conversion of DPI for gain[e], %	40.21[f]	30.67[g]	29.47[fg]	34.07[fg]	3.40

[a]Least square means; number of observations/mean = 12.
[b]C = control growing ration; R = restricted growing ration.
[c]SEM = standard error of the mean.
[d]MEI = metabolizable energy intake.
[e]DPI = digestible protein intake.
[fg]Means in the same row with different superscripts are different ($P<.05$).

Table 5. Body compositon based on hot carcass weight of steers slaughtered initially and at the end of the growing and finishing phases[a]

	Angus				Charolais				
	Older		Younger		Older		Younger		SEM[b]
Initial									
Hot carcass weight, lb (kg)	88.9		75.2		122.5		149.7		9.11
Moisture, %	79.5		70.2		78.7		72.3		3.29
Fat[c], %	5.6		8.3		4.8		3.6		1.01
Protein, %	19.5		19.8		20.0		20.5		0.15
Ash %	1.0		1.0		1.0		1.0		0.01
Treatment level	C[d]	R[d]	C	R	C	R	C	R	SEM
End of growing phase									
Hot carcass weight, lb (kg)	261.7	109.6	112.7	89.9	280.9	176.6	188.5	151.5	7.28
Moisture, %	60.9	77.2	73.9	74.1	68.8	78.0	76.4	78.7	1.16
Fat, %	21.4	7.7	10.0	9.3	13.6	5.1	6.5	4.5	1.13
Protein, %	16.1	18.7	19.2	18.9	18.7	19.5	20.4	20.2	0.40
Ash, %	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.01
End of finishing phase									
Hot carcass weight, lb (kg)	295.2	274.6	271.8	232.6	402.4	386.7	352.4	372.0	6.11
Moisture, %	55.4	49.0	50.2	50.3	62.4	59.2	62.2	61.9	1.31
Fat, %	28.7	35.6	34.9	33.8	20.2	24.3	21.3	21.5	1.45
Protein, %	15.3	14.5	14.4	15.2	17.7	16.9	17.2	17.5	0.40
Ash, %	0.8	0.7	0.7	0.8	0.8	0.9	0.9	1.0	0.03

[a]Number of observation/mean = 6
[b]SEM = standard error of the mean.
[c]Fat content was determined from ether extract procedure (A.O.A.C., 1975).
[d]C = control growing ration; R = restricted growing ration.

energy basis (Mcal intake/MCal gain). These results further indicate that efficiency was not affected by previous plane of nutrition in the small-frame steers.

Metabolizable energy required per Mcal carcass gain, however, did not differ for any breed, treatment or age subgroup (P>.05). A trend (non-significant P>.05) was observed for the restricted Charolais steers to be more efficient. The fact that no significant differences occurred when comparing energy efficiency for carcass energy gain suggests differences in the composition of the gain. Therefore, energy utilization may be more accurately compared among groups by considering the composition of the gain and not weight gain alone.

Daily digestible protein intake (DPI) was greater (P<.05) for older steers than younger steers (651.6 vs 540.7 g/day). Protein efficiency, as measured by DPI per unit of protein gain and by the conversion of digestible crude protein for protein gain above maintenance (%), was not different (P>.05) due to treatment or age within the Charolais breed (Table 4). These results agree with results of Fox et al. (1972) where no difference in protein efficiency above maintenance (%) was observed between compensatory and control Hereford steers slaughtered at 454 kg. However, Angus control steers were more efficient according to both these efficiency measurements than their restricted counterparts. No difference (P>.05) occurred in protein efficiency due to age.

Carcass composition

Carcass composition of all slaughter groups is presented in Table 5. Little differences occurred among the initial weaning calves. However, after the growing phase, carcass composition reflected the treatments in that those fed the control ration for a long period of time were fatter. Also, Angus were fatter than Charolais as expected. Little difference occurred between older restricted and younger controls, which is similar to results reported by Burton and Reid (1969) that size, not age, is the predominate factor in determining body composition. However, the rankings had reversed at final slaughter, and older Angus cattle which had been grown at the higher level finished with less total carcass fat at a higher carcass weight than the other groups. This suggests that fast maturing cattle are more suited to a scheme of production utilizing a period of backgrounding or forage feeding up to approximately 700-800 lb before placing them in the feedlot. However, few differences in carcass composition of Charolais were noted at final slaughter. Older-restricted steers tended to be slightly fatter. Most of the Charolais were slaughtered with less backfat than the Angus, but logistically it was not practical to keep them until they reached .5 in backfat, to which the Angus were carried. Charolais and similar slow-maturing cattle should be placed in the feedlot as quickly as possible to facilitate finishing rather than growing.

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Effect of Stage of Maturity on the Chemical Composition and In Vitro Digestibility of Sorghum Grain

C.A. Hibberd, D.G. Wagner and R.L. Hintz

Story in Brief

Dwarf Redlan (waxy), Redlan (normal) and Darset (bird-resistant) varieties of grain sorghum were collected at weekly intervals starting 35 days preharvest. The early maturing Darset (BR=Bird-resistant) variety contained 78.6 percent dry matter on day 35 while the Dwarf Redlan (waxy) was much less mature (58.6 percent dry matter) at the same point, indicating black layer formation and physiological maturity had not yet occurred for Dwarf Redlan. Moreover, dry seed weight did not plateau until day 28 preharvest for the Dwarf Redlan although the earlier maturing Darset (BR) and Redlan (normal) varieties had reached final dry matter deposition by day 35 preharvest. Dry matter deposition, as measured by dry seed weight, was essentially complete when the dry matter content of the grain reached 70 percent. Although the concentration of starch, ash and crude protein was very similar from day 35 through harvest for all three varieties, changes in soluble protein (Landry-Moureaux Fraction I) and tannin content continued throughout maturity, suggesting that physiological changes in the kernel may continue even after dry matter deposition is complete. In vitro dry matter disappearance (IVDMD) of the Dwarf Redlan (waxy) remained unaffected through maturity. Relative digestibility (IVDMD) of the Darset (BR) variety, however, continued to increase as maturity approached and as tannin levels decreased. These studies suggest that the success of early-harvesting sorghum grain may be partially dependent on the particular variety that is utilized.

Introduction

Underground water depletion in many areas, soaring costs of irrigation water and recent drought conditions in the Southern Great Plains have increased the appeal of sorghum grain as a production alternative. More livestock producers in Oklahoma will be faced with the opportunity or necessity of using sorghum grain in their feeding programs. In order to insure adequate utilization of sorghum grain, some form of processing is required. Unfortunately, sorghum grain is a highly variable product due to numerous factors such as variety, source, endosperm type and environmental conditions during growth. This variation may influence the success of sorghum grain processing efforts. One energy efficient grain processing alternative of current interest is to harvest grain before maturity (about 30 percent moisture) and store the material in a silo. Little is known, however, of the physiological changes that occur as the kernel matures, especially with BR sorghums. Consequently, the objective of this study was to monitor changes in chemical composition and in vitro digestibility of several varieties of sorghum grain as they progess through maturity.

Materials and Methods

Three varieties of sorghum grain (Table 1) were grown and harvested under similar conditions at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma. Grain samples were collected at weekly intervals starting about 5 weeks preharvest. Each sample was hand-threshed, cleaned and ground through a 20-mesh screen in a laboratory Wiley mill. Starch content was measured as α-linked glucose polymers using an enzymatic method, and tannin content was determined by a modified vanillin-HC1 assay. Crude protein was determined by Kjeldahl analysis and soluble protein by the first stage of the Landry-Moureaux Fractionation Sequence D. Relative digestibility of each sample was estimated by an in vitro dry matter disappearance (IVDMD) technique. Ground grain samples (.4 g dry matter) were placed in 50-ml centrifuge tubes and inoculated with buffered rumen fluid (15 ml McDougall's buffer: 15 ml strained rumen fluid) from a concentrate (80 percent corn) fed steer. After 18 hours of incubation at 39° C (102° F), the samples were centrifuged, decanted and dried. Percent IVDMD was calculated by difference.

Table 1. Descriptive characteristics of sorghum grain

			Endosperm		
Variety	Seed coat color	Testa[a] layer	color	starch type	Classification
Dwarf Redlan	red	absent	white	waxy[b]	waxy
Redlan	red	absent	white	normal[c]	normal
Darset	brown	present	white	normal	bird-resistant

[a]Presence of testa layer indicative of high tannin levels.
[b]Waxy starch contains essentially 100% amylopectin.
[c]Normal starch contains about 75% amylopectin and 25% amylose.

Results and Discussion

The three varieties used in this study appeared to mature at different rates (Figure 1). The Darset (BR) sorghum matured the earliest (78.6 percent dry matter on day 35 preharvest) while the Dwarf Redlan (waxy) matured much more slowly (58.6 percent dry matter on day 35). This pattern is also reflected in dry seed weight (Figure 1). The dry weight of 100 kernels for the Darset and Redlan varieties had reached harvest levels by day 35 preharvest, except for a slight deviation for the Redlan on day 21 preharvest, suggesting that the deposition of seed components (starch, protein, etc.) was complete. The slower maturing Dwarf Redlan, however, increased dry matter deposition until day 28 preharvest. These observations reinforce the theory that the deposition of dry seed components is complete when the dry matter of the kernel reaches about 70 percent.

The concentration (percent of dry matter) of starch and ash in each of the three varieties was very similar from day 35 preharvest to maturity (Figure 2). Crude protein content (percent of dry matter) was also fairly constant during this period (Figure 3). In contrast, the concentration of Landry-Moureaux Fraction I protein (highly soluble albumins and globulins) appeared to decrease during maturation for the Darset and increase for the Redlan (Figure 3). Although total protein deposition may be complete, changes in the physiological characteristics of that

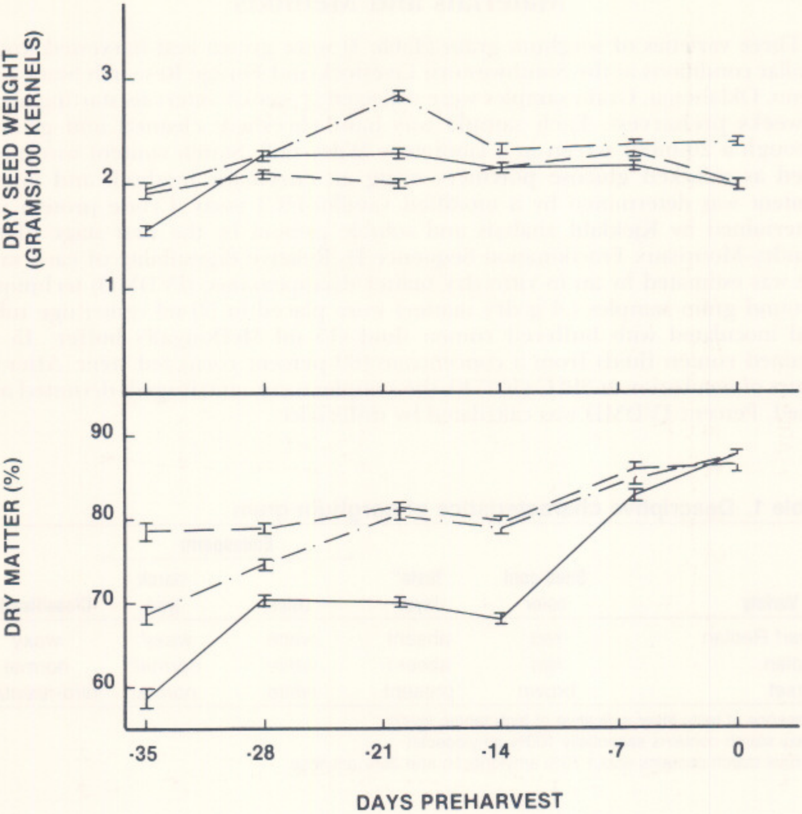

Figure 1. Effect of stage of maturity (mean ± S.E.) on dry matter content and dry seed weight (Dwarf Redlan —, Redlan -·-, Darset - -)

protein appear to continue. Tannin content of the Darset (BR) variety decreased between days 35 and 28 preharvest (Figure 4). If tannin content does decrease with maturity, as this study suggests, perhaps bird-resistant (high tannin) sorghums should not be harvested too early.

The digestibility (IVDMD) of the Darset (BR) variety appeared to increase as maturity progressed (Figure 4). The decrease in tannin content noted earlier may be partially responsible for this effect. The IVDMD of the Dwarf Redlan (waxy) was very constant from day 35 preharvest through maturity as was the Redlan variety except for an unexplainable depression on day 20 preharvest. Consequently, the digestibility of some varieties (Darset) may be affected by physiological changes in certain kernel components, i.e., tannin, while digestibility of other sorghum grain varieties remain unchanged.

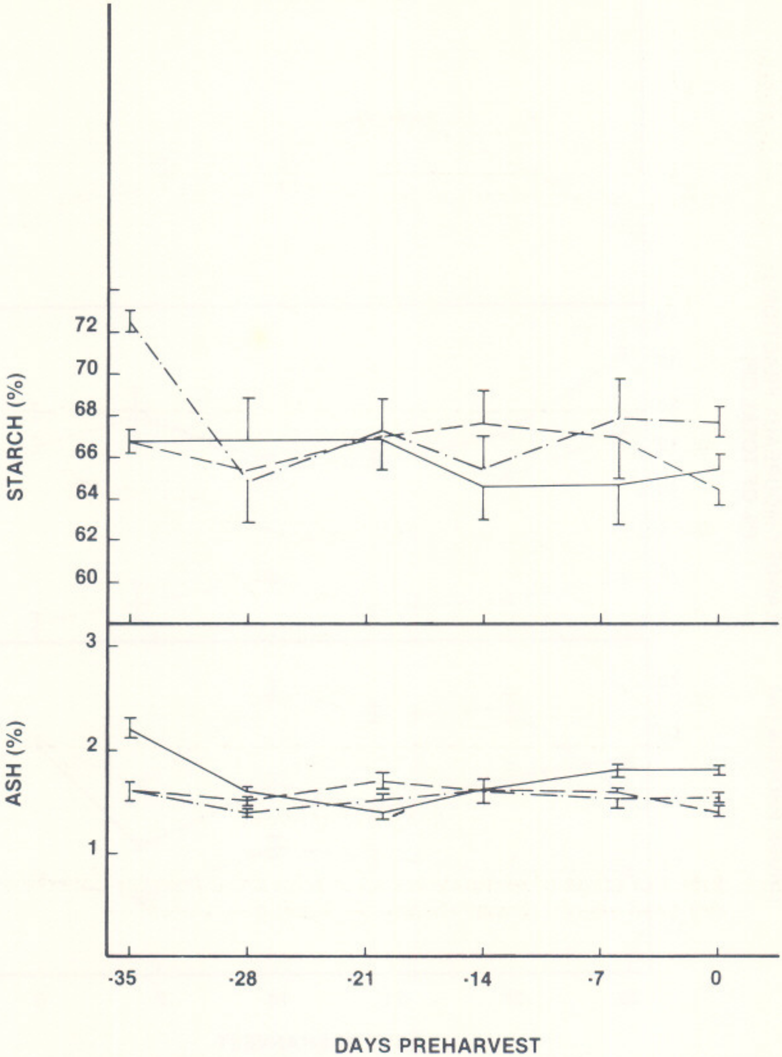

Figure 2. Effect of stage of maturity (mean ± S.E.) on starch and ash content (Dwarf Redlan —, Redlan -·-, Darset - - -)

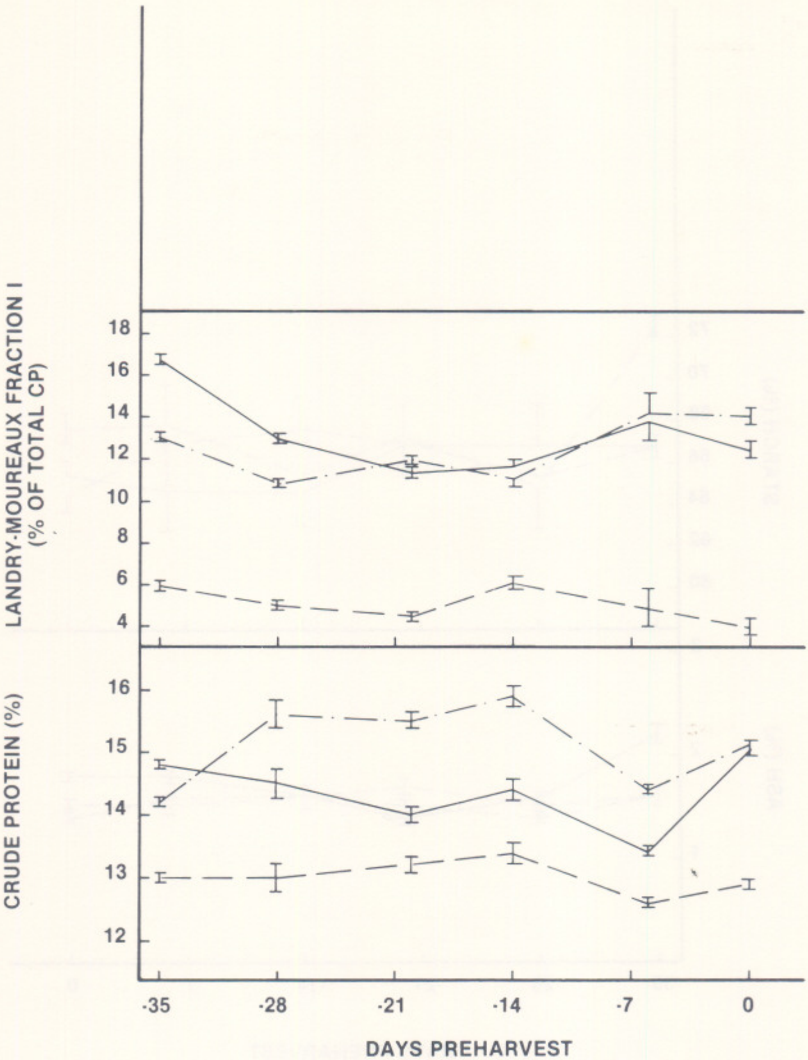

Figure 3. Effect of stage of maturity (mean ± S.E.) on crude protein and Landry-Moureaux Fraction I protein (Dwarf Redlan —, Redlan -·-, Darset - - -)

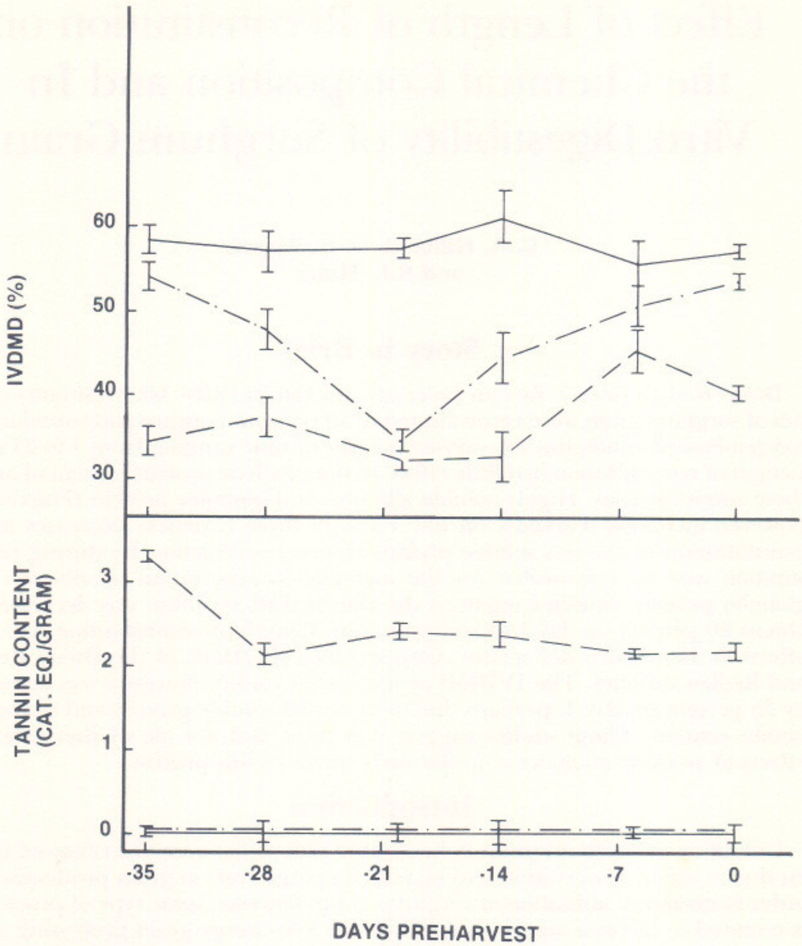

Figure 4. Effect of stage of maturity (mean ± S.E.) on tannin content and IVDMD (Dwarf Redlan —, Redlan -·-, Darset - - -)

High-moisture harvest of sorghum grain is normally initiated when the grain reaches about 30 percent moisture. These studies indicate that this practice is sound, at least for normal and waxy sorghums. The tannin content of the Darset variety declined in early maturity, suggesting that early harvesting of bird-resistant sorghums may not be feasible. However, in previous studies of reconstitution, fermentation of sorghum grain appeared to either inactivate or destroy most of the tannin in sorghum. If one can insure adequate fermentation of early harvested bird-resistant sorghum during ensiling, this concern may be of little consequence.

Effect of Length of Reconstitution on the Chemical Composition and In Vitro Digestibility of Sorghum Grain

C. A. Hibberd, D. G. Wagner
and R.L. Hintz

Story in Brief

Dwarf Redlan (waxy), Redlan (normal) and Darset (BR= bird-resistant) varieties of sorghum grain were reconstituted to 30 percent moisture and stored under oxygen-limited conditions for varying lengths of time ranging from 1 to 21 days. Length of reconstitution had little effect on the starch or protein content of any of these three varieties. Highly soluble albumin and globulin protein (Fraction I), however, increased markedly on day 1 for all three varieties. Decreases in the concentration of the less soluble prolamine protein (Fraction II) during reconstitution may be responsible for the increased concentration of albumin and globulin protein. Tannin content of the Darset (BR) sorghum was decreased by almost 60 percent on day 1 of reconstitution. Length of reconstitution had little effect on the in vitro dry matter disappearance (IVDMD) of the Dwarf Redlan and Redlan varieties. The IVDMD of the Darset variety, however, was increased by 35 percent on day 1, perhaps due to increased soluble protein and decreased tannin content. These studies suggest that most, but not all, of the beneficial effects of reconstitution occur in the early stages of this process.

Introduction

Utilization of sorghum grain in beef cattle rations has received renewed interest due to water conservation and increased energy costs in grain production. In order to maximize utilization of sorghum grain, however, some type of processing is required to increase starch availability. One low-energy grain processing alternative is to reconstitute the grain by raising the moisture level to 30 percent and storing it under oxygen-limited conditions for 21 days. Previous work in this laboratory has indicated that reconstitution is less effective for some varieties (waxy or normal) than for others (bird-resistant). In order to gain a better understanding of the sequence of events that occur during reconstitution, the chemical composition and relative digestibility (IVDMD) of several varieties of sorghum grain were monitored from day 1 through day 21 of reconstitution.

Materials and Methods

Three varieties of sorghum grain (Table 1) were grown and harvested under similar conditions at the Southwestern Livestock and Forage Research Station, El Reno, Oklahoma. Seventy grams of whole berries of each variety were placed in 250-ml glass bottles and sufficient water added to raise the moisture level to 30 percent. The bottles were sealed and agitated frequently until all free water had been absorbed. Duplicate bottles were removed on days 1, 2, 3, 4, 5, 7, 9, 12, 16

Table 1. Descriptive characteristics of sorghum grain

Variety	Seed coat color	Testa[a] layer	Endosperm color	Endosperm starch type	Classification
Dwarf Redlan	red	absent	white	waxy[b]	waxy
Redlan	red	absent	white	normal[c]	normal
Darset	brown	present	white	normal	bird-resistant

[a]Presence of testa layer indicative of high tannin levels.
[b]Waxy starch contains essentially 100% amylopectin.
[c]Normal starch contains about 75% amylopectin and 25% amylose.

and 21 of incubation and the samples were composited and ground through a 20-mesh screen in a laboratory Wiley mill with the aid of dry ice. Starch content was measured as α- linked glucose polymers using an enzymatic method and tannin content measured as catechin (tannin-like substance) equivalents by a modified vanillin-HCI assay. Crude protein was determined by Kjeldahl analysis and soluble protein by the first two stages of the Landry-Moureaux Fractionation Sequence D. Relative digestibility was measured by an in vitro dry matter disappearance (IVDMD) procedure. Ground grain samples (.4 g dry matter) were placed in 50-ml centrifuge tubes and inoculated with buffered rumen fluid (15 ml McDougall's buffer: 15 ml strained rumen fluid) from a concentrate (80 percent corn) fed steer. After 18 hours of incubation at 39° C (102° F), the tubes were centrifuged, decanted and dried. Percent IVDMD was calculated by difference.

Results and Discussion

Reconstitution had little effect on the starch content of any of these three varieties (Figure 1). Similarly, crude protein content was not markedly changed by length of reconstitution (Figure 1). Solubility properties of the sorghum protein, however, did appear to be altered. Highly soluble albumin and globulin protein increased on day 1 for all three varieties (Figure 2). This increase in soluble protein on day 1 may be due to water imbibition by the kernel as well as the initiation of germination. The concentration of these proteins decreased on day 2 for the Dwarf Redlan (waxy) and Redlan (normal) varieties. Perhaps fermentative action by bacteria reduces the concentration of soluble protein at this stage. By day 16, however, highly soluble Fraction I protein concentration had returned to pretreatment levels and continued to rise for the Redlan and Darset (BR) varieties through day 21. Soluble protein in Fraction I may have been increased at the expense of Fraction II protein (Figure 2). The concentration of prolamine (Fraction II) protein decreased as reconstitution progressed for all three varieties.

Other kernel components may also be changed by reconstitution. For example, tannin content of the Darset variety decreased markedly on day 1 (Figure 3), and continued to decrease, although more slowly, through day 21. The initial stages of the germination process may result in degradation or inactivation of tannin. Relative digestibility (IVDMD) of the Dwarf Redlan (waxy) and Redlan (normal) varieties was largely unaffected by reconstitution (Figure 3). In contrast, IVDMD of the Darset (BR) variety was increased almost 35 percent on day 1 of reconstitution, which raised this variety to a level similar to that of the Redlan variety. This

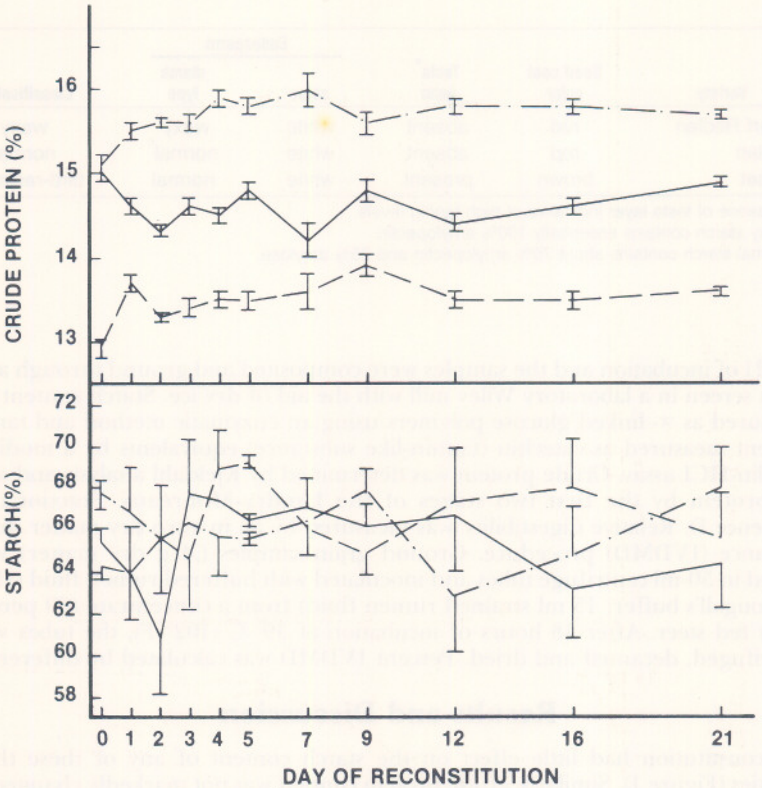

Figure 1. Effect of day of reconstitution (mean ± S.E.) on crude protein and starch content of different sorghum grains (Dwarf Redlan —, Redlan-.-, Darset - - -)

effect is probably related to the increase in soluble (Fraction I) protein and decrease in tannin observed for the Darset variety on day 1.

Rapid changes in the chemical constituents of sorghum grain in the early stages of reconstitution indicate that much of the benefit of this process may be accrued fairly early in the normal 21-day period. For example, increased soluble protein and decreased tannin content of the Darset (BR) variety on day 1 apparently resulted in a rapid increase in IVDMD. Although a 21-day incubation is probably required to maximize the effect of reconstitution, much of the response generated by this process appeared in this study to occur by day 2 or 3. Consequently, this study suggests that in situations where turnover time of processed grain is crtitical, shorter reconstitution periods of 3 to 5 days might be considered.

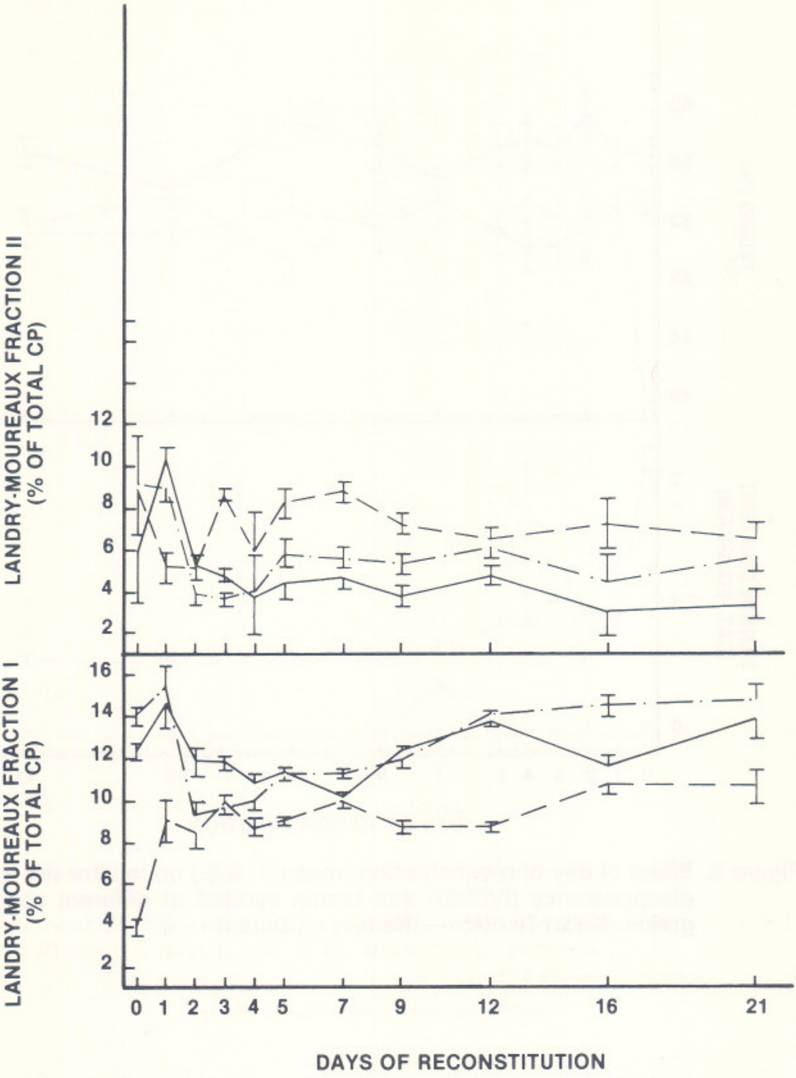

Figure 2. Effect of day of reconstitution (mean ± S.E.) on some protein fractions in different sorghum grains (Dwarf Redlan —, Redlan -.-, Darset - - -)

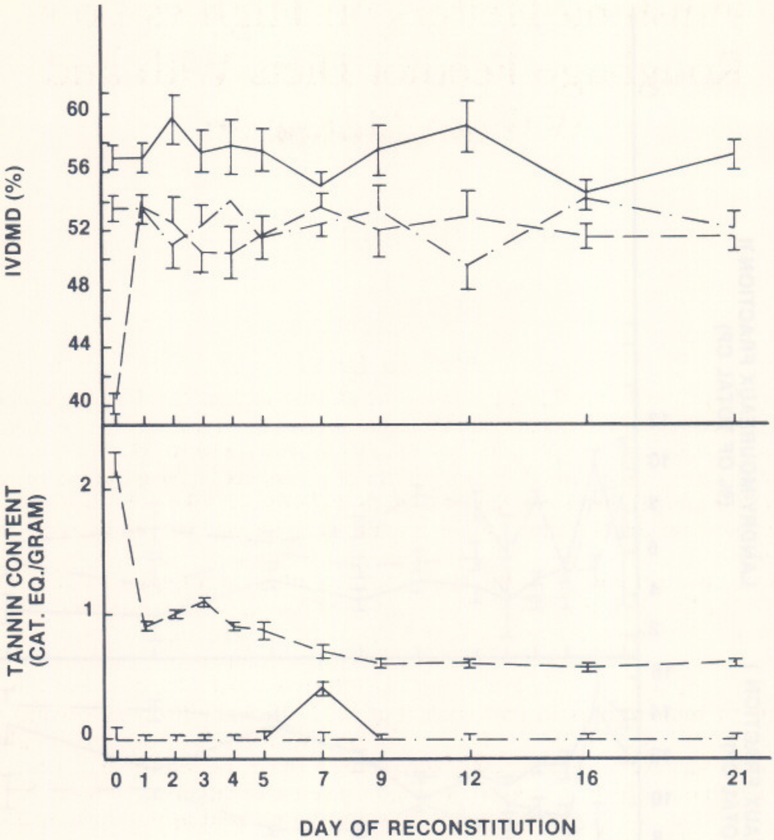

Figure 3. Effect of day of reconstitution (mean ± S.E.) on in vitro dry matter disappearance (IVDMD) and tannin content of different sorghum grains (Dwarf Redlan —, Redlan -.-, Darset - - -)

Finishing Heifers on High vs Low Roughage Feedlot Diets With and Without Monensin

D. G. Wagner and S. C. Ostlie

Story in Brief

Sixty-four 535-lb crossbred heifers were allotted to four finishing treatments: 1) high roughage (50 percent) ration, no monensin; 2) high roughage + monensin; 3) low roughage (10 percent), no monensin; and 4) low roughage + monensin. Monensin was included in two of the four rations at 30 g/ton, to provide about 300 mg per head per day at a 20-lb daily feed intake. The heifers were slaughtered after 119 days on feed, and routine carcass parameters were measured.

The 10 percent roughage finishing ration resulted in a higher average daily gain (+.32 lb), final live slaughter weight (+ 38.6 lb), dressing percent (+ 2.5 percent) and carcass weight (+ 44.2 lb) than the 50 percent roughage ration. Interestingly, the increase in carcass weight approximated the increase in final live slaughter weight. Monensin had no effect on gain. Intake was reduced slightly by monensin as in past trials, but feed efficiency (lb feed/lb gain) was improved only + 3.6 and + 3.3 percent on the 50 and 10 percent roughage rations, respectively. This is less improvement from monensin than generally reported in other feedlot trials where high concentrate rations were used. Nevertheless, a $1 expenditure on monensin would have saved approximately $4 on feed cost in this trial.

Introduction

A major limitation of finishing cattle on high forage diets is lower gains and usually higher costs of gain. Unless fed much longer, such cattle also tend to grade lower, using past or existing grading standards. However, cattle finished on higher forage diets should be leaner or lower in fat content while containing nearly the same quantity of total protein. The type of fat may also differ although this has received only very limited study. The long-term trend in the beef industry will likely be toward the production of leaner market beef than we have been accustomed to in the past. Reasons include high costs of production (fat is expensive to produce), consumer desire for leaner beef, more worldwide demand for grains, etc. Past changes in the grading standards have fostered a gradual shift to leaner beef. Potential future changes (several proposals for changes in grading are currently under consideration) will further promote the production of beef with a lower fat content. In general, such changes should result in a shorter feeding period on high grain diets and/or permit greater use of forages in market beef production.

Monensin is a biologically active compound with the trade name Rumensin. It is produced by an organism *Streptomyces cinnamonesis* in a fermentation process and has been shown to improve efficiency of feed utlitzation in high concentrate finish rations and in high forage diets in stocker programs. The effect of monensin on certain carcass characteristics in different types of finishing diets has received very limited study, including the effects of fat content and composition (e.g. type of fat and cholesterol level).

The objective of this study was to determine the feedlot performance and carcass characteristics of feedlot cattle fed conventional, high concentrate or high roughage finish rations, with or without monensin. Although not reported here, lipid analyses are being conducted to assess effects of roughage level and monensin on carcass fat composition.

Materials and Methods

Sixty-four Angus × Hereford heifers were blocked into four groups by weight and then randomly allotted within block to four treatments, giving 16 animals per treatment (four animals/pen and four pens/treatment). The treatments were:

1) 50 percent roughage finish ration, no monensin
2) 50 percent roughage finish ration + monensin
3) 10 percent roughage finish ration, no monensin
4) 10 percent roughage finish ration + monensin

Composition of the rations is shown in Table 1.

Table 1. Composition of high and low roughage finishing rations

Ingredient	High roughage[1] − Monensin	High roughage[1] + Monensin	Low roughage − Monensin	Low roughage + Monensin
	%	%	%	%
Corn, rolled	21.5	21.5	39.9	39.9
Sorghum, rolled	21.5	21.5	39.9	39.9
Cottonseed hulls	25.0	25.0	10.0	10.0
Dehydrated alfalfa pellets	25.0	25.0	—	—
Cottonseed meal	4.0	4.0	7.0	7.0
Molasses, blackstrap	2.0	2.0	2.0	2.0
Salt, T.M.	0.2	0.2	0.2	0.2
Ca carbonate	0.5	0.5	0.7	0.7
Dicalcium phosphate	0.3	0.3	0.3	0.3
Monensin	—	30g/ton	—	30g/ton

[1]Vit. A added.

Monensin was incorporated in the two monensin-containing rations at 30 g/ton to yield an intake of approximately 300 mg per head per day. The heifers averaged 535 lb at the beginning of the experiment and were fed 119 days before slaughter. Routine carcass measurements were obtained after 48 hr. A one-inch steak from the 12th rib section was removed from the right side of the carcass for later lipid analyses.

Results and Discussion

Feedlot performance data are shown in Table 2. Heifers on the 10 percent roughage treatments gained approximately 0.3 lb/day more than those on the two 50 percent roughage rations, resulting in a 38-lb heavier slaughter weight. Monensin had no effect on gain or slaughter weight on either the high or low

Table 2. Feedlot performance (119 days)

Item	High roughage		Low roughage	
	− Rumensin	+ Rumensin	− Rumensin	+ Rumensin
No. of animals	16	16	16	16
ADG, lb	2.33[a]	2.33[a]	2.69[b]	2.61[b]
Initial wt, lb	535.2	534.9	534.8	535.6
Final wt, lb	812.9[a]	812.6[a]	855.4[b]	847.2[b]
Feed intake/day, lb	21.3	20.5	17.9	16.8
Feed/gain, lb/lb[c]	9.14[a]	8.81[a]	6.63[b]	6.41[b]
Improvement, %		+ 3.6		+ 3.3

[a,b]($P<.05$).
[c]DM basis.

roughage treatment. This is in agreement with other research showing similar daily gains when monensin is included in high concentrate feedlot rations. Monensin supplementation resulted in a slight reduction in daily feed intake and produced only a 3.6 and 3.3 percent improvement in feed efficiency on the high and low roughage finishing rations, respectively. The improvements from monensin noted in this trial are considerably less than that generally reported in most other studies. However, an economic analysis would still show a favorable cost/benefit ratio for using monensin. In this trial, a $1.00 input for monensin would have produced approximately a $4.00 saving in feed costs, using realistic current prices.

Carcass parameters are indicated in Table 3. Generally, the low roughage rations resulted in somewhat higher carcass weights, including dressing percent. Little difference was noted in most other carcass parameters between the high and low roughage finishing programs, but fat thickness averaged .10 in. more on the low roughage diets. Monensin produced no major changes in carcass parameters on either diet, but monensin tended to produce a small increase in rib eye area, marbling score and quality grade on both the high and low roughage diets. This is in agreement with carcass trends repoted with monensin use in a previous study emphasizing a higher roughage finishing program (Ostlie et al., 1981).

Table 3. Carcass measurements

Item	50% Roughage		10% Roughage	
	− Rumensin	+ Rumensin	− Rumensin	+ Rumensin
Carcass weight, lb	483.7[a]	486.3[a]	532.3[b]	526.0[b]
Dressing percent	59.5[a]	59.8[a]	62.2[b]	62.1[b]
Rib eye area, in^2	9.21	9.45	9.87	10.2
Fat thickness, in	.55	.47	.60	.62
Marbling score[c]	15.7	16.8	14.8	15.81
Quality grade[d]	12.4	12.9	12.2	12.6

[a,b]($P<.05$).
[c]Marbling score: 14 = avg small, 17 = avg modest, 20 = avg moderate.
[d]Quality grade: 10 = avg good, 13 = avg choice.

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Protein Deposition Prediction Equation

R. L. Hintz and F. N. Owens

Story in Brief

The protein deposition prediction equation which is a component of a model being developed by the S-156 Regional Project to simulate forage-beef production is as follows: protein gain (lb/day) from conception to maximum rate of gain = $.37485\,[e^{(\ln(.006174/.37485)(DC-566)^2/566^2)}]$; protein gain (lb/day) from maximum rate of gain to maturity = $.37485\,[e^{(\ln(.00002867/.37485)(DM^2/1177^2))}]$ where e is 2.71828, ln is the natural logarithm, DC is days after conception and DM is days after maximum rate of gain. Comparison with other protein deposition and gain predictions indicates that the equation predictions agree with predictions of other equations, particularly at lighter cattle weights.

Introduction

A computer model to simulate forage-beef production in the Southern region is being developed by the S-156 Regional Project. The purpose of this paper is to present a component of this forage-beef model which describes the protein deposition from conception to maturity.

Materials and Methods

Data reported by Moulton et al. (1922) were used to determine parameters of a sigmoid curve to describe protein deposition of steers from conception to maturity. The following parameters of a sigmoid curve were estimated:
Rate of protein gain at conception (lb/day) = .006174;
Maximum rate of protein gain (lb/day) = .37485;
Rate of Protein gain at maturity (lb/day) = .00002867;
Days from conception to maximum rate of protein gain = 566;
Days from maximum rate of protein gain to maturity = 1177.

Results and Discussion

The equation derived from data reported by Moulton et al. (1922) is: net protein gain (lb/day) from conception to maximum rate of protein gain = .37485 $[e^{(\ln(.006174/.37485)(DC-566)^2/566^2)}]$ where DC = days after conception and protein gain (lb/day) from maximum rate of protein gain to maturity = .37485 $[e^{(\ln(.00002867/.37485)(DM^2/1177^2))}[$ where DM = days after maximum rate gain. (Figure 1).

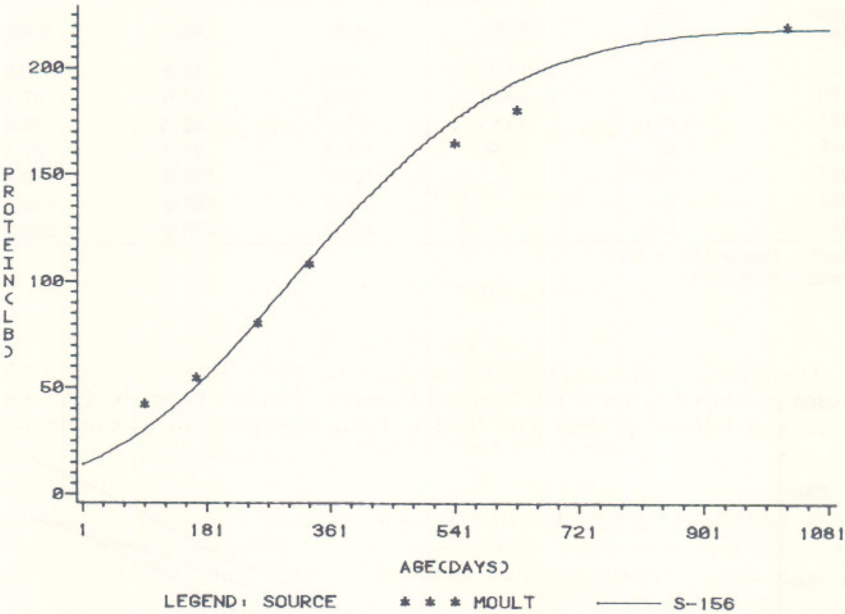

Figure 1. Plot of S-156 Equation and data reported by Moulton et al. (1922)

Similar equations as components of this forage-beef model have been developed to simulate retention of fat, water and ash. The summation of fat, water, ash and protein gain is an estimate of empty body weight gain. This approach can simulate animals of similar weights with different body composition. Also, simulation of animals with similar protein deposition and different empty body weights can be achieved.

Regression equations have been estimated to predict protein deposition and/or gain as a function of weight, average daily gain and/or mature weight (Reid and Robb, 1971; Reid, 1974; Byers and Rompala, 1979; Garrett, 1981; Lofgreen, 1981; ARC, 1980). An animal has been simulated with the S-156 forage-beef model to make comparisons with other predictions. In studying the results, recall that the S-156 forage-beef model can simulate animals with similar protein deposition and different empty body weights since fat, water, ash and protein deposition are predicted with different equations. Comparison of other protein deposition predictions with the S-156 prediction indicates that they agree well at lighter cattle weights, but the S-156 equation predicts a greater rate of protein for heavier cattle (Table 1). The S-156 equation predictions and predictions from two equations developed by Reid agree very closely from birth to 725 lb (Figure 2). The difference in protein deposition of the heavier weights of cattle can be reduced by simulating an animal with a faster rate of fat deposition without changing the protein deposition. Similar conclusions are

Table 1. Protein deposition predictions (lb)

Empty body weight (lb)	Empty body gain (lb/day)	Source[1]			
		Reid1	Reid2	ARC	S-156
77	.68	14.5	12.3	16.8	13.9
193	1.28	36.9	37.8	37.0	37.7
381	1.81	73.1	75.7	65.7	76.6
612	1.96	117.4	116.3	99.0	121.1
837	1.70		150.1	133.0	160.4
983	.88		168.7	161.0	188.9
1066	.51		178.2	176.6	206.0

[1]Reid1 = Reid and Robb, 1971.
Reid2 = Reid, 1974.

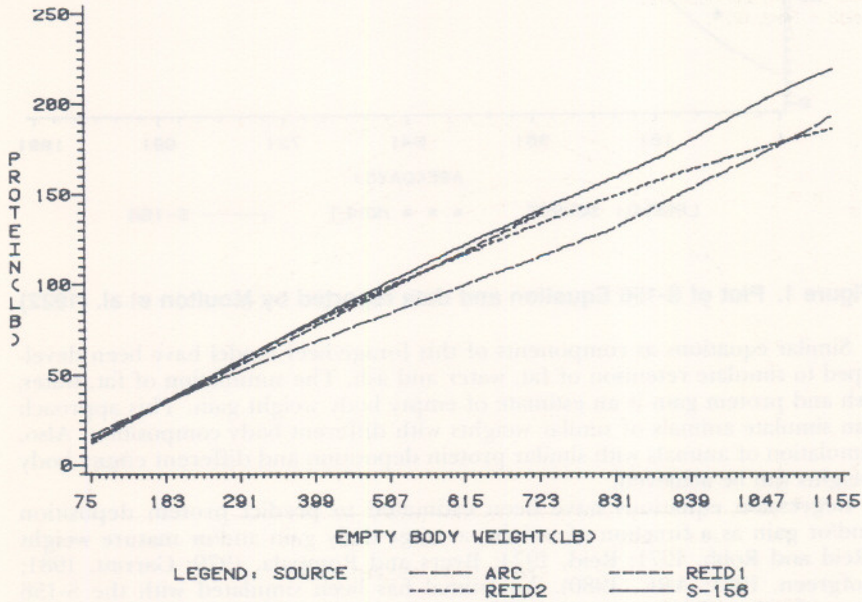

Figure 2. Protein deposition predictions

drawn when comparing other protein gain predictions with the S-156 prediction (Table 2). The protein gain increases as the animal grows until it reaches a certain weight; then the protein gain decreases as the animal grows (Figure 3). With the simulated animal, protein deposition and gain predictions agree at lighter weights of cattle but differ at heavier weights of cattle. The decrease in gain is a function of (1) decreased rate of gain and (2) decreased protein content of deposited tissue.

The flexibility of the S-156 forage-beef model allows one to simulate animals with different body composition. Simulation of the components, fat, water, ash and protein, will improve our ability to simulate animal performance (e.g. average daily gain and carcass composition). Continual refinement of these equations for the S-156 forage-beef model will improve their flexibility and usability.

Table 2. Protein gain predictions (lb/day)

Empty body weight (lb)	Empty body gain (lb/day)	Source[1]						
		Reid1	Reid2	Byers	Garrett	Lofgreen	ARC	S-156
77	.68	.131	.154				.118	.135
193	1.28	.247	.272				.204	.267
381	1.81	.348	.344		.320	.296	.259	.366
612	1.96	.377	.319	.348	.290	.275	.260	.360
837	1.70		.233	.237	.212	.200	.220	.288
983	.88		.104	.129	.101	.090	.117	.189
1066	.51		.057	.059	.057	.048	.070	.101

[1]Reid1 = Reid and Robb, 1971.
Reid2 = Reid, 1974.

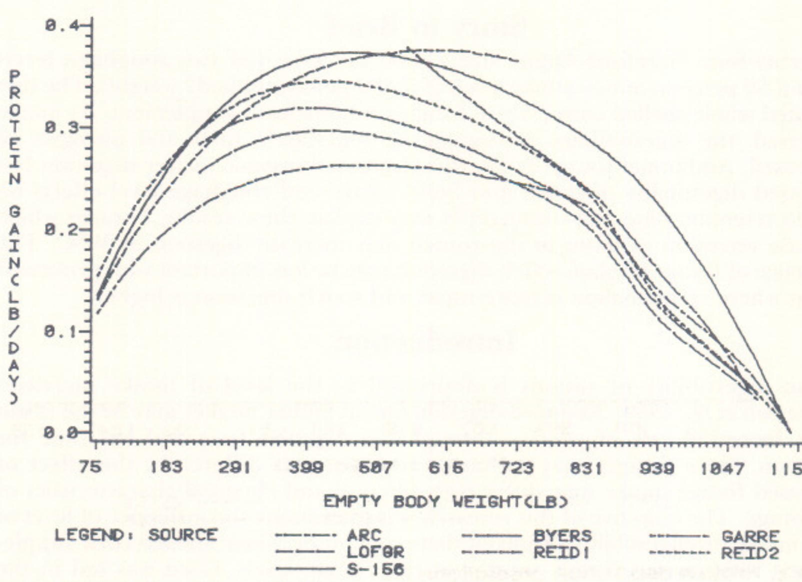

Figure 3. Protein gain predictions

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Effect of Intake and Roughage Level on Digestion

S. R. Rust and F. N. Owens

Story in Brief

Twenty-four Hereford-Angus steers (800 lb) were fed two roughage levels (10 and 50 percent) at two intake levels (1 and 2 percent of body weight). The diet included whole shelled corn (WSC), forage and 8 percent supplement. As intake increased, the digestibilities of organic matter, starch, fiber and nitrogen all decreased. Additional forage in the diet decreased organic matter digestion but increased digestibility of starch and fiber. Intake and roughage level effects on rumen retention time and ruminal pH may explain these results. Forages which increase retention of grain in the rumen may increase digestion of WSC. The influence of forage level on starch digestion may be less important with processed grains where fermentation is more rapid and starch digestion is higher.

Introduction

The digestibility of rations is depressed as the level of intake increases (Andersen et al., 1959). Reduced digestibilities at higher intakes may be the result of an increased rate of passage through the digestive tract and less time for digestion. Since forages may influence passage rates differently, the effect of increased forage intake may differ with physical and chemical characteristics of the forage. The objective of this research was to examine the influence of level of feed intake on digestibility of mixed diets containing whole shelled corn supplemented with various forage sources at two forage levels. Corn was fed in the whole form to enhance effects of intake and roughage level on digestibility.

Effects may have been different with corn fed in the rolled, ground, high moisture or steam flaked form.

Experimental Procedures

Twenty-four Hereford-Angus steers (800 lb) were fed six roughages including cottonseed hulls (CSH), prairie hay (PH), alfalfa (AH), sorghum plant silage (SS) and two types of corn plant silage (GCS — grain variety; FCS — forage variety). Steers were fed at 1 or 2 percent of body weight with feed presented twice daily. The diet (Table 1) consisted of 10 or 50 percent forage, 8 percent supplement and whole shelled corn (WSC). Supplements were formulated to ensure a minimum crude protein level of 10 percent. Chromic oxide was added to the supplement at .2 percent of ration dry matter as an indigestible marker to calculate digestibility from fecal samples. Animals were housed in individual pens with concrete slatted floors. Steers were fed their respective diets for 21 days. Fecal grab samples were collected at 0600 hr the last 5 days of each period. Fecal samples were analyzed for pH and frozen for future analysis. Feed and fecal samples were analyzed for organic matter, starch, acid detergent fiber (a fiber estimate) and nitrogen. Rumen samples were collected at 1330 hr the last day of each period. Rumen samples were analyzed for pH, ammonia and volatile fatty acid (VFA) content.

Table 1. Diet composition

	Forage level, %	
Feedstuff	10	50
Corn, whole shelled	82	42
Forage from one of six sources	10	50
Supplement	8	8

Results and Discussion

As feed intake increased, digestibility of organic matter, starch, fiber and nitrogen decreased markedly (Table 2). Data with dairy cattle suggests a 50 percent increase in feed intake results in an 11 percent reduction in rumen retention time (Campling et al., 1961). The faster WSC leaves the rumen, the lower the digestibility since little digestion of WSC occurs in the lower gastrointestinal tract. Substitution of roughage for grain in the diet reduced the digestibility of organic matter but increased fiber and starch digestion (Table 3). A reduction in ruminal retention and ruminal digestion of fiber would increase the amount of

Table 2. Effects of intake on digestibility

	Intake level[a], % of body weight		
Item	1	2	% change
Digestibility: (%)			
Organic matter	76.0[b]	69.7[a]	−8.4
Starch	91.3[b]	84.5[a]	−7.5
ADF	43.5	42.0	−3.5
Nitrogen	67.3[b]	60.9[a]	−9.5

[ab]Means in a row with different superscripts differ statistically (P<.01).

Table 3. Effect of roughage level on digestibility

	Roughage level, %		
	10	50	Difference
Digestibility: (%)			
Organic matter	74.8[b]	70.8[a]	−5.3
Starch	86.8	89.0	+2.6
ADF	36.6[a]	49.0[b]	+33.9
Nitrogen	64.9	63.2	−2.6

[ab]Means in a row with different superscripts differ statistically ($P<.01$).

material presented to the large intestine and colon for digestion. The small reduction in fiber digestion as intake was doubled in this study would suggest that fiber digestion in the large intestine and colon compensated for any reduction in digestibility in the rumen. Intakes of 1 and 2 percent of body weight approximate 1.2 and 1.9 multiples of maintenance, respectively. For each multiple of maintenance, organic matter digestibility was reduced 8.7 and 6.2 percent for the 10 and 50 percent roughage level diets, respectively. For example, increasing intake from 1X to 2X maintenance requirements would reduce organic matter digestion from 80 to 73 percent. These depressions are more than those suggested from experiments with dairy cows at higher intake levels. Differences may be due to the form of corn being fed. Studies with dairy cows indicate that form of corn definitely influences the degree of depression in digestibility due to feed intake (Moe and Tyrrell, 1977).

The term "associative effect" is used to describe the non-additive response in digestibility when two feedstuffs are fed in combination. Several studies have reported the presence of associative effects between feedstuffs. Increased intake level or accumulation of bulky feeds can increase ruminal passage rates and thus decrease digestion of organic matter in the rumen. Increased passage rate may be responsible for a portion of the associative effect. Passage rate should be greater at higher levels of feed intake and with higher forage diets.

Intake effects on digestibility within roughage levels are shown in Table 4. Since effect of intake level on digestibility was similar at both roughage levels, and effect of roughage level was similar across both intake levels, the overall effects of intake and roughage level on digestibility were calculated (Table 5). Digestion of organic matter was decreased for both increased intake and roughage. Effects of these two factors on starch and fiber digestion differed markedly. Deviation from expected digestion at the high intake and high forage diet can be used to calculate how much of the digestibility response can be explained by intake and roughage level. This interaction is often termed an associative effect. Difference between the observed and predicted digestibility of the high roughage-high intake diet is

Table 4. Roughage-intake level interaction effects on digestibility

Intake, % of BW	Roughage,%	Organic matter	Nutrient Digestibility, %		
			Starch	Fiber	Nitrogen
1	10	78.4	90.3	37.3	68.6
2	10	73.6	83.2	35.9	61.3
1	50	71.3	92.3	49.8	66.0
2	50	68.1	85.7	48.2	60.5

Table 5. Effect of intake and roughage level on digestibility (% change)

	Organic matter	Starch	Fiber	Nitrogen
Intake (% of BW)	−8.4	−7.5	−3.5	−9.5
Roughage level	−5.3	+2.6	+33.9	−2.6
Associative effect, %[a]	+.6	−.2	−.8	+.3

[a]Percentage difference between observed and predicted value for high intake and high roughage level diet.

listed as "associative effect" in Table 5. The size of the associative effects noted, from only .2 to .8 percent, indicates that associative effects beyond those attributable to intake and feed composition differences are small. Many of the associative effects noted with feeds in the past may be attributable to feed intake. Effects of specific roughage sources on organic matter digestibility of the diet are presented in Table 6. As intake increased, digestibility depressions were similar with all roughages tested. The influence of roughage level on digestibility can be attributed primarily to the differences between the digestibility of the specific roughage source and that of the rest of the diet, which is being displaced by added roughage.

Table 6. Influence of roughage source on digestibility

	Depression in organic matter digestibility (%)	
Roughage source	Intake level	Roughage level
CSH	−6.1	−12.9
PH	−7.6	−13.2
AH	−10.1	−2.8
SS	−9.7	−1.1
GCS	−9.5	+6.5
FCS	−7.0	−7.0

Since intake and roughage level influence digestibility of nutrients differently, one can suggest why these effects occur. High levels of intake and of roughage probably increase passage rate and decrease digestion, especially of grain. Because of the lower density and large particle size of forage, retention time would be influenced less. Added forage alone may increase chewing during feed consumption as well as rumination. With equal amounts of chewing and less grain fed in the higher roughage ration, starch digestion might be expected to increase. Another explanation relates to ruminal pH. High levels of grain intake reduce ruminal pH and alter volatile fatty acid concentration (Table 7). Work from USDA has shown fiber digestion and volatile fatty acid production is significantly reduced at ruminal pH values below 6.0. Ruminal ammonia values were highest for the low intake-high roughage diet. This is probably the result of increased protein degradation in the rumen due to greater retention time and higher pH. No relationship between ruminal ammonia levels and digestion was apparent in this study. The high grain diets produced greater concentrations of propionate and lower levels of acetate than the high roughage diets.

Increasing dietary intake had a larger effect on organic matter digestion and acetate and propionate concentrations with the low level than with the high level

Table 7. Roughage intake level interaction effects on ruminal parameters

Intake, % of BW	Roughage	Rumen pH	Rumen NH_3	Volatile fatty acid Total	Acetate	Propionate	Butyrate
1%	10%	6.25	10.1[d]	81.5	63.1[b]	20.3[b]	11.1
2%	10%	6.01	11.0[d]	85.8	57.6[a]	25.6[c]	10.6
1%	50%	6.54	14.0[e]	75.2	67.0[c]	16.6[a]	11.8
2%	50%	6.38	10.9[d]	87.9	66.1[c]	16.6[a]	12.8

[abc] Means in a column with different superscripts differ statistically (P<.05).
[de] Means in a column with different superscripts differ statistically (P<.10).

of roughage. This suggests finishing diets are more susceptible to intake effects on digestion than higher forage diets, and the depression in digestibility is due to reduced ruminal retention time.

In summary, altered digestibility seen with roughage addition to high concentrate diets can be subdivided into effects of level of feed intake and effects of level of roughage. Both would appear to alter passage rate through the gastrointestinal tract and influence ruminal pH. Passage rate and ruminal pH, in turn, influence the rate and extent of ruminal fermentation. Feeding forage sources which increase ruminal retention time or rate of digestion should maximize digestibility but, through fiber accumulation in the rumen, roughages retained in the rumen may decrease feed intake.

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Forage Sources with Whole Corn in Receiving Diets for Cattle

S. R. Rust and F. N. Owens

Story in Brief

Six different forages were fed in 50 percent roughage rations to 24 Hereford-Angus steers (800 lb). The diets of 50 percent forage, 42 percent whole shelled corn and 8 percent supplement were fed at a level equal to 2 percent of body weight daily. The six forages examined were cottonseed hulls (CSH), prairie hay (PH), alfalfa hay (AH), sorghum plant silage (SS) and two varieties of corn plant silage (FCS and GCS). Organic matter digestibility was greater with the corn silage diets. Some forage diets (CSH, PH and two of the three silages) were more digestible (+18, +4, +5 percent) than expected while alfalfa hay diets were 14 percent less digestible than expected. Results suggest that although forage digestibility is important in selecting a roughage for receiving cattle diets, forages may interact differently with whole shelled corn and have considerably more or less value in mixed diets than expected. Starch digestion was greatest with the cottonseed hull-supplemented diet.

Introduction

Upon arrival in commercial feedlots yearling feeder calves are fed diets containing 40 to 60 percent forage. Such high forage diets may be fed for 5 to 120 days depending on cattle size and economic conditions. Source of forage may influence energy availability from grain (Teeter amd Owens, 1981). The purpose of this research was to evaluate the influence various types of forages have on efficiency of nutrient utilization with high roughage diets.

Experimental Procedures

Procedures used in this study are presented elsewhere in this publication (Rust and Owens, 1982). The level of forage was 50 percent in this study whereas in the other study, diets contained 10 percent forage. Diets and supplement composition are shown in Tables 1 and 2. The forage sources were cottonseed hulls (CSH), prairie hay (PH), alfalfa hay (AH), sorghum plant silage (SS) and two varieties of corn plant silage (GCS and FCS).

Table 1 Diet composition (DM basis)

Item	%
Whole shelled corn	42
Forage	50
Supplement	8

Table 2. Supplement composition[a] (DM basis)

Item	Supplement		
	CSH & PH	AH	Silages
	----------	%	----------
SBM	72.3		45.3
Ground corn	5.1	50.4	4.9
Dicalcium phosphate	10.7	13.1	13.1
Limestone	2.7	15.1	15.1
Potassium chloride		5.6	5.6
Salt	1.6	3.1	3.1
Urea	3.8	7.5	7.5
Sodium sulfate	2.4	2.4	2.4
Trace mineral mix	.2	.3	.3
Chromic oxide	1.3	2.5	2.5

[a]Vitamin A and D were added to supply NRC requirements.

Results and Discussion

Organic matter digestion was greatest for the corn silage diets and lowest for the alfalfa hay-supplemented diet (Table 3). CSH, PH and two of the three silage-supplemented diets yielded greater than expected digestibilities based on TDN values from the NRC for dairy cattle while the alfalfa hay-supplemented diet produced lower than expected values. When digestibilities were higher than expected, starch digestibilities were also high and vice versa. Results suggest that certain forages may enhance the digestibility of whole corn while others, such as alfalfa, may reduce starch digestion from whole shelled corn. The selection of a forage for mixed diets to be used in receiving rations should be based not only on digestibility and nutrient content of the forage, but also on the influence the forage has on digestibility of the grain in the ration.

Starch digestion tended to be lower for the SS and PH-supplemented diets. Starch digestion was greatest (96.3 percent) for the cottonseed hull-supplemented diet, which agrees with previous studies (Rust and Owens, 1982; Teeter and Owens, 1981). A trend for greater fiber digestion was seen with the PH and silage diets.

Table 3. Effect of forage source on nutrient digestibility

Item	Forage Source					
	CSH	PH	AH	SS	GCS	FCS
Digestibility, % organic matter						
Determined	68.0[def]	65.9[de]	61.3[d]	65.2[de]	76.6[f]	71.6[ef]
Predicted[a]	57.7	63.1	65.8	64.4	71.9	71.9
Starch	96.3[c]	78.7[b]	83.7[bc]	76.7[b]	90.4[bc]	88.5[bc]
ADF	43.6[g]	56.3[h]	40.4[g]	46.5[gh]	56.0[h]	46.5[gh]
Nitrogen	54.4	57.0	57.1	60.4	69.7	64.4

[a]Calculated from TDN of ingredients listed in NRC for dairy cattle.
[bc]Means in a row with different superscripts differ statistically ($P<.06$).
[def]Means in a row with different superscripts differ statistically ($P<.10$).
[gh]Means in a row with different superscripts differ statistically ($P<.15$).

Effects of forage source on composition of feces is shown in Table 4. Fecal pH increased as fecal ash content increased (P<.0005). Some researchers have suggested that indigestible fiber or minerals bound to the indigestible fiber buffer intestinal and fecal pH. The relationship between fecal starch or fecal fiber with pH was poor in this study. Fecal starch content was lowest for the CSH-supplemented ration. Ruminal pH and ammonia levels were not significantly different for diets containing the six roughage sources (Table 5). Results conflict with the suggestion that certain forages produce higher ruminal pH than other forages. Volatile fatty acid concentrations were similar except for isobutyrate and valerate. These are branch chain fatty acids derived primarily from protein degradation. With lower protein forages, one might expect lower levels of these acids.

When selecting a roughage to supplement whole corn diets used for growing cattle, feeders need to consider not only digestibility of the forage has but also the influence forage has on grain digestibility. Based on expected digestibilities, the cottonseed hull diet was 18 percent more digestible than expected while the

Table 4. Effect of forage source on fecal parameters

Item	Forage source					
	CSH	PH	AH	SS	GCS	FCS
Fecal						
pH	6.04[i]	6.11[ij]	6.32[jk]	6.41[k]	6.36[k]	6.27[ijk]
Dry matter, %	25.5[h]	23.9[gh]	20.8[fg]	22.7[fgh]	24.1[h]	20.5[f]
Starch[a]	3.8[f]	19.5[gh]	13.0[fg]	25.1[h]	14.7[fgh]	14.5[fgh]
ADF[a]	57.7[d]	30.0[c]	33.8[c]	30.0[c]	27.9[c]	28.6[c]
Nitrogen[a]	2.61[k]	2.03	2.49[jk]	2.04[i]	2.14[ij]	2.19[ijk]
Ash[a]	6.9[e]	10.5[de]	10.9[de]	16.4[bc]	21.7[b]	14.8[cd]

[a]Percentage of dry matter.
[bcde]Means in a row with different superscripts differ statistically (P<.01).
[fgh]Means in a row with different superscripts differ statistically (P<.05).
[ijk]Means in a row with different superscripts differ statistically (P<.10).

Table 5. Effect of forage source on rumen pH, ammonia and volatile fatty acid concentration

Item	Forage source					
	CSH	PH	AH	SS	GCS	FCS
Ruminal						
pH	6.12	6.79	6.34	6.38	6.32	6.33
Ammonia, mg/dl	9.53	5.58	15.22	13.74	15.22	6.25
Volatile fatty acid, moles/100 moles						
Acetate	68.56	66.66	63.44	64.70	63.77	9.63
Propionate	13.78	17.93	15.54	18.26	17.56	16.29
Butyrate	13.88	12.06	13.51	12.81	13.85	10.53
Isobutyrate	.48[cd]	.76[cde]	1.35[e]	.19[c]	1.03[de]	.21[c]
Valerate	1.14[a]	.85[a]	2.64[b]	1.53[a]	1.49[a]	.81[a]
Isovalerate	1.51	1.50	2.78	1.85	1.89	1.10
Caproate	.65	.25	.76	.66	.40	1.43
Total	90.47	95.73	81.78	81.28	72.29	105.57

[ab]Means in a row with different superscripts differ statistically (P<.10).
[cd]Means in a row with different superscripts differ statistically (P<.15).

alfalfa diet was 7 percent less digestible than expected. Prairie hay, sorghum and corn silages were near expected values (+1 to +5 percent). Forage quality and type is more critical in diets containing high levels of roughage than feedlot finishing type diets. Positive and negative effects may be less when the grain in the ration has been more extensively processed. With steam-rolled barley, associative effects of alfalfa were not detected in a California study, but in Colorado, corn silage has consistently reduced digestibility of cracked corn diets. Selection of a forage should be based on the influence that forage has on digestion of the entire diet as well as forage digestibility, palatability, availability, protein content, physical characteristics and cost.

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Influence of Infrequent Feeding on Ruminal Digestion

D. C. Weakley and F. N. Owens

Story in Brief

Four ruminally cannulated Hereford heifers were fed once daily either a high concentrate or high roughage diet. Dacron polyester bags containing either soybean meal (SBM) or cottonseed meal (CSM) were placed in the rumen of these animals for six consecutive four-hour exposure periods to study the influence of time after feeding on ruminal digestion. Disappearance of dry matter (DM) from CSM and SBM was greatest in those animals fed the high concentrate diet. Furthermore, disappearance of these materials from bags was not constant over the entire 24-hr period after feeding. Disappearance tended to be highest immediately after and before feeding. This demonstrates that rumen fermentation is not constant. Feeding protein 4 to 12 hr after feeding energy may increase protein bypass.

Introduction

Studies of rumen fermentation usually assume a steady rate of digestion. Constant conditions may not exist when animals are fed only once or twice daily. Infrequent feeding practices are often utilized in laboratory studies and in dairy parlors.

A procedure to study digestion rate in the rumen is to suspend a feed in dacron bags within the rumen and measure feed loss. The objective of this study was to measure the variation in digestion rate in the rumen of cattle fed once daily.

Materials and Methods

Four ruminally cannulated Hereford heifers (950 lb) were fed once daily either a high concentrate or a high roughage diet at a level equal to 1.4 percent of their body weight. The high roughage diet consisted of 81 percent chopped prairie hay and 19 percent soybean meal with a crude protein content of 12.5 percent. The high concentrate diet contained 62 percent corn, 14 percent cottonseed hulls, 10 percent soybean meal, 6 percent ground alfalfa hay, 6 percent molasses and 2 percent minerals and vitamins with a crude protein content of 12.8 percent. Two heifers were placed on each of the two rations in the first period and switched for the second feeding period.

Polyester bags received 2 g of either SBM or CSM. The two protein sources had been sieved to a particle size between .5 and 1.0 mm and extracted with .9 percent saline solution for 6 hr to remove soluble components.

Five days after the ration was first fed, two bags of each protein source were suspended in the rumen of each heifer during six consecutive 4-hr exposure periods after feeding (0 to 4, 4 to 8, 8 to 12, 12 to 16, 16 to 20 and 20 to 24 hr). Upon removal from the rumen, bags were rinsed and contents analyzed for dry matter disappearance, an index of digestion rate.

Rumen samples were collected at 0, 4, 8, 16 and 24 hr after feeding for analysis of rumen ammonia to determine whether ammonia was adequate for microorganisms in the rumen.

Results and Discussion

Rates of disappearance of SBM and CSM dry matter from dacron bags in the rumen of roughage or concentrate-fed heifers are presented in Figure 1. Protein disappearance was more variable. Since protein and DM disappearance from bags are closely related, only DM disappearance is presented.

For all exposure periods studied, disappearance of both SBM and CSM was faster in the concentrate than roughage-fed animals. Exposure periods in the rumen longer than 4 hr have shown faster protein digestion with roughage diets in other studies, but little effect of diet on disappearance from dacron bags was observed at shorter exposure times. Whether differences are due to different ruminal pH, ammonia level or bacterial species is uncertain. Greater disappearance observed at longer exposure periods in animals fed roughage is probably the result of increased degradation of the cellulose, exposing more dry matter to microbial attack and digestion.

Rate of ruminal degradation was greater for SBM than CSM. Protein bypass has been consistently greater for cottonseed meal than soybean meal in steer trials.

Influence of time after feeding on ruminal digestion rate of SBM and CSM in the rumen of high concentrate and roughage-fed animals is presented in Table 1. Rate of digestion was lowest from 4 to 12 hr after feeding. Ruminal ammonia concentrations followed a similar pattern in animals fed the high concentrate ration (Table 1). Results suggest that the once-daily feeding regimen established a pattern of digestion in the rumen that was not constant over the day. Consequently, feeding frequency and diet composition probably alter the utilization and ruminal bypass of protein. Feeding protein supplements 4 to 12 hr after energy is fed, as might be possible in dairy parlors, may enhance escape of protein from ruminal digestion.

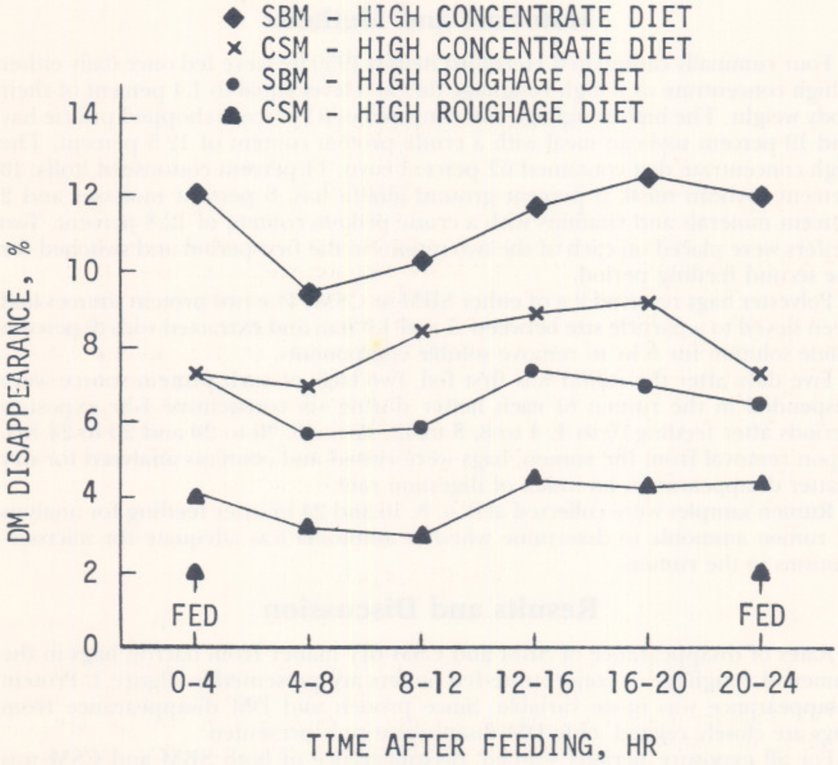

Figure 1. Dietary influence on DM disappearance of SBM and CSM from dacron bags

Table 1. Percent DM disappearance from dacron bags exposed for adjacent time periods in the rumen

Item	Exposure period, hr					
	0-4	4-8	8-12	12-16	16-20	20-24
Average DM disappearance, %	7.68[ab]	6.35[c]	6.92[bc]	8.13[a]	8.27[a]	7.56[ab]
Rumen NH_3-N, mg/dl						
High concentrate	13.3	7.9	7.3		14.1	12.4
High roughage	10.2	12.2	5.6		4.5	5.5

[abc]Means in a row with different superscripts differ statistically (P<.05).

Corn Moisture and Processing

D. R. Gill, F. N. Owens, J. J. Martin
R. A. Zinn, D. E. Williams
and R. J. Hillier

Story in Brief

Corn harvested at 24 and 31 percent moisture was stored at these moisture levels and compared with corn harvested at 24 percent moisture and reconstituted with water to 31 percent moisture. Each moisture level of corn was ensiled in the ground form or as a blend consisting of 60 percent whole kernel corn plus 40 percent ground corn. These six types of corn were fed to 150 steers (673 lb) for 112 days. Higher moisture content, whether present at harvest or from water added prior to ensiling, improved feed efficiency (8.5 percent) over corn at 24 percent moisture. Except for a slight sacrifice in rate of gain, adding water to high-moisture corn improved its feeding value. Corn processing prior to ensiling had little effect on performance. Feed efficiency was improved 1.5 percent by grinding. Source of supplemental protein also had little effect on animal performance. Results confirm previous studies which indicate that efficiency of feed use of high-moisture corn is greater when it contains about 30 percent moisture than when it contains only 24 percent moisture.

Introduction

Moisture level of high-moisture corn alters efficiency of feed use according to previous trails from Oklahoma (Teeter et al., 1979) and Kansas (Davis, 1981). High-moisture corn containing 20 to 24 percent moisture is not as well utilized as either dry corn or corn containing more than 27 percent moisture. To obtain higher moisture levels, corn can be harvested earlier, or water can be added at ensiling time. Method of processing high-moisture corn at ensiling time also is debated. Fine grinding assures packing and may improve digestibility of starch but requires additional energy and time. Nebraska trials with high-moisture corn stored and fed in the whole form seem promising, but packing of the grain to avoid air penetration and molding in trench silos is simplified when fine particles are present. The objectives of this trial were to determine the influence of moisture content (harvested or reconstituted high-moisture corn) and grain processing on value of high-moisture corn for feedlot steers. Because the ideal protein supplement for high-moisture corn is uncertain, soybean meal, urea and a mixture were tested as supplements.

Materials and Methods

Corn from western Kansas was harvested at 31 percent moisture or at 24 percent moisture and transported to Goodwell, Oklahoma. A portion of each batch of corn was ground with a tub grinder for storage in the ground form. A blend of high-moisture corn in the whole form (60 percent) with ground corn (40 percent) also was prepared for storage. These two processing methods will be termed "blend" and "ground" in this report. The corn was stored at harvest moisture levels, and half of the 24 percent moisture corn was reconsituted to 31 percent moisture by adding water to corn mixing in feed trucks. Each of the three grains was stored in plastic bags (Ag-Bag) from November until the following April.

One hundred fifty steers of mixed breeding weighing 673 lb were divided into 30 pens of 5 head each and fed the rations (Table 1) for 112 days. Steers had been on feed at Hitch Feedlot for over a month prior to initiation of this feeding trial.

Table 1. Ration composition (% of dry matter)[a]

	Supplemental protein		
Ingredient	Soybean meal	Urea	Mixture
Corn, high moisture	82.1	87.7	83.9
Corn silage	6.4	6.4	6.4
Alfalfa, chopped	3.6	3.6	3.6
Soybean meal	5.84	0	3.55
Limestone	.86	.82	.84
Urea	0	.87	.34
Ammonium sulfate	.15	.15	.15
KCl	.23	.43	.31
Salt	.38	.38	.38

[a]Crude protein of negative control was 9.4% and of other rations was 11.8% of dry feed. All rations contained .7% K, .5% Ca and .34% P plus rumensin (30 g/ton), Tylan (90 mg/head daily) and vitamin A (30,000 IU/head daily).

Results and Discussion

No interactions of moisture level, processing and protein source were apparent. A discussion of three factors follows.

Moisture level

Dry matter intakes were greater for the drier (24 percent moisture) corn than for corn with water added or corn higher in moisture at harvest. This has been observed in previous trials. Gains differed little with moisture content. Wetter and

Table 2. Influence of grain moisture on steer performance

	Moisture		
Item	Dry	Wet	Recon
Daily gain, lb			
0-55	2.83	2.84	2.58
56-112	3.08	3.21	3.15
0-112	2.96	3.03	2.87
Daily feed, lb			
0-55	16.4	15.4	14.3
56-112	17.3[a]	16.4[ab]	15.4[b]
0-112	16.8[a]	15.9[b]	14.8[b]
Feed/gain			
0-55	5.81	5.43	5.60
56-112	5.65[a]	5.13[ab]	4.89[b]
0-112	5.70[a]	5.25[b]	5.18[b]
ME, mcal/kg	3.15[b]	3.33[a]	3.36[a]

[ab]Means in a row with different superscripts differ statistically (P<.05).

reconstituted grain improved feed efficiency by 8.5 percent, and calculated energy content was 6.2 percent greater for grain containing more moisture than the 24 percent moisture corn. One could conclude that adding water to drier high-moisture corn decreases feed intake (5.3 percent) and increases efficiency of feed use (9.1 percent) with a slight sacrifice (3.0 percent) in daily gain. Higher moisture harvested grain does not appear to depress gains to the extent reconstitution may.

Grain processing

Effects of grain processing on steer performance are presented in Table 3. Performance of steers fed high-moisture corn stored and fed ground was little different than that of steers fed high-moisture corn in which 60 percent of the grain was stored and fed in the whole form. The advantage in feed efficiency attributable to grinding (1.5 percent) may not justify the additional cost of grinding. However, when corn is stored in a pit silo instead of being encased in plastic as it was in this study, packing and spoilage will be more of a problem with a product that has whole kernels than with a ground product.

Table 3. Influence of processing on steer performance

Item	Processing	
	Blend	Ground
Daily gain, lb		
0-55	2.73	2.73
56-112	3.08	3.19
0-112	2.91	2.96
Daily feed, lb		
0-55	15.4	15.3
56-112	16.2	16.5
0-112	15.8	15.9
Feed/gain		
0-55	5.65	5.64
56-112	5.29	5.20
0-112	5.44	5.36
ME, mcal/kg	3.25	3.29

Protein source

Effect of protein source on animal performance is presented in Table 4. Rate of gain and feed intakes were slightly lower for steers fed the soybean meal supplement. Differences in feed efficiency were very small. Previously, soybean meal supplements have usually proven superior to urea supplements with high moisture corn. Compared with other years, the urea supplements this year were balanced with the soybean supplement not only for nitrogen, calcium, phosphorus and potassium but also for sulfur from sodium sulfate. Also, monensin was included in the supplement. Sulfur and monensin additions to urea supplements for moisture corn diets need further research.

Gains and feed efficiencies for all treatments are presented in Table 5 for those who have interests in certain specific combinations.

Table 4. Influence of protein source on performance of feedlot steers

Item	Protein source		
	SBM	Urea	Mixture
Daily gain, lb			
0-55	2.68	2.72	2.79
56-112	3.11	3.18	3.11
0-112	2.90	2.95	2.95
Daily feed, lb			
0-55	14.9	15.7	15.5
56-112	16.6	16.4	16.1
0-112	15.7	16.0	15.8
Feed/gain			
0-55	5.59	5.79	5.55
56-112	5.36	5.18	5.20
0-112	5.42	5.43	5.35
ME, mcal/kg	3.27	3.27	3.27

Table 5. Gains and feed efficiency with high moisture corn diets

		Daily gain, lb			Feed/gain		
		Protein source			Protein source		
Moisture	Process	Urea	Mix	SBM	Urea	Mix	SBM
24H[a]	Blend	2.83	2.83	2.99	5.70	5.53	5.88
	Ground	2.88	3.21	2.99	5.90	5.66	5.53
31R[b]	Blend	2.84	2.90	2.84	5.37	5.19	5.10
	Ground	2.99	2.90	2.74	5.05	5.11	5.25
31H[a]	Blend	3.25	3.03	2.88	5.22	5.12	5.71
	Ground	3.20	2.79	3.02	5.08	5.38	4.98

[a]Harvested at this moisture level.
[b]Harvested at 24% moisture and reconstituted to 31% moisture.

Literature Cited

Davis, G. V. 1981. Cattle Feeders' Day, Garden City, KS. p. 14.
Teeter, R. G. et al. 1979. Okla. Agr. Exp. Sta. Res. Rep. MP-104:62.

Protein Sources with Steam Flaked Corn Diets for Finishing Steers

R. A. Zinn, F. N. Owens and D. R. Gill

Story in Brief

Soybean meal, urea, casein and no additional protein supplements were fed with steam flaked corn to 48 finishing steers (701 lb) for 139 days. Gain and feed efficiency increased with added protein. Gains, ruminal ammonia and blood urea levels were low for steers not receiving supplemental protein. Protein was added to their ration on day 89. Refeeding protein to the deficient group for 49 days restored efficiency but not rate of gain equal to that of other steers. Gains and feed efficiency favored urea over the soybean meal supplement by 11 and 3 percent, primarily due to greater feed intake of the urea supplemented diet. Steers fed casein consumed less feed and had gains similar to steers fed soybean meal . Efficiency of feed use was best for steers fed casein, with apparent metabolizable energy being about 7 percent superior to other diets.

Introduction

Protein needs for cattle over 700 pounds have been widely debated. Some researchers have recommended protein withdrawal while others have suggested that soybean meal is more useful than urea due to the amino acids it provides for ruminal digestion and the potential protein bypass. Two lines of evidence suggest that ammonia concentrations in the rumen of steers fed high levels of high concentrate rations may be deficient for bacteria to thrive. First, ruminal ammonia concentrations are sometimes low. Secondly, in a trial by Zinn with intestinally cannulated steers, efficiency of microbial protein synthesis in the rumen decreased when feed intake was increased from 1.8 to 2.1 percent of body weight, which might be due to inadequate amounts of ammonia in the rumen.

If ruminal ammonia is inadequate, deficits of postruminal protein could be alleviated by feeding either 1) more protein to bypass the rumen or 2) more urea to increase the production of microbial protein in the rumen which is flushed to the small intestine. When steers get heavier, and postruminal protein needs decline, it is unclear whether an ammonia deficiency reduces steer performance if postruminal protein needs are met. The objective of this trial was to determine the relative value of supplementing a steam flaked ration with soybean meal, urea or casein. Only about 30 percent of soybean protein may be degraded to amino acids and subsequently to ammonia in the rumen when fed with a high concentrate ration at high feed intake levels. Urea should be entirely degraded to ammonia within the rumen. Casein also should be extensively degraded to ammonia in the rumen but will provide amino acids for microbial use, which has been suggested by California workers to be beneficial. The zero supplementation treatment was included to check that the ration without supplementation was deficient for growth of these steers.

Materials and Methods

Forty-eight steers (701 lb) were allotted to eight pens at Panhandle State University, Goodwell, OK, and fed steam flaked corn rations without added protein or with added soybean meal, urea or casein (Table 1). The trial lasted 139 days, but after 89 days on feed, steers in the two pens fed no supplemental protein were switched to rations containing a protein supplement. One pen of steers received supplemental soybean meal while the other pen received a soybean meal-urea supplement for the remaining 49 days of the trial.

Table 1. Ration composition (% of dry matter)[a]

	Supplemental protein		
Ingredient	Soybean meal	Urea	None[b]
Corn, steam flaked	82.1	87.3	87.6
Corn silage	6.4	6.4	6.4
Alfalfa, chopped	3.6	3.6	3.6
Soybean meal	5.84	0	0
Limestone	.86	.82	.82
Urea	0	.87	0
Ammonium sulfate	.15	.15	.15
KCl	.23	.43	.43
Salt	.38	.38	.38

[a]Crude protein of negative control was 9.4% and of other rations, 11.8% of dry matter. All rations contained .7% K, .5% Ca and .34% P plus rumensin (30 g/ton), Tylan (90 mg/head daily) and vitamin A (30,000 IU/head daily).

[b]Casein-supplemented steers received a mixture of 50% "urea" supplement and 50% of the "none," plus 100 g of casein per steer twice daily.

Results and Discussion

Results are presented in Table 2. Performance and efficiency of feed use were very poor for steers fed no supplemental protein for 89 days. Ruminal ammonia and blood urea levels were much lower for these steers but not below the level indicated by some workers as required (5 mg/dl). Performance and efficiency indicate that protein was deficient for these steers. When protein was fed to these deficient steers, they responded well in gain and efficiency even though they weighed 864 pounds at that time. Feed intakes did not recover completely, but feed efficiency for the total trial was surprisingly good despite the long period of protein depletion and reduced gain. Results indicate that efficiency of gain of nutritionally deprived cattle can be very good.

Responses in gain and efficiency were greater with urea than with soybean meal supplementation. This same effect was apparent when the protein depleted steers were returned to soybean meal or urea plus soybean meal supplements. Greater gain response with urea than with soybean meal supplementation might be expected if the level of ruminal ammonia normally is low with soybean meal. Steam flaking of the grain may emphasize this effect since heat treatment usually reduces ruminal breakdown of protein to ammonia. This would make urea more useful with flaked corn diets than with high moisture corn diets as discussed in a 1980 review (Martin et al., 1980). However, ruminal ammonia on day 89 was almost equal for these two treatments. Possibly, buffering of rumen contents from

Table 2. Steer performance

	Supplement				Recovery Period[d]	
	SBM	Urea	Casein	None[d]	SBM	SBM + Urea
Pens	2	2	2	2	1	1
Steers	12	12	12	12	6	6
Daily gain, lb						
0-89 day	2.56[ab]	2.65[a]	2.40[b]	1.84[c]	—	—
90-139 day	2.83[ab]	3.46[a]	3.17[ab]	3.25[ab]	2.84	3.66
0-139 day	2.66[b]	2.94[a]	2.68[b]	2.35[c]	—	—
Daily feed, lb						
0-89 day	15.7[ab]	16.1[ab]	14.1[bc]	13.6[c]	—	—
90-139 day	15.1[bc]	17.6[a]	14.0[c]	13.9[c]	13.2	14.6
0-139 day	15.5[bc]	16.7[ab]	14.2[cd]	13.8[d]	—	—
Feed/gain						
0-89 day	6.15[b]	6.06[b]	5.92[b]	7.39[a]	—	—
90-139 day	5.32[b]	5.16[b]	4.40[b]	4.32[b]	4.7	4.0
0-139 day	5.84[ab]	5.69[ab]	5.29[b]	5.87[ab]	—	—
Metabolizable energy, mcal/kg	3.46[b]	3.49[b]	3.71[a]	3.49[b]	—	—
Ruminal ammonia[e] N, mg/dl	24.6	22.9	27.5	10.0	—	—
Blood urea[e] N, mg/dl	15.8	16.8	20.9	10.3	—	—

[abc]Means with different superscripts differ ($P<.05$).
[d]Protein readded on day 89, and recovery period is subdivided by type of protein fed during recovery.
[e]Measurements obtained on day 89 of the trial.

urea or saliva may have been greater with the urea diet which speeded fiber digestion and clearance from the rumen. Alternatively, production of end products in the rumen which are signals of food intake control may have differed with the two supplements.

Feed intake and gains were lower with casein than urea as a source of dietary nitrogen. This suggests that amino acid release in the rumen, one of the proposed benefits of soybean meal as a protein supplement, is probably not useful to increase gain of growing steers. Feed efficiency, however, in steers receiving supplemental casein was considerably superior (7 percent) to efficiency of steers fed other diets. Factors responsible are under study. With casein priced at $2 per pound, this efficiency advantage will not be pursued with feedlot steers.

Literature Cited

Martin, J. J. et al. 1980. Okla. Agr. Exp. Sta. Res. Rep. MP-107:114.

Protein Source and Potassium for Heavy Feedlot Steers

R. A. Zinn, F. N. Owens, D. R. Gill, D. E. Williams and R. P. Lake

Story in Brief

Ninety finishing steers (976 lb) received urea, soybean meal, or soybean meal plus potassium in their protein supplements with high moisture corn diets for the final 28 days of a finishing trial. Added potassium increased live weight gain and efficiency by 21 percent. Gain with urea was 39 percent more rapid and 19 percent more efficient than with the soybean meal supplement. Feed intake was greatest with urea supplementation. Further studies are needed to examine how much of these effects are due to gastrointestinal fill and how much is tissue retention of fluid or dry matter.

Introduction

Protein source and postassium level for finishing steers can influence rate and efficiency of gain. These differences have been noted primarily at the start of a finishing trial, but withdrawal of supplemental protein for steers over 850 lb has not reduced performance in some trials. This suggests that one would expect little effect from alteration of the diet for steers nearing 1000 pounds. This trial was conducted to determine if protein source or postassium level would influence performance of steers approaching market weight.

Material and Methods

Steers fed high moisture corn in a trial elsewhere in this publication (Gill et al., 1982) were used in this 28-day study. Two steers from each of the 30 pens were marketed leaving three steers (976 lb) in each of the 30 pens for this study. All steers received high moisture corn with corn silage. Each pen received one of three different supplements (Table 1). These supplements contained urea, soy-

Table 1. Ration composition (% of dry matter)[a]

	Supplement		
Ingredient	**Soybean meal**	**SBM & K**	**Urea**
Corn, high moisture	82.1	82.1	86.7
Corn silage	6.4	6.4	6.4
Alfalfa, chopped	3.6	3.6	3.6
Soybean meal	5.84	5.84	
Limestone	.86	.86	.82
Urea	0	0	.87
Ammonium sulfate	.15	.15	.15
KCl	.23	1.22	.43
Salt	.38	.38	.38

[a]Crude protein of rations was 11.8% of dry matter. All rations contained .7% K, .5% Ca and .34% P plus rumensin (30 g/ton), Tylan (90 mg/head daily) and vitamin A (30,000 IU/head daily).

bean meal or soybean meal plus added potassium (K) to increase dietary potassium level to 1 percent of the diet dry matter. Steers were weighed following 18 hr without feed and water at the start and end of this 28-day study.

Results and Discussion

Addition of K to the ration slightly reduced feed intake but improved live weight gain and fed efficiency by 21 percent in this short study (Table 2). Unfortunately, carcass data from this trial was not obtained to measure effects of added potassium on carcass weight. Dressing percentage decreased with supplemental K in another trial in this publication (Zinn et al., 1982). A decrease in dressing percentage of .7 percent could explain the gain response seen in this study. Nevertheless, more frequent feeding and increased ruminal buffering and digestion with added potassium could prove beneficial for these heavy steers.

Similar to results noted in the "Corn Moisture and Processing" study by Gill et al. (1982), gains, feed intakes, and feed efficiency favored the urea supplement. This also supports the suggestion that ruminal ammonia may be deficient with soybean meal supplementation of diets for finishing steers.

Table 2. Steer performance results

	Supplement		
Item	SBM	SBM & K	Urea
Daily gain, lb	2.05[b]	2.48[ab]	2.85[a]
Daily feed,lb	15.1[b]	14.9[b]	17.7[a]
Feed/gain	7.87[a]	6.19[b]	6.35[b]

Literature Cited

Zinn, R. A. et al. 1982 Limestone and potassium for feedlot steers. Elsewhere in this publication.

Protein Bypass Estimates for Finishing Steers

R. A. Zinn and F. N. Owens

Story in Brief

Protein bypass has been measured for five different protein sources using steers equipped with intestinal cannulas. Bypass decreased with higher amounts of roughage in the diet. To predict bypass, a combination test of solubility and disappearance from polyester bags was devised. Bypass of specific feed proteins varies with 1) level of roughage, 2) level of feed intake and 3) time of digestion in the rumen. Consequently, a bypass value determined with one intake level and one roughage level is not applicable to other feeding conditions. Intestinal digestibility of protein may be estimated by digestion of the protein source with pepsin.

Introduction

Value of supplemental protein for high producing dairy cattle and rapidly growing young steers is dependent on the amount that escapes degradation in the rumen and passes to the small intestine for digestion. High bypass proteins are widely advertised, and chemical treatments to increase bypass have been developed. Bypass values for different sources have been sought in many trials, and values for protein sources based on bypass have been calculated. Bypass values also differ among experiments. Bypass trials with animals are expensive and complex to conduct, so methods to predict bypass have been sought. To develop chemical methods to predict bypass, reliable bypass values from animals are needed.

Materials and Methods

Passage of several protein sources to the small intestine was measured using steers equipped with cannulas at the start of the small intestine. Bacterial protein was subtracted from total flow based on nucleic acid content of bacteria and of intestinal samples. Flow of protein to the intestine with or without the added protein was measured and bypass calculated. The difference was expressed as a percentage of the protein source fed. Bypass of soybean meal (SBM), cottonseed meal (CSM), dehydrated alfalfa meal (Dehy) of two types, meat meal (MM) and hardened casein (HCAS) were estimated with an 80 percent concentrate ration (Table 1). Bypass of soybean meal and cottonseed meal were also measured with a 40 percent concentrate ration which would be more similar to a starting feedlot or a dairy ration (Table 1). Steers also had cannulas at the end of the small intestine so digestibility in the small intestine could be measured. Additional characteristics of these protein sources which were measured included solubility in a salt solution, indigestibility by a pepsin-HCl mixture and disappearance from dacron bags suspended in the rumen of steers fed the diets being fed.

Table 1. Composition of basal diets

Ingredient	Concentrate Trials 1 and 2	Roughage Trial 3
	%	
Chopped prairie hay	20.0	60.0
Dry rolled corn	74.4	16.0
Soybean meal	—	9.9
Starch	—	5.0
Solka floc	—	5.0
Molasses	2.0	1.0
Urea	1.2	1.0
Trace mineral salt	.3	.3
$CaCO_3$	.6	—
$CaHPO_4$	.3	1.0
Na_2SO_4	.3	.2
KCl	.7	.4
Cr_2O_3	.2	.2

Results and Discussion

Bypass values for the protein sources tested are presented in Table 2. Bypass of SBM and CSM were considerably lower when fed with a roughage than with a concentrate ration. This confirms earlier measurements with dehy as a source of protein which showed that ration composition influences bypass (Zinn and Owens, 1980). Bypass was not related to solubility of the protein source. Casein was of a "hardened" variety and had a lower solubility (Table 2) than most types of casein and also had a higher bypass than in a previous study (Zinn et al., 1981). So solubility within a single protein source may sometimes be a predictor of bypass. Degradation rates in the rumen were measured for periods up to 24 hr. Since disappearance from dacron bags during the first 4 hr would include the fraction which is soluble in a dilute salt solution plus fine material which will sift through pores in the dacron bag, the first 4 hr of ruminal digestion were ignored. Disappearance rates for subsequent 8 and 12-hr periods differed by type of ration being fed, with the higher roughage ration having much higher degradation rates.

Table 2. Bypass and chemical characteristics of proteins

Item	Bypass, % Ration		Solubility in .15 N	Dacron bag disappearance			
				Concentrate diet		Roughage diet	
	Conc.	Rough.	NaCl	4-12 hr	12-20 hr	4-12 hr	12-20 hr
SBM	43	24	27,27	3.6	5.2	5.7	6.9
CSM	50	43	33,12	2.2	3.4	4.6	1.6
Dehy 1	57		42	0	1.0	5.3	1.4
Dehy 2	62		23	0	1.7	3.2	4.0
MM	76		24	0	.9	1.5	.2
Casein	36		6	8.6	8.3		

Assuming bypass includes the fraction which is insoluble and not degraded from nylon bags, bypass values were predicted based on the amount of protein which is insoluble plus the rates of degradation at the various times. Predicted bypass values are compared in Figure 1 with measured bypass from these studies and one previous study. The relationship suggests that bypass may be predictable based on one chemical measurement—protein solubility—plus an index of ruminal activity of animals fed the diet of interest—disappearance from dacron bags. Systems employing chemical or enzyme measurements alone or dacron bag measurements with only one diet result in a single estimate for bypass and cannot account for differences in the ruminal environment.

Digestion of nitrogen, not including ammonia, in the small intestine averaged 65 percent, matching other literature estimates (62 to 67 percent). To calculate digestibility of bypassed protein, the relationship of intestinal digestibility of nitrogen to amounts of bacterial and feed protein entering the small intestine was determined. That relationship: intestinal digestibility of nitrogen (IDN)= -8.6 + .73 × bypass N + .73× microbial N indicates that true digestibility of microbial protein and bypass N are about equal at 73 percent and that the amount of protein escaping digestion is approximately equal to the amount which resists

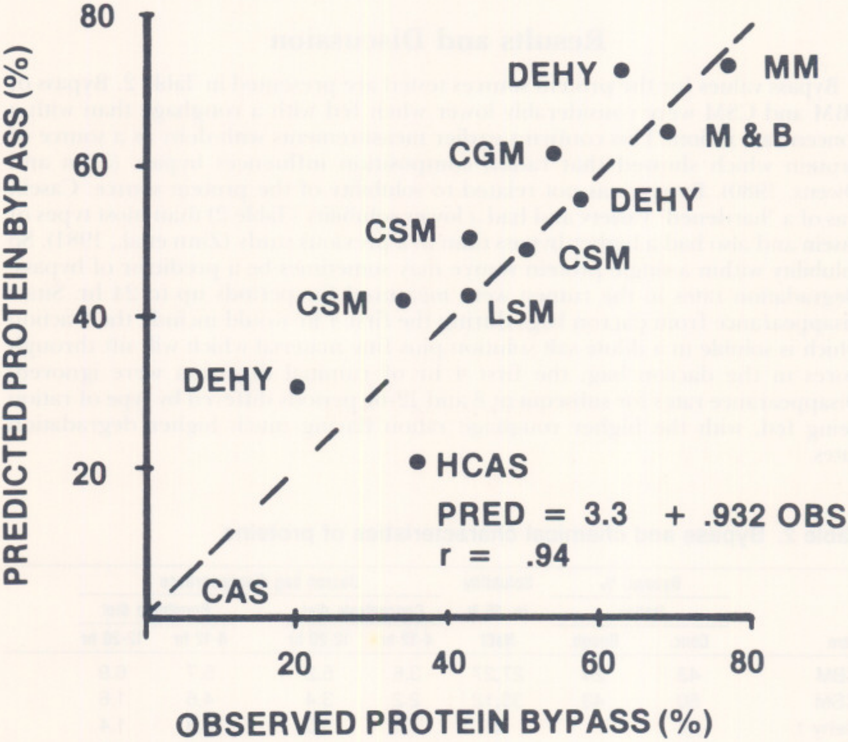

Figure 1. Observed vs predicted bypass from solubility and dacron bag values

digestion by pepsin. Pepsin digestibility can be used to calculate "intestinally digestible protein" or "metabolizable protein" values. Table 3 presents predicted bypass minus the indigestible fraction estimated by determining the amount of protein not solubilized by acid plus pepsin compared with measured "metabolizable protein." Except for dehydrated alfalfa meal, which had a much lower observed than predicted value, the relationship between expected and observed intestinally digested protein was reasonably good. Results indicate that bypass of intestinally digested protein can be predicted reasonably well based on a combination of solubility, degradation in dacron bags in the rumen and pepsin indigestibility. Solubility and pepsin indigestibility would be the primary factors with high intakes of high concentrate diets, but with higher roughage levels, all three factors appear important.

Table 3. Observed versus predicted metabolizable N value of test proteins

	Observed metabolizable N	Predicted[a] metabolizable N
	------------------%------------------	
Trial 1		
CSM	28	34
Dehy	32	33
SBM	32	34
Trial 2		
Casein	28	19
Dehy	21	47
MM	49	53
Trial 3		
CSM	31	35
SBM	16	15

[a]Standard reference bypass minus pepsin insoluble N.

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Ionophores and Digestibility of Feedlot Rations

M. C. Ferrell, F. N. Owens
D. A. Phelps and D. R. Gill

Story in Brief

Monensin, lasalocid and salinomycin were added to a 95 percent concentrate whole shelled corn ration at a level of 30 g per ton. Adding ionophores increased digestibilities of dry matter, organic matter and nitrogen. Starch digestibility tended to increase with ionophores, but nitrogen retention was unaffected. Results suggest that these compounds may have slight biological differences. Increased organic matter digestion can explain increased biological efficiency of 3.2 percent with these compounds.

Introduction

Ionophores are a class of feed additives which increase the efficiency of the feed use by feedlot cattle. Monensin is the most widely known ionophore. Salinomycin and lasalocid have been shown to have similar effects on efficiency but often depress intake less than monensin.

Energy, protein and starch digestibility were increased slightly with the addition of monensin to a whole shelled corn ration in two previous trials (Thorton, et al., 1978; Rust et al., 1979). Effects of these drugs on fecal measurements are outlined from other feeding studies in this report, but due to animal and feed intake differences, those measurements may be unreliable. This experiment was conducted to compare the effects of three similar compounds--monensin, lasalocid and salinomycin--on digestibility of a high concentrate ration.

Experimental Procedures

A ration containing whole shelled corn and cottonseed hulls (Table 1) was fed at 2 percent of body weight to 12 crossbred steers. The average initial weight of the steers was 640 lb, and the feed intake was limited to 11 lb dry matter per head daily. Steers were rotated among diets so each steer received each drug for 14 days. Supplements containing lasalocid, salinomycin and monensin were fed to achieve dietary levels of 30 g per ton of feed or 33 ppm of dry matter. Periods were 14 days in length, with total urine and feces collected during the final 5 days. Rumen samples were collected by stomach tube on day 15 of each period. Digestibilities of dry matter, starch, protein and organic matter were calculated. Ruminal and fecal pH were measured.

Results and Discussion

Addition of ionophores to this ration had no significant effect on ruminal pH but increased fecal pH (Table 2). Nitrogen percentage in fecal dry matter was higher with monensin than lasalocid or salinomycin supplementation. Fecal ash was also higher when steers were fed the monensin supplement than when fed

Table 1. Ration composition, dry matter basis

Ingredients	%
Whole shelled corn	88.58
Cottonseed hulls	5.16
Pelleted supplement	
Soybean meal	3.39
Alfalfa meal	.279
Dicalcium phosphate	.234
Calcium carbonate	1.069
Potassium chloride	.418
Salt	.318
Urea	.512
Trace mineral mix	.017
Vitamin A-30	.01
Drug[a]	+

[a]Premix added in amounts to yield dietary levels of 30 g per ton of feed of monensin, salinomycin or lasalocid.

Table 2. Ruminal, fecal and urinary measurements

	Drug			
Item	None	Monensin	Salinomycin	Lasalocid
Ruminal pH	6.23	6.16	6.29	6.23
Fecal pH[a]	5.67	6.15	5.91	6.03
Fecal dry matter, %[c]	29.3	29.9	28.3	31.1
Fecal starch, % DM	15.7	13.5	13.6	15.2
Fecal N, % DM[b]	2.90	3.11	2.99	2.89
Fecal ash, % wet matter[b]	2.25	2.47	2.20	2.36
Whole kernels in feces[d]	1.25	1.33	1.00	1.58
Urine, liter/day	5.92	7.06	8.88	6.99
Total fluid output, liter/day[e]	8.22	8.82	10.95	8.90

[a]Drugs altered measurement ($P<.05$).
[b]Response to monensin differs from other drugs ($P<.05$).
[c]Response to lasalocid differs from response to salinomycin ($P<.05$).
[d]Kernels not detected = 0; few particles = 1; large amounts = 3.
[e]Fecal plus urinary water output.

the other two drugs. Fecal dry matter was greater with lasalocid than with salinomycin. Fecal starch tended to be slightly higher with control and lasalocid supplements. The amount of whole kernels of corn observed in the feces was slightly lower with supplemental salinomycin than with other drugs. Output of fluid in urine plus feces was increased by 16 percent with added drugs suggesting that these compounds may increase water intake.

Digestibility of both organic matter and dry matter was increased by the addition of all three ionophores (Table 3) with greater effects from added monensin than either lasalocid or salinomycin. On the average, organic matter digestion was increased by 3.2 percent by added ionophores. Starch digestion also tended to increase with drug additions, but the difference was not significant. Ash digestion tended to be greater with monensin and lasalocid supplementation.

Ionophores decreased fecal nitrogen output (Table 4) but had little effect on loss of nitrogen in the urine. The digestibility of nitrogen was enhanced by added

Table 3. Digestibility

Item	Drug			
	None	Monensin	Salinomycin	Lasalocid
Dry matter[ab],%	81.4	84.8	82.5	83.0
Organic matter[ab], %	81.0	85.0	82.6	83.1
Starch, %	95.4	96.7	96.3	96.0
Ash, %	62.0	66.3	61.6	65.4

[a]Drugs altered measurement ($P<.05$).
[b]Response to monensin differs from other drugs.

Table 4. Nitrogen metabolism

Item	Drug			
	None	Monensin	Salinomycin	Lasalocid
Nitrogen intake, g/day	87.42	85.09	82.74	89.63
Fecal nitrogen output[a], g/day	27.40	23.14	24.59	25.24
Urinary nitrogen output, g/day	24.53	26.35	22.00	23.45
Digestibility, %[a]	68.6	72.6	70.0	71.7
Retention, g/day	35.49	35.60	36.13	40.94

[a]Drugs altered measurement ($P<.05$).

drugs while nitrogen retention was not significantly altered. Although these three compounds are chemically similar, some of their effects differ slightly. Since all three increased digestibility of most nutrients, they should all increase biological efficiency of feedlot steers.

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NUTRITION—POULTRY

Influence of Feed Withdrawal Time and Broiler Activity on Carcass Yield

R. G. Teeter, A. M. Saleh and J. G. Berry

Story in Brief

Ninety barred rock broilers were studied in a trial to determine the effects of fasting and differing levels of physical activity during the fasting period on broiler carcass characteristics. Physical activity was controlled by regulating the amount of environmental light available to the birds. Treatments included fasting in the presence or absence of light for 0, 12, 24, 36 and 48 hours prior to slaughter. Dressing percentage was enhanced by a mean of 5.7 percent at the 12, 24 and 36-hour time periods, but this effect was reduced to only 2.4 percent at 48 hours after feed withdrawal. Physical activity was reduced by the removal of light, but this had no effect upon carcass yield. Carcass weight remained constant through 24 hours of fasting but declined linearly ($P<.05$) thereafter. Liver weight declined linearly throughout the feed withdrawal period but at 24 hours accounted for only .4 percent of the marketable weight. The data indicates that purchasers of live broilers derive an economic advantage when the broilers are fasted for 12 to 24 hours before tallying purchase weight and that this advantage is reduced when the fasting period is extended beyond 24 hours.

Introduction

Broilers frequently undergo periods of intentional as well as unavoidable fasting prior to processing. Purchasers of live broilers prefer to buy birds that have undergone a period without feed so that dressing percentage will be increased, and they will not be forced fo pay live broiler prices for the feed contents of the gastrointestinal tract. Broilers are commonly held off feed but permitted to consume water before the purchase weight is tallied. Unavoidable periods of fasting (without feed and water) are encountered during transit to processing facilities. Although some fasting seems desirable from the purchaser's viewpoint, extensive time periods without feed may reduce the carcass weight. The following experiment was conducted to examine the influence that time without feed prior to slaughter has on the yield of saleable carcass and, further, to determine if bird activity during the deprivation period influences carcass yield.

Materials and Methods

Ninety barred rock cockerels with a mean initial live weight of 3.8 pounds were allocated to one of nine treatment groups. Replicates consisted of two pens of five birds each. The ration birds received 4 weeks prior to processing is shown in Table 1. Birds were fasted, either in the presence or absence of light, for 0, 12, 24, 36 and 48 hours. Lighting was used to control bird activity. Birds normally exhibit little physical activity when exposed to a dark environment. Presence or absence of light and length of fasting period coupled to form the treatment group. All birds were individually weighed 48 hours prior to and at the time of slaughter. Yield measurements obtained at slaughter included carcass weight (dressed and eviscerated bird weight without giblets) and liver weight. Feed contained in the crop and gizzard was collected, dried, weighed and used as an index of gastrointestinal tract fill.

Table 1. Ration composition

Ingredient	%
Ground corn grain	39.4
Soybean meal (44%)	22.5
Ground milo	14.8
Meat and bone scrap (50%)	10.9
Tallow	4.8
Alfalfa meal	4.0
Blood meal	2.6
Salt	.5
Vitamin mix	.25
dl methionine	.2
Trace mineral	.05

Results and Discussion

Broiler live weight (Table 2) at processing decreased linearly ($P < .05$) as length of fasting period increased. Live weight at slaughter was not influenced ($P > .1$) by the presence or absence of light, indicating that bird activity during the fasting period has little influence on live body weight. Carcass weight remained constant for the first 24 hours of fasting and then declined linearly ($P < .05$) as the fasting duration increased. Since carcass weight remained constant while live weight declined during the first 24 hours, dressing percentage (Figure 1) increased by a mean of 5.4 percent. Fasting birds prior to tallying live body weight results in a savings for the purchaser without reducing the quantity of edible carcass. The 68 percent reduction in crop and gizzard fill indicates that at least a portion of the enhanced dressing percentage is due to a reduced gastrointestinal tract fill. Even though carcass weight was declining after 24 hours of fasting, the dressing percentage remained high through 36 hours, indicating that live body weight and carcass weight are reduced in equal proportions during the 24 to 36-hour fasting period. However, dressing percentage at 48 hours of fasting was reduced ($P < .05$) compared to the 36-hour value, demonstrating that within the latter fasting period, carcass weight is lost at a higher rate than the other tissues included in live body weight. Data from this experiment indicates that in order for the maximum quantity of carcass to be obtained, broilers should not be without food for over 24 hours prior to processing.

A linear ($P < .05$) reduction in liver weight (Table 2) was detected as the length of fasting period increased. Liver tissue is metabolically active and constitutes the

Table 2. Broiler carcass characteristics

	Time before processing without feed (hr)								
	0	12		24		36		48	
	+L	+L	−L	+L	−L	+L	−L	+L	−L
Live wt 48 hr before processing (lb)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.6	3.8
Live wt at processing	3.9	3.8	3.8	3.7	3.7	3.5	3.5	3.2	3.5
Carcass wt.	2.5	2.5	2.6	2.5	2.5	2.4	2.4	2.1	2.3
Dressing %	64.1	65.8	68.4	67.6	67.6	68.6	68.6	65.6	65.7
Feed Detected in crop + gizzard (oz)	.5[a]	.1[b]	.2[b]	.2[b]	.1[b]	.2[b]	.2[b]	.1[b]	.1[b]
Liver wt (oz)	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1
Liver dry matter %	30.4	28.8	29.8	29.0	28.5	29.3	27.6	28.6	29.7

[ab]Means in a row with different superscripts differ statistically ($P<.05$).

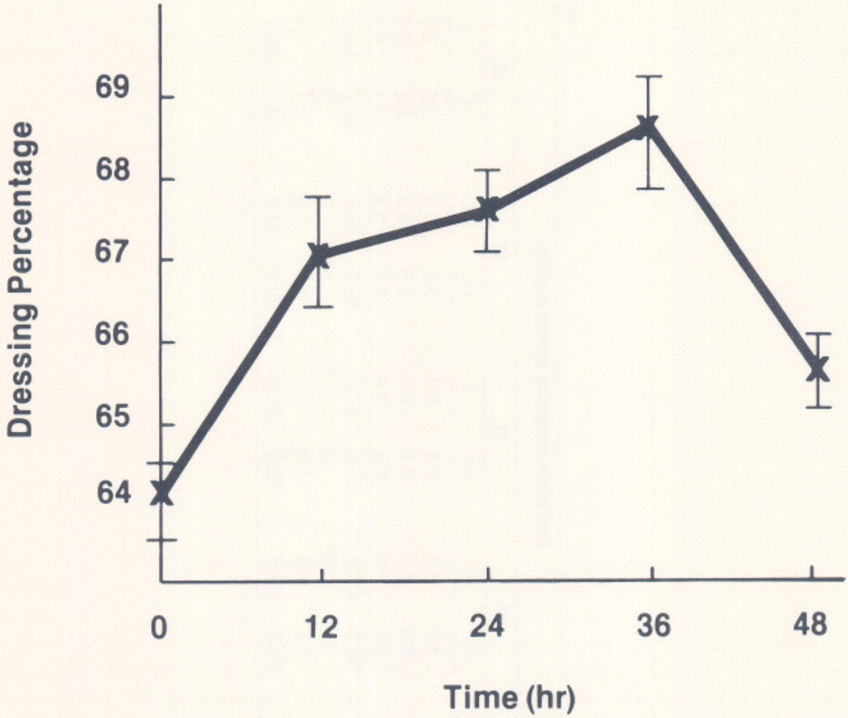

Figure 1. Dressing percentage as influenced by fasting period

principle storage site for glycogen. Glycogen is a readily available energy source and may constitute up to 30 percent of the liver's wet weight. The decrease in liver weight suggests that during the fasting period, liver glycogen is being mobilized to provide energy. The liver appears to be a sensitive organ for monitoring food deprivation. After broilers spent 24 hours without feed, liver weight was reduced by a mean of 10.7 percent. However, since the reduction in liver weight was only .2 percent of the carcass weight, and the savings which the fasting technique afforded the purchaser amounted to 5.4 percent of the purchase weight, it is advantageous for broiler purchasers to fast broilers prior to tallying purchase weight.

NUTRITION—SWINE

Swine Internal Parasites: Effect of Anthelmintic and Management System

W. R. Walker, C. V. Maxwell
H. E. Jordan, and W. G. Luce

Story in Brief

A total of 96 growing-finishing swine were used to study the effect of an anthelmintic treatment regime and management system on pig performance, liver lesions and intestinal worm burdens. Anthelmintics had no significant effect on rate of gain in pigs fed in confinement or in pasture lots. Feed efficiency was significantly (P<.01) improved by anthelminics only during the grower phase of pigs fed in pasture lots. Anthelmintics were effective in reducing the number of internal parasites in both confinement and pasture management systems. The type of parasites involved as well as the type of management system used may determine the most economical internal parasite control system for each swine producer.

Introduction

Infections of swine by internal parasites cause sizeable monetary losses in the swine industry because of growth retardation, uneconomical gains and occasional deaths. These losses have been estimated to average as much as $3.00 per pig.

A number of drugs with anthelmintic properties are available. However, conflicting results appear in the literature regarding the effectiveness of these compounds in improving rate of gain and efficiency of feed utilization. These inconsistent responses may result from environmental differences and/or disease variables. Swine reared in total confinement may require a different parasite control program than those reared in pasture lots.

The purpose of this study was to determine the effect of two anthelmintic treatment programs on rate of gain, efficiency of feed conversion, liver damage and number of internal parasites in Specific Pathogen Free (SPF) pigs fed in total confinement or in pasture lots.

Materials and Methods

A total of 90 SPF Yorkshire pigs and 6 SPF crossbred pigs (York x Hamp) from the Oklahoma State University research and teaching herd were used in this experiment. Sows that served as the source for the experimental pigs were treated with dichlorvos (Atgard) at approximately 110 days of gestation. The pigs were reared in total confinement facilities cleaned with water pressure and disinfectant. No additional anthelmintic was administered before allotment to treatment. The pigs, averaging 50 lb initially, were randomly allotted to one of six pens on pasture or total confinement in pens with solid concrete floors. One crossbred pig was assigned to each management treatment subclass. Each pen contained a self feeder and automatic waterer. All pens had been used in a continuous swine feeding program for years. Care was taken to clean and disinfect the concrete growing-finishing pens prior to the initiation of the trial. Composition of the basal diet used throughout the trial is shown in Table 1. Treatments were as follows:

Treatment 1: Basal diet with no anthelmintic.

Treatment 2: Basal diet plus dichlorvos (Atgard) at 348 grams/ton fed as the sole ration for 2 consecutive days at the initiation of the trial and at monthly intervals thereafter.

Treatment 3: Basal ration plus 12 grams/ton of Hygromycin fed continuously.

Pigs were removed from the trial at an average weight of 232 lb. At the end of the trial, pigs were examined for liver lesions, and an intestinal parasite count was made. In addition, a fecal egg count was made on a fecal sample obtained from the digestive tract.

Table 1 Composition of basal diet

Ingredient	%
Yellow corn	75.50
Soybean meal (44%)	21.15
Dicalcium phosphate	1.50
Calcium carbonate	0.75
Salt	0.50
Vitamin trace-mineral mix[a]	0.50
CTC-50[b]	0.10
Total	100.00

[a]Supplied 4,000,000 IU vitamin A, 300,000 IU vitamin D, 4 g riboflavin, 20 g pantothenic acid, 30 g niacin, 800 g choline chloride, 15 mg vitamin B_{12}, 10,000 IU vitamin E, 2 g menadione, 200 mg iodine, 90 g iron, 20 g manganese, 10 g copper, 90 g zinc and 100 mg selenium per ton of feed.
[b]Contains 50 g chlortetracycline per lb of premix.

Results and Discussion

Performance data are presented in Table 2. Anthelmintics had no significant effect on rate of gain in pigs fed in solid concrete pens or in pasture lots. Average daily gain over the entire trial was 1.72, 1.74 and 1.73 pounds for the untreated control, Atgard and Hygromycin treatments, respectively. It should be noted that during the growth phase average daily gain was similar for both management systems.

Anthelmintics had no significant effect on the efficiency of feed utilization during both the grower and finishing phases in pigs fed in solid concrete pens. However, in pigs fed in pasture lots, the efficiency of feed utilization was improved ($P<.01$) by both the periodic and continuous anthelmintic treatment when compared with the untreated control during the grower phase, but not during the finishing phase. When compared to the untreated control diet, this represented a 14.5 percent improvement in feed efficiency in pigs treated with Atgard

Table 2. Effect of anthelmintics and management system on average daily gain and feed efficiency

Management	Treatment		
	Control	Atgard	Hygromycin
Concrete			
Avg. daily gain, lb			
Grower phase (50-120 lb)	1.66	1.55	1.67
Finishing phase (120 lb-market)	1.86	1.97	1.83
Total (50 lb-market)	1.78	1.80	1.76
Feed per lb gain, lb			
Grower phase (50-120 lb)	2.67	2.80	3.23
Finishing phase (120 lb-market)	3.65	3.35	3.77
Total (50 lb-market)	3.28	3.16	3.56
Pasture			
Avg. daily gain, lb			
Grower phase (50-120 lb)	1.45	1.50	1.52
Finishing phase (120 lb-market)	1.84	1.84	1.85
Total (50 lb-market)	1.67	1.69	1.70
Feed per lb gain, lb			
Grower phase (50-120 lb)	3.37[a]	2.88[b]	2.84[b]
Finishing phase (120 lb-market)	3.75	4.01	3.86
Total (50 lb-market)	3.61	3.56	3.44

[ab]Means with different superscripts within management system are significantly different (P<.01).

and a 15.7 percent improvement in feed efficiency in pigs treated with Hygromycin during the growing phase. The improvement in feed efficiency in treated pigs on pasture, but not confinement, is similar to trends observed in previous studies (Maxwell et al., 1980).

The effects of anthelmintics and management system on necropsy evaluation are presented in Table 3. The number of liver lesions was not significantly affected by treatment in pigs fed on pasture or concrete. Ascarids and whipworms were the only parasites found in the intestine upon necropsy. The total number of both parasites was extremely small in pigs on all treatments and both management systems but tended to be lower in pigs on either anthelmintic treatment. This reduction was significant in the number of ascarids (P.<.05) in pigs fed Atgard in confinement and the number of whipworms (P<.1) in pigs fed Atgard on pasture. Pigs fed Atgard at 348 grams/ton of ration for 2 consecutive days and at monthly intervals thereafter on pasture or concrete had no ascarids or whipworms. The fecal egg counts followed the same trends as the intestinal parasite counts with the number of fecal ascarid eggs being higher for pigs on the untreated control diet. Both Atgard and Hygromycin reduced the fecal ascarid egg count (P<.01)in pigs fed in confinement and the whipworm fecal egg count (P<.1) in pigs fed in pasture lots.

These data indicate that anthelmintics are available which can effectively control ascarids and whipworms in swine fed on pasture or in total confinement. The type of parasite involved as well as the type of management system used should be considered in determining the most economical control system for each swine producer.

Table 3. The effect of anthelmintics and management system on average number of liver lesions, intestinal parasites and fecal egg counts

	Treatments		
Management	**Control**	**Atgard**	**Hygromycin**
Concrete			
Liver lesions	7.70	6.94	14.00
Ascarids			
Intestinal parasites	2.25^{c}	0.00^{d}	$.51^{cd}$
Fecal egg count	71.79^{a}	0.00^{b}	0.21^{b}
Whipworms			
Intestinal parasites	0.00	0.00	0.00
Fecal egg count	0.07	0.00	0.00
Pasture			
Liver lesions	17.63	20.96	10.44
Ascarids			
Intestinal parasites	1.68	0.00	1.00
Fecal egg count	34.32	0.43	3.38
Whipworms			
Intestinal parasites	6.36^{e}	0.00^{f}	1.81^{ef}
Fecal egg count	0.14^{e}	0.00^{f}	0.00^{f}

^{ab}Means in the same row with different superscripts are significantly different ($P<.01$).
^{cd}Means in the same row with different superscripts are significantly different ($P<.05$).
^{ef}Means in the same row with different superscripts are significantly different ($P<.10$).

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The Effect of Increased Feed Intake During Late Gestation on the Reproductive Performance of Sows

W. R. Walker, C. V. Maxwell,
R. L. Hintz and K. Brock

Story in Brief

The effect which increased feed intake during late gestation has on the reproductive performance of sows was studied in a trial utilizing 77 Yorkshire sows and 45 Yorkshire gilts. Treatments were a normal level of feed intake (4 lb per head per day in summer and 5 lb per head per day in winter) throughout gestation and a high level of feed intake (7 lb per head per day in summer and 8 lb per head per day in winter) from 90 days of gestation to farrowing. Sows on the high intake treatment were fed a normal intake from breeding to 90 days of gestation followed by the higher feed intake to farrowing.

No significant treatment differences were observed for litter size, sow weight, sow feed consumption, creep feed consumption, or pig survival.

A three-way interaction between treatment, parity and season of birth was significant.

The pigs from sows and gilts on the higher late gestation feed intake were consistantly heavier at birth, 21 and 42 days and had higher survival rates, resulting in increased litter size and larger pigs at weaning. Sow feed consumption during the first 21 days of lactation and creep feed consumption by pigs during the last 21 days of lactation were also higher for sows and gilts on the high intake treatment.

Introduction

A low survival rate of baby pigs from bith to weaning is a major problem in the swine industry. Estimates of survivability range from 70 to 80 percent. One of the major factors that has been shown to influence survival in baby pigs is birth weight. Past research indicates that heavier birth weight in pigs results in increased survival to weaning. Early studies demonstrate that most of the weight, protein, calcium and phosphorus is deposited in the fetuses during the last 21 days of pregnancy. Since birth weight may be related to energy intake of the sow during gestation, the level of nutrient intake during the last trimester of pregnancy should have an influence on the weight and composition of the newborn pig, thus having a major effect on the pig's chances for survival.

This study was conducted to determine what effect total feed intake level of the sow during late gestation has on litter size, birth weight, pig survival and subsequent pig performance.

Materials and Methods

A feeding study was conducted with 77 Yorkshire sows and 45 Yorkshire gilts to determine the effect on subsequent productivity of increasing the level of nutrition during late gestation. Prior to breeding, gilts and sows were fed a standard 14-percent crude protein corn-soybean meal ration. The specific feeding regime for each treatment through the entire gestation period is explained in Table 1. After farrowing, all sows were allowed to consume the 14-percent protein diet on an ad libitum basis throughout lactation. Creep feed was provided to pigs at 3 weeks of age and continued until weaning at 6 weeks of age. After weaning, all sows were returned to the prebreeding level of feed intake (4.0 lb per head per day) and rebred, when possible, on the first estrus.

Table 1. Feed intake for each treatment (lb)

	Treatment[a]			
	Normal Intake		High Intake	
	Gilts	Sows	Gilts	Sows
Prior to breeding	5	4	5	4
After breeding (day 1-90)	4	4	4	4
90 days (gestation to farrowing)	4	4	7	7

[a]Feed increased 1 additional pound during the months of December to February.

Gilts and sows were kept in dirt lots throughout the breeding and early gestation period. Pens were equipped with individual feeding stalls and nipple waterers. Gilts and sows were fed once daily in the morning. Shelter was provided in each lot with foggers for cooling during periods of high temperature and straw for bedding during periods of cold temperature. At approximately 110 days of gestation, gilts and sows were moved to a farrowing unit and kept in farrowing crates until 21 days after farrowing. Heat lamps were provided to supply supplemental heat to pigs. At 21 days postfarrowing, sows and litters were moved to nursery pens where pigs were allowed access to creep feed and water on an ad libitum basis. Nursery pens were on concrete floors with shelter provided for both sow and pigs. A hover area was provided with heat lamps to supply supplemental heat during the winter months. At 42 days postfarrowing pigs were weaned and sows returned to dirt lots. Measurements made included: 1) gilt and sow weight at breeding, 90 days and 110 days of gestation as well as within 24 hours of farrowing, on day 21 of lactation and at weaning; 2) individual pig weight at birth (live and dead pigs), 21 days and at weaning; 3) total and live pigs at birth, 21 days and at weaning; 4) feed consumption of sows from parturition to day 21; 5) consumption of creep feed by the baby pigs from 3 weeks until weaning.

Results and Discussion

No significant treatment differences were observed for sow weight at breeding, 90 or 110 days of gestation, farrowing and 21 or 42 days postfarrowing (Table 2). Sows and gilts on the high intake treatment showed a

Table 2. Least square means for sow weight, sow feed consumption and creep feed consumption for each treatment

	Treatment	
	Normal Intake (lb)	High Intake (lb)
Sow weight		
Breeding	388.9	375.9
90 Days gestation	434.4	441.0
110 Days gestation	454.3	465.5
Farrowing	426.4	437.5
21 Days lactation	408.2	405.5
42 Days (weaning)	418.3	416.3
Sow feed intake (farrow to 21 day postfarrowing	338.2	349.8
Creep feed consumption (21 days postfarrowing to weaning)	27.8	32.3

tendency to gain more weight from 90 days of gestation to farrowing and lose more weight during lactation than sows and gilts on the normal intake treatment. In addition, sow feed consumption from farrowing to 21 days postfarrowing was higher in sows fed the high intake level during gestation (349.8 lb vs 338.2 lb for the high vs normal intake, respectively). Likewise, pig creep consumption from 21 days postfarrowing to weaning at 42 days postfarrowing was higher in litters from sows fed the high intake during late gestation (32.3 lb vs 27.8 lb for the high vs normal intake, respectively). These differences in sow feed consumption and creep feed consumption were not significant.

Differences in individual pig weight at birth, 21 and 42 days postfarrowing were significant, but interpretation is difficult due to a significant three-way interaction between treatment, parity and season of birth (Table 3). However, averaged by treatment, pigs from sows and gilts on the high intake treatment were consistently heavier than pigs from sows and gilts on the normal intake at each weight period.

The number of live pigs and the pig survival rate at birth, 21 and 42 days postfarrowing were not significantly affected by the level of feed intake of the sow (Table 4). It should be noted, however, that the trend for larger pigs at birth from sows and gilts on the high intake treatment resulted in higher survival rates for pigs at birth, 21 and 42 days postfarrowing, which in turn led to more live pigs at weaning (7.39 vs 6.86 for the high vs normal intake, respectively). The survival rate was improved by 9.4 percent at 42 days, and survival rate from 21 to 42 days was improved by 10.7 percent.

These data suggest that no significant benefits are derived from increasing the feed intake of sows during the last trimester of gestation. However, performance was consistently higher for sows and gilts on the high level of feed intake. With the high degree of variation associated with the reproductive traits, a study with more animals may be necessary to accurately determine the real effect which nutritional treatment during gestation has on subsequent reproductive performance.

Table 3. Least square means of individual pig weight for each treatment parity and farrowing season

Treatment	Parity	Season of birth	Birth weight (lb)	21 Days post-farrowing (lb)	42 Days post-farrowing (lb)
Normal intake	Gilt	Jan-Mar	2.5	11.2	21.0
Normal intake	Gilt	Apr-Jun	3.3	11.4	19.0
Normal intake	Gilt	Jul-Sept	2.9	10.5	21.9
Normal intake	Gilt	Oct-Dec	2.7	11.3	23.2
Normal intake	Sow	Jan-Mar	3.0	11.9	21.5
Normal intake	Sow	Apr-Jun	3.0	12.1	24.2
Normal intake	Sow	Jul-Sept	2.4	9.4	21.9
Normal intake	Sow	Oct-Dec	2.8	12.5	23.7
Average for normal intake treatment			2.8	11.3	22.1
High intake	Gilt	Jan-Mar	3.1	10.5	18.3
High intake	Gilt	Apr-Jun	3.1	12.3	24.2
High intake	Gilt	Jul-Sept	2.9	12.1	22.6
High intake	Gilt	Oct-Dec	2.5	12.5	22.1
High intake	Sow	Jan-Mar	3.1	12.6	22.6
High Intake	Sow	Apr-Jun	3.3	12.3	23.9
High intake	Sow	Jul-Sept	2.5	8.7	19.4
High intake	Sow	Oct-Dec	3.3	13.4	26.5
Average for high intake treatment			3.0	11.8	22.5

Table 4. Average litter size and survival rate

	Number of live pigs			Survival rate (%)			
	Birth	21 days lactation	42 days (weaning)	Birth[1]	21 days[2] lactation	42 days[3] (weaning)	21-42[4] days
Normal intake	9.14	8.02	6.86	87.7	88.1	75.6	83.8
High intake	8.14	7.81	7.39	89.0	89.9	85.0	94.5

[1]Number of pigs born alive ÷ total pigs born.
[2]Number of pigs alive at 21 days ÷ number of pigs born alive.
[3]Number of pigs alive at 42 days ÷ number of pigs born alive.
[4]Number of pigs alive at 42 days ÷ number of pigs alive at 21 days.

Direct Comparisons of Antibiotics for Growing-Finishing Swine

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Story in Brief

Two trials were conducted to make direct comparisons among antibiotics commonly used by Oklahoma swine producers. In the first trial, gain, feed efficiency and daily feed intake were similar for pigs receiving the non-medicated control diet and pigs receiving chlortetracycline, tylosin or bambermycins. Pigs fed bambermycins tended to grow more slowly than pigs fed the other treatments during the growing period. In the second trial, pigs fed virginiamycin grew 9 percent faster and were 5 percent more efficient than pigs fed chlortetracycline.The pigs fed virginiamycin also grew 6 percent faster and were 4 percent more efficient than pigs fed the non-medicated control diet during the growing period. During the finishing period, average daily gain was similar among all treatments. Chlortetracycline in the diet during the finishing period improved feed efficiency by 4 percent when compared with virginiamycin-fed pigs. Backfat thickness was greater in antibiotic-fed pigs. Results of these trials suggest that substantial differences in antibiotic responses are likely to occur. More direct comparisons are needed to formulate specific antibiotic recommendations over the wide variety of environmental and management conditions found among swine producers.

Introduction

Antibiotics have been used extensively in growing-finishing swine rations for three decades. Such wide acceptance is attributed to their established benefits of increasing growth rate, improving feed efficiency and reducing the adverse effects of specific swine diseases.

Although a considerable volume of data concerning the effectiveness of antibiotics in improving performance for growing-finishing hogs has been published, the continued evaluation of the relative efficacy of both currently available and new drugs is needed. Most current data permits only indirect comparison of the relative effects of available antibiotics on performance. Data making direct comparisons are more limited. The objective of the research was to compare the feedlot performance of growing-finishing swine fed diets containing several antibiotics currently used by swine producers.

Materials and Methods

All pigs were housed in indoor concrete pens equipped with self feeders and waterers. Both trials were conducted at the Southwestern Livestock and Forage Research Station near El Reno, Oklahoma. In both trials, pigs from various breed groups in the animal breeding herd were randonly allotted within breed group, sex and litter to the experimental treatments.

Trial 1 consisted of 80 pigs with four pens (five pigs per pen) on each of four treatments. A 0.75 percent lysine corn-soybean meal ration (Table 1) was fed to all pigs fron an average weight of 49 to 112 lb. The lysine level was reduced to 0.62 percent during the finishing phase (122 to 222 lb). The four treatments consisted of a non-medicated control and three antibiotics: (1) chlortetracycline (Aureomycin[1]), (2) tylosin (Tylan[2]) and (3) bambermycins (Flavomycin[3]) fed at the highest levels recommended for increased rate of weight gain and improved feed effi-

Table 1. Composition of experimental rations

Ingredient	Trial 1, %		Trial 2, %	
	Grower	Finisher	Grower	Finisher
Corn, yellow	78.25	83.0	—	—
Wheat, hard red winter	—	—	81.70	86.93
Soybean meal (44%)	19.00	14.25	15.36	10.10
Dicalcium phosphate	1.35	1.25	0.97	1.00
Calcium carbonate	0.75	0.85	0.97	0.97
Salt	0.40	0.40	0.50	0.50
Vitamin trace-mineral mix[a]	0.25	0.25	0.50	0.50
Total	100.00	100.00	100.00	100.00
% Lysine	0.75	0.62	0.75	0.62
% Calcium	0.68	0.65	0.66	0.65
% Phosphorus	0.59	0.55	0.55	0.54

[a]Supplied 4,000,000 IU vitamin A, 400,000 IU vitamin D, 4 g riboflavin, 20 g pantothenic acid, 20 g niacin, 400 g choline chloride, 20 mg vitamin B_{12}, 10,000 IU vitamin E, 1 g menadione, 680 mg iodine, 45 g iron, 25 g manganese, 5 g copper, 90 g zinc, and 90 mg selenium per ton of feed in Trial 1 and 4,000,000 IU vitamin A, 300,000 IU vitamin D, 4 g riboflavin, 20 g pantothenic acid, 30 g niacin, 800 g choline chloride, 15 mg vitamin B_{12}, 10,000 IU vitamin E, 2 g menadione, 200 mg iodine, 90 g iron, 20 g manganese, 10 g copper, 90 g zinc and 100 mg selenium per ton of feed in Trial 2.

[1]Diamond Shamrock Corporation, Animal Health Division, Cleveland, Ohio.
[2]Elanco, Division of Eli Lilly Company, Indianapolis, IN.
[3]American Hoechst Corporation, Animal Health Division, Somerville, N.J.

ciency in growing-finishing swine. Levels of each antibiotic during both the growing and finishing phases are given in Table 2.

Trial 2 consisted of 498 pigs with 9 pens on treatment 1, 16 pens on treatment 2 and 17 pens on treatment 3. The unbalanced design was employed in this study because antibiotic responses compared to a negative control are well documented; therefore, the primary objective of this study was to make direct comparisons between the two antibiotics. A 0.75 percent lysine wheat-soybean meal ration (Table 1) was fed to all pigs from an average weight of 40 to 118 lb. The lysine level was reduced to 0.62 percent during the finishing phase (118 to 214 lb). The three treatments were: (1) a wheat-soybean meal non-medicated basal diet, (2) basal plus 10 g of virginiamycin (Stafac[4]) per ton during both the growing and finishing phase and (3) basal plus 50 g of chlortetracycline per ton of feed (Table 2). These levels of antibiotics are the highest levels recommended for increased rate of weight gain and improvement in feed efficiency in growing-finishing swine.

Table 2. Treatments and antibiotic levels used

Item	Antibiotic level, g/ton	
Treatment - Trial 1	Grower	Finisher
Basal	0	0
Basal plus Chlortetracycline	50	50
Basal plus Tylosin	100	20
Basal plus Bambermycins	4	2
Treatment - Trial 2		
Basal	0	0
Basal plus Virginiamycin	10	10
Basal plus Chlortetracycline	50	50

Results and Discussion

Results of Trial 1 for the growing, finishing and combined growing-finishing periods are presented in Tables 3, 4 and 5, respectively. Average daily gain was affected by treatment only during the growing period where pigs fed bambermycins tended to grow more slowly ($P<.1$) than pigs fed tylosin, chlortetracycline or the non-medicated control diet. It should be noted, however, that American Hoechst Corporation recommends starting pigs on bambermycin only after they reach 75 lb. Pigs fed tylosin had the highest average daily gain during the growing period, with pigs growing 9 percent faster than those fed bambermycins, 4 percent faster than those fed chlortetracycline and 3 percent faster than those receiving the non-medicated control diet, but differences were not significant. Gains during both the finishing and combined growing-finishing periods were similar across all treatments.

Average daily feed intake followed a pattern similar to that observed for average daily gain with pigs fed bambermycins consuming less feed ($P<.1$) than those fed tylosin, chlortetracycline or the non-medicated control diet during the

[4]SmithKline Animal Health Products, Philidelphia, PA.

Table 3. The effect of chlortetracycline, tylosin and bambermycins on performance and feed efficiency in growing swine: Trial 1

Item	1 Control	2 Chlortetracycline	3 Tylosin	4 Bambermycins
	Antibiotic level, g/ton			
	0	50	100	4
Pigs per treatment, no.[a]	20	20	20	20
Pens per treatment, no.	4	4	4	4
Avg. initial wt, lb	49.6	49.3	50.3	48.2
Avg. final wt, lb	121.9	121.9	126.3	118.1
Avg. daily gain, lb	1.48[b]	1.47[b]	1.53[b]	1.40[c]
Avg. daily feed intake, lb	3.67[b]	3.69[b]	3.99[b]	3.36[c]
Feed per lb gain, lb	2.62	2.58	2.63	2.58

[a]One pig was removed from treatments 1 and 3, and one pig on treatment 4 died.
[b,c]Values with different superscripts are significantly different $P<.1$.

Table 4. The effect of chlortetracycline, tylosin and bambermycins on performance and feed efficiency of finishing swine: Trial 1

Item	1 Control	2 Chlortetracycline	3 Tylosin	4 Bambermycins
	Antibiotic level, g/ton			
	0	50	20	2
Pigs per treatment, no.[a]	20	20	20	20
Pens per treatment, no.	4	4	4	4
Avg. initial wt, lb	121.9	121.9	126.3	118.1
Avg. final wt, lb	218.6	222.5	226.6	221
Avg. daily gain, lb	1.68	1.66	1.75	1.67
Avg. daily feed intake, lb	5.28	5.36	5.51	5.38
Feed per lb gain, lb	3.59	3.40	3.50	3.35

[a]One pig was removed from treatments 1 and 3, and one pig on treatment 4 died.

Table 5. The effect of chlortetracyclin, tylosin and bambermycins on performance, feed efficiency and backfat of growing-finishing swine: Trial 1

Item	1 Control	2 Chlortetracycline	3 Tylosin	4 Bambermycins
	Antibiotic level, g/ton			
Growing	0	50	100	4
Finishing	0	50	20	2
Pigs per treatment, no.[a]	20	20	20	20
Pens per treatment, no.	4	4	4	4
Avg. initial wt, lb	49.6	49.3	50.3	48.2
Avg. final wt, lb	218.6	222.5	226.6	221
Avg. daily gain, lb	1.58	1.58	1.64	1.55
Avg. daily feed intake, lb	4.56	4.62	4.83	4.42
Feed per lb gain, lb	3.10	3.06	3.10	3.04
Avg. adjusted backfat, in.	0.88	0.91	0.88	0.88

[a]One pig was removed from treatments 1 and 3 and one pig on treatment 4 died.

growing period. Differences in average daily feed intake were non-significant during both the finishing and combined growing-finishing periods. Likewise, feed efficiency of pigs fed all three antibiotics and those receiving the non-medicated control diet was similar in the growing, finishing and growing-finishing periods.

The lack of an antibiotic response in this trial is inconsistent with a considerable volume of published literature demonstrating improved gains and efficiency of gain with antibiotic supplementation. There are, however, many studies in the literature in which little or no response was observed to a recommended level of an antibiotic. It should be noted that the population density of animals in this trial was low, which is consistent with the observations that either a low disease level or low animal density may tend to reduce the antibiotic response.

In Trial 2 pigs fed virginiamycin during the growing period (40 to 118 lb, Table 6) grew faster ($P<.05$) and were more efficient ($P<.05$) than those receiving chlortetracycline. Likewise, pigs fed virginiamycin grew faster ($P<.05$) and tended to be more efficient ($P<.1$) than pigs fed the non-medicated control diet.

Table 6. The effect of virginiamycin and chlortetracycline on performance of growing swine: Trial 2

	Treatments		
	1 Control	2 Virginiamycin	3 Chlortetracycline
		Antibiotic level (g/ton)	
Item	0	10	50
Pigs per treatment, no.	93	196	209
Pens per treatment, no.	9	16	17
Avg. initial wt, lb	42.2^{a}	42.3^{a}	36.7^{b}
Avg. final wt, lb	118.8	117.7	118.3
Avg. daily gain, lb	1.33^{a}	1.41^{b}	1.29^{a}
Avg. daily feed intake, lb	3.56	3.60	3.56
Feed per lb gain, lb	2.67^{ab}	2.56^{b}	2.69^{a}

^{a,b} Means in the same row with different superscripts differ significantly ($P<.05$).

Average daily gain of pigs receiving virginiamycin was 9 percent faster than in pigs receiving the non-medicated control diet. Feed efficiency of pigs receiving virginiamycin during the growing period was improved by 5 percent over that observed in pigs fed chlortetracycline and 4 percent over that observed in pigs fed the non-medicated control diet. Average daily feed intake was similar for all three treatment groups. The lack of a response in pigs fed chlortetracycline may have been due to lighter weights ($P<.05$) at the initiation of the trial for chlortetracycline-fed pigs compared to pigs fed virginiamycin or the non-medicated controls. Since pigs were randomly allotted to treatments, this lower initial weight can only be attributed to chance.

The overall average daily gain response to virginiamycin and chlortetracycline was positive during the finishing period (118 to 214 lb, Table 7) although differences were not significant. Pigs fed chlortetracycline and virginiamycin grew 3 and 1 percent faster, respectively, than pigs fed the non-medicated control diet. Chlortetracycline tended to improve feed efficiency ($P<.1$) when compared with virginiamycin fed pigs. This represented an improvement in feed efficiency of 4 percent. Feed efficiency in pigs fed the non-medicated control diet and vir-

Table 7. The effect of virginiamycin and chlortetracycline on performance of growing swine: Trial 2

	Treatments		
	1 Control	2 Virginiamycin	3 Chlortetracycline
	Antibiotic level (g/ton)		
Item	0	10	50
Pigs per treatment, no.	93	196	209
Pens per treatment, no.	9	16	17
Avg. initial wt, lb	118.8	117.7	118.3
Avg. final wt, lb	213.0	215.9	212.6
Avg. daily gain, lb	1.46	1.49	1.51
Avg. daily feed intake, lb	4.56	4.78	4.86
Feed per lb gain, lb	3.49[ab]	3.50[a]	3.36[b]

[a,b] Means in the same row with different superscripts differ significantly ($P<.1$).

giniamycin during the finishing phase was similar. Likewise, average daily feed intake was similar across all dietary treatments.

Means for average daily gain, feed efficiency, average daily feed intake and backfat during the entire growing-finshing phase are presented in Table 8. Pigs fed virginiamycin grew 5 percent ($P<.05$) than pigs fed chlortetracycline. Differences in gain between either antibiotic and non-medicated control were not significant. The overall response to chlortetracycline and virginiamycin was positive for both average daily feed intake and feed efficiency during the entire growing-finishing period although these differences were not significant. Backfat thickness was higher in pigs fed either virginiamycin or chlortetracycline when compared to the non-medicated control-fed pigs. This may be due to the faster rate of gain observed in pigs fed virginiamycin during both the growing and the finishing phases and chlortetracycline during the finishing period.

Table 8. The effect of virginiamycin and chlortetracycline on performance of growing-finishing swine: Trial 2

	Treatments		
	1 Control	2 Virginiamycin	3 Chlortetracycline
Item	Antibiotic level (g/ton)		
Growing	0	10	50
Finishing	0	10	50
Pigs per treatment, no.	93	196	209
Pens per treatment, no.	9	16	17
Avg. initial wt, lb	42.2[a]	42.3[a]	36.7[b]
Avg. final wt, lb	213.0	215.9	212.6
Avg. daily gain, lb	1.42[ab]	1.47[a]	1.40[b]
Avg. daily feed intake, lb	4.09	4.24	4.24
Feed per lb gain, lb	3.10	3.05	3.05
Avg. adjusted backfat, in.	0.93[a]	0.96[b]	0.96[b]

[a,b] Means in the same row with different superscripts differ significantly ($P<.05$).

NUTRITION—DAIRY

Effect of Heating of Soybean Meal on Milk Production and Degradation of Protein in the Rumen of Lactating Dairy Cows

J.W. Ward, L.J. Bush, D. Griffin and G.D. Adams

Story in Brief

A feeding trial utilizing lactating cows was conducted to compare soybean meal (SBM) processed in a conventional manner with meal which received extra heat during processing. There was a trend for higher milk yield by cows fed the extra-heat SBM compared to cows fed control SBM in a higher production group; however, no response was observed in cows in a lower production group. Weight change was positive and similar for cows fed both types of SBM.

The extent of ruminal degradation of protein in rations containing the two types of SBM was estimated using lactating cows previously fitted with cannulae in the proximal duodenum. The percentage of feed protein bypassing the rumen was 28.8 percent in cows fed extra-heat SBM compared to 27.8 percent in those fed control SBM.

Introduction

The demand for nutrients for milk synthesis are especially high in the dairy cow during early lactation. A ration relatively high in protein content is needed to meet the requirements of lactating cows, partially because of a high rate of degradation of feed protein in the rumen. A great potential for improving the utilization of dietary protein has been demonstrated in trials wherein alternate sources of protein have been compared. Methods of treating soybean meal to enable a larger fraction of the protein to pass through the rumen without breakdown to the lower digestive tract and thus increase its feed value have been of particular interest. Alteration of soybean meal to reduce rumen degradation may increase the amount of metabolizable protein available at the site of absorptin and result in a more efficient use of this feed protein to meet the protein needs for milk synthesis. The objectives of this study were to compare the feeding value of regular soybean meal with meal heated more extensively during processing and to compare ruminal bypass of feed nitrogen in rations containing regular and extra-heat soybean meal.

Materials and Methods

Continuous Feeding Trial

Soybean meal with a protein dispersion index (PDI) value of 10 and regular soybean meal (PDI~40) were compared in a continuous feeding trial using lactating dairy cows. Solubility of nitrogen in NaCl was 11 and 19 percent of total nitrogen in the two soybean meals, respectively. These were included in concentrate rations at two protein levels (Table 1). The higher protein rations with the two types of soybean meal were fed to cows producing 70 lb or more of milk daily, and the lower protein rations to those with lower production. It was intended that protein intake would be sufficient to meet approximately 90 percent of the National Research Council standard for milk production during the early part of the trial, thus allowing ample opportunity for any difference in efficiency of utilizing protein in the two types of soybean meal to be reflected in a difference in milk yield.

Table 1. Composition of concentrate mixtures used in feeding trial

Item	Protein level	
	High	Low
Ingredients, % as fed		
Corn, ground	66	72
Soybean meal	26	20
Molasses, liquid	5	5
Dicalcium phosphate	1	1
Limestone	1	1
Salt	1	1
Protein content, % air dry	17.8	16.0

On a dry matter basis, all four rations initially consisted of 60 percent grain mix, 28 percent sorghum silage and 12 percent prairie hay; thus, they were equal in energy content. Adjustments in concentrate-to-forage ratio were made to minimize overfeeding protein as milk production declined over the lactation period.

Prior to initiating the study, 40 cows (28 Holsteins; 12 Aryshires) were adjusted to rations with a 60:40 concentrate-to-forage ratio. The cows were paired within two production groups. The higher production group consisted of cows producing 70 to 84 lb daily during the preliminary period, whereas cows in the lower production group ranged from 55 to 67 lb daily during this period. The cows were approximately 4 weeks postpartum when started on the trial. Cows were fed in individual stalls twice daily, and feed weighbacks were recorded daily. Sufficient feed was offered each cow to allow some feed weighback nearly every day. When the amount of weighback exceeded 10 percent of the feed offered on 2 or 3 days during a given week, the amount of ration was reduced. Milk yield was recorded twice daily, and samples were taken at four consecutive milkings each week for fat and protein analysis. Cows were weighed on 3 consecutive days at the end of the preliminary adjustment period and at the end of each 4 weeks of the 16-week trial.

Ruminal Bypass Trial

Soybean meal with a PDI value of 10 and regular soybean meal (PDI-40) were compared in a ruminal bypass study to determine the amount of feed nitrogen that bypassed the rumen. Soybean meal comprised 32 percent of the total concentrate mixtures used in this trial. Rations were formulated to meet NRC feeding standards for all required nutrients and consisted of 60 percent grain mix, 28 percent sorghum silage and 12 percent prairie hay on a dry basis.

Prior to initiation of the study, five cows (four Holsteins; one Aryshire) were fitted wtih T-cannulae in the proximal duodenum. After calving they were adjusted to rations with a 60:40 concentrate-to-forage ratio and were continued on rations with this percentage of concentrates throughout the trial from 4 to 22 weeks of lactation.

In a replicated crossover design, diets with chromic oxide as a digesta flow marker were fed in equal portions every 8 hours. Cows were fed in individual stalls three times daily, and feed weighbacks were recorded daily. Cows were fed the diets 2 weeks prior to two 4-day sampling periods. Duodenal digesta and fecal samples were collected every 8 hours during each of the 4-day periods.

Results and Discussion

In the feeding trial, intakes of dry matter by cows were similar for the two soybean meal treatment groups within production levels (Table 2). Soybean meal protein represented approximately 53 percent of the total protein intake by the high production group and 47 percent of the total by the lower production group. In both groups soybean meal protein constituted a high enough percent-

Table 2. Responses of cows in feeding trial

	Production group			
	Low		High	
Item	PDI-40	PDI-10	PDI-40	PDI-10
Feed intake				
Dry matter, lb/day	43.2	43.9	49.8	50.5
Total protein, lb/day	6.2	6.4	8.4	8.6
Protein, % of DM	14.3	14.6	16.8	17.0
Weight change, lb/day	.95	.97	1.08	1.12
Milk yield				
Milk, lb/day[a]	57.2	55.4	69.4	73.9
Fat, %	3.8	3.7	3.6	3.6
Protein, %	3.10	3.17	2.96	2.98

[a]Means adjusted by covariance for initial production.

age of the total protein intake that the treatment of the soybean meal could influence production responses. Protein intakes were higher in relation to the NRC standard than planned, especially in the higher production group during the second 4-week period of the trial (Table 3). This was the result of milk yield declining to the lower part of the range stipulated for cows to receive the higher protein ration. Although this situation probably decreased the likelihood for a difference between types of soybean meal to be expressed in milk yield, a response to feeding extra-heat soybean meal was observed in a previous trial (Bush et al., 1980) wherein protein intake exceeded NRC requirements.

Table 3. Protein intake relative to NRC standard

Item	Period of experiment[a] 1	2	3	4
Low group				
SBM PDI-40	75	91	97	85
SBM PDI-10	81	98	107	95
High group				
SBM PDI-40	100	117	104	105
SBM PDI-10	105	115	108	102

[a]Each period represents 4 weeks of the trial.

In both production groups, actual milk yield averaged over the entire 16-week trial was slightly higher for the cows fed PDI-10 soybean meal than for those fed regular soybean meal. However, in the lower production group initial daily production of cows assigned at random to receive extra-heat SBM was higher than that of cows fed control SBM (Figure 1); therefore, it was obvious that there was no response to extra-heat SBM. On the other hand, initial daily yield of cows fed both types of SBM averaged nearly the same amount in the high production

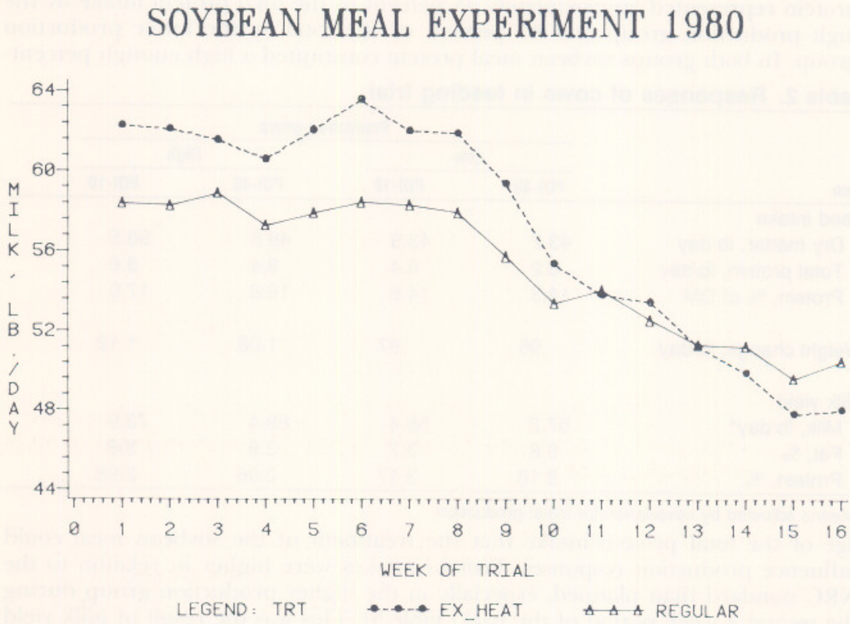

Figure 1. Milk yield of cows fed different types of soybean meal in low production group

group. There was a definite trend toward higher milk yield by cows fed extra-heat SBM than by the control cows in this production group (Figure 2). Comparative performance of one pair of cows in the group accounted for most of the inconsistency in response and, hence, lack of statistical significance of the difference between treatment groups. Milk composition was not affected by treatment (Table 2). Weight change was positive and similar for cows fed rations containing both types of soybean meal. The magnitude of the weight gains, i.e., approximately 1 lb/day over the 16-week trial, reflected adequate energy intake by cows in all groups.

In the bypass study, total nitrogen in digesta samples collected from the proximal duodenum was corrected for microbial nitrogen and non-ammonia nitrogen so that the portion of the protein in the total diet that bypassed degradation in the rumen was measured. Protein intake, expressed as a percentage of dry matter, and milk yield were similar for both treatments (Table 4).

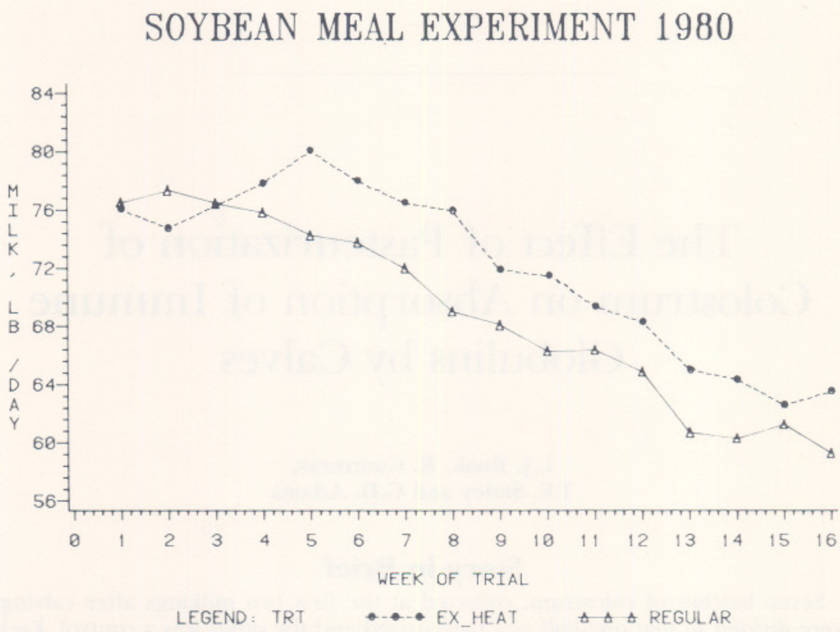

Figure 2. Milk yield of cows fed different types of soybean meal in high production group

Table 4. Effects of heating SBM on ruminal bypass of protein

	SBM treatment	
Item	PDI-40	PDI-10
Milk, lb/day	54.9	55.1
DM intake, lb/day	41.7	45.0
Total protein, lb/day	7.3	7.9
Protein, % of DM	17.5	17.6
% ruminal bypass of feed N	27.8	28.8

The protein from SBM in the rations comprised approximately 61 percent of total protein intake. The estimated percentage of ruminal bypass of feed protein was only slightly higher in cows fed extra-heat SBM compared to the control group (28.8 vs 27.8 percent). Therefore, based on these data and those in the feeding trial, it appeared that the extra-heat SBM (PDI-10) used in this trial was not heated extensively enough during processing to make it a high bypass feed protein source. Nevertheless, the values obtained on percentage of feed protein bypassing the rumen of cows consuming a 60 percent concentrate ration at the rate achieved in this trial are of interest. These data will be useful as reference points for future trials in which extent of degradation of different sources of feed protein will be estimated.

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The Effect of Pasteurization of Colostrum on Absorption of Immune Globulins by Calves

L.J. Bush, R. Contreras,
T.E. Staley and G.D. Adams

Story in Brief

Seven batches of colostrum, collected at the first two milkings after calving, were divided so that one-half was pasteurized and the other was a control. Each was fed to an equal number of newborn calves obtained before nursing their dams. Concentration of the IgG class of immune globulins, as measured by radial immunodiffusion, was higher at 12 hours in serum of calves fed pasteurized colostrum. IgG values at subsequent sampling periods were similar for both treatment groups as were concentrations of IgM at all sampling periods.

Introduction

The importance of the transfer of passive immunity against disease from a cow to her newborn calf by way of colostrum is well established. Moreover, this is especially important in large dairy operations where newborn calves are likely to be exposed to a wide range of disease organisms due to concentration of animals and repeated use of the same facilities for raising calves. In some instances calves left with their dams either consume an inadequate amount or no colostrum during the critical period soon after birth. To avoid this problem, a practice followed in some dairies is to feed colostrum to each newborn calf by nipple bottle or pail, or else administer it by drenching.

Regardless of the method by which calves are given colostrum soon after birth, there is concern about the effects of giving a calf colostrum that is heavily contaminated with bacteria due to udder infection in the cow. Although earlier work at this station (Corley et al., 1977) demonstrated that cells of infectious *Escherichia coli* were prevented from penetrating the intestinal barrier in the calf when introduced simultaneously with colostrum, the concern about feeding colostrum from infected cows continues to persist. One recommended method for handling the problem is to pasteurize colostrum prior to feeding it to calves. However, no information is available regarding the effects of this practice on the well-being of calves. The objective of this study was to evaluate the effects of pasteurizing colostrum on the absorption of immune globulins by newborn calves.

Materials and Methods

Seven batches of colostrum were collected from cows at the first two milkings postpartum. One-half of each batch was pasteurized by heating at 145° F for 30 minutes. Then, both the pasteurized and unpasteurized portions were packaged and frozen for storage. A sufficient amount of the appropriate type of colostrum was thawed and warmed for feeding to each calf as needed in the experiment.

Forty-eight calves were obtained immediately after birth, before nursing their dams. These were assigned at random to treatments within groups which were of a given breed and designated to receive a given batch of colostrum. One-half the calves within each group were fed pasteurized colostrum, whereas the other half received unpasteurized or control colostrum. The colostrum was fed at the rate of 10% of metabolic size per feeding generally within one hour after birth and 12 and 24 hours afterward.

Blood samples were obtained before the first feeding and at 12, 16, 20, 24, 28, 32 and 36 hours afterward. These were allowed to clot and then were centrifuged to separate the serum which was frozen until analysis for immune globulin concentration. The concentration of two classes of immunoglobulins, designated IgG and IgM, at each sampling period was determined by radial immunodiffusion.

Results and Discussion

The concentration of IgG in the blood serum of calves fed pasteurized colostrum was higher ($P<.005$) at 12 hours after first feeding than in calves fed control colostrum (Figure 1). Subsequently, the difference between groups was smaller and less consistent. Since the IgG class of immune globulins is the one occurring in greatest concentration in bovine serum, a higher concentration soon after first colostrum intake would have significance in terms of resistance of calves to infectious agents. A possible explanation for greater uptake of IgG in calves fed pasteurized colostrum than in control calves is that bacteria which might otherwise interfere with IgG uptake were destroyed. It has been demonstrated that bacteria penetrate the vacuolar tubules of the epithelial cells lining the intestine in much the same way as immune globulins (Staley et al., 1972). However, other work (James and Polan, 1978) has provided evidence that the presence of bacteria

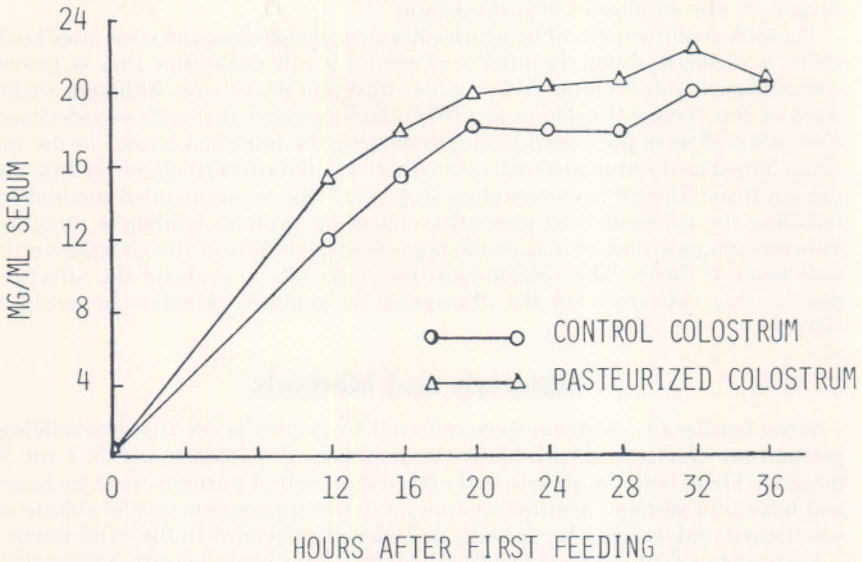

Figure 1. Concentration of IgG in blood serum of calves at different times after first feeding of colostrum

does not interfere with immune globulin absorption, unless exposure to bacteria occurs prior to colostrum consumption.

An alternative explanation for the higher concentration of IgG at 12 hours in serum of calves fed pasteurized colostrum is that the zones of antigen-antibody precipitate measured in the radial immunodiffusion test are not indicative of the actual quantity of intact IgG in the serum. If fragments of the IgG molecules resulting from breakdown of some of the IgG during pasteurization were precipitated, resulting values would tend to be high. Since it is important that a calf absorb sufficient intact immunoglobulins to afford some degree of resistance to infectious agents, the point as to whether the immune globulin concentrations measured in serum of calves fed pasteurized colostrum represent intact molecules capable of reacting with appropriate antigenetic agents, e.g., bacteria, needs to be resolved. Preliminary data from another experiment provide some evidence that antibody activity against specific antigens may be reduced in serum of calves fed pasteurized colostrum. Further work is planned to clarify this point.

Concentrations of IgM in the serum of calves were similar at each sampling period (Figure 2). Moreover, the highest average concentration of both IgM and IgG occurred at 32 hours after first feeding, indicating that closure of the intestinal epithelium to immune globulin transfer probably was between 24 and 32 hours. This demonstrates that intake of colostrum during the early life of a calf is important both from the standpoint of providing protection against infectious agents within the intestine and the attainment of satisfactory serum concentration of immune globulins.

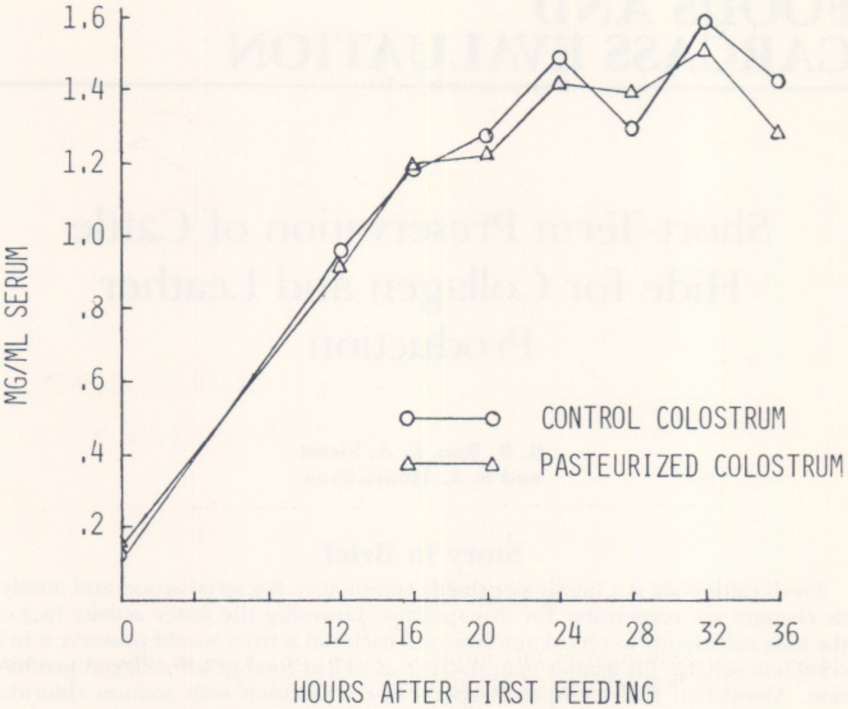

Figure 2. Concentration of IgM in blood serum of calves at different times after first feeding of colostrum

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FOODS AND CARCASS EVALUATION

Short-Term Preservation of Cattle Hide for Collagen and Leather Production

B. R. Rao, L. A. Sweet
and R. L. Henrickson

Story in Brief

Fresh cattle hide is a highly perishable commodity. Bacterial action and autolytic changes are responsible for this spoilage. Lowering the water activity (a_w) of the hide sufficiently to retard autolysis and bacterial activity would preserve it in a condition suitable for leather manufacture as well as food-grade collagen production. Absorption flakes (Super-Slurpers) in combination with sodium chloride, each 5 percent by weight of the hide, were found to lower the a_w enough to prevent mold growth and hair slippage (decomposition). Soda ash and anhydrous sodium carbonate in a 15 or 20 percent solution in water also seemed to prevent mold growth and hair slippage for 9 days storage after being immersed for 24 hours.

Introduction

Raw cattle hide is a highly perishable product due to autolysis and bacterial action immediately after its removal from the carcass. This perishability reduces the value of the hide for leather manufacturing. Development of collagen, a fibrous component of hide, as a possible protein extender or for other food uses has set new limits and demands on potential preservation methods for cattle hide. Several methods have been proposed for short-term preservation of hide; only a few of the methods have been found to be satisfactory for leather production. However, most have been developed without food quality considerations.

Water is essential for the growth of microorganisms, germination of bacterial spores and enzyme activity. If the water activity (a_w) of hide is controlled or brought to a level where microorganisms fail to grow and the enzymes are inactivated, the hide can be preserved for the production of leather as well as food-grade collagen.

The purpose of this research was to develop a short-term (up to 7 days) method of preserving cattle hide suitable for leather production and the manufacture of food-grade collagen at a reasonable cost, keeping in mind the current industrial procedures and pollution control guidelines.

Materials and Methods

Experiment 1

Various combinations of Super-Slurper (hydrolyzed starch-polyacrylonitrile graft co-polymers) and sodium chloride were used to adjust the a_w of raw cattle hide to a microbiostatic state. Immediately following flaying, the hide was washed thoroughly by spraying cold water to remove blood, dirt and manure and to cool the hide. Samples of hide (20 cm × 25 cm) were placed over saw horses flesh side down and allowed to drain for 45 minutes. After draining, the samples were weighed and each sample rubbed, on the flesh side, with a dry mixture containing Super-Slurper and granulated sodium chloride (each 5 or 2.5 percent of hide weight). The samples were stacked on racks. Completed packs were covered with butcher paper to control evaporation and air-borne mold contamination and stored at room temperature (25 to 28°C). Each pack contained five hide samples. The top, bottom and middle sample served as controls while the remaining two samples were used to test for moisture, residual salt and total plate counts.

Moisture was determined using the microwave oven drying method developed by Kellenberger and Loller (1979). Drying cycles were extended to 30, 45, and 60-second intervals, separated by a 2-minute moisture evaporation period for each of the four cycles. The carousel feature in the oven alleviated the problem of sample location. Microwave dried samples were placed in a 105°C forced air drying oven for 1 hour and then allowed to cool for 1 hour in a desiccating cabinet before weighing.

Residual salt content was determined using AOAC (1980) and a Dicromat 1-20 Salt Analyzer (Diamond Crystal Salt Co., St. Clair, Minnesota). Standard plate counts were done in duplicate every 4 days using the FDA-AOAC Aerobic Plate Count Method (AOAC, 1975).

Experiment 2

Granular soda ash (100 percent pure, 58 percent Na_2O minimum) and anhydrous sodium carbonate were dissolved separately in water to make a concentration of 10, 15 and 20 percent (w/v) each. Raw hide samples about 10 cm × 15 cm were washed thoroughly in water to remove blood, dirt and manure and drained for about 30 minutes. Four samples of hide were placed in each of the above solutions taking care that the hides were completely immersed and that there was at least 2.5 cm high excess fluid over the samples. The solutions and the samples were occasionally agitated to ensure thorough distribution. Samples were tested over a 7-day period. After each day's treatment one hide sample from each of the solutions was removed, drained and allowed to dry at room temperature (25 to 28°C). Each sample was packaged in a PVC bag and left at room temperature without sealing the bag. The samples were examined visually for hair slippage and mold growth.

Results and Discussion

Experiment 1

"Super-Slurpers" are water jelling absorbents made by chemically grafting man-made acrylic compounds to cereal grain starch and hydrolyzing the combinations. These co-polymers were introduced in various forms between 1973 and 1977 by the USDA Northern Regional Research Center, Peoria, Illinois. None of the Super-Slurpers tested alone or in various combinations with sodium chloride were effective in preventing hair slippage and/or mold growth except Absorption

Flakes (Table 1). Yellow Absorption Flakes in combination with sodium lactate and sodium chloride were tested over a 5-day period (Table 2). Sodium chloride 5 or 7 percent combination with the Super-Slurper was found to be more effective in preventing hair slippage and mold growth.

Hydrophillic colloids have a higher affinity for the unbound water than does the hide; as a result, the colloid draws water away from both the hide and bacteria causing osmotic stress and an uninhabitable environment for the microbes. Microbial growth within the colloid itself is hindered by lack of nutrients. The resulting low water in the hide also retards enzyme activity, thus preventing autolytic changes. A combination of sodium chloride and Super-Slurper resulted in a a_w which prevented the spoilage of hide even after 5 days. However, an excess of colloid may remove too much moisture from the hide making it unsuitable for leather production. Lower concentration of colloid can be incorporated by addition of sodium chloride.

Experiment 2

This experiment is in progress. The effect on hair slippage and mold growth only were examined with the following results.

Samples treated with 10 percent soda ash solution for 24 hours showed slight mold growth but no hair slippage after 9 days storage. No mold or hair slippage was noticed for any of the other treatments. Samples which received a treatment with 10 and 15 percent solution of anhydrous sodium carbonate for 1 and 2 days

Table 1. Effect of Super-Slurpers on hair slippage and mold growth

Super-Slurper Combinations	Hair slippage	Mold growth
Stasorb 372 (A.E. Staley Co., Decatur, IL)		
5% Stasorb	Extensive - 6 days	Extensive - 6 days
2.5% NaCl + 2.5% Stasorb	Extensive - 6 days	Extensive - 6 days
2.5% NaCl + 5% Stasorb	Extensive - 6 days	Extensive - 6 days
5% NaCl + 2.5% Stasorb	—	Extensive - 2 weeks
Waterlock (Grain Processing Co., Muscatine, IA)		
5% Waterlock	Extensive - 6 days	Extensive - 6 days
2.5% NaCl + 2.5% Waterlock	Extensive - 6 days	Extensive - 6 days
5% NaCl + 2.5% Waterlock	—	Extensive - 2 weeks
SGP Absorbent Polymer 502 S (Henkel Corp., Minneapolis, MN)		
5% SGP	Extensive - 6 days	—
2.5% NaCl + 2.5% SGP	—	Extensive - 2 weeks
5% NaCl + 2.5% SGP	—	Extensive - 2 weeks
2.5% NaCl + 5% SGP	—	Moderate - 6 days
2.5% NaCl + 5% SGP + 0.1% Pot Sorbate	—	Scattered
2.5% NaCl + 7.5% SGP + 0.25% Pot Sorbate	—	Scattered around edges
Absorption Flakes (Spenco Medical Corp., Waco, TX)		
5% Yellow Absorption flakes (YAF)	—	Minute amount
2.5% NaCl + 2.5% YAF	—	Minute amount
5% NaCl + 2.5% YAF	—	No mold growth
5% NaCl + 2.5% YAF + 2.5% White AF	—	No mold growth

Table 2. Effect of Absorption Flakes on hair slippage and mold growth

5% Yellow Absorption Flakes, 1% sodium lactate, 0% sodium chloride
Average Moisture Content = 52.18% Residual Salt Content = 9.50% (hide only)
Day 2 — developed filamentous white growth
Day 3 — developed black and green colonial growth
Day 4 — developed moderate hair slip
Day 5 — extreme hair slippage and mold growth evident

5% Yellow Absorption Flakes, 1% sodium lactate, 2.5% sodium chloride
Average Moisture Content = 51.00% Residual Salt Content = 2.00%
Day 2 — developed minute hair slip
Day 3 — developed green and white colonies and moderate hair slip
Day 4 — developed extensive hair slip
Day 5 — extreme hair slippage and mold growth evident

5% Yellow Absorption Flakes, 1% sodium lactate, 5% chloride
Average Moisture Content = 46.83% Residual Salt Content = 3.65%
Day 5 — developed minute green and white scattered colonies, but no hair slip was apparent

5% Yellow Absorption Flakes, 1% sodium lactate, 7.5% sodium chloride
Average Moisture Content = 45.63% Residual Salt Content = 4.04%
Day 5 — developed scattered minute green and white colonies, but no hair slip was apparent

5% Yellow Absorption Flakes, 0% sodium lactate, 5% sodium chloride
Average Moisture Content = 47.63% Residual Salt Content = 3.53%
Day 5 — no signs of decay (no mold growth or hair slippage)

5% Yellow Absorption Flakes, 0% sodium lactate, 7.5% sodium chloride
Average Moisture Content = 44.07% Residual Salt Content = 3.77%
Day 5 — no signs of decay (no mold growth or hair slippage)

developed mold growth after 9-day storage but no hair slippage while none of the other treatments showed evidence of spoilage (hair slippage, mold growth).

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Bovine Hide Collagen as a Protein Extender in Bologna

**B. R. Rao, D. Schalk,
R. Gielissen and R. L. Henrickson**

Story in Brief

Slaughter of beef animals in the U.S. yields approximately 1.5 million tons of hide each year. The price paid for the "flesh" splits varies considerably; periods of low demand result in underutilization. Periods of low price have encouraged investigations into alternate uses for these splits. The USDA Eastern Regional Research Center has developed a process to manufacture foodgrade collagen from the "flesh" splits. This research reports the use of food-grade collagen to replace a part of lean meat in bologna formulations.

Coarse bologna was made with 0, 10, 20 and 30 percent replacement of lean meat with fibrous collagen. In the fine emulsion bologna, lean meat was replaced with fibrous collagen at 0, 4.7, 8.9 and 12.8 percent levels. Crude protein, lipid, moisture, pressed fluid, cooking loss, emulsion stability, pH, color and shear studies were conducted.

No adverse effects of added collagen were found on shrinkage, volume change, emulsion stability, free and total water or fat and protein content of coarse bologna as compared to that of control. Significant objective color and textural changes were noticed in the product with higher levels of collagen. However, such changes were not apparent upon visual inspection.

Replacement of lean meat with hide collagen in the fine emulsion bologna did not significantly affect the lipid, moisture, or crude protein in the raw or cooked emulsion. The pH, pressed fluid, cooking loss and color differences due to collagen replacement were also not significant. However, the peak force required to shear the bologna slices increased significantly but no visible textural changes were evident. Collagen also significantly decreased emulsion stability but not below acceptable levels.

Based on these results it was concluded that the use of bovine hide collagen in coarse bologna and fine emulsion bologna is feasible.

Introduction

Sausage products such as weiners and bologna are frequently made with less tender cuts (more collagen). Partially defatted tissue high in collagen is a common ingredient in such products. Sausage manufacturers use meat with high collagen content to reduce processing costs. However, the collagen content is often limited to 12 to 15 percent of the total meat ingredients to avoid major defects in the final product such as gel-pockets, gel-caps and poor peelability. Satterlee et al. (1973) reported the use of limed bovine flesh splits in sausage as a binder-extender. They found that hydrolyzed collagen preparations could be used to replace nonfat dried milk in meat emulsion. Whitmore et al. (1970) suggested that the binding and texturizing properties of fibrous collagen may have other functions in food. Elias et al. (1970) pointed out some possible use of collagen in fiber or granular form in meat products.

A process has been developed for the production of fibrous collagen from bovine hide for food uses (Komanowsky et al., 1974) which ensures its availability on a commercial scale. The use of this food-grade collagen as a protein extender offers great potential for the meat industry in the area of processed meats. The utilization of collagen in sausage would be advantageous from a labeling point of view since it could be listed under beef. This research reports the effects of food-grade fibrous collagen when used as a protein extender in coarse bologna and in a fine emulsion bologna.

Materials and Methods

Coarse bologna

Ground beef from a canner grade cow carcass and food-grade bovine hide collagen (USDA Eastern Regional Research Center, Philadelphia, Pennsylvania) having an average moisture content of 78.2 percent and an average solids content of 21.8 percent were the raw materials used. The chilled boned meat (48 hr postmortem) was ground (.54 cm plate) and blended in a paddle type mixer, frozen and stored at −20°C until use. The frozen ground beef and collagen were thawed overnight at 3.3°C. Food-grade collagen was added to the ground beef at levels of 0, 10, 20 and 30 percent (Table 1). The meat and collagen were mixed and ground twice (.32 cm plate), spices and water were added and the product was mixed for 5 minutes in a paddle type mixer. The seasoned batter was held in a cooler at 3.3°C for 22 hours and then stuffed into #2.5 Union Carbide fibrous casings using a Vogt hand stuffer, making approximately 1000 g sticks of bologna.

Table 1. Formulation of coarse bologna sausage, containing different levels of food-grade fibrous bovine hide collagen

Collagen %	Collagen added g	Ground beef g	Fat added g
0	0	4471.90	68.10
10	340.50	4063.30	136.20
20	681.00	3586.60	272.40
30	1021.50	3132.60	385.90

Each of the four batches was added with the following spices and additives: salt 136.0 g; white pepper 16.8 g; coriander 5.6 g; allspice 2.8 g; sage 2.8 g; garlic powder 0.7 g; onion powder 1.4 g; sodium nitrite 0.45 g; erythorbate 2.5 g; water (5 C) 1026 g. Lean: fat ratio was kept constant at 75:25.

Just before stuffing, samples were taken for emulsion stability of the batter. Each bologna stick was marked to keep the identity of front and back end to ensure that all the bologna sticks were placed in the oven for cooking in the same manner, and to ensure that slices were cut from identical locations for color and texture studies. The bologna was cooked in a Blodget convection air oven by following a heating schedule of 54.4°C for the first 90 minutes, 65.5°C for the next 60 minutes, 71.1°C for the next 60 minutes and 76.6°C for about 30 minutes until an internal temperature of 68°C was reached. The internal temperature was recorded by inserting thermocouples to the geometrical center of the product.

Table 2. **Functional and chemical characteristics of cooked, coarse bologna containing different levels of food-grade bovine hide collagen**

Characteristics	Food-grade hide collagen			
	0%	10%	20%	30%
Percent shrinkage[a]	7.19 ± 0.07	7.58 ± 0.13	7.51 ± 0.47	7.47 ± 0.38
Volume change[b] cc	9.37 ± 1.76	10.84 ± 2.54	9.07 ± 3.50	9.50 ± 1.84
Emulsion stability of raw[c]	5.63 ± 1.22	6.63 ± 0.52	6.75 ± 0.51	7.15 ± 2.63
Expressible juice[b]	54.60 ± 30.40	54.80 ± 20.60	54.60 ± 28.20	56.26 ± 37.20
Percent moisture[b]	62.23 ± 0.38	62.05 ± 0.31	62.36 ± 0.45	63.22 ± 0.84
Percent protein[b]	13.92 ± 0.09	13.67 ± 0.05	13.84 ± 0.12	14.04 ± 0.05
Percent fat[b]	20.24 ± 0.59	20.81 ± 3.18	19.81 ± 4.94	19.21 ± 1.28
Color value				
L value[b]	41.34 ± 0.64	41.98 ± 0.65	42.66 ± 0.99	42.52 ± 0.68
a value[b]	10.67 ± 0.28	10.52 ± 0.35	9.86 ± 0.64	9.43 ± 0.22
b value[b]	7.65 ± 0.22	7.67 ± 0.19	7.50 ± 0.19	7.43 ± 0.14
Texture				
Peak force[b] kg-f	22.69 ± 2.82	19.38 ± 2.94	21.40 ± 2.59	20.19 ± 2.54
Peak area[b] cm^2	2.30 ± 0.31	2.11 ± 0.29	2.26 ± 0.21	2.11 ± 0.32

[a]Number of observations = 48.
[b]Number of observations = 64.
[c]Number of observations = 16.

Table 3. Mean values of chemical composition of collagen #1

Collagen batch	Fat (%)	Moisture (%)	Ash (%)	Crude protein (%)	Soluble collagen (mg/g)	Insoluble collagen (mg/g)	Total collagen (mg/g)
1	0.23	74.01	0.17	21.98	22.51	161.08	184.09
2	0.28	78.81	0.16	20.41	23.18	157.10	184.77
3	0.26	75.48	0.18	19.89	21.10	159.14	182.75
4	0.25	78.97	0.19	22.07	22.14	158.91	184.00
5	0.27	74.50	0.15	21.08	23.01	159.61	182.31

Fine emulsion bologna

The source of raw meat was the lean and fatty tissue from an electrically stimulated bullock carcass. The lean and fat trim was ground (1.27cm plate) separately. The lean was throughly mixed in a paddle type mixer. The ground lean and fat trim was frozen separately and stored at −20°C until used. Bovine hide collagen #1 as described by Turkot et al. (1978) was used to replace lean in the sausage formula. This product was selected because its composition most closely resembled the lean meat to be replaced. Samples of lean, fat trim and collagen were analyzed for proximate composition. Based on this analysis, four different 9.08 kg sausage recipes were formulated using hide collagen to replace fractions of the non-lipid constituents. The lipid to non-lipid ratio was held at 25:75, making the non-lipid collagen levels 0, 4.7, 8.9 and 12.8 percent prior to the addition of water. Water was added to bring the moisture up to a level of 4 times the percent protein plus 10 percent (Table 4). Ground lean, fat trim and collagen were thawed at 1°C for 24 hours. The lean was chopped first in a cold silent cutter, then water in the form of ice and the seasonings (Table 5) were added, and the chopping was continued until the mixture reached 8°C. Then fat trim was added and chopping continued at high speed until the emulsion temperature reached 13°C. The emulsion was stuffed into 2.5 x 16 inch Union Carbide clear fibrous casings using a Vogt hand stuffer. Before the emulsion was stuffed, samples were taken for analysis. The sausage was cooked in a preheated (54°C)

Table 4. Bologna formulations (fine emulsion)

Nonlipid replacement level (percent)	Lean tissue (kg)	Fatty tissue (kg)	Collagen (kg)	Water (kg)
0.0	6.760	2.320	0.000	1.094
4.7	6.397	2.361	0.318	1.085
8.9	6.084	2.388	0.608	1.080
12.8	5.766	2.447	0.867	1.067

Table 5. Bologna ingredients* (fine emulsion)

Item	Grams
Sodium chloride	272.0
White pepper	33.6
Coriander	11.2
Allspice	5.6
Sage	5.6
Garlic powder	1.4
Onion powder	2.8
Sodium nitrite	0.9
Sodium erythorbate	5.9

*Added to each 9.08 kilogram formulation.

Blodgett model convection oven. The cooking schedule was 54°C for 1 hour 20 minutes, 66°C for the next 1 hour and 77°C until an internal temperature of 67°C was reached. The internal temperature in the sausage was monitored by inserting thermocouples to the geometrical center. After cooking, the sausage was cooled by immersion in ice water for 10 minutes, removed, dried with paper towels, wrapped in freezer paper and stored at 1°C for 48 hours.

Raw emulsion stability was tested by the method of Saffle et al. (1964), and pH was determined by the method of Sebranek (1978). Volume change was measured by Archimedes' principle of water displacement. Extractable lipid, crude protein, moisture and ash were determined following the AOAC methods (1970). Cooking loss was calculated by weighing the sausage before and after cooking and chilling. Color of the sausage was evaluated with a Hunter Lab Colorimeter as described by Hunter (1976). Results were recorded as L, a, b values. Textural changes were estimated using an Instron Universal Testing Instrument Model 1122 with a LEE Kramer Shear Cell. The resistance force experienced by the cell was expressed as kilograms of peak and area force. The water holding capacity was measured by the filter paper moisture absorption technique of Grau and Hamm (1953), modified by Urbin et al. (1962). The soluble and insoluble fractions of food-grade bovine hide collagen were determined as described by Wiley et al. (1979). The results were statistically analyzed by one-way analysis of variance (Steel and Torrie, 1960) and calculations made by the computer program of Barr et al. (1976).

Results and Discussion

Coarse bologna

The mean values for shrinkage (cooking loss), volume change, moisture percentage, expressible juice, fat and protein content of coarse bologna with 10, 20 and 30 percent hide collagen were not statistically different (Table 2) from the control (0 percent collagen). Color of the bologna showed a significant difference ($P<.05$) in the L value (lightness, darkness), a value (redness, greenness) and b value (yellowness, blueness) among the treatments. The lightness tended to increase whereas redness and yellowness tended to decrease with increase in collagen levels. This tendency may be due to the whitish color of the collagen.

The texture of cooked bologna was determined as a shear value obtained from the resultant force/distant curve (Figure 1). The force measured at the yield point A indicated firmness whereas the area under the shear curve indicated the total work performed by the Kramer cell to shear the bologna sample. The results on textural study (Table 2) indicated that firmness of bologna decreased at the 10 percent level, increased at the 20 percent level and decreased again at the 30 percent level of added collagen. The total area under the curve showed a similar trend. The changes in texture may be associated with the chemical changes in the collagen although relatively more gelatinization of collagen would be expected in cooked bologna containing higher levels of added collagen and, hence, a decrease in firmness. Although the data on emulsion stability did not reveal any significant differences (Table 2) between treatments, the emulsion stability values were generally higher than the acceptable levels for a true emulsion. According to Saffle et al. (1967) emulsion stability values up to 4 are within an acceptable range; beyond that a weak emulsion results. Even though coarse bologna is not an emulsion type sausage, the emulsion stability test was done to compare the effects of added collagen at different levels. The mean values for protein, fat, ash, soluble collagen, insoluble collagen and total collagen (Table 3) did not vary

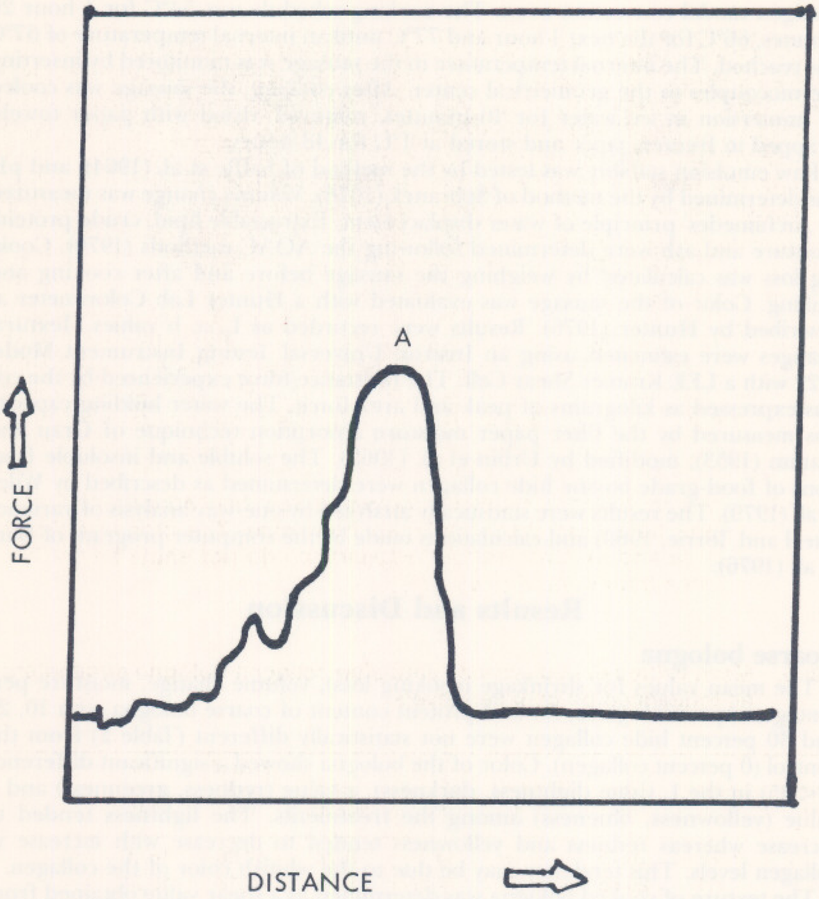

Figure 1. Typical force/distance curve for shear of bologna sausage (casing and about 10 mm peripheral portion was reamed before shear). A = yield point indicative of firmness.

significantly between cans of collagen used in this study. Figure 2 shows no deformations in the appearance of external surface of bologna. The physical texture and shape of the cross sectional area of the bologna did not show any gel-pockets due to added collagen. This supports the findings of Wiley et al. (1979) that only the soluble fraction of collagen is responsible for gel-pocket formation in the sausages.

Fine emulsion bologna

Replacing lean with hide collagen did not significantly (P>.05) affect the lipid, moisture or crude protein in the raw or cooked emulsion (Table 6). The press fluid, cooking loss and color differences in the cooked sausage were also deemed non-significant (P>.05). Collagen was also found to have no effect on the pH of

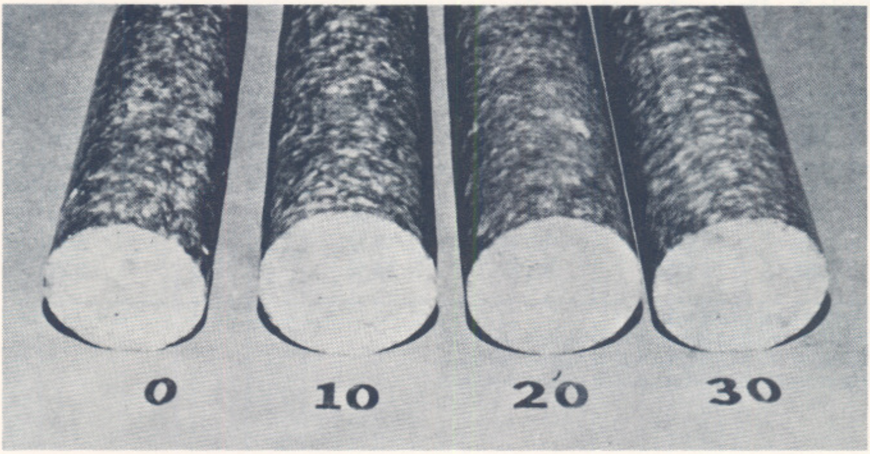

Figure 2. **Coarse bologna sausages, prepared from beef added with 10, 20 and 30% food-grade collagen from hide. The cross-sectional area and external surface appearance do not show any difference from control (0%).**

Table 6. Mean values of cooked, fine emulsion collagen-bologna parameters as influenced by collagen levels

Collagen level	Cookloss[3] (%)	Lipid[4] (%)	Moisture[4] (%)	Crude protein[5] (%)	pH[2,6] (cooked)	Pressed fluid[4] (%)	Peak shear[4] (kg)
0	5.78	20.75	60.18	14.77	6.07	47.68	16.16
4.7	6.04	20.65	60.28	14.96	6.09	46.18	16.91
8.9	6.12	20.59	60.12	14.76	6.04	43.03	20.93
12.8	6.00	20.66	60.21	14.71	6.06	44.40	22.30

[1]Nonlipid replacement level.
[2]Based on the mean hydrogen ion concentration.
[3]Based on 24 observations at each replacement level.
[4]Based on 96 observations at each replacement level.
[5]Based on 48 observations at each replacement level.
[6]Based on 12 observations at each replacement level.

raw or cooked emulsion. Emulsion stability testing revealed significant ($P<.05$) differences between the treatments; the control group was more stable while no difference was found between 8.9 and 12.8 replacements (Table 7). However, according to Saffle et al. (1964), emulsion stability values below 4 are acceptable. Collagen replacement significantly ($P<.05$) increased the peak force required to shear bologna slices (Table 6). The collagen added to the sausage formula in this study was of a fibrous nature with a low soluble fraction and may therefore have resulted in an increase in the force required to shear the slices. Again, the collagen which was incorporated into the aqueous phase of the emulsion might have been enmeshed in the web of myofibrillar proteins. Cooking would have

Table 7. Mean values of raw, fine emulsion collagen-bologna parameters as influenced by collagen levels

Collagen level	Lipid[2] (%)	Moisture[2] (%)	Protein[3] (%)	Emulsion stability[4]	pH[3] (raw)
0.0	20.14	62.17	14.07	0.77	5.78
4.7	19.73	62.29	14.26	1.84	5.79
8.9	19.87	62.30	14.18	1.57	5.78
12.8	19.60	62.30	14.16	2.86	5.79

[1]Nonlipid replacement level.
[2]Based on 90 observations at each replacement level.
[3]Based on 12 observations at each replacement level.
[4]Based on 72 observations at each replacement level.

fixed the insoluble collagen in the three dimensional overlap of myosin molecules, resulting in a higher tensile strength. However, it may be noted that the textural changes as well as the changes noticed in emulsion stability were not obvious upon casual inspection of the product but could only be detected objectively.

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Influence of *Lactobacillus acidophilus* Added to Milk on Lactose Malabsorption in Humans

S. E. Gilliland and H. S. Kim

Story in Brief

Consumption by lactose malabsorbers of milk containing viable cells of *Lactobacillus acidophilus* from a frozen concentrated culture significantly reduced lactose malabsorption. The degree of lactose malabsorption was measured using a breath hydrogen test (BHT). The effect of *L. acidophilus* on lactose malabsorption was determined by comparing the amount of hydrogen excreted in the breath of six human test subjects in each experimental group at the start of the trial and after consuming milk containing either 0, 2.5×10^6, 2.5×10^7, or 2.5×10^8 *L. acidophilus* per ml daily for 6 days. Consumption of milk without cells of *L. acidophilus* did not affect lactose malabsorption, but consumption of milk containing 2.5×10^6 or 2.5×10^8 *L. acidophilus* per ml significantly reduced malabsorption. However, milk containing an intermediate level (2.5×10^7/ml) did not influence malabsorption. The lack of a significant effect in the latter group of test subjects was probably due to large increases in excreted hydrogen on day 7 as compared to day 0 by two of the six test subjects. An additional trial showed that the beneficial effect of *L. acidophilus* on lactose malabsorption did not require that the milk be consumed daily. The reduced malabsorption was not due to hydrolysis of the lactose prior to consumption, which indicated that the beneficial effect must have occurred in the digestive tract after consuming milk containing *L. acidophilus*.

Introduction

The inability to absorb lactose, which is one of the several causes for milk intolerance in humans, has been associated with deficiency of lactase in the intestines. In lactase-deficient individuals the ingestion of one or two glasses of milk often leads to a gastrointestinal disorder which is called lactose intolerance and includes such symptoms as cramps, flatulence, and diarrhea. These symptoms discourage lactose malabsorbers from consuming milk.

The objectives of this study were to determine if the addition of cells of *L. acidophilus* to milk can prevent or reduce lactose malabsorption in humans and, if so, to determine whether or not the effect is dependent on consuming the milk over a period of time.

Materials and Methods

Frozen concentrated cultures of *L. acidophilus* NCFM (of human origin) were obtained from Marschall Products, Miles Laboratories, Inc. (Madison, WI) and stored at -196 C in liquid nitrogen. The milk containing the desired numbers of *L. acidophilus* was prepared by adding the needed amount of thawed concentrated culture to pasteurized whole milk obtained from the Dairy Processing Plant in the Animal Science Department of Oklahoma State University. The frozen concentrated culture was thawed by submerging the container (5 g cryogenic vial) in one liter of tap water at 30-35 C until thawing was complete. Total populations of *L. acidophilus* in milk were confirmed by plate counts using lactobacilli MRS agar (Speck, 1976). The milk was stored in a refrigerator until used (not more than 3 days).

The breath hydrogen test (BHT) used to measure lactose malabsorption in human test subjects was a slight modification of that reported by Levitt and Donaldson (1970). Breath hydrogen was quantitated using a Varian Model 920 Gas Chromatograph equipped with a thermal conductivity detector, a 1 ml sample loop, and a six port gas sampling valve. Separation of hydrogen from other gaseous components of the breath was obtained using a column (12 ft long, 1/16 in. inside diameter) packed with 60-80 mesh 5A molecular sieve (Supeloco, Inc., Bellofonte, PA). Separation was achieved at a column temperature of 53 C with argon as the carrier gas at a flow rate of 18 cc/min. The detector temperature was 107 C. When a breath sample was to be analyzed, a 1-ml sample from the sample bag was transferred into a sample loop via the gas sampling valve by vacuum created with a 25-ml gastight syringe. Concentrations of hydrogen (ppm) were determined by comparing the area of the hydrogen peak obtained from each sample with a standard curve prepared using mixtures of hydrogen (99.998 percent purity) and nitrogen.

The breath hydrogen test was conducted in the morning following a 12-hr fasting period. The sample bags were flushed with nitrogen and evacuated by vacuum prior to each use. While standing, the subject inhaled deeply, retained his breath for 10 sec, then exhaled into the sample bag. Following the initial breath sample the test subjects consumed the indicated milk product (5 ml/kg body wt) as the lactose dose. Additional breath samples were collected by the same procedure 60 min after consuming the test dose and thereafter at 30-min intervals for 2 to 3 hr. The collected samples were analyzed immediately for hydrogen content by gas chromatography, and the average hydrogen content (ppm) of the three consecutive samples exhibiting the greatest levels of hydrogen was used as the hydrogen concentration in the breath of each subject.

Test subjects determined to be lactose malabsorbers were selected from international students (20 to 31 yr of age) at Oklahoma State University. Only those lactose malabsorbers excreting at least 30 ppm hydrogen were accepted as test subjects. All were apparently healthy with no recent history of gastrointestinal disturbance and were not currently using oral antibiotics. None of the subjects had consumed commercially available acidophilus milk. All subjects gave consent for participating in the study after being informed of the nature and the purpose of the study. The individuals were not told whether or not the milk they were to consume contained cells of *L. acidophilus*.

Twelve test subjects who were determined to be lactose malabsorbers were randomly assigned to one of two groups. One group was assigned milk containing 2.5×10^8 cells of *L. acidophilus* per ml (acidophilus group) and the other was assigned milk without the cells of *L. acidophilus* (control group). Using the assigned milk, subjects consumed 0.8 oz (5 g) per 2.2 lb (1 kg) body wt twice daily for 6 days. The milk was delivered to the subjects with instructions to keep it refrigerated until consumed. Sufficient milk for

3 days was delivered each time; thus, none of the milk was used beyond 3 days after preparation.

The intensities of lactose malabsorption for each subject in both groups were determined on day 0 using the BHT in which pasteurized whole milk was used as the test dose. On day 7, the BHT was repeated. The lactose test dose for the subjects in the control group was again pasteurized whole milk. The test dose for the subjects in the acidophilus group was pasteurized whole milk containing 2.5×10^8 *L. acidophilus* per ml. Neither the test subjects nor the analyst knew which subjects received control milk or milk containing lactobacilli until the trial was completed. Comparison of breath hydrogen content of test subjects on day 0 and day 7 for each group was made by treating the data as a paired experiment for statistical analysis.

Additional trials were conducted to determine if the number of cells of *L. acidophilus* in the milk was critical. Milk containing different populations of *L. acidophilus* cells was evaluated in a manner similar to that in the first trial. Twelve test subjects (not used in the previous trial) who were determined to be lactose malabsorbers were randomly assigned to one of two groups and drank the assigned milk for 6 days. One group was assigned milk containing 2.5×10^7 cells of *L. acidophilus* per ml, and the other received milk containing 2.5×10^6 cells of *L. acidophilus* per ml. Control milk was used as the test dose for the BHT on day 0, and the milk containing lactobacilli as assigned was used as the test dose on day 7. Neither the test subjects nor the analyst knew which subjects received milk containing 2.5×10^7 cells or 2.5×10^6 cells of *L. acidophilus* per ml. The data was treated for statistical evaluation as in the first trial.

To determine if consumption of milk containing cells of *L. acidophilus* had an immediate effect on lactose malabsorption, milk containing 2.5×10^6 cells of *L. acidophilus* per ml was evaluated using a randomized complete block design. A BHT was done on five new subjects twice (day 0 and day 7) using pasteurized whole milk as the lactose test dose. The BHT was repeated on days 14 and 21 using milk containing 2.5×10^6 *L. acidophilus* per ml as the test dose. No milk was consumed by any of the subjects during the periods between the breath hydrogen tests.

To determine if lactose in refrigerated milk containing cells of *L. acidophilus* was hydrolyzed prior to consumption, the amounts of lactose were quantitated periodically during refrigerated storage of the milk using an enzymatic method (Taylor, 1970)

Results

Concentrations (ppm) of breath hydrogen before (day 0) and after (day 7) from each of six subjects consuming pasteurized whole milk (control) twice daily for 6 days are shown in Table 1. While there was some individual variation, the average values for day 0 and day 7 were essentially the same. Statistical analysis of the data revealed no significant difference ($P>0.50$) between day 0 and day 7. For the group that consumed milk containing 2.5×10^8 *L. acidophilus* per ml, the breath hydrogen was significantly ($P<0.01$) lower on day 7 than on day 0 (Table 2). All subjects, except for the second one, exhibited much lower levels of hydrogen on day 7 than on day 0. Thus, daily consumption of pasteurized whole milk containing 2.5×10^8 cells of *L. acidophilus* per ml reduced lactose malabsorption in humans.

Table 1. Effect of daily consumption of pasteurized whole milk on lactose malabsorption in humans

Subject	PPM H_2 in Breath Day 0	PPM H_2 in Breath Day 7
1	70.6	60.1
2	34.5	29.3
3	59.1	74.4
4	38.0	39.4
5	30.1	28.1
6	35.5	34.4
Average	44.6[a]	44.3[a]

[a]Not significantly different ($P>0.50$).

In the second trial the effect of daily consumption of pasteurized whole milk containing 2.5×10^6 cells of *L. acidophilus* per ml on lactose malabsorption also was significant ($P<0.025$) (Table 3). Each test subject included in this group excreted less hydrogen on day 7 than on day 0.

The group of six test subjects that daily consumed pasteurized whole milk containing 2.5×10^7 *L. acidophilus* per ml for 6 days did not reveal a significant ($P>0.35$) reduction in breath hydrogen (Table 4). Three of the six subjects (2, 3 and 4) excreted more hydrogen on day 7 than on day 0. The remaining subjects exhibited lower levels of breath hydrogen on day 7 than on day 0.

Table 2. Effect of daily consumption of pasteurized whole milk containing 2.5×10^8 cells of *L. acidophilus* per ml on lactose malabsorption in humans

Subject	PPM H_2 in Breath Day 0	PPM H_2 in Breath Day 7
1	47.0	12.1
2	56.0	53.0
3	33.8	13.9
4	45.9	19.4
5	49.1	33.9
6	53.5	38.0
Average	47.6[a]	28.4[a]

[a]Significantly lower on day 7 ($P<0.01$).

Table 3. Effect of daily consumption of pasteurized whole milk containing 2.5×10^6 cells of *L. acidophilus* per ml on lactose malabsorption in humans

Subject	PPM H_2 in Breath	
	Day 0	Day 7
1	49.0	43.3
2	58.5	23.0
3	72.8	44.8
4	37.7	23.8
5	72.7	69.7
6	43.9	38.8
Average	58.8[a]	40.6[a]

[a]Significantly lower on day 7 ($P<0.025$).

Table 4. Effect of daily consumption of pasteurized whole milk containing 2.5×10^7 cells of *L. acidophilus* per ml on lactose malabsorption in humans

Subject	PPM H_2 in Breath	
	Day 0	Day 7
1	34.6	22.7
2	31.5	50.0
3	34.5	51.6
4	41.1	46.1
5	38.3	33.9
6	40.1	9.5
Average	36.7[a]	35.6[a]

[a]No significant difference ($P>0.35$).

To determine if daily consumption of milk containing *L. acidophilus* was necessary to reduce lactose malabsorption, an additional trial was conducted (Table 5). In this trial the subjects did not consume milk with or without lactobacilli during the periods between breath hydrogen tests. Concentrations of breath hydrogen for the test subjects were determined on days 0 and 7 (control milk as test dose) and on days 14 and 21 (milk containing 2.5×10^6 *L. acidophilus* per ml as test dose). For the 2 days (0 and 7) on which control milk was used as the test dose, there was not a significant difference in BHT results ($P>0.70$). There also was not a significant difference ($P>0.95$) between the concentrations of hydrogen in the breath of the subjects for the days (14 and 21) on which milk containing *L. acidophilus* was used as the test dose. However, the overall average of breath hydrogen concentrations on days 14 and 21 was significantly lower than that for days 0 and 7 ($P<0.01$). Thus, the presence of *L. acidophilus* (2.5×10^6/ml) in the milk used as a test dose for the BHT significantly reduced lactose malabsorption, and it was not necessary to consume the milk daily for it to be beneficial in this regard.

The lactose content of the milk did not change during 7 days of refrigerated storage. No free glucose due to the hydrolysis of lactose was detected. The population of *L. acidophilus* in milk during refrigerated storage also did not change.

Table 5. Immediate effect of consuming milk containing *L. acidophilus* on lactose malabsorption in humans[a]

	PPM H_2 in Breath			
	Control Milk		Milk containing *L. acidophilus*[b]	
Subject	Day 0	Day 7	Day 14	Day 21
1	51.3	46.1	17.4	35.7
2	57.9	40.9	45.6	45.3
3	39.5	38.8	21.3	21.6
4	54.8	66.0	58.2	38.7
5	35.2	37.0	30.3	29.9
Averages	47.7[c]	45.8[c]	31.1[c]	34.2[c]
Overall averages	46.8[d]		32.7[d]	

[a]No milk with or without *L. acidophilus* was consumed during the periods between breath hydrogen tests.
[b]2.5×10^6 cells of *L. acidophilus* per ml.
[c]Day 0 not significantly different from day 7 ($P>0.70$); day 14 not significantly different from day 21 ($P>0.95$).
[d]Significantly lower for *L. acidophilus* milk ($P<0.01$).

Discussion

Many individuals who are classified as lactose malabsorbers on the basis of clinical tests involving a standard lactose dose of 1.8 oz (50 g) can consume dietary amounts of lactose, such as would be contained in a glass of milk, without experiencing symptoms of lactose intolerance (Torun et al., 1979). From a practical standpoint the lactose dose for determining lactose malabsorption should be a smaller dose, such as 0.18 oz (5 g) of milk per 2.2 lb (1 kg) of body wt. For most of the test subjects in this study this resulted in test doses similar to 8 to 9 oz of milk, which contained about 0.42 oz (12 g) of lactose. This amount of milk should not have resulted in the digestive system merely being "overloaded" with lactose.

Since the lactose content of milk containing cells of *L. acidophilus* remained unchanged during refrigerated storage, the reduction of lactose malabsorption was not due to the lactose in milk being hydrolyzed prior to ingestion. Thus, the *L. acidophilus* must have exerted its beneficial effect in the digestive system.

It seems that daily consumption of pasteurized whole milk containing 2.5×10^7 cells of *L. acidophilus* per ml should have shown a significant difference between the hydrogen excretions on days 0 and 7 since milk containing both 2.5×10^8 and 2.5×10^6 cells per ml effectively reduced lactose malabsorption. The unexpected result was probably due to the abnormally increased hydrogen excretion by subjects 2 and 3 on day 7. The possible explanations of this unexpected result included variations in diet and other activities of the test subjects that may have imposed stresses on the digestive system.

Individual variations among the test subjects appeared to influence the degree of hydrogen excretion as well as the effect of consuming milk containing cells of *L. acidophilus*. For some subjects, the effect was very beneficial; for others it was not. Thus, we might expect that every lactose malabsorbing person who consumes milk containing *L. acidophilus* might not realize total relief from symptoms associated with lactose malabsorption.

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Frozen Concentrated Cultures from Cells of *Lactobacillus acidophilus* Grown in Pepsinized Whey Media

S. E. Gilliland and S. L. Mitchell

Story in Brief

Three pepsinized whey based media were compared for growing cells of *Lactobacillus acidophilus* to be used in preparing frozen concentrated cultures. Concentrations of dried sweet whey tested in the media were 2.5, 5.0, and 7.5 percent. The pH of the media was maintained at 6.0 during growth of *L. acidophilus* at 37 C with a neutralizer consisting of 20 perecent Na_2CO_3 in 20 percent NH_4OH. As the level of whey solids was increased in the media, maximum populations attained during growth decreased. The culture reached maximum populations in the media containing 2.5 percent and 5.0 percent whey solids after 12 and 18 hr, respectively, then remained constant for the remainder of the 24-hr incubation period. However, in the medium containing 7.5 percent whey solids, the culture appeared to enter a death phase after only 12 hr of incubation. The maximum population in the 7.5 percent medium was also considerably lower than those in the other two media. Frozen concentrated cultures were prepared from cells of *L. acidophilus* grown in the media containing 2.5 percent and 5.0 percent whey solids and stored in liquid nitrogen at − 196 C. The viability and bile resistance of the cultures during storage in liquid nitrogen and subsequent storage in refrigerated milk was highest for cells which had been grown in the 2.5 percent pepsinized whey medium.

Introduction

Currently there is much interest in the use of *Lactobacillus acidophilus* as a dietary adjunct. Cells of *L. acidophilus*, in the form of a concentrated culture added to refrigerated low-fat milk, may help maintain intestinal health and improve intestinal function. Consumption of milk containing this organism can help maintain a desirable balance among bacteria in the intestinal tract. It can also aid in preventing symptoms associated with lactose malabsorption in persons suffering from this malady.

Originally, acidophilus milk was available only as a fermented product which had an unpleasant flavor. Cells of *L. acidophilus* rapidly died during refrigerated storage in such a product. Because of low numbers of viable cells of *L. acidophilus* in the fermented milk and the milk's unpleasant flavor, an unfermented acidophilus milk was developed. A low-fat non-fermented milk product containing *L. acidophilus* was made commercially available in 1975. The milk is prepared by adding a concentrated culture of *L. acidophilus* to pasteurized low-fat milk. The flavor is the same as ordinary milk, but the milk contains several million viable and bile resistant cells of *L. acidophilus* per ml.

One of the most important considerations in preparing a frozen concentrated culture of *L. acidophilus* to be used as a dietary adjunct is the growth medium used to grow the cells. The growth medium should permit maximum growth of the bacterial cells and produce cells that will retain viability and their desirable characteristics during frozen storage of the resulting concentrated culture. These characteristics should also be maintained during subsequent refrigerated storage of the milk containing the cells of *L. acidophilus*.

The objective of this study was to develop a pepsinized whey based medium in which to grow cells of *L. acidophilus* to be used in the preparation of frozen concentrated cultures for use as dietary adjuncts.

Materials and Methods

Dried sweet whey (Associated Milk Producers Inc., Tulsa, OK) was reconstituted at the desired concentration (2.5 percent, 5.0 percent or 7.5 per percent) in 4 liters of distilled water containing 0.1 percent Tween 80 (Sigma Chemical Co.). The pH was adjusted to 3.0 with 5N phosphoric acid, and 1 g of pepsin (Sigma Chemical Co.) was added. This mixture was incubated 30 min in a 37 C water bath. The digested whey was adjusted to pH 7.0 with 5N ammonium hydroxide. One-tenth percent yeast extract and 1.0 percent thiotone were added to the mixture. After the added ingredients were dissolved, the medium was equally divided into two 4-liter flasks and autoclaved for 15 min at 121 C.

The 4 liters of sterile pepsinized whey medium were aseptically added to an empty sterile fermenter jar. The fermenter jar, equipped with a combination pH electrode, was connected to an automatic pH controller. The temperature of the whey was adjusted to 37 C, and the automatic pH controller was adjusted to maintain the growth medium at pH 6.0. The whey medium was then inoculated with 40 ml of an 18-hr milk culture (37 C) of *L. acidophilus* NCFM and incubated for 24 hr at 37 C. The medium was maintained at pH 6.0 during growth of the culture with a neutralizer consisting of 20 percent Na_2CO_3 in 20 percent NH_4OH.

Beginning at 10-hr and at 2-hr intervals thereafter, 10 ml samples of the culture were aseptically removed from the fermenter using sterile pipettes and placed into sterile screw-capped test tubes in an ice-water bath. The total numbers of lactobacilli and bile resistant lactobacilli were determined by plating appropriate dilutions of the samples on MRS and MRSO agar media. The MRS agar provided total numbers of lactobacilli, and the MRSO agar (MRS plus 0.1 percent oxgall) provided numbers of bile resistant lactobacilli.

Cells were harvested after 16 hr of growth from 800 ml of the cultures of *L. acidophilus* grown in the 2.5 and 5 percent whey media. The cells were harvested by centrifugation and resuspended in twice their weight of cold sterile 10 percent NFMS. The resulting concentrated cultures were dispensed into sterile freezing vials (2 g each), then frozen and stored in liquid nitrogen (− 196 C).

Numbers of *L. acidophilus* in the concentrated cultures were determined prior to freezing (Day 0) and after 1, 14 and 28 days of storage in liquid nitrogen by plating appropriate dilutions on MRS and MRSO agar. The vials of frozen concentrated cultures were thawed by submerging them in 1 liter of tap water at 30 C for 5 min.

Milk for preparing nonfermented acidophilus milk was prepared by dividing 400 ml of 10 percent reconstituted nonfat milk solids (NFMS) into four bottles and heating at 100 C for 30 min. The heated milk was immediately cooled to 5 C. Thawed concentrated culture was diluted, as required, and added to each of four bottles containing the cold 10 percent NFMS to achieve a population of about 2 x 10^6/ml. The milk was then stored at 5 C. Bottles were removed for examination on Days 1, 7, 14 and 21. The total numbers of lactobacilli and bile resistant lactobacilli were determined.

Results

Considerable variation was observed in the growth of *L. acidophilus* NCFM in the media containing different concentrations of whey solids (Figure 1). In this figure the $\log_{10}$ of counts on MRS agar (solid lines) and on MRSO agar (broken lines) are plotted against incubation time. The highest population attained, based on counts on MRS agar, was 1 x 10^9/ml in the 2.5 percent whey medium, which was significantly higher than that obtained in the 5 percent or the 7.5 percent media ($P<.05$). Growth of *L. acidophilus* in the 2.5 percent and 5.0 percent whey media reached maximum numbers at 16-18 hr and then remained constant with little or no reduction in numbers for the remainder of the incubation time. The growth of *L. acidophilus* in the medium containing 7.5 percent whey solids, however, reached its maximum at approximately 12 hr and then decreased throughout the remainder of the incubation period. It is apparent from this data that as the level of whey solids was increased in the media, the maximum populations attained during growth at pH 6.0 decreased. The differences between MRS and MRSO counts for the culture growing in each level of whey solids increased as the level of whey solids was increased. Due to the poor performance of the culture in the 7.5 percent medium, further experiments with this medium were not done.

The survival of the concentrated cultures of *L. acidophilus* NCFM during storage in liquid nitrogen is shown in Table 1. The data in this table represent the average $\log_{10}$ counts from six trials. For the concentrated cultures prepared from cells grown in the medium containing 2.5 percent whey solids, counts on both the

Table 1. Survival of *Lactobacillus acidophilus* NCFM in concentrated cultures during storage in liquid nitrogen[a]

Days in liquid nitrogen	2.5% Whey solids		5.0% Whey solids	
	MRS	MRSO	MRS	MRSO
0	10.31	10.26	9.81	9.65
1	10.27	10.13	9.67	9.53
14	10.28	10.24	9.61	9.51
28	10.27	10.21	9.63	9.36

[a]Each value is the average $\log_{10}$ count/g from 6 trials.

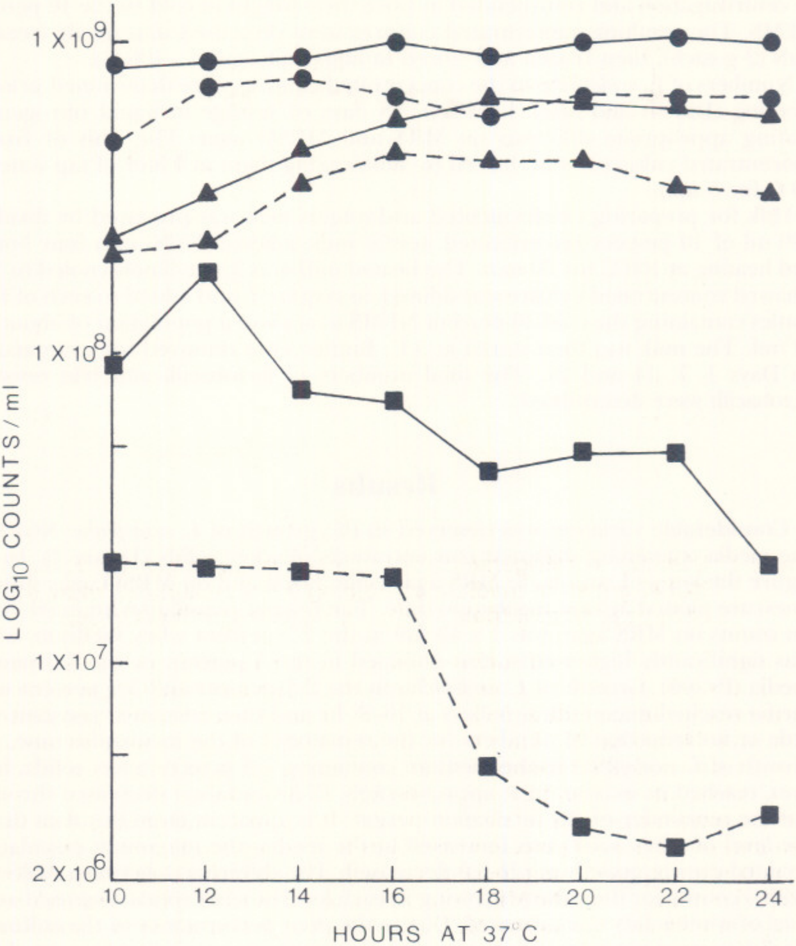

Figure 1. Growth of *Lactobacillus acidophilus* NCFM at pH 6.0 in pepsinized whey based media. ● 2.5% whey solids (averages from 6 trials); ▲ 5.0% whey solids (averages from 6 trials); ■ 7.5% whey (averages from 4 trials); plotted on semi-logarithmic paper; solid lines = counts on MRS agar; broken lines = counts on MRSO agar

MRS and MRSO agar remained fairly constant, exhibiting only slight reductions during 28 days of storage in liquid nitrogen. However, the MRS and MRSO counts for the concentrated cultures prepared from cells grown in the 5.0 percent medium showed greater reductions after 1 day of storage in liquid nitorgen. The MRS counts then remained about the same from Day 1 to Day 28, but the MRSO count was further reduced after 28 days of storage in liquid nitrogen.

Figure 2 shows the effect of storage in refrigerated milk on the viability and bile resistance of cells of *L. acidophilus* NCFM which were grown in the 2.5 percent

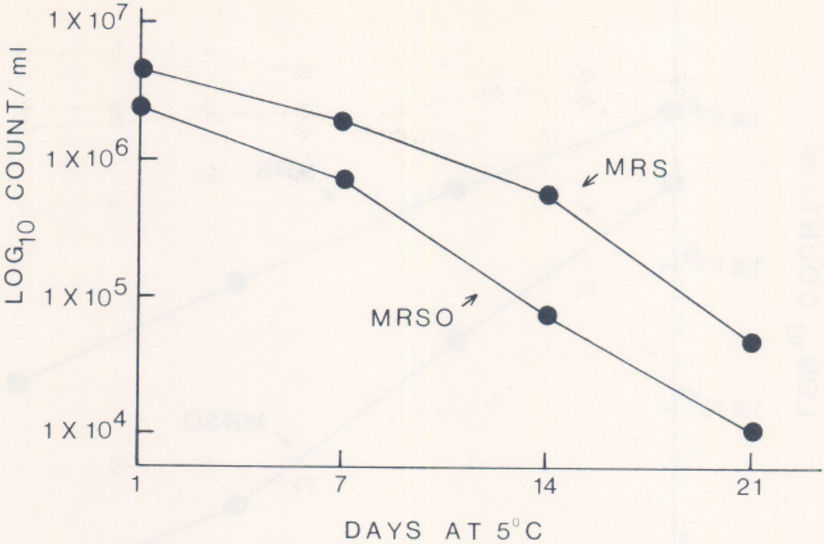

Figure 2. Stability in refrigerated milk of cells of *Lactobacillus acidophilus* NCFM grown in medium containing 2.5% pepsinized whey solids. (Averages from 6 trials, plotted on semi-logarithmic paper)

medium. The concentrated culture used to prepare the milk had been stored in liquid nitrogen for 28 days. Counts obtained on MRS and MRSO agar decreased during storage in the milk at 5 C. The MRS counts showed the sharpest decrease from Day 14 to Day 21. The counts obtained on MRS agar were significantly higher than the MRSO counts ($P<0.005$), and the greatest difference in counts was observed after 14 and 21 days of refrigerated storage.

The storage stability in refrigerated milk of cells of *L. acidophilus* grown in the medium containing 5.0 percent whey solids is presented in Figure 3. Once again the milk was prepared using concentrated cultures which had been stored 28 days in liquid nitrogen. Both the MRS and MRSO agar counts dropped steadily during storage in milk at 5 C, but the MRSO counts dropped much more rapidly than the MRS agar counts. The counts obtained on MRS agar were significantly higher than the MRSO agar counts ($P<0.005$). As in the 2.5 percent medium, the greatest difference between MRS and MRSO counts was seen after 14 and 21 days of refrigerated storage.

Discussion

The reductions in maximum populations observed as the amount of whey solids in the growth medium was increased could be due to inhibitory metabolic products produced from the higher concentration of whey components. Increasing concentrations of whey components might also have created an "imbalance" among nutrients in the medium. For instance, the media with higher levels of whey solids might require different levels of yeast extract, thiotone, or Tween 80 to attain maximum growth of lactobacilli.

The type of neutralizer used to maintain the pH at 6.0 during growth of the culture could influence the maximum populations attained. The type of neutralizer has been shown to influence the growth of other lactic acid bacteria. It is

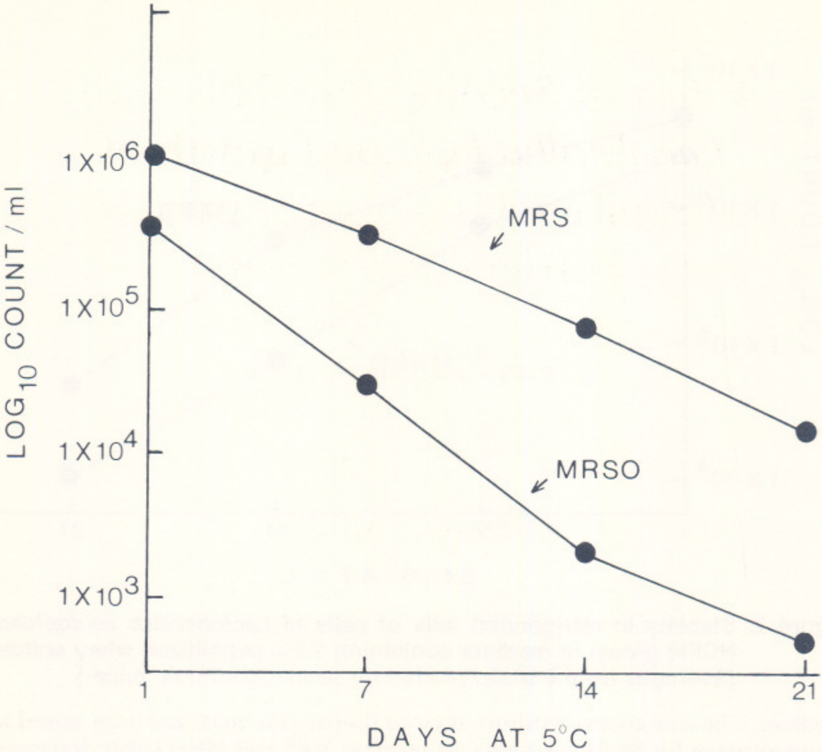

Figure 3. Stability in refrigerated milk of cells of *Lactobacillus acidophilus* NCFM grown in medium containing 5.0% pepsinized whey solids (averages from 6 trials, plotted on semi-logarithmic paper)

possible that a different neutralizer may have been more effective in the media containing higher concentrations of whey. While there is no information available as to the optimum level of various minerals and/or salts on the growth of *L. acidophilus,* an alteration in the amounts of the various salts caused by increasing the whey solids could have influenced the culture.

The lower stability of the concentrated cultures in liquid nitrogen prepared from cells grown in the 5.0 percent medium could be due to some damage to the cells during growth at 37 C. Damage or injury to the cells is also indicated by larger differences between MRS and MRSO agar counts for the culture grown in the 5.0 percent medium than for the cells grown in the 2.5 percent medium. The lower counts on MRSO agar indicated reduced resistance of the culture to bile salts.

In summary, the medium containing 2.5 percent pepsinized whey solids would be the most desirable for producing cells of *L. acidophilus* for preparing frozen, concentrated cultures to be used as dietary adjuncts. However, the survival of the culture during storage in refrigerated milk needs to be improved. Factors other than the level of whey--such as pH during growth, neutralizer used for maintaining pH, and growth temperature need to be researched.

Effect of Seeding Raw Milk with *Lactobacillus lactis* on Growth of Spoilage Organisms during Refrigerated Storage

S. E. Gilliland and H. R. Ewell

Story in Brief

Cells of *Lactobacillus lactis* from frozen concentrated cultures were added to refrigerated raw milk to determine their effect on growth of psychrotrophic spoilage bacteria in the milk during storage at 5 or 7 C. Some strains of *L. lactis* were significantly inhibitory at both temperatures. Two selected strains of *L. lactis* were added along with potassium sorbate to refrigerated raw milk stored at 5 C to determine their combined effect on growth of the psychrotrophs. The combination of cells of lactobacilli and sorbate was more inhibitory than either lactobacilli or sorbate alone.

Introduction

The growth of psychrotrophic microorganisms in raw milk during refrigeration in bulk storage tanks can reduce the quality of the milk. While they are easily killed by heat treatment, some of them produce heat stable enzymes that can survive pasteurization or sterilization treatments and adversely affect the quality of products made from the heat processed milk.

Lactic acid bacteria including lactobacilli can inhibit the growth of food-borne pathogens and spoilage microorganisms in various foods at refrigeration temperatures. The inhibitory agent produced by the lactobacilli has been identified as hydrogen peroxide. Since cells of lactobacilli accumulate hydrogen peroxide in the suspending menstrum during refrigerated storage even though they do not grow, the possibility exists that they might produce sufficient peroxide to inhibit the growth of psychrotrophs in refrigerated food.

Sorbic acid has been used in many foods as a preservative. It is said to be more inhibitory to bacteria similar to those causing spoilage of refrigerated foods than to the lactobacilli. Therefore, a combination of sorbate and cells of *L. lactis* might be expected to exert greater inhibitory action on psychrotrophic spoilage microorganisms in raw milk than would either alone.

The objectives of this study were to determine if the growth of psychrotrophic microorganisms in refrigerated raw milk could be retarded by adding cells of *L. lactis* and to determine if the additions of potassium sorbate along with cells would enhance any inhibition caused by the lactobacilli.

Materials and Methods

The cultures of *L. lactis* were maintained by subculturing (1 percent inocula) weekly into sterile (121 C for 15 min) 10 percent non-fat milk solids (NFMS). The inoculated milk was incubated at 37 C for 24 hr. These cultures were stored in a refrigerator between weekly subcultures. Before use in experiments, the cultures were subcultured twice in 10 ml of sterile lactobacilli MRS broth (Difco) using a one percent inocula and incubating 18 hr at 37 C.

Each of the cultures of *L. lactic* was inoculated into 600 ml of lactobacilli MRS broth (Difco) and incubated at 37 C until the culture reached the late exponential or early stationary phase of growth. The cells were harvested by centrifugation and resuspended in 30 ml of cold, sterile 10 percent NFMS. The resulting concentrated cultures were dispensed in 2 g portions into sterile plastic freezing vials and placed immediately into liquid nitrogen (−196 C) for storage. For experimental use, each frozen concentrated culture was thawed by submerging in 1 liter of tap water (24 C) for 5 min.

Raw milk was obtained from the bulk storage tanks at the Oklahoma State University Dairy Cattle Center. The raw milk was aseptically placed into a sterile flask contained in an ice-water bath for transport to the laboratory and held there until used (never held longer than 2 hr). The raw milk was then dispensed in 100 ml volumes into sterile 250 ml flasks. Thawed concentrated cultures were added to the raw milk in the quantities necessary to obtain 1×10^8 lactobacilli per ml. One flask of raw milk was used as a control. The flasks were then placed in a refrigerated Gyrotory Water Bath Shaker for storage. The bath was at either 5 or 7 C, and agitation was adjusted to 160 RPM. Samples for microbial analyses were taken from each flask initially and daily for 6 days. In all trials pH values were determined on the final day of storage.

Lactobacilli were enumerated in the initial samples by plating the appropriate dilutions with MRS agar (Speck, 1975). The plates were incubated for 48 hr at 37 C. Non-lactobacilli were enumerated by plating appropriate dilutions with Plate Count Agar (PCA) and incubating the plates at 21 C for 5 days. The lactobacilli used in this study did not form colonies on PCA under these conditions. This enabled us to follow the growth of psychrotrophic bacteria in the milk during storage.

Thawed concentrated cultures of selected strains of L. lactis (39A1 and 39A2) were added to raw milk to yield populations of 1×10^8/ml. Three flasks of raw milk (100 ml) were prepared for each strain. A set of three flasks of raw milk without lactobacilli was also prepared. To each set of three flasks with and without lactobacilli, a sterile 10 percent solution of potassium sorbate was added to yield final concentrations of 0, 0.1 percent, and 0.2 percent. The samples were stored at 5 C as in previous experiments. Samples (10 ml) were taken from each flask initially and on the third and fourth days of storage for microbial analyses as indicated in the previous experiments.

Results

Table 1 is a summary of results from four trials in which the antagonistic action of six strains of *L. lactis* toward the growth of psychrotrophs in raw milk was measured at 7 C. The data are presented as the $\log_{10}$ of counts of non-lactobacilli per ml obtained after the milk samples had been stored 4 days at 7 C. When compared to the average count for the control samples, *L. lactis* 403E-15 was the most inhibitory followed in order by strains 39A1, 12315, B, 39A2, and Farr.

Table 1. Numbers of non-lactobacilli in raw milk with and without added cells of *Lactobacillus lactis* after 4 days of storage at 7 C

Sample	Days at 7 C	Non-lactobacilli count/ml[b]				
		Trial 1	Trial 2	Trial 3	Trial 4	Avg.
Control	0	3.56	3.63	4.04	3.40	
Control	4	6.20	7.20	7.65	5.64	6.67
L. lactis B	4	5.70	7.18	6.30	5.18	6.09
L. lactis Farr	4	5.60	7.04	7.11	5.60	6.34
L. lactis 12315	4	5.86	6.85	6.38	5.28	6.09
L. lactis 403E-15	4	5.62	6.53	6.45	5.08	5.92
L. lactis 39A1	4	5.85	6.64	6.88	4.43	5.96
L. lactis 39A2	4	6.15	6.91	6.20	5.08	6.09

[a]*L. lactis* counts were approximately 1 x 10^8/ml.
[b]Counts recorded as $\log_{10}$ of numbers of non-lactobacilli/ml.

There were no differences in the amounts of inhibition produced by strains B, 12315 and 39A2. Statistical analysis of the data revealed that strains B, 12315, and 39A2 were significantly inhibitory at $P<0.05$ and strains 403E-15 and 39A1 were significantly inhibitory at $P<0.01$. Little or no change in acidity was observed in any of the milk samples during storage at 7 C.

Table 2 is a summary of results from six trials in which the antagonistic action of the six strains of *L. lactis* toward the growth of psychrotrophs in raw milk was measured at 5 C. The data are presented as $\log_{10}$ of counts of non-lactobacilli per ml after the milk samples had been stored 4 days at 5 C. *L. lactis* 39A1 was the most inhibitory followed in order by strains B, 403E-15, Farr, and 39A2. Strains 403E-15, 12315, Farr, and 39A2 exhibited minimal differences in inhibition. Only *L. lactis* 39A1 and B were significantly inhibitory ($P<0.01$ and $P<0.05$ respectively). The pH of none of the milk samples changed during the storage period.

L. lactis in conjunction with potassium sorbate exhibited greater inhibition of the growth of psychrotrophs in raw milk at 5 C than did either treatment alone (Table 3). The data from four trials are represented as the $\log_{10}$ count of non-lactobacilli per ml after the milk samples had been stored 4 days at 5 C. Strains 39A1 and 39A2 combined with either 0.1 percent or 0.2 percent potassium sorbate were significantly ($P<0.01$) more inhibitory than either strain or sorbate alone. Sorbate alone had minimal inhibitory effect on the growth of the psychrotrophs. Both strains in combination with 0.2 percent sorbate were significantly more inhibitory than either strain combined with 0.1 percent sorbate ($P<0.01$).

Discussion

We observed in a previous study (Martin and Gilliland, 1980) that cells of *L. bulgaricus* had an antagonistic effect toward a psychrotrophic bacteria (isolated from raw milk) in autoclaved milk at 5.5 C. However, the *L. bulgaricus* did not inhibit growth of psychrotrophs in raw milk at 5.5 C. Apparently, the cultures of *L. bulgaricus* did not produce sufficient peroxide to inhibit psychrotrophs in raw milk. Since *L. lactis* reportedly produces more hydrogen peroxide than *L. bulgaricus,* it might be more likely to have an inhibitory effect on psychrotrophs in raw milk during refrigerated storage than would *L. bulgaricus.* In experiments related to the present study, the strains of *L. lactis* exerting the greatest inhibition of psychrotrophs in raw milk also produced the greatest amounts of peroxide.

Table 2. Numbers of non-lactobacilli in raw milk with and without added cells of *Lactobacillus lactis*[a] after 4 days of storage at 5°C

Sample	Days at 5°C	Non-lactobacilli/ml[b]						
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Avg.
Control	0	3.72	3.18	3.34	3.45	3.82	3.60	
Control	4	4.20	3.61	7.23	5.40	4.58	7.38	5.40
L. lactis B	4	4.00	3.34	5.85	5.40	4.20	6.76	4.93
L. lactis Farr	4	4.04	3.56	5.79	5.72	4.59	6.69	5.07
L. lactis 12315	4	3.96	3.77	5.92	5.23	4.53	6.70	5.02
L. lactis 403E-15	4	4.08	3.20	5.69	5.76	4.67	6.68	5.01
L. lactis 39A1	4	4.15	3.15	5.77	3.89	4.41	6.57	4.66
L. lactis 39A2	4	4.18	3.57	5.79	5.79	4.54	6.91	5.13

[a]*L. lactis* counts were approximately 1 x 10^8/ml.
[b]Counts recorded as $\log_{10}$ of numbers of non-lactobacilli/ml.

Table 3. Numbers of non-lactobacilli in raw milk with added cells of *Lactobacillus lactis* and/or sorbate after 4 days of storage at 5 °C

Treatment		Non-lactobacilli/ml[a]				
Culture[b]	Percent sorbate	Trial 1	Trial 2	Trial 3	Trial 4	Avg.
	0	3.85	3.96	4.26	3.88	3.99
Control	0.1	3.52	3.54	4.26	3.75	3.77
	0.2	3.52	3.49	4.26	4.90	3.79
	0	3.54	3.63	4.20	3.57	3.74
L. lactis 39A1	0.1	3.26	3.62	3.91	3.54	3.58
	0.2	2.70	2.59	3.91	3.59	3.20
	0	3.65	3.70	4.11	3.71	3.79
L. lactis 39A2	0.1	3.20	3.20	4.00	3.59	3.50
	0.2	3.26	3.00	3.98	3.60	3.46

[a]Counts recorded as $\log_{10}$ of numbers of non-lactobacilli on day four of storage; the counts on day zero were as follows: Trial 1 = 3.11; Trial 2 = 3.42; Trial 3 = 3.11; Trial 4 = 3.28.
[b]*L. lactis* counts were approximately 1 x 10^8/ml.

The differences in the intensity of the inhibition of psychrotrophs in raw milk by *L. lactis* among different trials in the present study may have been in part due to variations in the microflora present in the different lots of raw milk. There was no attempt to control types of microflora other than to include those organisms naturally present in the raw milk. These organisms might vary in susceptibility to the inhibitory action of lactobacilli. If the initial population of non-lactobacilli in the raw milk was too great and increased too rapidly, the high numbers may have overcome the inhibitory action of the lactobacilli. A slight variation in storage temperature can have considerable influence on the growth of psychrotrophs in raw milk. Storage of the raw milk samples at 7 C appeared to result in faster growth of the psychrotrophs than at 5 C. However, the degree of inhibition was similar at both temperatures.

Some have suggested that sorbate might inhibit catalase. If the catalase in raw milk were inhibited by the addition of sorbate, the hydrogen peroxide produced by *L. lactis* should be more inhibitory toward psychrotrophs in the milk. Thus, the use of sorbate in conjunction with *L. lactis* should significantly increase the inhibition of psychrotrophs in raw milk. The combined treatments of *L. lactis* with sorbate were more inhibitory to the growth of psychrotrophs in refrigerated raw milk than was either *L. lactis* or sorbate alone. At present we do not know whether or not this enhanced inhibition was due to reduced catalase activity in the raw milk.

The hydrogen peroxide production by the lactobacilli appears to be the most important means whereby they inhibit psychrotrophs in refrigerated raw milk. Additional research is needed to find means of improving the hydrogen peroxide production by *L. lactis* to increase the antagonism towards psychrotrophs.

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Evaluation of Certain Electrical Parameters for Stimulating Lamb Carcasses

N. H. Rashid, R. L. Henrickson, A. Asghar, P. L. Claypool and B. R. Rao

Story in Brief

The efficiency of electrical stimulation at two voltages (50 V and 350 V) and three frequencies (10, 100 and 250 Hz) was evaluated on lamb carcass sides using direct current pulsed as a square wave with a 20 percent duty factor. The carcass sides were electrically stimulated within 15 minutes of bleeding using appropriate voltage and frequency for 4 minutes. All sides were kept in a 16°C cooler until the pH of the *Longissimus dorsi* (LD) and *Semimembranosus* (SM) muscles reached 6.0 and then transferred to a chilling room at 2°C. LD, SM and *Semitendinosus* (ST) muscles were used to study some physico-chemical changes. Stimulating lamb sides at 350 V and 10 Hz gave the fastest glycolysis (drop in pH) at 2 and 4 hours postmortem, and the period required to reach pH 6.0 was much shorter than achieved by stimulation with any other combination of voltage and frequency in LD and SM muscles. The energy output per pulse which was highest at 350 V and 10 Hz was the governing factor for glycolysis rather than the total energy output. Cold shortening was minimal in the ST muscle of electrically stimulated sides at 350 V and 10 Hz compared to the controls. In general, electrical stimulation, while reducing cold shortening, had no effect on lean color. Similarly, different protein fractions (Sarcoplasmic, myofibrillar and stroma proteins) were not affected by any combinations of voltage and frequency.

Introduction

There is ample evidence that postmortem electrical stimulation of carcasses of food animals provides many benefits. However, there appears to be much variation in the electrical parameters — type of current, voltage, frequency, pulse duration, pulse shape, etc. — used. In most cases a particular electrical stimulation condition was used empirically rather than based on any theoretical considerations. Voltages as high as 3600 and as low as 5 and frequencies ranging from 2400 Hz to 5 Hz were used. It is likely that a relationship between electrical parameters like voltage and frequency exists for accelerating postmortem muscle glycolysis. Such a relationship has not been studied previously on intact carcasses. This study was conducted to investigate the effect of electrical stimulation of lamb carcasses at different voltages and frequency levels on some biochemical and quality characteristics of lamb muscles.

Materials and Methods

Two voltage levels, 50 and 350 volts, and three frequencies, 10, 100 and 250 Hz, within each voltage were used to stimulate Suffolk lamb carcasses. The lambs were slaughtered, skinned, eviscerated and divided into sides (carcass weight 19 to 25 kg.) The sides were randomly assigned to electrical stimulation within 15 minutes postmortem. Two electrodes were applied, one at the neck near the 5th and 6th cervical vertebrae and the other at the muscular portion of the achilles tendon. A direct current with a square wave pulse at the designated voltage and frequency was applied to each carcass side in a cooler at 16°C for 4 minutes. The physical response of the muscles during stimulation was observed and recorded. Samples from LD and SM muscles were taken for measurement of pH. Internal temperature of intact LD and SM was recorded at 0, 2, 4, and 24 hour postmortem, the same time at which pH was measured. The extent of cold shortening was measured on ST muscle strips, and the lean color was measured using a Hunterlab tristimulus colorimeter and recorded as L, a, b values. The ratio of redness to yellowness was calculated. The solubility of different protein fractions (sarcoplasmic, myofibrillar and stroma protein) was studied. Samples from the homogenous LD muscles were extracted sequentially with different buffer systems using protein extraction apparatus.

Results and Discussion

Based on visual observations, the cervical and thoracic regions of the sides flexed more vigorously in a lateral direction when stimulated at a high voltage (350 V) than at a low voltage (50 V). Most of the muscles on the carcass surface exhibited fast twitching at low frequency (10 Hz) without regard to voltage; however, twitching continued for a longer period at the low voltage. At 250 Hz the whole side went into tetanic contraction without showing any twitching of individual muscle at both the voltages.

How fast the postmortem muscle pH drops to 6.0 has been used as a criterion to determine the effectiveness of electrical stimulation in accelerating glycolysis. Significant differences in time for the LD and SM to reach pH 6.0 were observed when carcass sides were stimulated at 350 V and 50V, and the frequency varied from 10 to 250 Hz as shown in Figure 1. Stimulation at 350 V and 10 Hz provided the shortest time for the muscles to reach pH 6.0, while other stimulation treatments required more time; yet they were significantly different from the controls for both the LD and SM muscles. Frequency also had an effect in reducing the time for the muscle to reach pH 6.0. Low frequency was more effective. This study provided evidence that frequency, along with voltage, increases the rate of postmortem glycolysis in muscles due to stimulation.

Stimulation of the sides with 350 V resulted in a much higher total energy output than at 50 V. A change in frequency from 10 to 250 Hz had little effect on the total energy output. The output energy per pulse decreased as the frequency was increased. The decrease in jules per pulse was also affected by voltage. Electrical stimulation at 350 V and 10 Hz provided the greatest energy ouput per pulse. The energy per pulse was markedly lower at 50 V and further decreased with an increase in frequency.

Electrical stimulation at 350 V and 10 Hz caused the greatest pH drop in the LD and SM muscles at the 2 and 4 hour poststimulation periods. At 24 hour postmortem the ultimate pH of the muscles was not significantly different between treatments. The pattern of postmortem temperature changes of intact LD and SM muscles at 0, 2, 4, and 24 hour poststimulation was not significantly different at any given time among treatments.

Electrical stimulation had a significant influence on the potential of Ca^{++} induced shortening of muscle. High voltage (350) had a greater effect than

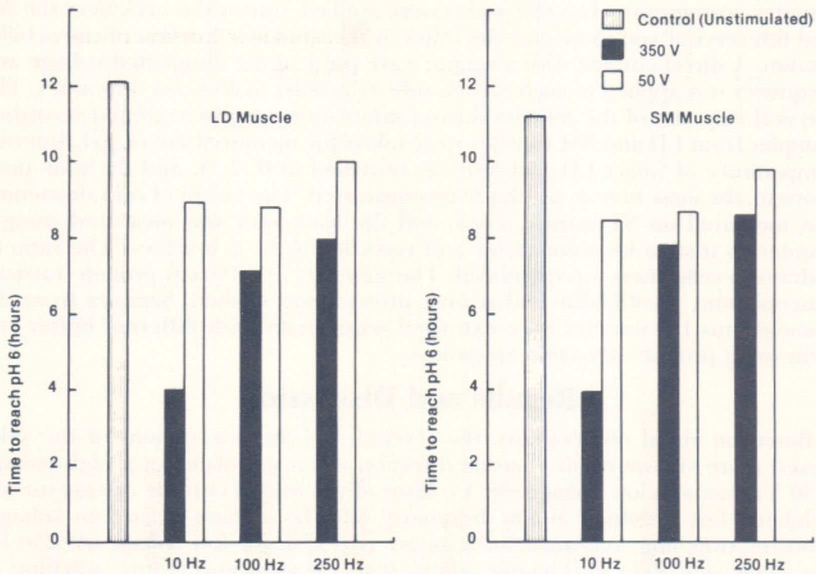

Figure 1. Time required to reach pH for intact LD and SM muscles as affected by electrical stimulation at different voltages (V) and frequencies (Hz)

stimulation at a low voltage (50 V). At 50 V, the frequency had no effect on the shortening of the ST whereas at 350 V different frequencies exhibited a significant effect (Figure 2). The excised ST muscle from the carcass side which was stimulated at 350 V and 10 Hz experienced the least shortening. The postmortem release of Ca^{++} from the sarcoplasmic reticulum and (or) from the mitochondria at the time that the adenosine triphosphate (ATP) level in muscle is still high results in a significant level of cold shortening. However if the Ca^{++} is released after some depletion of ATP from muscle has taken place, only a minor amount of shortening occurs. It is known that electrical stimulation causes rapid depletion of ATP, which is the primary source of energy for the cold shortening. This study suggested that stimulation of carcasses at 350 V and 10 Hz resulted in a more rapid depletion of the energy source from muscle than the other treatments.

Lean color of the muscle, measured and calculated as L, a, b values and the a/b ratio, which is an indicator of redness, was not significantly different among the treatments. Similarly, the protein solubility of different fractions of muscle proteins was not affected by electrical stimulation with any of the combinations of voltage and frequency.

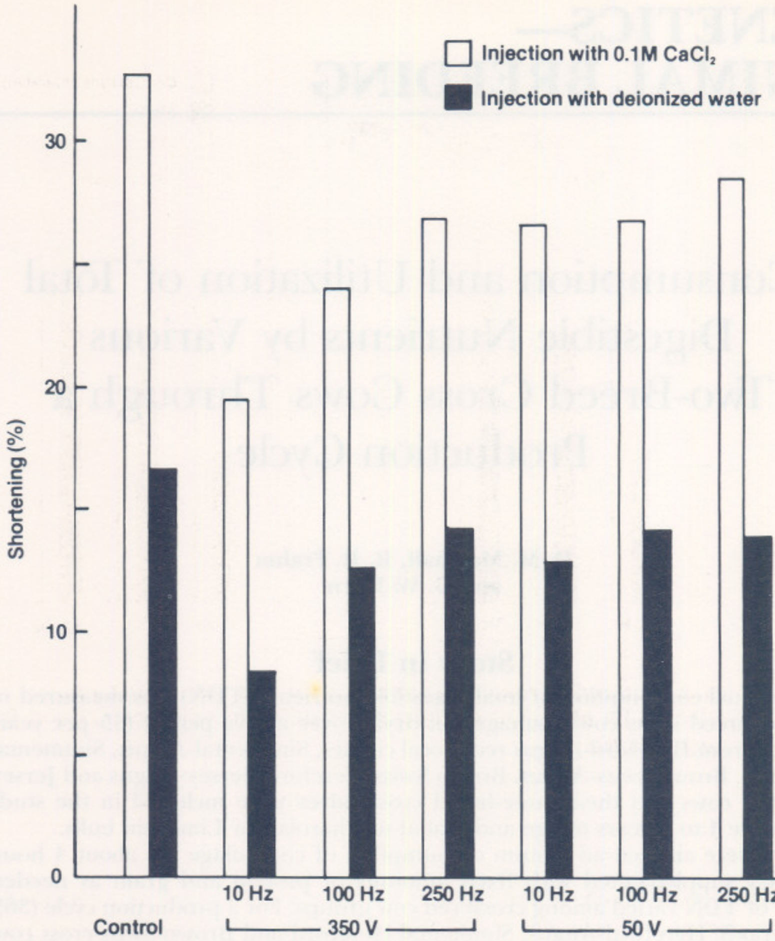

Figure 2. The effect of electrical stimulation at different voltages (V) and frequencies (Hz) on the extent of shortening of ST muscle strips

GENETICS—
ANIMAL BREEDING

Consumption and Utilization of Total Digestible Nutrients by Various Two-Breed Cross Cows Through a Production Cycle

D. M. Marshall, R. R. Frahm and G. W. Horn

Story in Brief

Individual consumption of total digestible nutrients (TDN) was measured on 105 two-breed cross cows managed in drylot over a 3-yr period (35 per year). Records from Hereford-Angus reciprocal crosses, Simmental-Angus, Simmental-Hereford, Brown Swiss-Angus, Brown Swiss-Hereford, Jersey-Angus and Jersey-Hereford cows and their three-breed cross calves were included in the study. Cows were 4 to 6 years of age and mated to Charolais or Limousin bulls.

Cows were allowed ad libitum consumption of corn silage for about 4 hours each day supplemented with fixed amounts of protein and grain as needed. Intake of TDN varied among crossbred cow groups. For a production cycle (365-day period), Hereford-Angus, Simmental-Hereford and Brown Swiss cross cows had similar TDN consumption (averaged 4588 lb). Compared to these intermediate crossbred cow groups, Simmental-Angus cows consumed 503 lb (11 percent) more TDN and Jersey cross cows consumed 293 lb (6.4 percent) less TDN. Heavier cows tended to consume more TDN than cows of lighter weights although the smaller Jersey crosses consumed more TDN per unit of body weight than other crosses. Daily TDN intake per 100 lb cow weight was 1.48 lb/day for Jersey crosses, 1.34 lb/day for Simmental-Angus and Brown Swiss-Angus, 1.28 lb/day for Hereford-Angus and Brown Swiss-Hereford and 1.24 lb/day for Simmental-Hereford cows. On the average, Angus cross cows consumed 5.8 percent more TDN per 100 lb body weight than Hereford cross cows.

Efficiency of TDN conversion to calf weaning weight (lb TDN/lb calf weight) favored Jersey-Hereford, Brown Swiss-Hereford and Simmental-Hereford cows (averaged 10.0 lb), followed by Hereford-Angus and Brown Swiss-Angus cows (averaged 10.5 lb) and Jersey-Angus and Simmental-Angus cows (averaged 10.9 lb). Hereford cross cows consistently required less TDN to produce a pound of weaned calf than Angus cross cows (10.0 vs 10.8 lb).

Introduction

Due to increased production costs, many cattlemen have been seeking new methods of improving production efficiency of their breeding herds. Research has indicated that systematic crossbreeding can effectively increase production output of commercial beef cow herds. Studies have been conducted to identify specific breed combinations that are most desirable under given mating systems and particular environmental conditions.

An extensive research project is in progress at the Oklahoma Agricultural Experiment Station to evaluate lifetime productivity of various two-breed cross cows when mated to bulls of a third breed. It is important to consider feed requirements of the various crossbred groups to adequately measure efficiency of production since feed costs constitute a major portion of production expenses in a beef cow herd. Thus, the objectives of this study were to compare TDN requirements and efficiency of TDN conversion to calf weaning weight of various two-breed cross cows and their calves through a production cycle.

Experimental Procedure

The crossbred cows involved in this study were produced in 1973, 1974 and 1975 by Angus and Hereford cows mated to Angus, Hereford, Simmental, Brown Swiss and Jersey bulls. All heifer calves produced by these matings were introduced into the herd for subsequent evaluation as cows. Cows were maintained on native and bermudagrass pastures at the Lake Carl Blackwell Research Range west of Stillwater.

Five pregnant cows of each crossbred group (Hereford x Angus and Angus x Hereford crosses were combined into one group) were transported to a drylot at the Southwestern Livestock and Forage Research Station near El Reno in the fall of 1976, 1977 and 1979 to measure individual feed intake for one production cycle (approximately one year). Thus, a total of 105 cows were involved in the study (35 per year). Each cow had weaned a calf just prior to entering the drylot and remained in drylot until weaning her next calf. If a cow or her calf died in drylot, a replacement cow (or cow-calf pair) of the same age and breed group was brought into drylot from the cow herd on range. Cows entering the drylot in the fall of 1976, 1977 and 1979 were 4-, 5- and 6-yr-old, respectively, at calving time in the spring. Cows entering the drylot in 1976 were mated to Charolais bulls whereas those entering the drylot in 1977 and 1979 were mated to Charolais or Limousin bulls.

Cows were moved into individual feeding stalls each morning at about 8:00 a.m. and were allowed ad libitum consumption of corn silage (for about a 4-hr period) plus a specific amount of grain and (or) protein supplement as needed. Weights of cows in drylot and on range were analyzed monthly so that consumption of supplement could be adjusted to keep weight changes of drylot cows parallel to those of range cows. Creep feed was available to drylot calves during the later portion of lactation.

Composition of feedstuffs utilized by drylot cows and calves is presented in Table 1. Weekly silage samples were analyzed for content of dry matter and crude protein at the station research lab. In vitro dry matter digestibility (IVDMD) was estimated each month on a composite of weekly silage samples. Tabular values were used to estimate composition of grain, protein supplement and calf creep feed.

Twenty-four hour milk yield of drylot cows was estimated by the calf nursing method during the first 2 years of the study and by machine milkout during the last year of the study.

Table 1. Composition of feedstuffs utilized in drylot

			Dry matter basis	
	Ingredient	Dry matter (%)	TDN (%)	Crude protein (%)
	Corn silage	34.3	61.1	8.0
Year	Protein supplement	89.4	67.0	56.7
One	Whole shell corn	89.0	91.0	10.0
	Calf creep feed	89.5	81.1	15.4
Year	Corn silage	37.2	58.5	9.2
Two	Protein supplement	89.4	67.0	56.7
	Calf creep feed	89.5	81.1	15.4
	Corn silage	39.1	61.1	9.4
Year	Protein supplement	89.4	67.0	56.7
Three	Ground milo	89.0	80.0	12.4
	Calf creep feed	89.5	81.1	15.4

Results and Discussion

Total TDN consumption and TDN consumption per 100 lb cow weight are presented in Table 2. Feed intake was adjusted to 160 and 205 days for non-lactating and lactating periods, respectively, to account for variation among cows with regard to calving date. The 205-day lactating period corresponds to the average lactation length of the entire cow herd (drylot and range cows). Lactating intake includes calf creep feed consumption along with cow intake.

Overall, cows consumed an average of 1590, 2981 and 4576 lb TDN for the 160-day non-lactating, 205-day lactating and 365-day total periods, respectively. Relative differences in intake among crossbred cow groups were similar for the non-lactating and lactating periods. Simmental-Angus cows consumed 5091 lb TDN for the 365-day total period, which was significantly more than all other crossbred groups, and Jersey cross cows consumed 4295 lb TDN which was significantly less than all other crossbred cow groups. Hereford-Angus, Simmental-Hereford and Brown Swiss crosses consumed similar amounts of TDN (averaged 4588 lb) for the 365-day period. Compared to this intermediate group, Simmental-Angus cows consumed 503 lb (11.0 percent) more TDN whereas the Jersey cross cows consumed 293 lb (6.4 percent) less TDN.

Although heavier cows tended to consume more TDN than cows of lighter weights, the smaller Jersey crosses consumed the most TDN per unit of body weight. Daily TDN intake per 100 lb cow weight averaged 1.48 lb/day for Jersey

Table 2. TDN consumption by each crossbred cow group

Crossbred cow group	No. cows	TDN intake (lb) 160-day non-lactating period	TDN intake (lb) 205-day lactating period	TDN intake (lb) 365-day total	Daily TDN intake per 100 lb cow weight (lb/day) 160-day non-lactating period	Daily TDN intake per 100 lb cow weight (lb/day) 205-day lactating period	Daily TDN intake per 100 lb cow weight (lb/day) 365-day total
Hereford-Angus	15	1578^{bc}	2997^{b}	4576^{bc}	$.998^{d}$	1.487^{bc}	1.274^{bc}
Simmental-Angus	15	1775^{a}	3311^{a}	5091^{a}	1.056^{bcd}	1.552^{b}	1.336^{b}
Simmental-Hereford	15	1598^{bc}	3011^{b}	4575^{bc}	$.989^{d}$	1.449^{c}	1.239^{c}
Brown Swiss-Angus	15	1651^{b}	3000^{b}	4672^{b}	1.083^{bc}	1.540^{bc}	1.345^{b}
Brown Swiss-Hereford	15	1584^{bc}	2953^{bc}	4530^{bc}	1.031^{cd}	1.496^{bc}	1.289^{bc}
Jersey-Angus	15	1449^{d}	2770^{d}	4248^{d}	1.198^{a}	1.754^{a}	1.514^{a}
Jersey-Hereford	15	1497^{cd}	2822^{cd}	4342^{cd}	1.124^{ab}	1.677^{a}	1.439^{a}
Total or Average	105	1590	2981	4576	1.068	1.565	1.348

^{abcd}Means in the same column not sharing at least one superscript significantly differ ($P<.05$).

crosses, 1.34 lb/day for Simmental-Angus and Brown Swiss-Angus cows, 1.28 lb/day for Hereford-Angus and Brown Swiss-Hereford cows and 1.24 lb/day for Simmental-Hereford cows during the 365-day total period. Averaged over all crossbred groups, cows consumed 47 percent more daily TDN per 100 lb body weight during lactation than during non-lactation. Excluding the Hereford-Angus group, Angus crosses consumed, on the average, 6.1, 4.8 and 5.8 percent more daily TDN per 100 lb cow weight than Hereford crosses for the dry, lactating and 365-day total periods, respectively.

Various productivity and efficiency traits of the drylot cows and their three-breed cross calves are presented in Table 3. Productivity comparisons of these crossbred groups based on evaluation of the entire herd (range and drylot cows) have been previously reported by Belcher et al. (1978), Frahm et al. (1979), Frahm et al. (1981) and Marshall et al. (1981).

Birth weights were heaviest for calves from Brown Swiss-Hereford and Simmental-Angus cows (averaged 94.5 lb) followed by calves from Simmental-Hereford, Brown Swiss-Angus and Hereford-Angus cows (averaged 84.5 lb). The lightest calves at birth were produced by Jersey crosses (averaged 74.9 lb).

Twenty-four hour milk yield averaged 14.2 lb/day over all crossbred cow groups. Milk yields were 1.8 and 2.1 lb/day higher for Brown Swiss-Angus cows than for Hereford-Angus and Simmental-Hereford cows, respectively. No other differences between breed groups were statistically significant.

The average 205-day weaning weight for all drylot calves was 444 lb. Cows in drylot generally produced calves that were lighter at weaning than calves produced on range, especially during the last 2 years of the study. Drylot calves produced by Jersey-Angus cows averaged 50 lb lighter at 205-days than calves of the other crossbred groups. This surprisingly low weaning weight is atypical for this breed group based on weaning weights obtained from calves produced by cows on range and reflects the relatively low birth weights and cow weights of the Jersey-Angus group. Although the means varied from 436 to 464 lb among other breed groups, the differences were not statistically significant.

Cow weights ranged from 1048 lb for Simmental-Angus cows to 762 lb for Jersey-Angus cows. Weights were intermediate for Hereford-Angus cows (1002 lb), Simmental-Hereford cows and Brown Swiss crosses (averaged 959 lb) and Jersey-Hereford cows (827 lb). Relative to other crossbred cow groups, weights of Hereford-Angus cows in drylot were heavier than the average of Hereford-Angus cows in the entire herd while the reverse situation occurred for Jersey-Angus cows.

Efficient production of weaned calves is critical to maximize profit in a commercial beef cow enterprise. Larger cows have higher feed requirements for body maintenance and thus need to produce larger calves to be as efficient as smaller cows. Three measures of cow efficiency are presented in Table 3. The ratio of 365-day TDN intake (of cow and calf) to calf weaning weight is a more direct and probably more useful measure of efficiency than the other two ratios. Pounds of TDN required to produce a pound of 205-day calf weight ranged from 9.9 for Jersey-Hereford cows to 11.0 for Simmental-Angus cows. The most efficient groups were Jersey-Hereford, Brown Swiss-Hereford and Simmental-Hereford (averaged 10.0 lb/lb) followed by Hereford-Angus and Brown Swiss-Angus (averaged 10.5 lb/lb). The least efficient groups were Jersey-Angus and Simmental-Angus (averaged 10.9 lb/lb). The Hereford crosses were consistently more efficient than the Angus crosses (10.0 vs 10.8 lb/lb excluding the Hereford-Angus group). The unusually low weaning weights of calves produced by Jersey-Angus cows in drylot may have caused the ratio of TDN intake to calf weaning weight to be higher than it might have been with a different sample of Jersey-Angus cows.

Table 3. Herd productivity traits and measures of efficiency

Crossbred cow group	No. cow-calf pairs	Birth wt (lb)	24-hour milk yield (lb)	205-day weaning wt (lb)	Average cow wt (lb)[1]	365-day TDN intake (lb) / calf wn wt (lb)	Calf wn wt (lb) / cow wt (lb)	Calf wn wt (lb) / cow metabolic wt (lb)
Hereford-Angus	15	82.2[cd]	13.8[b]	436[a]	1002[ab]	10.5[abc]	.440[c]	2.47[c]
Simmental-Angus	15	92.2[ab]	14.0[ab]	464[a]	1048[a]	11.0[a]	.446[bc]	2.53[bc]
Simmental-Hereford	15	86.0[bc]	13.5[b]	445[a]	961[b]	10.1[bc]	.465[bc]	2.58[abc]
Brown Swiss-Angus	15	85.2[bc]	15.6[a]	448[a]	958[b]	10.5[abc]	.475[bc]	2.63[abc]
Brown Swiss-Hereford	15	96.8[a]	14.1[ab]	464[a]	958[b]	10.0[bc]	.488[ab]	2.70[ab]
Jersey-Angus	15	73.3[e]	14.2[ab]	401[b]	762[d]	10.8[ab]	.527[a]	2.76[a]
Jersey-Hereford	15	76.4[de]	14.2[ab]	447[a]	827[c]	9.9[c]	.529[a]	2.83[a]
Total or average	105	85.6	14.2	444	931	10.4	.481	2.64

[1]Average of eight monthly weights (March through October).

[abcde]Means in the same column not sharing at least one common superscript are significantly different at the .05 probability level.

Another measure of cow efficiency is the ratio of calf weaning weight to cow weight. On this basis, Jersey crosses were most efficient, weaning 53 percent of their body weight, followed by Simmental crosses and Brown Swiss-Angus cows (averaged 46 percent) and Hereford-Angus cows (44 percent).

Feed requirements for maintenance of a cow are dependent upon the metabolic size of the animal, which can be estimated as the cow's weight taken to the 0.75 power. Differences in feed requirements should be estimated more accurately when based on metabolic cow weight. Thus, the ratio of calf weaning weight to cow metabolic weight was calculated as a third estimate of efficiency. On this basis, rankings of crossbred cow groups were the same as when calculated based on cow weight.

These data suggest important differences in feed requirements, herd productivity and efficiency of feed conversion to calf weaning weight among the various crossbred cow groups involved in this study. While the differences reported in this study are important, reproductive performance must also be considered to evaluate net efficiency of weaned calf production.

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Growth and Carcass Performance of Calves Sired by Bulls from Hereford and Angus Lines Selected for Weaning or Yearling Weight

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Story in Brief

Growth and carcass performance of calves sired by bulls chosen from two lines selected for weaning weight (WWL) and yearling weight (YWL), respectively, were evaluated in both Hereford and Angus cattle. The final group of selected Hereford bulls (top three bulls from each line born in 1976 and 1977) in a 15-yr selection project were mated randomly to a group of Angus cows to produce 83 crossbred calves in 1979. The final group of selected Angus bulls (top four bulls per line born in 1978) were mated randomly to a group of Angus cows to produce 98 straightbred calves in 1980.

Sire lines were compared separately for each breed. In both breeds differences between the WWL and YWL sires were small and generally nonsignificant. Within the Hereford breed, calves from WWL sires were 2.8 lb lighter at birth, gained .08 lb/day faster preweaning ($P<.10$), were 17 lb heavier at weaning, gained .13 lb/day slower postweaning and thus were 14 lb lighter in yearling weight than calves from YWL sires. WWL sired calves were in the feedlot 7 fewer days, required .11 lb more feed per pound of gain, were 38 lb lighter ($P<.10$) and 9 days younger at slaughter and thus were 32 lb lighter ($P<.05$) in carcass weight. Calves from WWL sires tended to mature earlier as indicated by a higher marbling score (5.2 vs 4.7 units, $P<.05$) and higher carcass grade (10.1 vs 9.6 units, $P<.10$) even though they were lighter and younger at slaughter.

Within the Angus breed, calves sired by WWL bulls were 1.6 lb heavier at birth, gained equally fast from birth to weaning, were 3 lb heavier at weaning and 10 lb lighter in yearling weight. Calves sired by bulls from WWL gained .17 lb/day ($P<.05$) slower in the feedlot, were in the feedlot 9 more days ($P<.05$), were 9 days ($P<.10$) older but 14 lb lighter at slaughter and had 11 lb lighter carcass. Also, calves sired by WWL bulls had .08 in. ($P<.01$) more fat over the rib eye. All other carcass traits were similar for both lines.

These data indicate that selection for weaning weight or yearling weight has resulted in similar responses in total growth performance and carcass merit.

Introduction

Selection is the primary force by which breeders can change the genetic composition of their herds. This study was part of a long-term selection project at the Oklahoma Agricultural Research Station designed to evaluate the effectiveness of selection for increased weaning weight and yearling weight. The purpose of this study was to compare growth and carcass performance of calves sired by bulls from two lines selected for weaning weight and yearling weight, respectively, in both Angus and Hereford cattle. Differences between calves sired by bulls selected for weaning weight and bulls selected for yearling weight in each breed would indicate if selection for weaning weight gives different responses than selection for yearling weight.

Materials and Methods

The data utilized in this study was collected in 1979 and 1980 for the Hereford and Angus sired calves, respectively, as a portion of a beef cattle selection project. In both Hereford and Angus one line was selected for increased weaning weight and one line for increased yearling weight during the 15-yr period, 1964 through 1979. The final group of selected Hereford and Angus bulls from this project sired calves utilized in this study. In the two Hereford lines the top three bulls per line were selected in 1976 and 1977 and randomly mated to a group of Angus cows to produce 83 crossbred calves in 1979. In the two Angus lines the top four bulls per line were selected in 1978 and mated to Angus cows to produce 98 straightbred calves in 1980.

Managerial procedures were similar in both breeds. Cows were managed on native and bermudagrass pastures at the Southwestern Livestock and Forage Research Station at El Reno. Calves were born from early February through April, and birth weights were recorded within 24 hours after birth. Calves were allowed to run with their dams on pasture and received no creep feed. After weaning at an average age of 205 days, all calves were placed in the feedlot and fed ad libitum a corn based finishing ration. Calves were individually removed from the feedlot and slaughtered when an anticipated low choice carcass grade was reached. Growth and carcass traits were analyzed separately for each breed by least squares procedures.

Results and Discussion

Calves sired by selected Hereford bulls

Performance through a year of age of calves sired by selected WWL and YWL Hereford bulls is presented in Table 1. Generally, differences between sire lines were small and nonsignificant. WWL sired calves were 2.8 pounds lighter at birth than YWL sired calves but gained .08 pounds per day ($P<.10$) faster from birth to weaning and were 17 pounds heavier at 205 days. After weaning, however, calves sired by WWL bulls gained more slowly (2.29 vs 2.42 lb) and were lighter at 365 days (837 vs 851 lb) than calves sired by YWL bulls.

Table 1. Performance through a year of age of calves sired by selected weaning weight line and yearling weight line Hereford bulls

Trait	Sire line		Difference
	WWL	YWL	(WWL-YWL)
Number of calves	41	42	
Birth weight (lb)	77.3	80.1	−2.8
Preweaning ADG (lb/day)	1.91	1.83	.08[+]
205-day weaning weight (lb)	469	452	17
Weaning to yearling ADG (lb/day)	2.29	2.42	−.13
365-day weight (lb)	837	851	−14

[+]Difference significant at the .10 probability level.

Feedlot and carcass performance of calves sired by selected WWL and YWL Hereford bulls is summarized in Table 2. In general, differences between progeny of sires from the two selection lines were small and nonsignificant. WWL sired calves were heavier going into the feedlot (467 vs 552 lb), were in the feedlot fewer days (212 vs 219 days) but required .11 lb more feed per pound of gain than YWL sired calves. Final feedlot weight was lighter (-38 lb, P<.10) for calves of WWL sires, and, as a result, hot carcass weight was also lighter (-32 lb, P<.05) than calves of YWL sires. Calves sired by WWL bulls were in the feedlot fewer days (212 vs 219 days) and were younger at slaughter (415 vs 424 days) than calves by YWL bulls. Differences in carcass traits between progeny of the two sire lines were small and generally nonsignificant although calves by WWL sires had higher marbling scores (+.5 units, P<.05) and higher carcass grades (+.5 units, P<.10) than calves by YWL sires.

Table 2. Feedlot and carcass performance of calves sired by selected weaning weight line and yearling weight line Hereford bulls

	Sire line		Difference
Trait	WWL	YWL	WWL-YWL)
Number of calves	41	42	
Initial weight on test (lb)	467	552	15
Final weight (lb)	925	963	−38[+]
ADG on test (lb/day)	2.19	2.31	−.12
Days on feed	212	219	−7
Feed efficiency (lb feed/lb gain)	7.35	7.24	.11
Age at slaughter (days)	415	424	−9
Hot carcass weight (lb)	585	617	−32*
Average fat thickness (in)	.76	.75	−.01
KHP fat (%)	2.9	3.1	−.2
Marbling score[a]	5.2	4.7	−.5*
Carcass grade[b]	10.1	9.6	.5[+]
Rib eye area (sq in)	11.0	11.1	−.1
Carcass cutability (%)	49.1	49.1	0

* Difference significant at the .05 probability level.
[+]Difference significant at the .10 probability level.
[a] Marbling score: 4 slight, 5 = small.
[b] Carcass grade: 9 = high good, 10 = low choice.

Calves sired by selected Angus bulls

Performance through a year of age of calves sired by selected WWL and YWL Angus bulls is presented in Table 3. Although differences between WWL and YWL were not significant, calves sired by WWL bulls were slightly heavier at birth (69.7 vs 68.1 lb), gained equally fast from birth to weaning and were similar at weaning (383 vs 380 lb). Weaning to yearling ADG and yearling weight were slightly lower for calves from WWL bulls (2.55 vs 2.62 lb/day and 729 vs 802 lb, respectively).

Feedlot and carcass performance of calves sired by selected WWL and YWL Angus bulls is summarized in Table 4. Calves from the two sire lines had similar weights upon entering the feedlot (398 vs 397 lb for WWL and YWL sired calves, respectively), but WWL sired calves gained more slowly in the feedlot (2.46 vs 2.63 lb/day), were in the feedlot longer (228 vs 219 days, P<.05) and were older (442 vs 433 days) than YWL sired calves. Also, WWL sired calves were lighter at

Table 3. Performance through a year of age of calves sired by selected weaning weight line and yearling weight line Angus bulls

Trait	Sire line WWL	Sire line YWL	Difference[a] (WWL-YWL)
Number of calves	51	47	
Birth weight (lb)	69.7	68.1	1.6
Preweaning ADG (lb/day)	1.53	1.52	.01
205-day weaning weight (lb)	383	380	3
Weaning to yearling ADG (lb/day)	2.55	2.62	−.07
365-day weight (lb)	792	802	−10

[a]None of the differences were significant.

Table 4. Feedlot and carcass performance of calves sired by selected weaning weight line and yearling weight line Angus bulls

Trait	Sire line WWL	Sire line YWL	Difference (WWL-YWL)
Number of calves	51	47	
Initial weight on test (lb)	389	397	1
Final weight (lb)	952	966	−14
ADG on test (lb/day)	2.46	2.63	−.17*
Days on feed	228	219	9*
Feed efficiency (lb feed/lb gain)	6.9	7.1	−.2
Age at slaughter (days)	442	433	9[+]
Hot carcass weight (lb)	602	613	−11
Average fat thickness (in)	.80	.88	.08**
KHP fat (%)	3.1	3.3	−.20
Marbling score[a]	5.0	5.2	−.20
Carcass grade[b]	10.0	10.2	−.20
Rib eye area (sq in)	10.3	10.4	−.10
Carcass cutability (%)	48.3	47.6	−.70

** Difference significant at the .01 probability level.
* Difference significant at the .05 probability level.
[+] Difference significant at the .10 probability level.
[a] Marbling score: 5 = small.
[b] Carcass grade: 10 = low choice.

slaughter (952 vs 966 lb) and had a lighter carcass (602 vs 613 lb) than YWL sired calves. Calves sired by WWL bulls had less fat over the rib eye (.80 vs .88 in, P<.01), less KHP fat (3.1 vs 3.3 percent) and higher carcass cutability (48.3 vs 47.6 percent) than calves sired by YWL bulls. Sire line differences for other carcass traits were small and nonsignificant.

Summary

In summary, these data indicate that selection for weaning weight or yearling weight has resulted in similar response in growth and carcass traits in both Hereford and Angus cattle. Thus, the breeder has the option of using either weaning weight or yearling weight or a combination of the two and can expect similar selection responses. Since weaning weight can be selected for earlier in life, selection for weaning weight may be more economical than selection for yearling weight.

Direct and Correlated Responses to Selection for Increased Weaning and Yearling Weights in Hereford Cattle I. Measurement of Selection Applied

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Story in Brief

The objective of this portion of the study was to quantify selection pressure in two lines of Hereford cattle selected for weaning weight (WWL) and yearling weight (YWL) over a 15-year period from 1964 to 1978. An Angus control line (CL) was also maintained to monitor environmental fluctuations. The primary data were collected on 1273 Hereford calves and 723 Angus calves. Each line consisted of 50 cows with two bulls and 10 heifers being selected each year. Selection was for heaviest weaning weight (WW) in the WWL, and heaviest yearling weight (YW) at 365 days for bulls and 425 days for heifers in the YWL. Over the 15-year period, 3.22 generations of selection had been practiced in the WWL and YWL. Cumulative selection differentials (CSD), a measure of applied selection pressure, in 1978 were 161 lb ($3.42\sigma_p$, pheontypic standard deviation) for WW in the WWL and 279 lb ($3.61\sigma_p$) for YW in the YWL. Rates of accumulation for these CSDs were 12.11 ± .53 lb/year and 21.42 ± .70 lb/year, respectively. Correlated CSDs for YW in the WWL and WW in YWL were 75 percent and 87 percent, respectively, as effective as direct selection. Selected bulls accounted for 74 percent and 83 percent of the selection pressure for WW in the WWL and YW in the YWL, respectively. The proportion of potential selection pressure achieved for WW in the WWL were 88 percent for sires and 70 percent for dams while the corresponding values in the YWL for YW were 100 percent and 43 percent.

Introduction

Improvement of the genetic composition of a cattle herd can essentially be achieved only through selection of individuals genetically superior for economically important traits. Most producers today put considerable emphasis on growth rate of cattle. We need fast growing, efficient cattle from birth to slaughter — cattle that will produce heavy weaning weights for cow calf producers; efficient gains for stocker operators and feedlots; heavy, lean, high yielding carcasses for packers; and tasty, tender products for the consumer.

Many selection studies have been conducted with laboratory species that demonstrate selecting for increased growth rate can be effective, but very few experiments have been designed to evaluate selection for growth rate in livestock species, especially cattle. Information is needed to demonstrate how rapid improvement can be made in certain traits along with an evaluation of how this selection also affects other economically important traits.

This study was started in the early sixties, but this article will focus on only one objective of the study: to quantify selection pressure achieved in a long-term study involving selection for growth in beef cattle.

Materials and Methods

Data used in this study were collected from 1964 to 1979 as part of the beef cattle breeding project at the Oklahoma Agricultural Experiment Station. Performance records of 1273 purebred Hereford calves, 239 selected Hereford cows and 57 selected Hereford bulls were analyzed. In addition, records of 723 purebred Angus calves, 126 Angus cows and 31 Angus bulls were also analyzed from an unselected control line (CL). Ideally, a control line has no selection pressure put on it for any trait, so the only fluctuations in average animal performance should be due to the management, environment or other nongenetic year-to-year variation. Comparisons between the selection lines and control line should give accurate measures of genetic trends realized by selection.

Foundation animals for the herd were assembled in 1960, and Hereford cows were randomly alloted to one of the two lines: (1) increased weaning weight line (WWL) and (2) increased yearling weight line (YWL). All lines were closed by 1967. An animal was considered "selected" if it produced at least one offspring in the selection line. Each year two bulls were selected from each line based upon the respective selection criteria, used for two years, then discarded. Thirteen top ranking heifers were retained from WWL and YWL each year and bred as yearlings. The 10 highest ranking pregnant heifers were selected to replace cows culled in each line. Fifty breeding age females were maintained per line.

Prior to 1969 the Angus line had been a progeny test line with selection based on increasing yearling weight. The decision was made in 1969 to convert this line to an unselected control line to monitor yearly environmental fluctuations. Up to this time only two calf crops had been sired by progeny tested bulls, so very little selection had actually occurred.

All lines were managed as a single herd except during breeding season, and every effort was made to insure as uniform an environment as possible for all cattle. Calves were born from early February through April of each year, and actual calf weights were recorded within 24 hours of birth. Calves were maintained with their dams on native and bermuda grass pastures without creep feed until weaning at an average age of 205 days. Following a 2-week warm up period after weaning, all bull calves were put on full feed for a 140-day gain test. Heifers were grazed out on wheat pasture, supplemented with prairie hay, alfalfa and concentrate to gain from .75 to 1.00 lb/day, and long yearling weights were taken at an average age of 425 days.

Complete performance records were collected on each calf through 365 days or 425 days for bulls and heifers, respectively. The following trait records were used in this study; birth weight (BW), preweaning average daily gain (WADG), weaning weight (WW), weaning grade (WG), weaning condition score (WC), postweaning average daily gain (YADG), yearling weight (YW), yearling grade (YG) and yearling condition score (YC).

Results and Discussion

Generations of selection

The first selections were made in 1964, and over the following 15-year period both WWL and YWL had undergone 3.22 generations of selection, while the CL was similiar, involving 3.21 generations by the time the 1978 calf crop was produced. Interpretation of selection intensity and response to selection was easier since all lines were at the same state of selection. The generations of selection also point out that due to the long generation interval in cattle, it takes many years to substantially increase the frequencies of beneficial genes in a cattle herd through selection.

Cumulative selection applied

The average cumulative selection differential (CSD) for a trait measures the total amount of selection pressure applied since the beginning of the selection program in producing calves born in a given year. The total average cumulative selection differentials for each trait realized by the 1978 calf crop are given in Tables 1 and 2 for the WWL and YWL, respectively. These are presented as

Table 1. Cumulative selection differentials for sires (ΔS), dams (ΔD) and parent average (ΔM) in WWL

		Average cumulative selection differential (1978)		
Trait	Type of CSD	Lb	Standard measure σ_p	Regression on year
Birth weight (lb)	ΔS	17.96	2.13	
	ΔD	10.14	1.17	
	ΔM	14.05	1.65	1.04 ± .08
Preweaning ADG (lb/day)	ΔS	.93	4.23	
	ΔD	.50	2.44	
	ΔM	.72	3.35	.05 ± .00
Weaning weight (lb)	ΔS	209.22	4.32	
	ΔD	113.63	2.51	
	ΔM	161.42	3.42	12.11 ± .53
Weaning grade[a]	ΔS	2.60	3.07	
	ΔD	1.35	1.68	
	ΔM	1.98	2.38	.15 ± .01
Weaning condition[b]	ΔS	1.53	2.01	
	ΔD	1.26	1.68	
	ΔM	1.39	1.85	.11 ± .00
Yearling weight (lb)	ΔS	250.47	3.28	
	ΔD	146.00	2.12	
	ΔM	198.19	2.71	15.94 ± .84
Postweaning ADG (lb/day)	ΔS	.27	.74	
	ΔD	.24	.77	
	ΔM	.26	.76	.03 ± .00
Yearling grade[a]	ΔS	2.30	3.10	
	ΔD	2.04	1.81	
	ΔM	2.17	2.46	.18 ± .02
Yearling condition[b]	ΔS	.80	1.28	
	ΔD	.84	1.37	
	ΔM	.82	1.33	.07 ± .01

[a]17-point scoring system where 13 = average choice, 14 = high choice, etc.
[b]17-point scoring system where 13 = average fat cover.

amount due to sires (ΔS), amount due to dams (ΔD) and parent average (ΔM). Also, the CSDs are reported in standard measure so comparisons can be made between various traits in amount of selection pressure realized even though the actual trait measurements are in various units (i.e., lb vs lb/day). In addition, ΔM was regressed on years to give an estimate of the average yearly selection pressure on each trait during the 15-year period.

Selection for WW in WWL and YW in YWL progressed at fairly regular rates throughout the study. In 1978, ΔM was 161 lb ($3.42\sigma_p$-phenotypic standard deviations) for WW in the WWL and had accumulated at a rate of 12.11 ± .53 lb per year, while corresponding values for YW in the YWL were 279 lb ($3.61\sigma_p$) and 21.42 ± .53 lb per year, while corresponding values for YW in the YWL were 279 lb ($3.61\sigma_p$) and 21.42 ± .70 lb per year. These CSDs occurred during 3.22

Table 2. Cumulative selection differentials for sires (ΔS), dams (ΔD) and parent averages (ΔM) in YWL

Trait	Type of CSD	Average cumulative selection differential (1978) Lb	Standard measure σ_p	Regression on year
Birth weight	ΔS	21.80	2.52	
(lb)	ΔD	10.48	1.23	
	ΔM	16.14	1.88	1.07 ± .07
Preweaning ADG	ΔS	.80	3.54	
(lb/day)	ΔD	.44	2.07	
	ΔM	.62	2.81	.05 ± .00
Weaning weight	ΔS	185.02	3.76	
(lb)	ΔD	101.78	2.20	
	ΔM	143.40	2.98	10.76 ± .47
Weaning grade[a]	ΔS	2.30	2.74	
	ΔD	1.18	1.45	
	ΔM	1.74	2.09	.13 ± .01
Weaning condition[b]	ΔS	1.37	1.87	
	ΔD	.82	1.10	
	ΔM	1.10	1.49	.07 ± .00
Yearling weight	ΔS	362.84	4.59	
(lb)	ΔD	194.98	2.63	
	ΔM	278.91	3.61	21.42 ± .70
Postweaning ADG	ΔS	1.19	3.47	
(lb/day)	ΔD	.59	1.89	
	ΔM	.89	2.68	.07 ± .00
Yearling grade[a]	ΔS	1.27	3.03	
	ΔD	1.79	1.54	
	ΔM	1.60	2.29	.12 ± .01
Yearling condition[b]	ΔS	1.60	2.53	
	ΔD	1.14	1.64	
	ΔM	1.37	2.08	.11 ± .01

[a]17-point scoring system where 13 = average choice, 14 = high choice, etc.
[b]17-point scoring system where 13 = average fat cover.

generations of selection, which means that selection pressure occurred at the rate of 1.06 and $1.12\sigma_p$ per generation for WW and YW, respectively.

Although selection was for WW in the WWL and YW in the YWL, other correlated traits also experienced selection pressure because genes that affect WW also affect other traits. Correlated CSDs in the WWL were 14 lb, .72 lb/day, 198 lb, .26 lb/day, 1.98 units, 1.39 units, 2.17 units and .82 units for BW, WADG, YW, YADG, WG, WC, YG and YC, respectively. Comparisons of the various traits in standard measure CSDs indicate most selection pressure occurred on WW in the WWL followed by WADG. It is of primary interest to evaluate the correlated CSD for YW in the WWL because if appreciable selection can be applied for YW by selecting for WW, considerable savings in time and money can be realized by selecting animals at weaning instead of waiting until calves are a year of age. YW underwent $2.71\sigma_p$ of selection pressure in the WWL or 75 percent as much pressure as direct selection for YW in the YWL. This suggests that animals selected for heaviest WW are also above average for YW.

In the YWL, correlated CSDs were 161 lb, .62 lb/day, 143 lb, .89 lb/day, 1.74 units, 1.10 units, 1.79 units and 1.37 units for BW, WADG, WW, WG, WC, YG and YC, respectively. Most selection pressure occurred for YW ($3.61\sigma_p$) with considerable correlated pressure in WW ($2.98\sigma_p$); therefore, selecting for YW alone will also tend to increase WW. Since WW and YW are both traits that are influenced by numerous components, it is important to evaluate correlated selection intensity. BW is of specific concern since heavy BWs have been associated with calving difficulty. CSD for BW in both lines was positive, increasing 1.06 lb/year or approximately accumulating at 50 percent of the selection pressure exerted on primary selection traits for each line.

Concern has also been expressed by some in the industry that selection for performance will result in the deterioration of conformation unless conformation is included in the selection program. Another concern is that selection for increased weight will increase fatness of animals at a given age. Weaning conformation (WG) and yearling conformation (YG) both showed considerable positive selection pressure in both lines. Correlated emphasis on fatness, although positive, was much smaller.

Table 3 presents CDSs for the control line. CSDs accumulated in a sporadic manner for most traits with most of it occurring in the first few years prior to the conversion of the line to a control line. Although positive CSDs were realized for all traits, they were generally small with only 13.0 lb ($.36\sigma_p$) and 42.1 lb ($.70\sigma_p$) CSD for WW and YW, respectively, in the 1978 calf crop.

Cumulated selection differentials are the result of sire and dam selection over the long term. In this experiment the proportion of the total selection pressure attributable to sires was 74 percent for WW in the WWL and 83 percent for YW in the YWL. Sire selection pressure is usually greater than dam selection because of the large proportion of heifers that must be saved for replacement. Replacement of females in the lines was somewhat faster than replacement rates in most commerical herds; thus, in most practical situations the relative contribution of bull selection to genetic improvement of the herd would be expected to be even larger than experienced in this study.

Maximum potential selection

The proportion of potential selection realized can be evaluated by comparing the actual vs potential selection differentials for the traits of primary selection in each line. Selection differentials per generation were calculated for the selected parents of calves born in the study and for the actual top bulls and heifers available for selection in each line according to line criteria. In the WWL, 88 percent and 70 percent of potential selection was realized in WW for sires and dams, respectively, while corresponding values in the YWL for YW were 100 percent and 43 percent respectively. Selection criteria for bulls in the YWL was followed exactly; however, heifer selection in the YWL was quite a bit poorer than in the WWL. In heifers, failure to conceive was probably the largest reason for loss of selection pressure, with other unsoundnesses also contributing.

Table 3. Cumulative selection differentials for sires (ΔS), dams (ΔD) and parent averages (ΔM) in CL

		Average cumulative selection differential (1978)		
Trait	Type of CSD	Lb	Standard measure σ_p	Regression on year
Birth weight	ΔS	−.42	−.03	
(lb)	ΔD	1.57	.19	
	ΔM	.57	.08	.70 ± .06
Preweaning ADG	ΔS	.05	.30	
(lb/day)	ΔD	.07	.40	
	ΔM	.06	.35	.08 ± .03
Weaning weight	ΔS	10.08	.30	
(lb)	ΔD	15.91	.42	
	ΔM	12.99	.36	10.92 ± .72
Weaning grade[a]	ΔS	.29	.48	
	ΔD	.21	.34	
	ΔM	.25	.41	.10 ± .01
Weaning condition[b]	ΔS	.22	.25	
	ΔD	.14	.06	
	ΔM	.18	.16	.07 ± .01
Yearling weight	ΔS	36.81	.56	
(lb)	ΔD	47.29	.83	
	ΔM	42.50	.70	15.37 ± 1.28
Postweaning ADG	ΔS	.23	.99	
(lb/day)	ΔD	.22	.83	
	ΔM	.23	.93	.17 ± .15
Yearling grade[a]	ΔS	.42	.53	
	ΔD	.78	1.06	
	ΔM	.60	.80	.08 ± .01
Yearling conditon[b]	ΔS	.60	.29	
	ΔD	.29	.97	
	ΔM	.47	.63	.03 ± .01

[a]17-point scoring system where 13 = average choice, 14 = high choice, etc.
[b]17-point scoring system where 13 = average fat cover.

Direct and Correlated Responses to Selection for Increased Weaning and Yearling Weights in Hereford Cattle II. Evaluation of Response

C.G. Chenette, R.R. Frahm, J.V. Whiteman and D.S. Buchanan

Story in Brief

This portion of the study dealt with estimating phenotypic and genetic response to selection for increased weaning (WWL) and yearling weight (YWL) in two lines of Hereford cattle from 1964 to 1978. An Angus control line was also maintained to monitor year-to-year environmental variations. Data was collected on a total of 1273 Hereford calves and 723 Angus calves. Each line maintained 50 cows, with two bulls and 10 heifers selected each year. The basis for selection was heaviest weaning weight (WW) in the WWL and heaviest 365-day weight for bulls and 425-day weight for heifers in the YWL. Bulls and heifers in the control line were selected to have as close to zero selection differentials for both WW and YW as possible.

Negative phenotypic trends for WW and YW were observed in all three lines, indicating a negative or degenerating environmental trend. However, a larger negative phenotypic trend in the control line indicated genetic progress had occurred in the selection lines. Genetic change estimated as deviations of WWL vs control line showed direct response for WW of 3.06 lb/year for bulls and 1.68 lb/year for heifers. Correlated response for WW in the YWL was 2.16 lb/year for bulls and 1.94 lb/year for heifers. The direct response for YW in the YWL was 3.27 lb/year and 2.67 lb/year for bulls and heifers, respectively, while as a correlated response in the WWL, it was considerably lower in bulls (1.50 lb/year) and similar in heifers (2.23 lb/year). Realized heritabilities were .20 for WW and .14 for YW. All genetic responses and realized heritabilities were probably underestimated as some selection pressure was indicated in the control line for WW and YW. Positive correlated genetic changes occurred in all other traits measured in both selection lines.

Introduction

Producers often place considerable emphasis on growth rate in order to improve their efficiency of beef production. The alterations that selection produces in the genetic makeup of a herd or population are difficult to see or directly measure, but these changes are cumulative over generations. Changes made by selection often are difficult to evaluate as they often are coupled with the impact of improved management practices as well as large environmental variations which influence levels of performance.

Few studies have dealt with the long-term effects of selection on a cattle population although information is needed to quantify how much improvement can be made in economically important traits through selection. The cattle selection research at OSU was initiated in the early sixties with the objectives of: (1) estimating direct response to selection for weaning and yearling weights in Hereford cattle and (2) estimating correlated responses in other economically important traits. Hopefully, information gained from this study will aid the industry in developing selection programs aimed at choosing cattle genetically superior for economically important traits.

Materials and Methods

Performance records of 1273 purebred Hereford calves, 239 selected Hereford cows and 57 selected Hereford bulls were analyzed for this study. These records were collected over the 15-year period from 1964 to 1979 at the Oklahoma Agricultural Experiment Station. Records of 723 purebred Angus calves, 126 Angus cows and 31 Angus bulls from an unselected control line were also analyzed.

Two Hereford lines, one selected for increased weaning weight (WWL) and one for increased yearling weight (YWL), and the unselected Angus control line (CL) were each maintained as 50 cow lines. Each year, on the average, two bulls and 10 heifers were selected. An animal was considered "selected" if it produced at least one offspring in the selection line.

Prior to 1969 the Angus line had been maintained as a progeny test line with selection criteria based on increasing yearling weight. In 1969 the line was converted to a control line in which animals with selection differentials as near zero as possible for WW and YW were used as replacements. Up to this point only two calf crops had been sired by progeny tested bulls, so very little selection had been practiced.

Every effort was made to keep the environment similar for all lines. Cattle were pastured on native range typical of central Oklahoma during most of the year. Calves were born in the spring and remained with their dams until weaning at an average age of 205 days. Following weaning, bull calves were placed on a 140-day feedlot gain test after a 2-week warm up period. Heifers were placed on pasture gain tests, including wheat pasture when available, to gain from .75 to 1.00 lb/day, and long yearling weights were taken at an average of 425 days of age.

Complete performance records were collected on all calves. Birth weights (BW) were obtained within 24 hours of birth. In addition, preweaning average daily gain (WADG), 205-day adjusted weaning weight (WW), weaning grade (WG), weaning condition (WC), yearling weight (YW), postweaning average daily gain (YADG), yearling grade (YG) and yearling condition (YC) were all collected. YW was adjusted to 365 days for bulls and 425 days for heifers. WG and YG are both indicators of calf conformation or muscling degree while WC and YC are indicators of fatness.

Results and Discussion

Phenotypic trends

Annual phenotypic trends for each line are presented in Figures 1-3 for BW, WW and YW. Since the two Hereford lines were developed from a common foundation, they should not differ except for sampling error until 1966 when the first calves from selected parents were born. Differences between the Angus CL and Hereford selection lines until 1966 should be due mostly to breed differences. Since the CL was a progeny tested line until the 1970 calf crop, some selection pressure for growth had been applied, but from 1970 on, any increase in

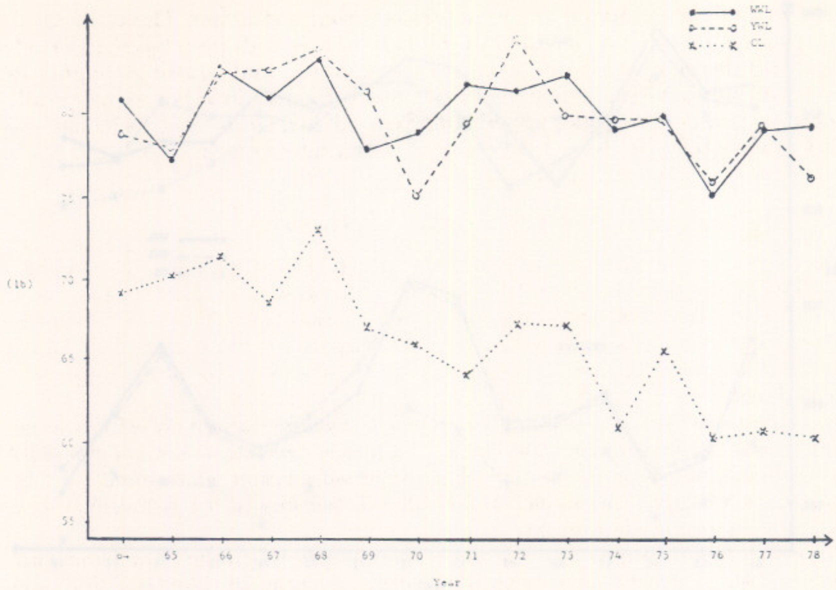

Figure 1. Annual phenotypic means for birthweight averaged over sex

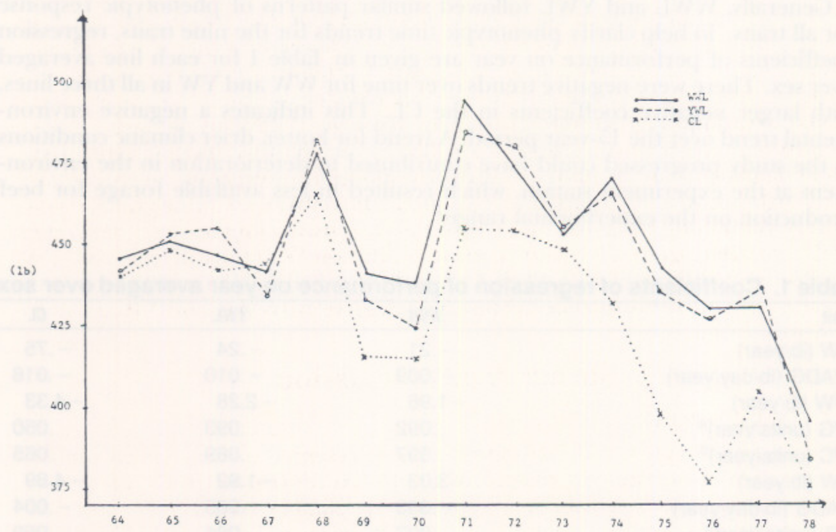

Figure 2. Annual phenotypic means for weaning weight averaged over sex

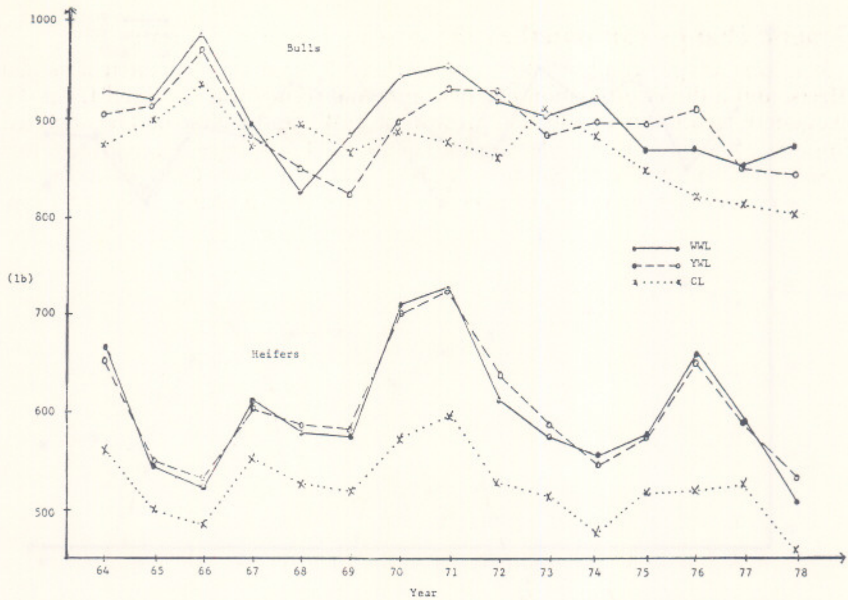

Figure 3. Annual phenotypic means for yearling weight for bulls and heifers

the differences between selection lines and CL should be due to genetic response to selection for increased weaning or yearling weights.

Generally, WWL and YWL followed similar patterns of phenotypic response for all traits. To help clarify phenotypic time trends for the nine traits, regression coefficients of performance on year are given in Table 1 for each line averaged over sex. There were negative trends over time for WW and YW in all three lines, with larger negative coefficients in the CL. This indicates a negative environmental trend over the 15-year period. A trend for hotter, drier climatic conditions as the study progressed could have contributed to deterioration in the environment at the experiment station, which resulted in less available forage for beef production on the experimental range.

Table 1. Coefficients of regression of performance on year averaged over sex

Trait	WWL	YWL	CL
BW (lb/year)	−.21	−.24	−.75
WADG (lb/day/year)	−.009	−.010	−.018
WW (lb/year)	−1.96	−2.28	−4.33
WG (units/year)[a]	.092	.093	.050
WC (units/year)[b]	.097	.089	.065
YW (lb/year)	−3.03	−1.92	−4.89
YADG (lb/day/year)	−.003	.003	−.004
YG (units/year)[a]	.097	.084	.059
YC (units/year)[b]	.057	.070	.066

[a]17-point scoring system where 13 = average choice, 14 = high choice, etc.
[b]17-point scoring system where 13 = average fat cover, etc.

Genetic change estimated as deviations for control line

Since phenotypic trends are the combined result of genetic and environmental effects, and a direct estimation of environmental trends was obtained from the CL, genetic trends due to selection pressure in WWL and YWL could be obtained simply by deviations of the selection lines from the CL. Figure 4 portrays annual genetic trends in WW averaged over sex for WWL and YWL. Genetically the two lines progressed at similar rates over time, improving until the 1977 calf crop.

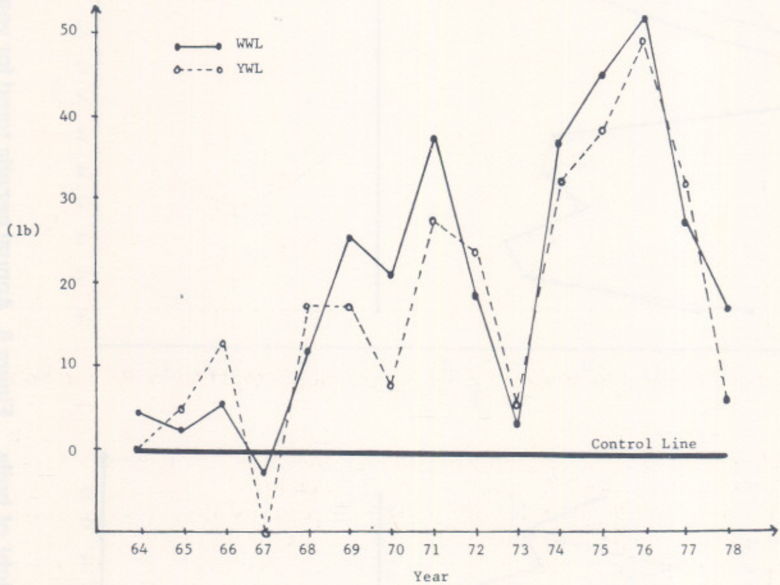

Figure 4. Annual genetic trend for weaning weight averaged over sex as deviations from control

Figures 5 and 6 represent genetic trends for YW of bulls and heifers, respectively, in WWL and YWL. Again the annual genetic means for both Hereford lines followed similar patterns; however, there was considerably more fluctuation in genetic trends of bulls than heifers.

Table 2 gives the genetic trends realized per year of bulls and heifers and averaged over sex for the nine traits of primary interest. Direct genetic response for WW in the WWL was estimated to be 3.06 lb/year in bulls and 1.68 lb/year in heifers for an average of 2.37 lb/year. Correlated response of WW when selecting for YW was 2.16 lb/year and 1.94 lb/year for bulls and heifers, respectively, averaging 2.05 lb/year. More genetic response in WW was realized by direct selection than indirect selection in bulls while the opposite was true for heifers. When considering YW, direct genetic response was 3.27 lb/year in bulls and 2.67 lb/year in heifers (average 2.97 lb/year) while correlated response was considerably lower in bulls (1.50 lb/year) and similar in heifers (2.23 lb/year).

Realized heritabilities based on genetic response and mean accumulated selection differentials were .20 for WW and .14 for YW. These realized heritabilities

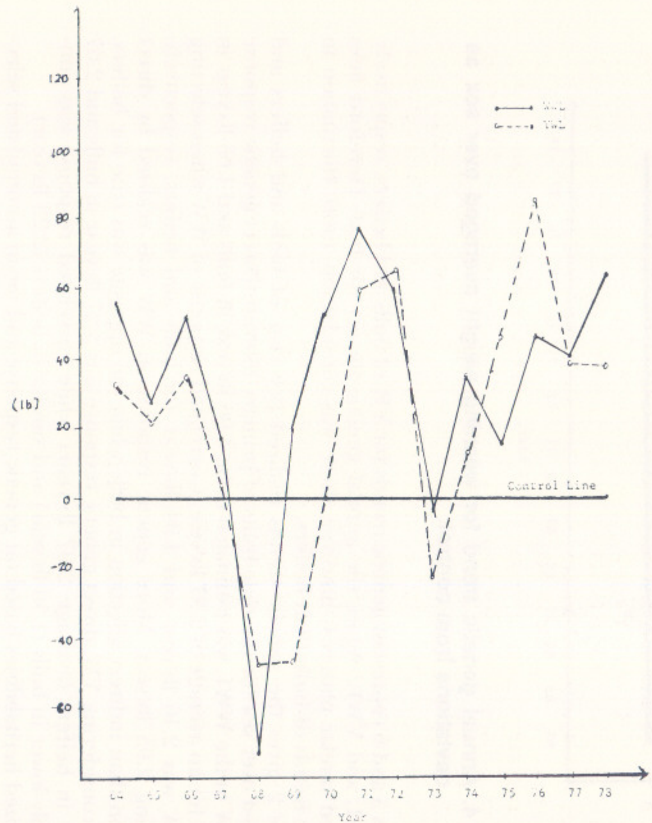

Figure 5. Annual genetic trend for yearling weight of bulls as deviations from the control

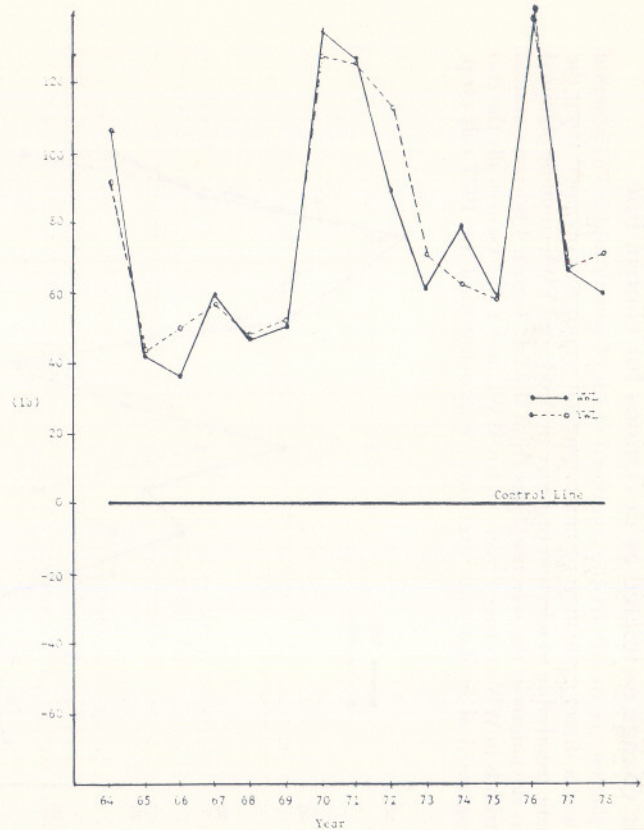

Figure 6. Annual genetic trend for yearling weight of heifers as deviations from the control

Table 2. Estimates of genetic trend per year from differences of the control line and selection lines

Trait	WWL			YWL		
	Bulls	Heifers	Average	Bulls	Heifers	Average
BW, lb	.58	.50	.54	.53	.49	.51
WADG, lb/day	.012	.006	.009	.008	.007	.008
WW, lb	3.06	1.68	2.37	2.16	1.94	2.05
WG[a]	.024	.059	.042	.021	.065	.043
WC[b]	.030	.035	.033	.014	.034	.024
YW, lb	1.50	2.23	1.86	3.27	2.67	2.97
YADG, lb/day	.002	.003	.003	.008	.004	.006
YG[a]	.031	.044	.038	.024	.025	.025
YC[b]	.001	−.019	−.009	.015	−.008	.004

[a]17-point scoring system where 13 = average choice, 14 = high choice, etc.
[b]17-point scoring system where 13 = average fat cover.

are probably underestimated as there was some selection pressure on the CL for WW and YW as previously discussed. Selection pressure realized in the CL would also tend to make the deviation for CL an underestimate of genetic trends in the selection lines.

Correlated genetic changes also occurred. BW increased in both lines by .54 and .51 lb/year for WWL and YWL, respectively. WADG also had positive correlated genetic change per year in both lines with bulls in the WWL increasing twice as much as heifers (.012 vs .006 lb per day per year). In the YWL, correlated WADG increase was similar in both sexes averaging .008 lb per day per year. This data indicates selection for WW or YW give similar effects on WADG. Correlated response for YADG was twice as large in YWL as in WWL (.006 vs .003 lb per day per year) indicating, unlike WADG, YW selection puts more emphasis on YADG than does WW selection. Also, correlated response in the YWL for bulls was twice the magnitude of response in heifers.

Other concerns of beef cattle producers are indirect responses in conformation and fatness when selecting for weight traits. Conformation or degree of muscling as a correlated response at weaning increased in both lines by a similar magnitude (.043 units/year). Correlated YG responses were greater in the WWL (.038 units/year) than the YWL (.025 units/year). Condition scores measure degree of finish at a particular weight. Correlated genetic changes in WC were similar in WWL bulls, WWL heifers and YWL heifers (average .033 units/year), while YWL bulls were lower (.014 units/year). Negative genetic changes occurred in YC for heifers of both lines (average −.013 units/year) with a positive change in YWL bulls (.015 units/year) and essentially no change in YC of WWL bulls. All correlated measures of response in conformation and condition were quite small, with more positive change occurring in degree of muscling than fatness, which is desirable from an industry viewpoint.

Performance of Swine Sired by High vs Low Indexing Hampshire Boars

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Story in Brief

Hampshire boars were purchased from test stations in pairs, with each pair including one high indexing boar and one low indexing boar. The index used included average daily gain, backfat and feed efficiency. Offspring of these boars were evaluated for postweaning performance and carcass traits to compare use of high vs low indexing boars. Barrow and gilt offspring of high indexing boars were faster growing ($P<.1$), had less backfat ($P<.1$) and were more efficient ($P<.1$). A sample of barrow offspring showed little advantage for either high or low indexing sires for carcass traits. These results indicate that high performing boars from test stations will sire pigs that perform better during the postweaning phase and will, therefore, improve the efficiency of production during that period.

Introduction

Selection is the practice of allowing only those animals that are superior to reproduce. It is the way that populations of animals are improved genetically. There are two primary ways that selection in swine is practiced. The first, and potentially the most important, is the on-farm testing program. The second is the boar test station. The function of a boar test station is to evaluate average daily gain, feed efficiency and backfat of boars from various sources in a common testing environment. Numerous research studies have shown that selection for these traits could be effective. These studies were conducted under rather rigid experimental conditions and did not include some aspects, such as varying pre-test nutrition, which the buyer of a test station boar would encounter. This study was initiated to compare the offspring of boars that performed well in a test station with offspring of boars that performed poorly.

Materials and Methods

The test station index recommended by the National Swine Improvement Federation is $I = 100 + 60 (G-\bar{G})-75 (F-\bar{F}) - 70 (B-\bar{B})$ where G is average daily gain, F is feed efficiency, B is backfat thickness and $\bar{G}$, $\bar{F}$ and $\bar{B}$ are the test group means for these three traits. The index is constructed in such a way that the average boar has an index of 100, and approximately 68 percent of the boars have an index between 75 and 125. Most test stations keep any boar with an index below 80 out of the sale.

Twelve Hampshire boars were purchased for each of two seasons from test stations which test boars in pens of three boars with the same sire. Boars were purchased in pairs, with each pair including one boar with an index over 120 and one boar with an index below 90. More than one pair of boars was purchased at a given sale on several occasions. Performance summaries of the purchased boars are shown in Table 1. There were 48 and 41 index units separating the high indexing and the low indexing boars for the two seasons, respectively. These differences were largely due to differences in average daily gain and feed efficiency.

The 12 boars were randomly mated to 100 crossbred gilts in each season of mating. Pigs were farrowed in a central farrowing barn, weaned at 42 days of age and put on test when they were approximately 63 days old. Test pens contained between 12 and 18 pigs (single sire groups as much as possible). They were fed a growing ration with 16 percent crude protein until the pen averaged 120 lb and then a 14 percent crude protein finishing ration until the end of the test. Pigs were weighed weekly and were removed from test when they exceeded 220 lb. An estimate of backfat thickness was obtained with an ultrasonic backfat probe when each pig was removed from the test. Average daily gain was calculated for each pig from the beginning of the test to the time when that pig reached 220 lb, and feed efficiency (lb feed/lb gain) was calculated for each pen.

One barrow was chosen at random from each litter for obtaining carcass data. These barrows were slaughtered at the OSU Meat Laboratory and length (first rib to tip of the aitchbone); backfat thickness (average of first rib, last lumbar vertebrae); loin eye area at the tenth rib; the weights of the ham, loin, shoulder and belly; and percent lean cuts (percent of the live weight) were obtained.

There were 790 barrows and gilts measured for average daily gain, feed efficiency and backfat and 127 barrows slaughtered for carcass data. Data were analyzed so that high vs low sired pigs could be compared with the effects of sex, season and breeding of the dam accounted for.

Table 1. Performance of Hampshire boars purchased from test stations

Season	Average daily gain lb/day	Feed efficiency lb feed/lb gain	Backfat in.	Index units
		High Indexing Boars		
Fall 1979	2.27	2.34	.73	131
Spring 1980	2.19	2.55	.69	128
		Low Indexing Boars		
Fall 1979	1.80	2.62	.74	83
Spring 1980	1.87	2.84	.71	87

Table 2. Performance of barrows and gilts sired by Hampshire boars purchased from test stations

Line of Sire	Number of offspring	Average daily gain lb/day	Feed efficiency lb feed/lb gain	Backfat in.
High	409	1.400[a]	2.981[b]	.855[c]
Low	381	1.375	3.041	.901

[a,b,c] The high vs low comparison for these traits approaches statistical significance (P<.10).

Table 3. Carcass traits of barrows sired by Hampshire boars purchased from test stations

Line of Sire	Number of barrows	Length in.	Backfat in.	Loin eye area in^2	Ham wt lb	Loin wt lb	Shoulder wt lb	Belly wt lb	% lean cuts
High	59	31.09	1.034	4.270	33.25	28.66	28.06	17.42	39.27
Low	68	31.31	1.041	4.208	34.92	28.97	27.74	17.47	39.11

Results and Discussion

The performance of barrows and gilts sired by high and low indexing Hampshire boars is shown (Table 2). The pigs sired by the high indexing boars grew faster (P<.1), were more efficient (P<.1) and had less backfat (P<.1). The differences were not large but were similar to what was expected based on the heritabilities of the traits. The expected heritability of the index, based on heritabilities of .30, .35 and .50 for average daily gain, feed efficiency and backfat, respectively, was .36. The effective heritability based on the high vs low comparisons was .32. This difference between expected and effective heritability is unsurprising in view of the widely varying pre-test conditions the boars were exposed to.

Comparison of carcass traits of barrows sired by high vs low indexing Hampshire boars showed little advantage for either type of sire. Barrows sired by high indexing boars had less length and backfat; larger loin eye; less ham, loin and belly weight; and more shoulder weight as well as a higher proportion of lean cuts (percent of live weight) than those barrows sired by low indexing boars. None of these differences were statistically significant. These results suggest that fairly small changes in carcass composition would be expected when selection is for postweaning performance.

These results indicate that superior performing boars sire offspring that perform better during the postweaning period than boars with inferior performance. The differences were not large but were close to the expected differences, based on the heritabilities of the traits. Test stations should be a good source of boars for both commercial and seedstock producers interested in improving the performance of their pigs. They provide confidence that the boars were objectively appraised and were tested fairly. Use of high indexing boars from test stations should gradually improve the performance of a swine herd. Each small increment should be reasonably permanent, and they will accumulate with time.

A very important aspect of this study is that it provides an example of how testing will work when it is used on the farm by seedstock producers. Routine evaluation of growth rate and backfat of boars and gilts in seedstock herds will result in improved performance in the herds of their commercial customers if the information is used in making selection decisions.

Inbreeding and Relationship Among Prominent Hampshire Boars

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Story in Brief

A listing of leading Hampshire boars published by the Hampshire Swine Registry was used to evaluate the inbreeding of and the relationships among prominent Hampshire boars during the 1970's. The average inbreeding coefficient in the most recent listing was .103. The average relationship of these boars to the five most prominent boars of the 1970's ranged from .202 to .385. These results indicate that while the average inbreeding has remained relatively low, the average relationship is close to what would be expected from a half-sib or grandparent-grand offspring relationship. If the inbreeding and relationship coefficients of these 45 boars reflect levels in the Hampshire breed in general, then Hampshire breeders must remain cautious that the average inbreeding level does not increase much more and that such high relationships are maintained with only truly superior herdsires.

Introduction

Seedstock producers who are trying to develop a uniform set of breeding stock to sell frequently resort to inbreeding, which is the mating of individuals more closely related than the average of the breed. Extensive inbreeding results in a detrimental effect called inbreeding depression. This depression in performance can be substantial for traits associated with reproduction. However, inbreeding does promote uniformity and makes family development possible. The purpose of this study is to evaluate the level of inbreeding in some widely used Hampshire boars.

Materials and Methods

In the July issue of the *Hampshire Herdsman* the Hampshire Swine Registry publishes a list of the top herdsires of the breed. The list for 1981 included 45 boars. The ranking was based on the performance of descendents in breeding shows, barrow shows and test stations. More than 1200 total descendents of these 45 boars were used to establish the ranking for 1981.

Pedigrees were developed for these 45 boars which included at least three generations and, in most cases, up to seven or eight generations. These pedigrees were combined to form a composite pedigree of 203 individuals. This pedigree illustrated the relationships among all individuals and made the high degree of relationship among the leading boars apparent. The composite pedigree was used to identify all sires and dams of pigs, and this information was submitted to the Inbreeding Program that is part of the Statistical Analysis System. This program was used to calculate all inbreedings and relationships among the pigs in the composite pedigree.

The inbreeding coefficient is a measure of the probability that an individual received identical genes from each parent as a result of the parent's having ancestors in common. It is a function of how often the common ancestors appear in the pedigree and how closely they are related to the individual in question. The inbreeding is increased if the common ancestor is also inbred.

The coefficient of relationship is the probable proportion of genes that are the same for two individuals because of common ancestry. It is also a function of how closely the common ancestors are related to the two individuals in question and the number of times they appear in the pedigree.

Results and Discussion

The inbreeding coefficients of the 45 boars in the 1981 listing are shown in Table 1 along with their relationships to five prominent Hampshire boars of the 1970's. The averages and ranges of these coefficients are in Table 2 to provide a summary. The average inbreeding was .103, with a range of 0 to .297. The average is slightly less than the .125 which would be expected when a half-sib mating is made. It is not large enough to expect a large decline in performance due to inbreeding depression.

The highest inbreeding level for any of these boars was .297 for a boar named Willie whose parents were full sibs. The inbreeding for an individual resulting from mating non-inbred full-sibs is .25. The added inbreeding is a result of Willie's parents being inbred themselves.

Five of the boars in the composite pedigree were designated as the most prominent boars (Ugh, Roughneck, Gem, Oh and Eric). This was based upon the number of offspring they had that were also in the composite pedigree. These boars were prominent boars in the Hampshire breed throughout the 1970's. Ugh, Roughneck and Gem were still on the list of leading herdsires in 1981. Oh and Eric were both on the list during previous years. None of these boars have very high inbreeding coefficients. Ugh has the highest with a coefficient of .076.

The average relationship of these boars to the leading herdsires of 1981 is quite high. Ugh, Roughneck and Gem all have an average relationship to the other boars on the 1981 list over .34. Individual boars have relationships to these boars of near .60. An offspring-parent relationship is .50 if there are no other sources of relationship. Full sibs also have a relationship of .50. A half-sib or a grandparent-grand offspring relationship is .25. The average relationship of the leading herdsires of 1981 with Ugh, Roughneck and Gem is between those of full-sibs and half-sibs.

Oh and Eric were active herdsires in the early to mid-1970's. They appeared in the pedigrees of the sires on the 1981 list no closer than grandsire and frequently from four to eight generations back. Despite this, their average relationships to the boars on the 1981 list were .202 and .234 for Oh and Eric, respectively. These were nearly as high as if they were grandsires of all the boars. The magnitude of the relationships is due to the large number of times they appear in the pedigrees of many of the boars. An example of this was the relationship of Ark and Eric (.238). The nearest Eric appears in Ark's pedigree is five generations back but he is in the pedigree more than 10 times.

Linebreeding is a commonly used practice in pure breeds of livestock. The goal of linebreeding is to maximize relationship to a certain outstanding individual while keeping inbreeding at an acceptably low level. It appears that if Hampshire breeders have been trying to linebreed to some of these prominent boars they have been successful. The dangers of linebreeding are that inbreeding may

Table 1. Inbreeding coefficients of leading Hampshire boars of 1981 with their relationships to 5 prominent boars of the last decade

Sire	1981 Rank	Inbreeding	Relationship				
			Ugh	Roughneck	Gem	Oh	Eric
Roughneck	1	.075	.572	—	.567	.121	.350
Ugh	2	.076	—	.572	.370	.169	.262
Brad	3	.082	.397	.576	.347	.147	.320
Sap 14-3	4	.126	.606	.447	.452	.148	.243
Gem	5	.054	.370	.567	-	.190	.236
Dino	6	.093	.248	.335	.579	.398	.116
Ha Invoice	7	.170	.240	.340	.546	.238	.224
Willie 25-2	8	.297	.236	.324	.523	.315	.214
Ha Oliver	9	.121	.602	.433	.447	.252	.186
M 43-1	9	.133	.366	.611	.420	.105	.342
DL Bracer	11	.116	.276	.422	.432	.270	.173
Slim	12	.016	.322	.530	.315	.191	.180
Flex	13	.160	.628	.490	.456	.207	.240
Haymaker	14	.081	.254	.340	.571	.362	.175
Ark 11-2	15	.109	.422	.410	.351	.117	.238
Wildman	16	.039	.161	.208	.324	.277	.119
Gembo	17	.088	.276	.386	.575	.356	.232
Ha Noel	18	.133	.610	.459	.451	.129	.299
Capt Ugly	18	.054	.220	.356	.197	.072	.206
Bombshell	20	.145	.148	.172	.211	.309	.113
Pioneer	21	.134	.341	.451	.458	.203	.242
TWA	21	.123	.280	.393	.598	.169	.343
Bulldozer	23	.066	.211	.249	.353	.374	.117
Ha Trigger	24	.151	.622	.474	.453	.160	.241
Lumberjack	24	.128	.164	.214	.158	.072	.457
Izaac	26	.062	.174	.227	.348	.256	.177
Fred	27	.153	.479	.485	.378	.136	.247
Ha Acutron	28	.138	.468	.461	.331	.162	.235
DL Eric	28	.151	.353	.485	.392	.215	.212
PBR	30	.041	.342	.547	.352	.217	.178
DL Kevin	31	.165	.339	.527	.315	.161	.239
Clout	32	.173	.468	.448	.447	.163	.266
ELK	32	.080	.259	.399	.236	.086	.175
Waylon	32	.137	.613	.445	.458	.259	.213
Guts	32	.204	.210	.313	.358	.186	.207
Bigfoot	36	.000	.209	.317	.147	.057	.483
Smokey	36	.023	.334	.145	.177	.222	.180
Duff 22-2	38	.086	.273	.374	.320	.140	.204
Flat Tires	39	.016	.315	.530	.315	.191	.180
Ha Quota	39	.151	.622	.474	.453	.160	.241
Iron Horse	39	.029	.115	.148	.138	.070	.283
Grouchy	42	.081	.258	.353	.571	.343	.233
Harvey	42	.100	.360	.190	.186	.319	.347
Stump	44	.025	.119	.144	.130	.131	.258
W Trucker	45	.052	.137	.167	.221	.257	.118

eventually build up and cause a decline in performance and that the individuals that are line bred to may not be truly outstanding. Hampshire breeders need to be aware of these dangers if they plan on continuing the types of breeding systems they currently have.

Table 2. Average inbreeding of the leading Hampshire boars of 1981 and the average relationship between those boars and the most prominent boars in the pedigrees

		Relationship				
	Inbreeding	Ugh	Roughneck	Gem	Oh	Eric
Average	.103	.341	.385	.373	.202	.234
Range	0-.30	.12-.63	.14-.58	.13-.60	.06-.40	.11-.48

Correlations Between Type and Performance of Boars at the Oklahoma Swine Evaluation Station

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Story in Brief

Visual scores and performance data accumulated on 201 boars during the fall of 1980 and the spring of 1981 were used to evaluate the relationship between visual appraisal and performance data. Performance traits measured were: average daily gain, backfat thickness, feed efficiency and loin eye area. Visual scores for frame, capacity, muscling, front and rear leg structure and movement were assigned at the beginning and the end of the test.

Few of the visual scores were highly correlated with the performance traits. The correlations between average daily gain and final frame score (.329) and final capacity scores (.664) suggest that larger framed, higher capacity boars grow faster than smaller framed boars with less capacity. Correlations between initial and final body type scores were moderate (.449 to .613) while correlations between initial and final leg structure and movement scores were small (.078 to .226). There was more agreement among scorers for body type scores than for feet and leg scores, and the scores agreed more closely at the end of the test than at the beginning.

Introduction

Trends in the swine industry have often been dominated by the selection of visual characteristics that were thought to be correlated with performance traits. Performance testing was introduced so that traits of economic importance to the commercial producer could be properly evaluated prior to the selection of seedstock. Despite this, many seedstock producers still use visual evaluation as the main criterion in their selection program.

The purpose of this study was to determine if relationships exist between measurable performance traits and those traits evaluated visually. Data were obtained from boars of similar ages that were tested at the Oklahoma Swine Evaluation Station in the fall of 1980 and spring of 1981.

Materials and Methods

During the fall of 1980 and the spring of 1981, 201 boars from several swine breeders in Oklahoma were evaluated at the Oklahoma Swine Evaluation Station. The station has been in operation since 1970 and tests boars in two barns with 24 open-front pens (5 ft by 15 ft) in each barn.

Each pen held three boars or two boars and a barrow, representing a single sire. Pigs averaged 70 lb at the start of the test period and were removed from test on a weekly basis when they reached 230 lb.

Performance data included: pig weight at the beginning and end of test, average daily gain, pen feed efficiency and ultra sonic scanogram (Ithaco Scanogram Model 721) estimates for loin eye area and backfat thickness. Feed efficiency for pens containing barrows was adjusted to a boar equivalent basis. Loin eye area was measured at approximately the tenth rib. Backfat thickness was the average of the measurements at the shoulder, the last rib and the last lumbar vertebrae. Loin eye area and backfat thickness estimates were adjusted to a 230 lb basis by adjustment factors suggested by the National Swine Improvement Federation.

Pigs were scored at the beginning and the end of the period for visual traits by a committee of three comprised of an Animal Science Department faculty member, a University swine herdsman and an independent purebred swine breeder. Categories considered for visual appraisal were: frame size, body capacity, muscling and front and rear feet and leg structure and movement. The numerical scores and criteria used when assigning visual scores are given in Table 1. The scores were assigned independently, and the scores of the three evaluators were averaged.

The statistic used to estimate the association between the performance data and the visual scores is the correlation. A correlation can have any value within the range of -1.0 to 1.0. A value of 1.0 would indicate a complete agreement between two traits, and high values of one would be associated with high values of the other. A value of -1.0 also indicates a complete association between two traits, but high values of one trait would be associated with low values of the other. A value near zero ($-.10$ to .10) would suggest that no relationship exists between the two traits. A correlation should have an absolute value of at least .6 to have much predictive value.

Results and Discussion

Correlations between initial visual scores and performance traits are shown in Tables 2 and 3. The only correlation over .3 is that between initial capacity and

Table 1. Scoring system for conformation and soundness

Frame (1-10)
- 1-4 small frame, short bodied
- 5-6 medium frame, moderate body length
- 7-10 large frame, long bodied

Capacity (1-10)
- 1-4 thin, shallow body
- 5-6 medium thickness and depth of body
- 7-10 thick, deep body

Muscling (1-10)
- 1-4 thick, heavy, bulging muscling
- 5-6 moderately thick muscling
- 7-10 flat muscling

Feet and Legs (front and rear)

Movement
- 1-2 buckkneed, goose stepping, choppy strides
- 3 moderate in movement faults
- 4-5 shows a balanced animated stride, free of faults

Structure (front and rear)
- 1-2 straight set of shoulders, winged shoulders, knockkneed, toes in, etc. Straight and stiff hocks, sickle hocks, weak pasterns, steep rump, etc.
- 3 moderate in structural faults
- 4-5 free of structural faults

Table 2. Correlations between performance traits and initial body type scores

	Average daily gain lb/day	Backfat in.	Feed efficiency lb feed/lb gain	Loin eye area sq in.
Frame	.024	−.149	.206	−.021
Capacity	.307	.047	.009	−.028
Muscling	−.114	.039	.143	−.081

Table 3. Correlations between performance traits and initial feet and leg scores

	Average daily gain lb/day	Backfat in.	Feed efficiency lb feed/lb gain	Loin eye area sq in.
Front Leg				
Structure	.055	−.085	−.120	−.042
Movement	.190	−.029	−.092	−.034
Rear Leg				
Structure	−.182	−.093	−.176	.092
Movement	−.165	−.037	−.161	.058

average daily gain (.307). This suggests a small tendency for boars that have more capacity to also be faster growing.

The correlations between performance traits and initial feet and leg scores were quite low.

Similarly, performance traits were correlated with final visual scores (Tables 4 and 5). These correlations were also generally quite low. The only correlation with much predictive value was the correlation between final capacity and average daily gain (.664). This, along with the moderate correlation between frame and average daily gain (.329), indicates that higher capacity, larger framed boars tended to grow faster than smaller framed boars with less capacity. None of the correlations between the performance traits and final feet and leg scores were large enough to have any predictive value.

The low-to-moderate correlation (.499-.613) between initial and final body conformation scores (Table 6) suggests that initial body conformation is not a really good predictor of final conformation. Both the subjective nature of the scores and actual changes in the pigs may have contributed to the size of the correlations. The low correlations (.078-.226) between initial and final feet and leg scores indicate the lack of predictive value of the initial scores.

Table 4. Correlations between performance traits and final body type scores

	Average daily gain lb/day	Backfat in.	Feed efficiency lb feed/lb gain	Loin eye area sq in.
Frame	.329	−.199	.020	.015
Capacity	.664	.113	.249	.051
Muscling	−.044	−.126	.198	−.108

Table 5. Correlations between performance traits and final feet and leg scores

	Average daily gain lb/day	Backfat in.	Feed efficiency lb feed/lb gain	Loin eye area sq in.
Front Leg				
Structure	.168	.032	−.117	−.011
Movement	.178	.006	−.104	−.019
Rear Leg				
Structure	.228	−.107	−.063	.097
Movement	.188	−.101	−.069	.103

Table 6. Correlations between initial and final visual scores

Frame	Capacity	Muscling
.613	.449	.579

Front Leg		Rear Leg	
Structure	Movement	Structure	Movement
.078	.147	.141	.226

Tables 7 and 8 contain correlations among scorers and show the amount of agreement among the committee members on visual appraisal. There was more agreement on the body type scores than on the leg movement and structure scores. The correlations among the scorers were moderate to small in size, suggesting that there was a partial agreement regarding visual evaluation. However, the scorers certainly differed in some instances. There was more agreement among scorers at the end of the test period.

The data in this study gives evidence that visual appraisal cannot accurately predict how boars will grow and perform. There is some suggestion that higher capacity, larger framed boars tend to gain at a faster rate than do small capacity, smaller framed boars; however, the relationship is too small to be of much practical use. Correlations among scorers suggest that there is only partial agreement among individuals assigning visual scores to visual traits of interest. Improvement in performance will more likely occur when producers incorporate objective measures of performance into their selection of replacement breeding stock.

Table 7. Correlations among scorers for initial visual scores

Frame	Capacity	Muscling
.545	.554	.524

Front Leg		Rear Leg	
Structure	Movement	Structure	Movement
.316	.271	.140	.184

Table 8. Correlations among scorers for final visual scores

Frame	Capacity	Muscling
.609	.668	.564

Front Leg		Rear Leg	
Structure	Movement	Structure	Movement
.402	.476	.294	.343

Progress in Developing a Fall Lambing Dorset × Finnsheep Line

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Story in Brief

A flock of ½ Dorset ½ Finnish Landrace (Finn or Finnsheep) has been assembled gradually since 1976 to serve as the basis for developing a new line of sheep that are both fertile and prolific when bred during May and June. The purpose of this line would be to furnish rams for mating to Rambouillet ewes to produce highly productive fall lambing ewes for commercial sheep production. There are currently in excess of 130 second cross (F_2) ewes that are being mated during May and June. The descendants of those matings will become the line. During the development period, procedures have peen perfected relative to ram, ewe and lamb management. The current status of the project is that the base is established and procedures perfected. The next few years will produce the data that will determine the feasability of the endeavor.

Introduction

Many Oklahoma sheep producers prefer their ewes to lamb during fall to utilize wheat pasture and market the lambs produced during the period of seasonally highest prices in the spring. Dorset × Rambouillet crossbred ewes are the most productive breed combination available but have only a moderate lambing rate when lambing during October and November. The introduction of Finnsheep breeding into the ewe flocks to increase prolificacy results in a lowered fertility (percent of ewes lambing) and no net gain in lambs born per ewe exposed.

One of the most serious restrictions that prevents sheep from supplying more meat on a continuous basis to the consumers is the seasonal nature of reproduction in most sheep breeds. The vast majority of lambs are born during the period of January through April of each year.

If a new line of sheep could be developed that were both fertile in May and June, such as the Dorset breed, and prolific, such as the Finnsheep (Finn), rams from the line mated to Rambouillet ewes should produce excellent fall lambing ewes. Further, the successful development of such a line would demostrate that the seasonal restriction of reproduction in sheep could be corrected by selection.

This progress report summarizes our effort to develop a line of sheep based on a Dorset × Finnsheep foundation that is fertile and prolific when bred during May and June.

Materials and Methods

The crossbred foundation for the line has been assembled slowly since 1975 through the purchase of 39 ewes from two sources and the production of additional ewes annually until we have had about 100 F_1 (first cross) ewes. Over 15 different sources of breeding stock have contributed to the flock.

The management of the F_1 ewes has involved exposing each ewe during the spring (at least two times) to record her willingness to mate and her fertility if mated. Following this test period, ewes have been mated during the fall to speed the production of F_2 (second cross) ewes from which, it is anticipated, the more fertile animals will be selected to create the new line.

There are now in excess of 130 F_2 ewes, most of which are ewe lambs or yearlings. These ewes will be mated only during the spring, and those ewes and rams that are most productive will produce the next generation. Thus, natural selection under the defined conditions will determine the future direction and success of the line.

Initially the ewes were mated in one-sire pastures with rams rotated frequently. Poor breeding performance by some rams indicated that several rams should be in each pasture to increase the likelihood that any fertile ewe would be mated to a fertile ram.

All ewe lambs have been mated first during the spring breeding season. Rams have been used first as yearlings. Inability to determine which ewes or rams are most fertile has forced the use of most physically sound rams. (In order to investigate possible ways to detect which rams are more fertile, a new study has been added, and preliminary results are reported in a separate paper in the 1982 Research Reports.)

No culling of ewes that are physically sound has been done in order to build as large a base for fertility selection as possible. Some new F_1 crossbred ewe and ram lambs are being added each year, also, to broaden the base.

Early observations indicated that the Dorset x Finn crossbred animals were apparently less fertile in May and June than in April. Because it is the intent of the study to develop a line of sheep that are not seasonal in their fertility, it was decided to time the mating season when the flock was the least fertile, thereby insuring that those individuals that are most fertile during the critical time will produce the next generation. During the breeding season the rams are fitted with marking harnesses with different colors of crayons. The flock is observed for rump marks daily or every other day to monitor the mating behavior of the rams and ewes. After the lambing season, the lambing records plus the mating records are used to get the best estimates of the mating behavior of the various rams and ewes. This information plus the actual lambing performance data make it possible to identify the most fertile rams and ewes.

Results

A summary of the reproductive performance of the various groups of F_1 ewes is presented by season of breeding in Table 1. The reproductive performance is below expectations, especially from fall breeding. Our analysis of the causes leads us to believe (1) the relatively few animals involved during the early years were not given adequate care and attention because of our other, more extensive studies, (2) an outbreak of epididymitis interrupted our plans for about 2 years and (3) these sheep require a different nutritional and perhaps climatic environment than the sheep that we are familiar with.

Nevertheless, the data suggest that 70 to 80 percent of these ewes mate during the spring, but only 40 to 50 percent lamb. Blood tests taken on the ewes that mate during May and June indicate that about 20 percent of the ewes that mate probably do not produce eggs (ovulate). The records further suggest that perhaps as high as 30 or 40 percent of the ewes that do ovulate do not become pregnant or do not maintain their pregnancy to term. Further research is planned to more accurately estimate the nature and extent of these losses.

Table 1. Historical record of reproductive performance (spring and fall breeding) of the F_1 Dorset x Finn ewes

Breeding season	Ewes exposed	Percent mated	Percent lambed	Lambs/ewe lambing	Birth wt
Spr 1976	10	90.0	40.0	1.75	5.23
Spr 1977	35	88.6	17.1	2.00	5.86
Spr 1978	58	72.4	25.9	2.13	5.70
Fall 1978	31	90.3	35.5[a]	2.27	6.97
Spr 1979	72	93.1	44.4	1.75	5.36
Fall 1979	53	88.0	81.0	2.33	6.66
Spr 1980	32	78.0	50.0[b]	1.63	6.22
Fall 1980	51	98.0	86.3	2.45	7.11
Spr 1981	46	82.6	43.5[b]	1.75	5.83

[a]Rams infected with epididymitis.
[b]All ewes were ewe lambs or yearlings.

The early results from the F_2 (second generation) ewes is presented in Table 2. The majority of these ewes are ewe lambs or yearlings. These ewes are mated only during May and June. These ewes and rams are expected to be highly variable in fertility and prolificacy (lambing rate). When we have completed study of this generation of ewes and rams over several years of performance, we can more accurately evaluate the likelihood of success with the effort. It is expected that a few of the ewes and rams in this generation will obtain both the out-of-season breeding ability of the Dorset ancestry and the high prolificacy of the Finnsheep ancestry. If identifiable, these animals should be the basis of the new line.

It is believed that at least part of the relatively poor performance shown in Table 2 can be corrected by improved feeding of the ewes prior to breeding and prior to lambing.

Table 2. The reproductive performance of the F_2 and F_3 (second and third generation) ewes of Dorset x Finn breeding

Breeding season	Ewes exposed	Percent mated	Percent lambed	Lambs/ewe lambing	Birth wt
Spr 1979	20	95.0	50.0	1.50	4.47
Spr 1980					
Ewes[1]	17	64.0	29.4	1.80	5.24
Ewe lambs	19	73.7	31.6	1.67	4.52
Spr 1981					
Ewes[1]	81	81.5	38.3	1.68	5.48
Ewe lambs	17	94.1	52.9	1.78	4.54

[1]Yearling and older ewes.

Observations

The establishment of this flock under the desired conditions was a challenging experience for all personnel concerned. Through experience the following observations seem warranted:

• The Dorset x Finn sheep are apparently reasonably fertile about April 1 but become less fertile from then until sometime in June at which time there is little sexual activity. For this reason the breeding season is in May and June so that those breeding animals that are most fertile at that time are the ones that produce the next generation.

• These sheep are not good foragers. When grazed with ewes that are one-half or more Rambouillet, they do not maintain themselves nearly as well as do the ewes that are part Rambouillet. At least a portion of the poor productivity of the ewes may have resulted from their lack of adequate nutrition at breeding.

• The newborn lambs are smaller than expected, and they do not grow well as compared to usual commercial lambs with which the personnel are more familiar. Small lambs during the fall can result from the effect of summer heat on the pregnant ewes. This does not explain the frequent smaller-than-expected spring-born lambs, however. Also, when ewes produce litters of 4 to 6 lambs, the lambs are usually quite small and difficult if not impossible to raise.

These observations might lead one to conclude that with all these problems, why be concerned with sheep of this kind? Past research has demonstrated that ewes that are ¼ Finn ¼ Dorset and ½ Rambouillet are excellent commercial ewes except that they do not lamb well during October and November. Therefore, the rewards to be obained with success in the endeavor will make the effort worthwhile and it is the purpose of research to try to learn what can be done.

RESEARCH IN PROGRESS

Effect of Feeding Choline and Dichlorvos to Gestating Sows

W. G. Luce, D. S. Buchanan, H. E. Jordan, C. V. Maxwell, and R. Vencl

Reproductive efficiency, the number of pigs marketed per sow kept for breeding, is the most important economic factor in swine production. Therefore, it is essential that all breeding females conceive promptly, farrow large litters and wean a high percentage of pigs farrowed. The feeding of nutritional supplements is one plausible method of improving reproductive efficiency.

Previous research at the Oklahoma Agricultural Experiment Station and other institutions has shown that feeding high levels of choline (approximately 350 mg per lb of diet) to bred sows throughout the gestation period may result in increased litter size at birth and weaning and heavier litter weights at weaning. However, previous research at the Oklahoma Agricultural Experiment Station and other institutions did not show choline to be beneficial in reducing the incidence of the spraddle leg syndrome in baby pigs as reported several years ago in the popular press.

Research at other institutions has also shown that the feeding of the anthelmintic, dichlorvos (2, 2-dichlorovinyl dimethyl phosphate) at approximately 250 mg per lb of diet during the last 30 days of gestation may result in improved reproductive performance. Improvements usually observed included increased litter size at birth and weaning, heavier litter weights at birth and weaning and increased mean birth or weaning weight. Research also reveals that the improvement in reproductive performance is apparently not the result of the anthelmintic effect of dichlorvos.

There appears to be no previous research conducted that presents any information as to whether an additive effect would occur on reproductive performance if both choline and dichlorvos were fed to gestating females. Thus, this project was initiated in November, 1980, at the Southwestern Livestock and Forage Research Station, El Reno (Fort Reno) to determine whether there is an additive or interactive effect on litter size at birth, litter size at weaning, birth weights and weaning weights when supplementing diets for gestating sows with choline and/or dichlorvos.

An experiment, involving two replicates of 100 brood sows each, has been conducted to date. All sows were fed a 14 percent and 16 percent crude protein, grain sorghum-soybean meal type ration during gestation and lactation, respectively. The sows in each trial were divided into four experimental treatments as follows:

1. Control. No supplemental choline or dichlorvos was fed during gestation.
2. 350 mg of choline per lb of diet during the entire gestation period was fed.
3. 250 mg of dichlorvos per lb of diet during the last 30 days of gestation was fed.
4. Combination of treatments 2 and 3 was fed.

Data collected included total number of pigs at birth, number of live pigs at birth and number of live pigs at 21 and 42 days of age. Individual pig and litter weights at birth, 21 and 42 days were also collected. Fecal examination for gastrointestinal parasites in each sow and two randomly selected pigs from her litter when 42 days of age was also conducted. One randomly selected pig from each of 10 different sows in each treatment was examined at slaughter for evidence of parasite migration.

Data from the two described trials will be analyzed to study the effects of supplemental choline and dichlorvos and the interaction of the two on reproductive performance. In addition, it is planned for two additional trials involving 100 brood sows each to also be conducted.

Utilization of Wheat Silage in Wheat and Bermudagrass Stocker Programs

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Problems associated with cattle grazing wheat pasture have been described for many years and include wheat pasture poisoning of cows and frothy bloat of stocker cattle. Although these problems may result in substantial economic losses, losses incurred by wheat pasture stocker operators as a result of poor stocker weight gains, due to (1) inadequate fall and(or) winter wheat forage and (2)stockers being out of feed because of snow and(or) ice cover of wheat forage,while being much less dramatic, are probably greater. Identification of sound feeding programs for wheat pasture stockers, therefore, has the potential of increasing total beef production from wheat pasture and adding stability to wheat pasture stocker operations.

Large variations in the amount of forage available for grazing also represents a critical management problem in bermudagrass stocker programs. Stocking rates designed for the periods of lower forage production coupled with hay removal during periods of peak forage growth represent the usual approach to this problem. Use of heavier stocking rates and a silage supplemental feeding program would be an alternative approach.

A large percentage of total beef produced in this country is merchandised as ground beef. Many studies have been conducted relative to producing choice beef on all forage or limited-forage production systems. Similar studies in which the beef carcass was intended primarily for the ground beef market have not been conducted.

This research project was initiated at the Southwestern Livestock and Forage Research Station, El Reno (Ft. Reno) in the fall of 1981 and will continue through the bermudagrass growing season of 1984. The objectives of the project are:

1. To determine the effect of feeding wheat silage to stockers grazed on wheat and bermudagrass pastures on:
   - Live and carcass weight gains, and total beef production per acre. The effect of stocking rate on silage consumption will also be measured.
   - Amount of forage produced, and quality of available forage.
   - Wheat and bermudagrass forage intake.
   - Total ration (wheat or bermudagrass forage plus silage) dry matter digestibility.
   - Carcass characteristics of the cattle at the end of the bermudagrass growing season.
2. To determine the economics of the two beef production systems (i.e., wheat and bermudagrass pasture alone versus wheat and bermudagrass pasture plus supplemental silage).

Reproductive Development and Performance of Hereford Heifers Calving at 24 and 30 Months of Age

E. J. Turman, R. P. Wettemann and K. S. Lusby

Two major problems are associated with calving heifers at 24 months of age: (1) the large number of heifers requiring assistance and (2) poor rebreeding performance. Research has shown that these problems can be greatly reduced by delaying calving until the heifers are 36 months of age. However, it is very difficult, on an economic basis, to justify delaying the onset of a heifer's productive life by a year. Calving at 30 months of age may reduce the problems associated with earlier calving and also be economically feasible, but there has been very little research conducted to date on calving at this age.

This study was initiated at the Southwestern Livestock and Forage Research Station, El Reno (Fort Reno) in the fall of 1979 and will continue until December 31, 1983. The objectives are : 1) to compare the reproductive performance of heifers calving at 30 months of age with heifers fed at a high level of winter supplemental feeding of protein and energy and calving in the spring at 24 months of age; and 2) to determine the effects of a low and moderate level of winter supplemental feeding on the growth, development and reproductive performance of heifers calving in the spring at 30 months of age. Reproductive performance traits being measured include breeding performance as heifers, incidence and magnitude of calving difficulties and rebreeding performance following their first calving.

The heifers being utilized in this study are produced in experimental cow herds at the Lake Carl Blackwell Range Area. The total number of heifers that are available to be placed on experiment in a given year is limited. Therefore, in order to obtain sufficient numbers of heifers for the results to be meaningful, the study will consist of three replications. Three groups of weaner and yearling heifers were obtained in the falls of 1979, 1980 and 1981. They will remain in the study until they wean their first calf. When the third replicate is completed in the fall of 1983, the results for all three replicates will be combined, analyzed and published.

The heifers of replicate 1 calved during spring, 1981, weaned their calves last fall, thus completing replicate 1. Heifers of replicate 2, obtained in the fall of 1980, were bred during a 60-day period beginning May 5, 1981, and will calve in spring, 1982. Heifers of replicate 3 were placed on trail in November, 1981, and will be bred in spring, 1982.

Development of a Systems Analysis Model for Lean Beef Production

D. S. Hale, L. E. Walters, R. L. Hintz and F. N. Owens

To meet the demand for leaner beef, management systems which most efficiently produce lean beef of acceptable quality must be identified. The objective of this research is to analyze production data from different management systems to determine the most efficient procedures for the production of lean beef. Ration composition, feedlot performance, carcass characteristics and breed group data were obtained from 1,972 head of cattle used in nutrition trials at the Panhandle State University at Goodwell, Oklahoma, and Oklahoma State University, Stillwater, Oklahoma.

Five identifiable breed groups, ration protein levels of 9 to 13 percent, concentrate levels of 25 to 95 percent and feeding periods of 112 to 196 days illustrate the diversity of trials. Some trials utilized feed additives (monensin), non-protein nitrogen and cement dust. In addition, implants (ralgro or Synovex) were administered to some animals both before and during the trials. Feed consumption and gain data were recorded at regular intervals throughout each feeding trial.

Initial and final weights, rib-eye area, fat thickness, marbling score, carcass quality grades, carcass cutability and yield grade are presented by breed group in Table 1. Among the identifiable breed groups, mean initial weights were highest for the Exotic × Exotic crossbred cattle while weights for other groups were similar. Further analyses of these and other data sets will be used to identify those variables (i.e. breed group, initial weight, days on feed, type of ration, etc.) most closely related to economically important carcass characteristics, including dressing percentage, carcass quality grade and carcass cutability.

Table 1. Means and standard deviations of performance traits from feedlot cattle

Breed group	No.	Initial weight lb	Ending weight lb	Fat th. inches	Ribeye area sq. in.	Cut-ability %	Yield grade	Marbling score[1]	Quality grade
British	661	632	1083	.60	11.9	48.9	3.5	14.4	Ch−
SD[2]		86	92	.19	1.2	1.7		3.0	
British × British	660	612	1101	.59	12.5	49.4	3.3	14.6	Ch−
SD		121	49	.20	1.3	1.7		3.0	
British × Exotic	346	621	1114	.48	13.0	50.5	2.8	13.3	Ch−
SD		100	94	.18	1.2	1.7		2.9	
British × Brahman	154	614	1041	.32	12.8	51.8	2.2	10.7	Gd
SD		47	99	.15	1.3	1.7		2.2	
Exotic × Exotic	141	682	1109	.49	12.4	50.2	2.9	12.8	Ch−
SD		69	99	.16	1.4	1.5		2.6	
Unknown	10	692	1112	.36	13.5	51.4	2.4	11.9	Gd+
SD		61	89	.18	1.1	2.0		2.6	

[1]Slight− is 10, Slight is 11, Slight + is 12, Small− is 13, Small is 14 and Small+ is 15.
[2]Standard deviation.

Potential Utilization of By-Product Feeds Varying in Fiber Level and Fiber Composition by Poultry

R. G. Teeter and W. N. Cannon

With the high cost of production encountered today, poultry producers are continually looking for ways to reduce operating cost. One potential method to cut feed costs is the incorporation of by-product feeds into poultry rations. By-product feeds can frequently supply energy and protein, but, unfortunately, they often contain 20 percent or more crude fiber. Incorporation of high fiber feeds into poultry rations reduces productivity if the birds are not able to adjust their feed intake up and maintain adequate energy consumption. Fiber characteristics that limit feed consumption in poultry, if any, are not well understood, and information is needed to ensure that by-product feeds can be adequately utilized.

A preliminary trial was initiated in the fall of 1981 to examine what influence purified fiber sources added to a nutritionally complete basal diet would have upon feed intake, rate of ration passage through the gastrointestinal tract and body weight of 16-day-old chicks. Purified fiber sources fed to chicks constituting 40 percent of the ration included wood cellulose, lignin[1] and hemicellulose[2] as well as polyethylene, a synthetic fiber. The degree to which fiber sources influenced the parameters measured varied ($P<.05$) among fiber sources even though they were all present at a level of 40 percent of the ration composition. Ration intake (pounds per 100 birds per day), ration digestibility (percent), relative ranking for rate of feed passage (1 = fastest rate, 5 = slowest rate) and body weight gain (pounds per day per 100 birds) were, respectively, 2.2, 53, 2, .76 for the basal ration; 2.8, 47, 3, .4 for basal plus cellulose; .8, 31, 4, -.6 for basal plus hemicellulose; 2.5, 32, 5, .65 for basal plus lignin; and 3.3, 33, 1, .73 for basal plus polyethylene.

Purified fiber sources should not be considered as a homogeneous class even though they are all highly indigestible. Fiber characteristics such as density, water absorbing capacity, particle size and palatability may be responsible for the differences observed. Deleterious effects caused by hemicellulose addition appeared to be due to the ration's forming a sticky material during consumption. This material held the birds' beaks together and thereby inhibited feed consumption. Postmortem anaylsis indicated that birds fed the ration high in hemicellulose performed poorly due to starvation. Whether the fiber effects observed in this study for the purified sources are exhibited in natural feedstuffs containing these fibers is unknown. Additional work in this area is under consideration.

[1]West Yaco, Charleston Height, Charleston, S.C.
[2]Withrop Lab, 90 Park Avenue, New York, N.Y.

Nutrition-Environmental Temperature Interactions in Broilers

R.G. Teeter and M.O. Smith

Total productivity and(or) production efficiency of broilers declines as the ambient temperature diverges from the zone of thermoneutrality. Decreased productivity due to environmental temperature changes results in substantial economic hardship to poultry producers and consumers. The economic strain during periods of environmental stress is due only in part to increased mortality. Substantial declines in productivity result from altered feed consumption and efficiency of feed utilization. At environmental temperatures below the thermoneutral zone, the maintenance requirement for energy is increased. Broilers eat more feed to maintain normal levels of production, and efficiency of feed energy use declines. At environmental temperatures above the thermoneutral zone, maintenance requirements for energy are also increased, but feed intake is reduced. This lowers productivity and feed efficiency.

Since the nutritional and economic principles that govern poultry feeding practice are based largely upon studies conducted within the zone of thermoneutrality, and both heat and cold stress occur seasonally in Oklahoma, optimal feeding practices under conditions of environmental temperature stress need to be researched. Research is currently being initiated to study interactions between nutrition and environmental temperature.

The Effect of Dietary Fiber Source on Apparent Digestibility of Specific Fiber Components and Other Nutrients

W. N. Cannon and C. V. Maxwell

Swine producers have always maintained an interest in the utilization of by-products in their feeding program as a means of reducing feed cost. Many of the by-products available for use in swine rations are higher in fiber than more traditional feedstuffs. While earlier studies have demonstrated the efficacy of feeding these fibrous feedstuffs to swine, little is known about the digestibility of specific fiber components and their effect on digestibility of other nutrients. We have initiated a series of studies to determine effect(s) of dietary fiber source on digestion of specific fiber components using ileally cannulated pigs.

In an initial trial wheat bran and beet pulp were selected because they are readily available to producers and consist of widely differing fiber components. In this trial three ileally cannulated pigs weighing 160-180 lb were fed diets consisting of a corn-soybean meal basal, basal plus 25 percent wheat bran and basal plus 25 percent beet pulp. Chromic oxide was added as a digesta marker. The experimental design was a 3x3 Latin square with each treatment period consisting of 10 days. Each pig was maintained in an individual metabolism crate and fed twice daily in two equal feedings. Ileal samples were collected 3 hours after feeding until 100 ml of digesta was collected. Fecal samples were collected daily.

In a second trial 10 ileally cannulated pigs were used in a 5x5 Latin square design to determine the effects of semi-purified fiber sources on the apparent digestion of different fiber components and other nutrients. The rations used in this study consisted of: control (corn-soybean meal); control + 10 percent Solka floc, a source of cellulose; control + 10 percent mucilose flakes, a hemi-cellulose source; control + 10 percent guar gum; and control + 10 percent lignin.

Analysis of these samples should provide data on the effects of digestion and absorption of fiber on other nutrients when different fiber sources are added to swine rations. These data should be useful for producers considering fibrous by-product feeds for swine.

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The following is a listing of those who have contributed to the research program of the Animal Science Department during the preceding year.

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