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Beef Cattle Research in Texas, 1984

The Texas Agricultural Experiment Station
Neville P. Clarke, Director, College Station, Texas
The Texas A&M University System

CONTENTS

Feedstuff-Forage Utilization

Biological Efficiency of Growth

Marketing Options

Reproductive Efficiency

Infectious, Nutritional, and Toxic Diseases

Role of Beef in Human Nutrition and Health

Metric Units — English Equivalents

Metric Unit	*English Equivalent*
Centimeter	0.394 inch
Hectare	2.47 acres
Kilogram	2.205 pounds
Kilogram per hectare	0.893 pounds per acre
Kilometer	0.62 statute mile
Kilometer per hour	0.62 miles per hour
Liter	0.264 gallons
Meter	3.28 feet
Square meter	10.758 square feet
(Degrees centigrade x 1.8 +32)	Degrees Fahrenheit

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Foreword

Beef production is a land-based industry. Cattle provide an effective means of harvesting range and pasture resources, while also utilizing harvested roughage, by-product feeds, and feed grains. Texas has more than 100 million acres of range and pasture and millions of additional acres are used grow feed crops such as sorghum and corn. Proximity of cattle, feed, and climate make Texas well suited to cattle production.

Like many industries, the beef industry is faced with increasing costs of production and increasing competition. To compete in the market place, the beef industry must become more efficient. The Experiment Station has targeted research to increase production efficiency and product utilization. These areas include enhancement of nutritive value of forages and feeds, basic research to learn how forage and feed are converted to muscle, connective tissue and fat, and how each is deposited during the growth process and relates to consumer acceptance.

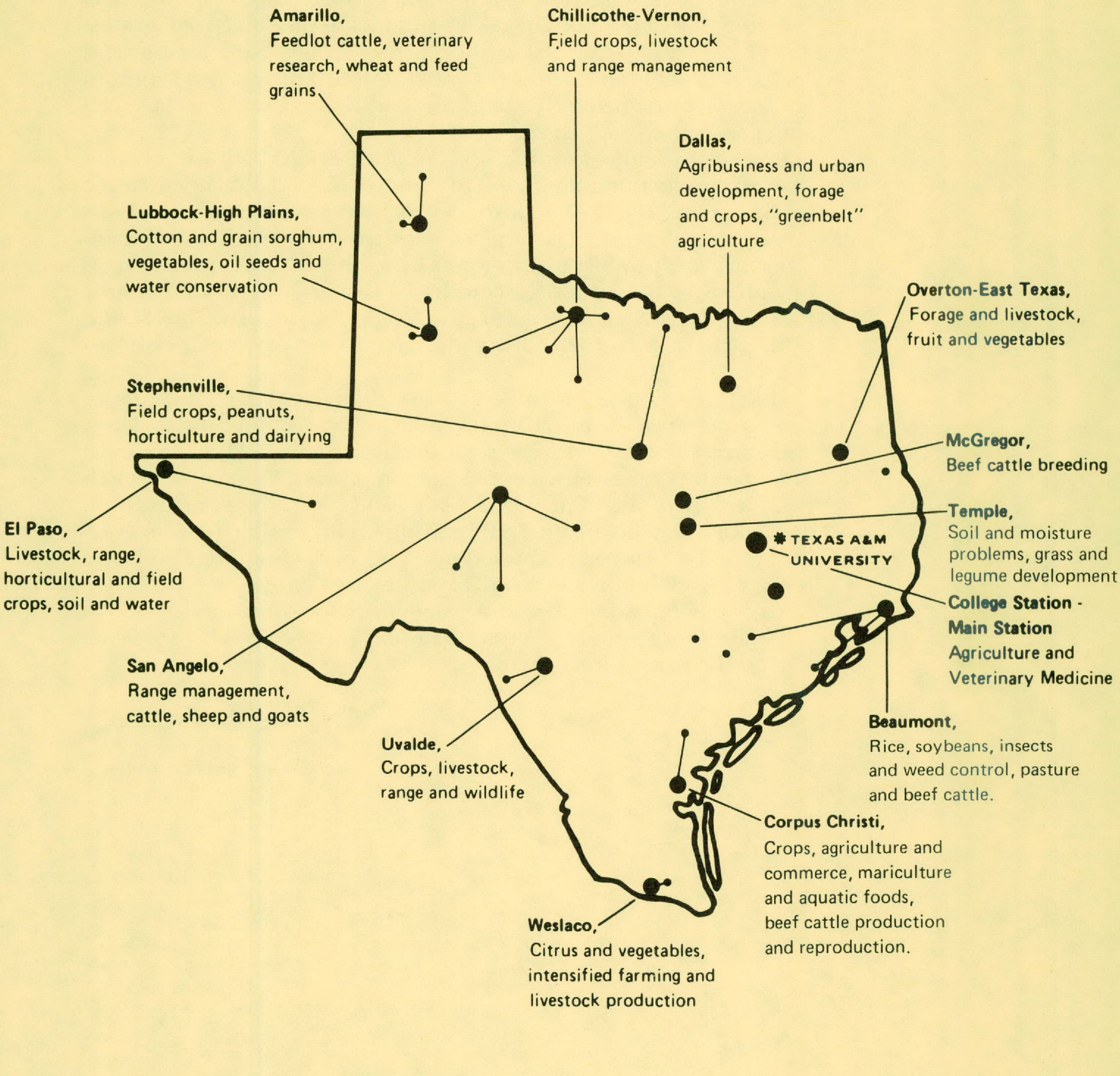
Other researchers are investigating the reproductive process to determine causes of infertility in bulls and cows and how to detect and correct them to increase reproductive efficiency. Health care is also necessary for an efficient production process. Extensive research is underway to maintain cattle health and fight diseases, parasites, and toxic elements in the cattle raising and feeding environment.

Slaughter, processing, preserving, and marketing are also being studied. And finally, the end product is examined for increased nutrition, wholesomeness, and palatability for consumers.

This report summarizes results in beef cattle research conducted during the past year.

Neville P. Clarke, Director

THE TEXAS A&M UNIVERSITY SYSTEM RESEARCH AND EXTENSION CENTERS



Beef Cattle Research In Texas, 1984

Feedstuff-Forage Utilization

Brief PR-4209

The Role of Germination in Sorghum Reconstitution

R. L. Pflugfelder, L. W. Rooney and L. M. Schake

A study was made of the effects that partial germination of sorghum during reconstitution may have on the process. Commercial reconstitution of sorghum by cattle feeders has been reported to improve feed efficiency from 6 to over 20%, with values of 9-15% most common. This study was designed to determine if the wide range of values might be explained in part by differences in the time the wet grain is exposed to air in commercial processes. Variations in the extent of germination may have a profound effect on the changes occurring during reconstitution.

Samples of red hybrid sorghum grain were steeped to 30-35% moisture in excess water. The grain was allowed to germinate for 0 to 2 days in aerated pans and then sealed in fruit jars for 0, 5, 13 and 21 days of anaerobic storage. Changes in nitrogen and carbohydrate solubility, reducing sugars, enzyme activities, dry matter loss, and particle size index were determined.

Chemical and physical modification of the grain appeared to be very slow during anaerobic storage when it was not preceded by germination. Soluble nitrogen and soluble carbohydrates were increased two-fold and three-fold, respectively, by allowing the grain to germinate for 1.0 day prior to 5 days of anaerobic storage ($P < 0.05$). Nitrogen solubility reached 50% after 1.5 days of germination and 21 days of storage.

Dry matter losses were substantially increased by germination. Dry matter losses during storage were small, apparently due to the rapid incorporation of soluble nutrients into bacterial cells and exo-polysaccharide shells (slime). Particle size index (average particle size after grinding) reflected physical modification of the grain. Particle size reductions could be attributed to steeping, germination, and storage effects; the largest component appearing to result from steeping.

Short periods of germination appear to accelerate the beneficial bacterial fermentation which is a key component of successful reconstitution of sorghum. Sorghum grain can begin germinating very quickly when moisture content and oxygen are adequate. An aerobic phase early in reconstitution, whether intentional or not, may be a critical factor in achieving significantly higher sorghum feed efficiency for cattle.

Brief PR-4210

The Effect of Heat Treatment on Ruminal Protein Degradation of Sorghum Stillage

B. J. MAY, N. D. TURNER, G. T. SCHELLING, J. M. SWEETEN, F. M. BYERS AND L. W. GREENE

Availability of dietary protein in ruminants for intestinal digestion and absorption is determined by its solubility and degradation by the rumen microbes. Ruminal escape of dietary protein sources may result in more efficient nitrogen utilization as a result of enhanced amino acid balance or minimized ammonia losses from the rumen. Previous work in this laboratory has demonstrated a high level of escape protein in wet sorghum stillage. However, stillage products are often fed after drying, and studies have not been conducted to determine the effect of drying sorghum stillage on its protein escape. This research was conducted to determine the inherent ruminal escape value of wet sorghum stillage protein and to determine the ruminal escape due to drying the wet stillage at various temperatures. The stillage was dried at 90, 105, 120, 135 and 150 C for two hours in a forced-draft oven. Ruminal degradation of wet stillage and dried stillage was determined by a nylon bag in situ technique using four rumen cannulated steers. The rate of degradation during various time periods in the rumen was determined and an equation using ruminal retention times was used to calculate the predicted escape values. The predicted level of protein escape for animals being fed stillage as wet solids or dried at 90, 105, 120, 135 and 150 C was 67, 63, 75, 81, 81 and 86%, respectively. The values indicate there is an inherent quality of sorghum stillage which allows a high percentage of ruminal escape relative to sorghum grain. Drying stillage with temperatures of 105 C or above will further increase ruminal protein escape ($P < .05$). However, using high temperatures, such as 150 C, could possibly be deleterious to subsequent protein utilization, since processing feedstuffs at high temperatures has been shown to decrease intestinal digestion. This research indicates that sorghum stillage is a good source of escape protein for ruminants when it is fed in a wet form, and has an even higher ruminal escape when it is dried at moderate temperatures.

Brief PR-4211

Use of Cytosine to Estimate Microbial Protein and Determine Escaped Protein in Feeds

K. M. HEGERLE, G. T. SCHELLING, J. M. SWEETEN, L. W. GREENE AND F. M. BYERS

Protein fed to cattle is subjected to fermentation in the rumen and is partially degraded. The degraded portion is incorporated into microbial protein. Since some dietary protein escapes ruminal degradation, the resulting mix of microbial and dietary protein reaching the small intestine provides the source of amino acids for the animal. The challenge is to feed the appropriate sources of protein and nitrogen to nourish the rumen microbes as well as to provide proper amino acid nutrition for the animal. Determining the relative contribution of feed and microbial protein to the animal is difficult with the current technology; commonly used marker systems have not been very satisfactory. Recent research has demonstrated a good correlation between microbial nucleic acid components and the amount of microbial protein. The excellent correlation between the pyrimidine cytosine and microbial nitrogen indicates that the concentration of cytosine could be used to estimate the amount of microbial nitrogen present in a sample. The advantage of cytosine over other methods is the relative ease of determining its concentration. In order to be an effective marker, the ratio of cytosine to microbial nitrogen must be constant despite changes in the microbial growth rate and/or the microbial population present. A continuous culture in vitro system was employed to investigate this relationship with urea (two levels), casein, and corn as nitrogen sources. The two levels of urea produced nearly identical cytosine to microbial nitrogen ratios despite widely differing microbial growth rates. Casein and corn were studied as divergent dietary protein sources since amino acids in the diet have been shown to alter the efficiency of microbial synthesis and could alter the microbial population present. There was no significant change in the cytosine to microbial nitrogen ratio when casein or corn were the sources of nitrogen. Based on this technique, 52% of the corn protein escaped microbial degradation. An animal trial was conducted to extend the use of this technique to cattle. Duodenally cannulated steers were fed three diets containing cottonseed hulls and sorghum stillage. The diets contained either 33%, 50% or 67% sorghum stillage with the remainder being cottonseed hulls. The results indicated that with increased stillage (thus increased dietary protein intake), there was an increase in total protein reaching the small intestine. While the relative amount of non-ammonia nitrogen reaching the small intestine was 100, 107 and 136% for the increasing dietary stillage levels, the ratio of microbial nitrogen to escaped sorghum stillage nitrogen was similar. The sorghum stillage protein represented 70, 77, and 80% of non-ammonia nitrogen reaching the small intestine for the increasing dietary stillage levels, respectively. These values are in agreement with previous reported values for stillage and indicate that cytosine is an acceptable marker for microbial protein.

Brief PR-4212

The Effects of Monensin on Tissue and Rumen Fluid Mineral Content in Ruminants

D. J. Kirk, L. W. Greene, G. T. Schelling, and F. M. Byers

The effect of monensin on sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P) and zinc (Zn) levels in various tissues and rumen fluid of lambs was examined. Eight crossbred wethers (average weight 35 kg) were used in a randomized block design, blocked by weight, and fed a 70 percent concentrate diet with or without 20 parts per million (ppm) monensin (fed as Rumensin). During the first 18 days of this study lambs were housed in pens, according to treatment, and fed ad libitum. On day 19, lambs were placed in metabolism stalls and fed 600 grams each twice daily. Beginning on day 28, feces and urine were collected daily for 10 days to determine mineral balance. Blood samples were collected 3 hours after the morning feeding and rumen fluid was collected 4 to 5 hours after feeding on day 39 of the trial. All lambs were slaughtered on day 40 following the morning feeding. Heart, liver, kidney, brain muscle, duodenum, ileum and bone samples were collected at slaughter.

Sodium concentration increased ($P < .05$) 17 and 6 percent in muscle and dry, fat-free bone, respectively, and decreased ($P < .10$) in ileal tissue 36 percent when monensin was fed. Heart magnesium decreased ($P < .05$) 15 percent in lambs fed monensin. Monensin supplementation also decreased ($P < .05$) liver phosphorus 5 percent and decreased ($P < .10$) brain phosphorus 2 percent. Heart and serum potassium were reduced ($P < .10$) 22 and 5 percent, respectively. Rumen fluid zinc was reduced ($P < .10$) by 150 percent. Calcium concentration in the tissues examined was not affected by the addition of monensin to the diet.

These results indicate that monensin alters mineral concentration in tissues of lambs, possibly because of its ionophorous activity.

Brief PR-4213

The Effect of Sodium Upon Mineral Digestibility in Steers Grazing Small Grain Forages.

L. W. Greene, L. D. Roth, W. C. Ellis, G. T. Schelling, and F. M. Byers

Potassium decreases the apparent availability of magnesium in the stomach of ruminants. In vitro experiments indicate that magnesium is absorbed from the rumen-reticular area by means of active transport. These studies suggest that the mechanism of magnesium absorption involves a Na^+, K^+, Mg^{++} -ATPase in the epithelial cells of the rumen wall. The level of potassium in the diet seems not as important in magnesium absorption as the relationship of potassium and sodium. Current research involves increasing dietary potassium, thereby altering the K:Na ratios. Results suggest that tetany is more likely to occur if animals consume diets high in potassium and low to normal in sodium.

The objective of the present study was to determine the effect of sodium on magnesium, calcium and phosphorus absorption in ruminants grazing ryegrass pastures. Ten rumen-cannulated steers were grazed on a 10-hectare pasture composed primarily of ryegrass. Animals were penned daily and five steers were given .2 percent sodium bicarbonate (by animal's body weight) via rumen cannula. Magnesium, calcium and phosphorus digestibilities were determined using indigestible neutral detergent fiber as a digestive tract marker. Esophageal masticate was collected from three esophageally cannulated pregnant cows on days 3 and 4 after beginning daily administration of sodium. Fecal grab samples were collected from steers daily, beginning on day 3 of sodium supplementation and continuing for 4 days. Rumen samples were collected through the rumen cannula each time feces were collected. Rumen pH increased from 5.62 to 5.75 with the addition of sodium bicarbonate. Sodium bicarbonate decreased apparent magnesium digestibility from 19.3 to 3.1 percent. The potassium and sodium content in dried rumen digesta was 1.18 and 1.12 percent for steers fed ryegrass with and without sodium, respectively. Apparent phosphorus digestibility decreased from 65.0 to 38.6 percent when steers were supplemented with sodium bicarbonate. Apparent calcium digestibility was not affected by the addition of sodium. Although the proposed mechanism of magnesium absorption is based on the relationship of sodium and potassium and the transmural potential across the epithelial cell membrane, the addition of sodium bicarbonate to a diet high in potassium could further enhance magnesium deficiency.

PR-4214

Intake, Digestibility and Fecal Output of Forage Selected by Cattle of Different Age and Physiological Status

R. B. Machen, J. E. Huston, W. C. Ellis, and K. W. Bales

Summary

Estimates of organic matter digestibility (DOM), fecal output (FO), and forage intake (FI) were made with cattle of different ages and physiological status during a mid-summer grazing study at the Winters Ranch near Brady, Texas. Calves appear to have selected a diet lower in digestibility than that selected

by heifers or lactating or non-lactating cows. When expressed as kg/100 kg body weight, no differences ($P > .05$) were found in FO or FI due to status or age. However, when intake was expressed as a function of metabolic body weight (kg/wt. $^{.75}$), calves consumed significantly less forage than did lactating cows.

Introduction

Both ranchers and range specialists traditionally have expressed the forage requirements for grazing cattle in terms of animal units; one cow with an unweaned calf represents one animal unit equivalent, while yearling heifers represent .75 of an animal unit equivalent. However, few efforts have been made to quantitate forage intake by unweaned calves, and little information is available on forage intake by cattle under mid-summer West Texas range conditions. By knowning the quantity of forage consumed by calves, heifers and cows, perhaps cattlemen could more efficiently utilize their range resources. Therefore, the purpose of this study was to quantitate forage intake by heifers, dry cows, lactating cows and unweaned calves grazing native range during mid-summer.

Experimental Procedure

Ten mature, non-lactating cows (DC), ten lactating cows (LC) with calves (C) at side, and ten yearling crossbred heifers (H) were selected from a larger herd and used in this grazing study during July, 1982. Two steers and two cows, each fitted with esophageal cannulae, were used to obtain samples of forage being grazed. The masticate collected from mature cattle was assumed to represent that selected by calves. Nursing calves were relatively young and therefore a large portion of their intake was material other than forage. Marker dosing, fecal collection, sample handling, analysis and calculations were outlined previously (1). With respect to marker dosing, calves and heifers received one-half the dose given the mature cows.

Results and Discussion

Mean values for organic digestibility, fecal output and forage intake are presented in Table 1, and average body weights of the cattle are shown in Table 2. Nursing calves apparently selected a diet which was lower in DOM than the diets selected by older cattle.

When expressed as kg organic matter/100 kg body weight, no significant differences in FO or FI were found as to age or physiological status of these cattle. If the amount of forage consumed was proportional to the animal's requirements, then dry cows should, and indeed did, have the numerically lowest forage intake. Forage intake for calves may be deceptively high in relation to the older animals, but when experessed as FI/day, the data indicates that calves consumed significantly less total forage per day than did dry cows and heifers, both of which consumed less than did the lactating cows ($P < .05$).

TABLE 1. MEAN VALUES FOR DIGESTIBLE ORGANIC MATTER (DOM), FECAL OUTPUT (FO) AND FORAGE INTAKE (FI)

Age/ Physiological Status	DOM %	FO kg/100 kg body wt.	FI	FI/day	FI/wt. $^{.75}$ kg
Calf	43.28^{a}	.89	1.60	1.82^{c}	$.0519^{f}$
Dry Cow	50.99^{b}	.63	1.28	6.32^{d}	$.0603^{fg}$
Heifer	48.33^{b}	.83	1.61	5.37^{d}	$.0689^{fg}$
Lactating Cow	48.90^{b}	.87	1.70	8.03^{e}	$.0792^{g}$

^{a,b,c,d,e,f,g}Means in the same column with different superscripts differ ($P < .05$).

TABLE 2. MEAN ANIMAL WEIGHTS BY AGE AND PHYSIOLOGICAL STATUS

Type	$\overline{X}$ wt (kg)
Calves	117.9
Dry Cows	531.8
Heifers	341.4
Lactating Cows	482.7

As previously described by Pond et al. (2), rare earth elements (Yb, La) were used to mark esophageal masticate and subsequently served as particulate flow markers. This technique requires cannulated animals, time and labor. If these rare earth markers could be dosed in solution and allowed to adhere to digesta in the rumen, time and labor could be saved. To test such a hypothesis, another rare earth element, Samarium (Sm), was dosed in an aqueous solution. As seen in Table 3, fecal output estimates yielded by the presence of Sm in the feces were significantly higher ($P < .05$) than those derived from the appearance of La and Yb in the feces. The Sm, upon entering the rumen, may have adhered to small particles, which have a large surface area in relation to their weight. These smaller particles would leave the rumen faster than would larger masticate particles, and thus yield a greater than actual estimate for FO. Therefore, Sm does not appear to hold potential as a rumen dose marker under these conditions.

TABLE 3. MEAN FEED OUTPUT (FO) ANALYSIS FOR ALL CATTLE TYPES

Marker	Form of Dose	FO Kg/100 kg body wt.
Sm	solute	3.1396
La	particle	1.0905
Yb	particle	0.9265

^{a,b}Means with different superscripts differ ($P < .05$).

Literature Cited

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PR-4215

Sward Attributes and Nutritive Value of Coastal Bermudagrass as Influenced by Grazing Pressure

L. D. ROTH, F. M. ROUQUETTE, AND W. C. ELLIS

Summary

Coastal Bermudagrass *(Cynodon dactylon)* was continuously grazed by cattle at one of four grazing levels (kilograms forage dry matter per 100 kilograms animal liveweight): high (7.4); medium high (27.5); medium low (75.5); and low (155.6). Forage and esophageal samples were collected in early, mid- and late summer. Average daily gain (ADG, kg/day) of stocker calves was measured over a 114-day period. Grazing pressure level affected the calves' ADG ($P < 0.0001$) and the specific forage growth rate (forage growth rate/kg dry matter/hectare (ha)) ($P < 0.02$), but not the forage growth rate (kg dry matter/ha/day) ($P > 0.72$). Different grazing pressure levels affected leaf proportion in the available forage ($P < 0.02$), but there were no differences in leaf proportion of the diet ($P > 0.53$). The fiber content of leaf in the available forage decreased ($P < 0.01$) as grazing pressure was increased, as did fiber content of leaf in the diet ($P < 0.0001$). Grazing pressure levels did not significantly affect fiber content of stem in the available forage ($P > 0.23$) or in the diet ($P > 0.33$). These results indicate that increased grazing pressure increased the specific growth rate of the forage, and thereby decreased the average age of forage available and forage consumed. Thus its nutritive value to the animal was increased.

Introduction

The performance of individual grazing animals generally decreases as grazing pressure increases. This depressed performance may be due to effects of grazing pressure on the morphology, physiology and growth of the forage plant. This study was conducted to examine the influence of grazing pressure on animal production. Leaf and stem proportions and fiber content of the available forage and the diet were used as indicators of selectively grazed components of the forage, its nutritive potential, and responses by the plant to grazing pressure.

Materials and Methods

A 4-month study was conducted during the summer of 1983 at the Texas A&M University Agricultural Research and Extension Center, Overton, Texas. Four pastures of Coastal Bermudagrass *(Cynodon dactylon)* were continuously grazed, with a put-and-take variable stocking rate to maintain four levels of grazing pressure (kg forage dry matter/100 kg animal liveweight). The pasture sizes in hectares (ha) and grazing pressure levels were: 2.2 ha (low, L); 2.2 ha (medium low, ML); 1.3 ha (medium high, MH); 0.9 ha (high, H) (Table 1).Each pasture was stocked with two yearling Brahman steers that were esophageally and ruminally fistulated, four F-1 Brahman x Hereford cows and their calves, five stocker calves, and a variable number of put-and-take animals as required to regulate grazing pressure and forage availability. The resulting stocking weights (100 kg animal liveweight/ha) and targeted forage availability levels are in Table 1, as well as the actual grazing pressure levels achieved. All animals were weighed at 28-day intervals, with gains of the stocker calves reported over a 114-day period.

TABLE 1. PASTURE SIZE, STOCKING WEIGHT, TARGETED FORAGE AVAILABILITY AND ACTUAL GRAZING PRESSURE BY GRAZING PRESSURE LEVEL

	Level of Grazing Pressure			
Item	Low	Medium Low	Medium High	High
Pasture size, hectare	2.2	2.2	1.0	0.9
Stocking weight, 100 kg of animal liveweight/ha	29.3	37.9	54.9	92.4
Targeted forage availability, kg dry matter/ha	5000	2750	1500	750
Actual grazing pressure, kg forage DM/100 kg of animal liveweight	155.6	75.5	27.5	7.4

Samples of available forage and esophageal extrusa were collected in early (June 28), mid- (August 20) and late summer (September 17). Forage availability was measured by clipping four areas of 0.25 square meter each to ground level. The clipped forage was hand separated into leaf and stem portions of the available forage, and dried for 48 hours at 55° C in a forced draft oven. Neutral detergent fiber (NDF) content (3) was determined on the leaf and stem components after grinding in a Wylie mill to pass a 2 millimeter screen. Forage growth rate was calculated as the difference in forage availability at the end of an accretion period and forage availability measured at the start of the accretion period. The accretion periods were: 26 days (date 1), 18 days (date 2) and 14 days (date 3).

$$\text{Forage Growth Rate} = \frac{(\text{Protected Dm/ha})_{t=N} - (\text{Unprotected DM/ha})_{t=0}}{N}$$

Specific forage growth rate was calculated as:

$$\text{Specific Forage Growth Rate} = \frac{\text{Forage Growth Rate}}{\text{Forage Availability}}$$

Esophageal extrusa (diet) samples were collected daily from the two esophageally fistulated steers at each grazing pressure level during three consecutive days for date 1, and two days for dates 2 and 3. The extrusa samples were freeze-dried and separated into leaf and stem components by a vertical-draft air column. The separated components were used to determine proportions of leaf and stem and fiber content of the diet.

Effects of grazing pressure were compared using the General Linear Model procedure of the Statistical Analysis System (5), in which the effects of grazing pressure were assessed by regression across grazing pressure levels.

Results and Discussion

The resulting mean forage availability and average daily gain of stocker calves is displayed in Figure 1. Forage availability ranged from 5,037 kg/ha for L to 808 kg/ha for H. This relatively wide range in forage availability contributes to the study of sward attributes as affected by varied grazing pressure. The ADG of the stocker calves was influenced by grazing pressure levels ($P < 0.0001$), and ranged from 0.63 kg/day for L to 0.13 kg/day for H. The linear decrease of ADG with increased grazing pressure is in agreement with findings of Hart (4) and others.

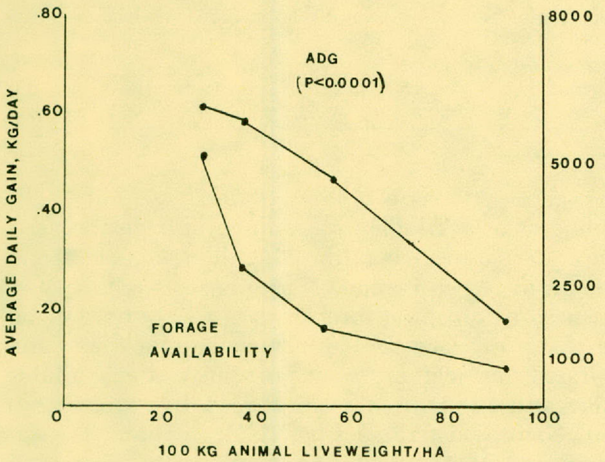

Figure 1. Average daily gain by stocker calves and forage availability.

The mean values for forage growth rate and specific forage growth rate are presented in Figure 2. The variation in forage availability in this study did not alter forage growth rate ($P > 0.72$), which varied from 27 kg/ha/day for L to 77.5 kg/ha/day for ML. Consequently, specific forage growth rate increased inversely with forage availability ($P < 0.02$). Specific forage growth rate was lowest in L at 0.005, and increased to 0.096 for H. These results indicate that forage growth rate per area was not altered, but that specific forage growth rate was increased.

The mean leaf proportions of available forage and diet are shown in Figure 3. This measurement differed ($P < 0.02$) according to grazing pressure levels, with a low value of 39.7 percent for L and 51.6 percent for H. No differences ($P > 0.53$) existed among grazing pressure levels for mean leaf proportion in the diet, which varied from 82.7 percent for L to 78.5 percent for H. The differences in leaf proportions of available forage and

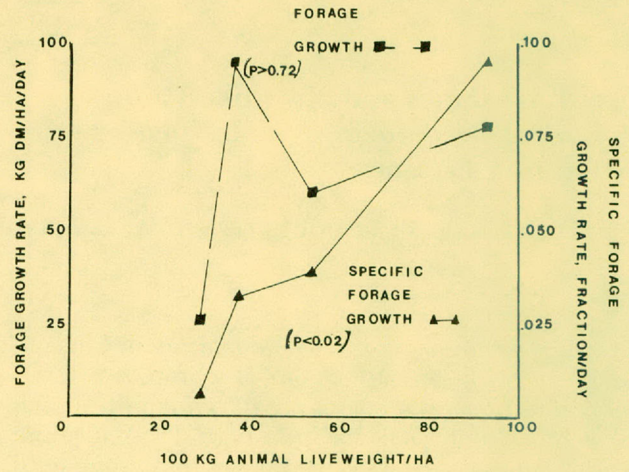

Figure 2. Forage growth rate and specific forage growth rate.

of the diet for various grazing pressure levels indicates an apparent selectivity by the grazing animal for the leaf component of the available forage.

The mean NDF content of leaf in the available forage is shown in Figure 4. The NDF content of leaf in the available forage differed ($P < 0.01$)from 75.2 percent in L to 71.3 percent for H. The fiber content of plants usually increases with advancing maturity (1), although this also may be a result of higher temperatures (2). The lower fiber content of leaf in H is indicative of younger material associated with higher specific forage growth rates produced by increased grazing pressure. Differences ($P < 0.0001$) in NDF content of leaf in the diet existed among grazing pressure levels. Mean leaf NDF content was highest in L at 72.1 percent and lowest in H at 59.6 percent. The fiber content of the selectively grazed leaf tended to be lower than the fiber content of the leaf present in the available forage at the

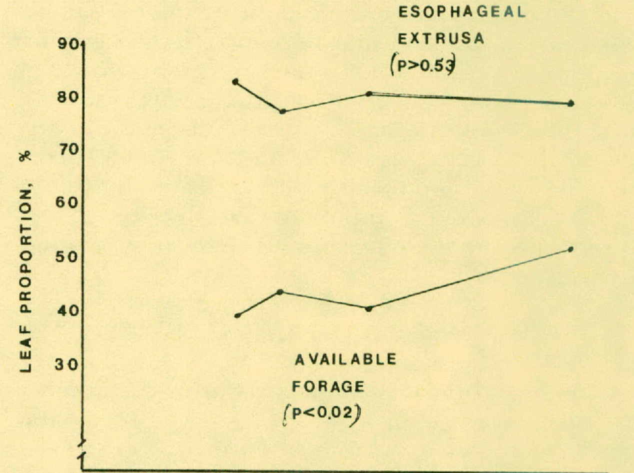

Figure 3. Leaf proportion of available forage and esophageal extrusa.

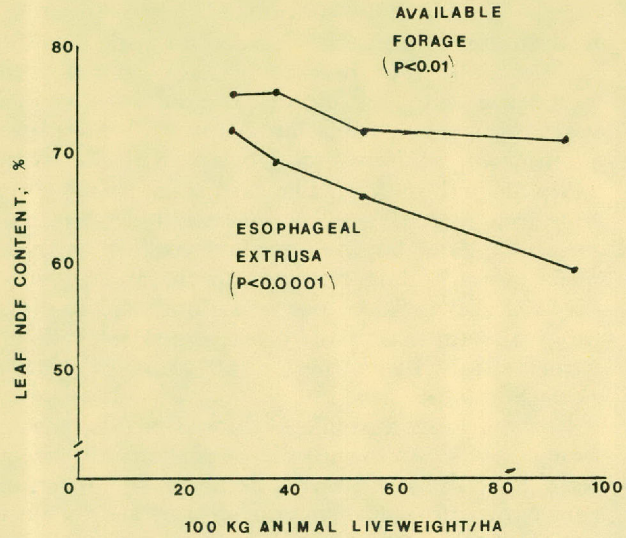

Figure 4. NDF content of leaf fragments in the available forage and esophageal extrusa.

same grazing pressure level. This suggests the animals' ability to selectively graze the younger leaves present in the available forage.

As shown in Figure 5, no significant differences in NDF content of stem existed in the available forage ($P > 0.23$) or in the diet ($P > 0.33$). The fiber content of stem fromt he diet was generally less than the fiber content of stem in the available forage at the same grazing pressure level. The similarity in fiber content of stem in the diet suggests that animals on different grazing pressure levels were consuming stem of similar maturity, or that temperatures may have equalized the fiber content of selected stem between grazing pressure levels.

These results indicate that increased grazing pressure increases specific growth rate, and thereby decreases the average age of both the available forage and the consumed forage and decreases the fiber content of the diet selected by the grazing animal. In this study, as grazing pressure increased, the leaf proportion in the diet did not change, but fiber content of the leaf declined. This could result in a higher quality diet. However, animal performance declined as grazing pressure increased. This would suggest that although forage utilization may have been improved by increasing grazing pressure, forage intake per animal was decreased to the point of restricting animal performance. These results demonstrate the complexity of the interaction between plants and animals.

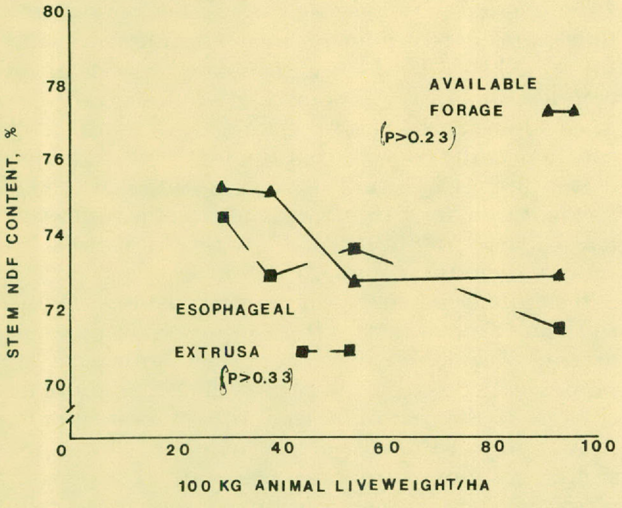

Figure 5. NDF content of stem fragments in the available forage and esophageal extrusa.

Further research is needed to understand the preferences an animal has in selecting its diet, and how these preferences and forage growth interact with grazing pressure. Knowledge of these variables is necessary to plan the most economical systems of animal production.

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PR-4216

Factors Affecting Intake and Nutritive Value of Annual Ryegrass

W. C. Ellis, J. P. Telford, H. Lippke, and M. E. Riewe

Summary

Grazing trials with annual ryegrass showed that animal productivity varied with forage availability resulting from varied grazing pressure. Results were similar to those observed for other classes of forages. The trials suggest that ryegrass may not meet the growing animals' complete nutrient requirements for maximum production. Grazing the vegetative ryegrass plant below a critical availability or height reduces its digestibility. This was associated with reductions in forage intake without depressing fecal output. Selective grazing altered the potential digestibility of the residual forage and was associated with reduced intake. Under these conditions, rather constant fecal

output by the grazing animal indicated the quantity of prehensible forage was not the factor limiting forage intake. These results indicate that the digestibility of ryegrass may regulate its intake by the grazing animal. This conclusion is contrary to the concept that intake of forage of greater than 65 percent digestibility is regulated by metabolic means.

Introduction

By most nutritional criteria, the cool season annual grasses are extremely high quality feedstuffs. But animal production research has not determined the effects of forage quantity and quality upon production. This report is based on several studies of grazing management and forage availability as they affect the nutritive value of annual ryegrass.

Review of Literature

Two main factors normally determine the level of production of an individual animal: 1. The animal's genetically determined capacity to utilize nutrients, which establishes its requirement for dietary nutrients; and 2. The animal's ability to acquire nutrients from its feed supply to contribute to this nutrient requirement.

The ability to acquire nutrients is the factor most frequently limiting ruminant productivity from forages, especially from less digestible (< 65 percent) forages (2, 5). Less digestible forages tend to have too large a volume of bulky residue for the size of the rumen (5), as depicted in Figure 1.

Forbes (5) has proposed a model for regulating feed intake based on factors affecting the frequency and size of individual meals. Cattle begin individual meals when the rate of absorption of nutrients falls below a certain minimal threshold. The meal may then be either metabolically terminated when the rate of nutrient absorption exceeds a certain upper threshold, or physically terminated when the rumen is full. According to these concepts, the daily intake of less digestible forages will be largely controlled by physical termination of meals to conform with the volume available in the rumen. The daily intake of more digestible forages is largely, if not entirely, controlled by metabolic termination of meals to conform with short term (< than daily) metabolic balances between digested and required nutrients. Both metabolic and physical termination of meals occurs for forages of intermediate digestibility (60 to 70 percent for example).

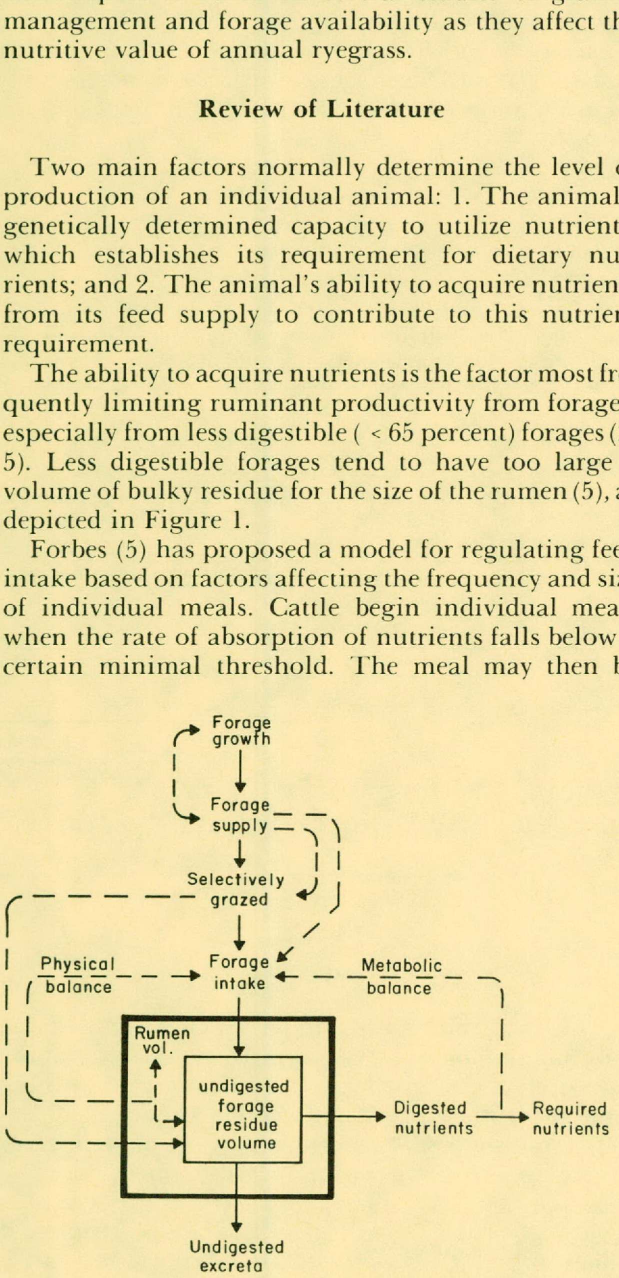

Figure 1. Regulation of intake in the grazing ruminant and its interactions (———) with forage availability and forage/animal attributes.

In the grazing animal, additional factors may limit forage intake. As the supply of prehensible forage is reduced (relative to the demand for nutrients) ruminants increase their grazing time (1) to compensate. However, as the animal extends its grazing time the compensation becomes progressively more incomplete and forage intake decreases. At extremely high grazing pressures, forage intake will equal forage growth rate. Forage growth rate may be supressed under such high grazing pressures (Figure 1).

At intermediate grazing pressures, forage intake may be indirectly influenced by selective grazing. Increasing the quantity of prehensible forage allows the animal to selectively consume more nutritious plants until some maximum selectivity is achieved (1, 6). By this means, forage intake may be increased because of greater digestibility of selected forage.

It is clear that performance of grazing animals may be the result of a number of interactions involving the forage, the animal and grazing management involved. Figure 2 summarizes results of a 4-year study in which four different levels of grazing pressure were maintained to yield varying levels of forage availability (Forage/area) using ryegrass (13). The animal gain response to varied forage availability is typical of that obtained with many forages, and its implications have been extensively discussed (12, 7). The results in Figure 2 suggest that steers grazing ryegrass did not have all of their nutrient requirements met. This interpretation is supported by the higher gains made by steers grazing ryegrass plus clover as compared to those grazing ryegrass alone at all levels of forage availability. This contradicts the concept that the intake of such highly digestible (> 65 percent) forages is regulated solely by metabolic balance. If this was the case, the full productive capacity of the animal should be realized from forages such as ryegrass (2).

It should be noted that the animal responses reported in Figure 2 are means for those occuring over the entire grazing season. Measurement of such "long term " responses is necessary to minimize effects of short term changes in the gastrointestinal fill component of liveweight measured. However, Taylor (14) has shown similar responses to forage availability for perennial ryegrass when animal responses were measured as digesta free body weight, energy gain, forage intake or intake of digestible organic matter. Some results of his studies are summarized in Table 1, and indicate the

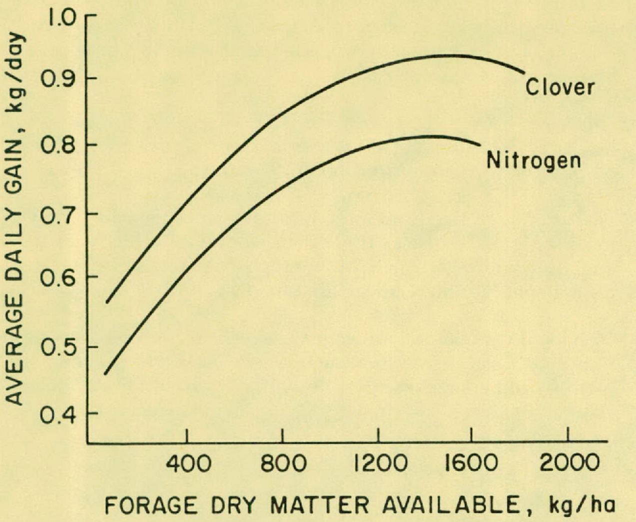

Figure 2. The relative relationships of average kg forage dry matter available per ha to 4-year average daily gain for steers grazing Gulf ryegrass fertilized with nitrogen or grown in Abon Persian clover (Angleton, Texas).

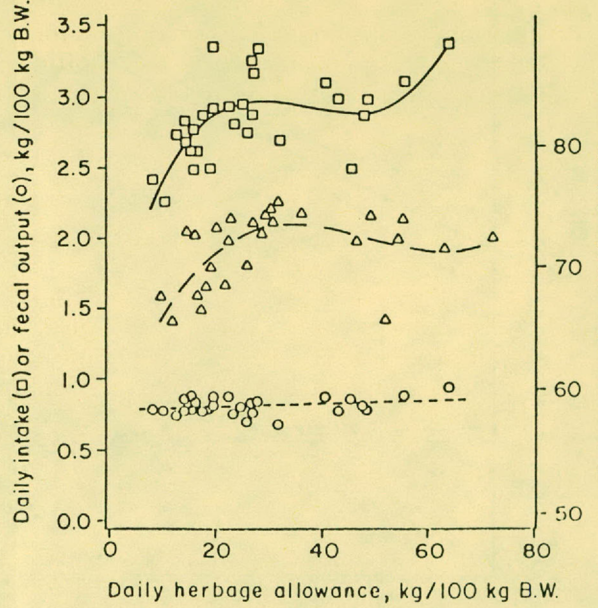

Figure 3. Relationships for daily intake, fecal output and dry matter digestibility to changes in daily herbage allowance due to duration of grazing.

forage availabilities or height required for specified levels of animal performance. These and other date (1) emphasize the importance of forage height rather than forage/area in determining the quantity of prehensible forage. Such aspects of grazing prehension of forage are discussed in greater detail by Hodgson (10).

Successive first, second and third grazer cattle have been used to measure effects of progressive reductions in the daily herbage allowance (quantity of forage/quantity of animal/time) of rotationally grazed annual ryegrass. These effects on the intake and digestibility of the forage and the fecal output by cattle are summarized in Figure 3.

The progressive reduction in daily herbage allowance from 70 to 10 kg dry matter per 100 kg animal body weight had no significant effect on daily fecal output, which averaged 0.84 kg per 100 kg body weight. In contrast, dry matter digestibility and daily intake were significantly ($P < .01$) and progressively reduced when daily herbage allowance was reduced below 30 kg per 100 kg body weight. These studies indicate that quality rather than quantity of ryegrass forage limited forage intake. The effects on digestibility indicate that in this progressive harvest cattle grazed selectively. This resulted in depressed digestibility of the ungrazed residue and the subsequent diet when daily herbage allowance was reduced to less than 20 to 30 kg DM per 100 kg body weight.

Of equal, if not greater significance, is the high correlation between intake and digestibility of these highly digestible forages. This relationship is further illustrated in Figure 4, which emphasizes that most of the variation in observed intake was linearly related to the digestibility of the consumed forage. This is surprising since such highly digestible forages contribute relatively small amounts of the undigested dry matter required in the rumen (Figure 1) to affect physical regulation of intake (2,5). Alternatively, the volume of masticated ryegrass entering the rumen may be effective in a stratigraphic manner in reducing rumination, and thereby forage intake, as was observed by Deswysen and Ehrlein (4).

A number of investigators have reported significant correlations between intake of perennial ryegrass and its digestibility when such digestibility was in the order of 65 to 80 percent and altered by grazing management (8, 9, 10). This relationship also has been reported for highly digestible temperate forages other than ryegrass (3, 11). Thus, regulation of intake of highly digestible, cool season, temperate forages by means related to their digestibility appears to be a general phenomenon.

TABLE 1. ESTIMATED AVAILABILITY[a] OF PERENNIAL RYEGRASS REQUIRED FOR MAXIMUM AND MAINTENANCE LEVELS OF PERFORMANCE BY GROWING CATTLE (14)

Index of herbage availability	Maximum gain per head	Maintenance of liveweight
Kg 0.M./ha		
All residue[b]	2466.0	841-1457
"Grazed" residue[c]	1906.0	673-1233
Mean height, cm		
All residue[b]	13.5	5.1
"Grazed" residue[c]	9.7	3.0

[a]Availability measured as above ground level.

[b]Includes areas contaminated with dung which were avoided by grazing activities.

[c]Includes only areas being actively grazed; does not include dung contaminated areas.

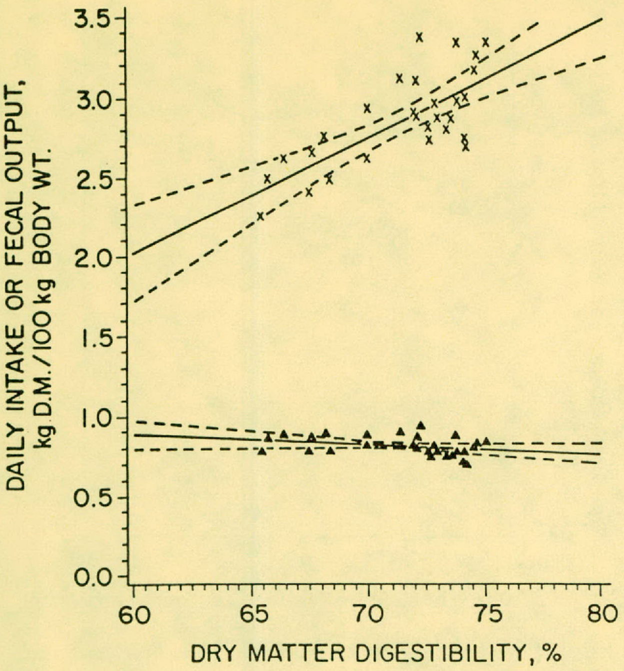

Figure 4. Intake of ryegrass and fecal output of steers grazing ryegrass of varied digestibility due to the maturity and grazing management of the ryegrass.

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PR-4217

The Effect of $NaHCO_3$ Upon Rumen pH and Dry Matter Digestibility of Grazed Ryegrass

L. D. Roth, W. C. Ellis, G. A. Wall, L. W. Greene, and H. Lippke

Summary

The effect of $NaHCO_3$ upon the pH of rumen digesta and dry matter digestibility (DMD) of grazed ryegrass was studied using 10 yearling, rumen-fistulated steers. The pH of rumen digesta and DMD were measured at the end of a 3-week period of adaptation to bermudagrass hay, and then on days 3 through 7 after animals were transferred to a ryegrass pasture. Steers consuming ryegrass pasture had a lower pH in their rumen digesta and greater DMD than on bermudagrass hay. Steers receiving ryegrass pasture plus $NaHCO_3$, at the rate of 0.2 percent of body weight, had a higher rumen digesta pH (5.75 vs. 5.62), but did not differ in DMD from steers receiving only ryegrass pasture.

Introduction

The short term reduced performance of ruminants after transition from roughage to highly digestible diets is well recognized (5). A similar decline in performance is often noted following transition to highly digestible forages such as cool-season annuals, including wheat, oats and ryegrass. This reduced performance probably is due in part to changes in gastrointestinal fill. However, observations suggest that diet-induced digestive disturbances are also present.

Animals tend to exhibit a profuse diarrhea within 2 to 3 days of entering a cool-season annual pasture. This may persist for 2 to 4 weeks, with accompanying signs of dehydration and respiratory stress. The diarrhea may be the result of an increased flow of reaidly fermentable nutrients from the rumen (3). The early growth of cool-season annuals may contain 25 to 30 percent soluble carbohydrates and 30 percent crude protein (6). These high levels of readily fermentable substrates could yield substantial amounts of acidic fermentation by-products such as the L (+) and D (-) forms of lactate. The lush forage also may cause less mastication and remastication by the grazing animal, thereby decreasing the flow of saliva to buffer the fermentation products (4). This increased lactate formation and reduced saliva production may cause ruminal acidosis, which could be made worse by the loss of alkali reserves due to the diarrhea. There might be a sodium deficiency, especially, because of the high potassium content of early growth, cool-season annuals. For these reasons, this study was conducted to determine the effect of $NaHCO_3$ upon pH of rumen digesta and dry matter digestibility of grazed ryegrass.

Procedure

Ten yearling, rumen-fistulated steers with an average weight of 415 kilograms (kg) were fed bermudagrass hay for 3 weeks. At the end of this time all 10 steers were transferred to a 10-hectare ryegrass pasture in an early stage of growth, and five animals were allotted to each of two treatment groups. All animals were gathered from the pasture and penned each morning, with one treatment group released to graze the pasture. The remaining five animals were administered $NaHCO_3$ via the rumen cannula at the rate of 0.2 percent of body weight, or approximately 0.83 kg daily, and then released to graze with the other steers.

Esophageally-fistulated animals were used to determine the composition of diet selected during the bermudagrass hay and ryegrass pasture periods. Fecal grab samples were obtained for 5 consecutive days at the end of the bermudagrass hay period, and during days 3 through 7 after the transfer to ryegrass pasture. Fecal grab samples were obtained three times daily — at the time of administering $NaHCO_3$, and 8 and 16 hours later. Indigestible neutral detergent fiber content of fecal and esophageal samples was defined as the neutral detergent fiber organic matter remaining after a 6-day in vitro fermentation period. Dry matter digestibility (DMD) was calculated by the formula:

$$DMD = \left(\left(1 - \frac{\text{INDF of Diet DM}}{\text{INDF of Fecal DM}} \right) \right) \times 100$$

Rumen digesta samples were obtained for 5 consecutive days at the same times of day fecal samples were collected. These samples were collected via the rumen cannulae and transferred to storage cups. The pH was measured with a pH meter within 30 minutes of collection.

Differences between treatments were tested using the General Linear Model procedure of the Statistical Analysis System (7).

Results and Discussion

The mean pH's of rumen digesta are displayed in Table 1. During the adjustment period to bermudagrass hay, the 10 steers had a mean rumen digesta pH of 6.3. After transfer to the ryegrass pasture, the ryegrass plus $NaHCO_3$ steers had a rumen digesta pH of 5.75, which was higher ($P < .05$) than the rumen digesta pH (5.62) of the steers receiving only ryegrass pasture. While the rumen digesta pH decreased from the adjustment period to the treatment period, it did not approach ruminal acidosis conditions of pH 4.0-4.5 (1). Thus the animals were not threatened by ruminal acidosis. Due to the pH levels experienced, the $NaHCO_3$ may not have exhibited its total buffering capacity (2). Further, the profuse diarrhea and other symptoms associated with transition to winter pasture were not observed in these animals.

TABLE 1. RUMEN DIGESTA pH

Period	Bermudagrass Hay N=10	Ryegrass Pasture N=5	Ryegrass + $NaHCO_3$ N=5
Adaptation	6.3	-	-
Treatment	-	5.62^b	5.75^a

^{a,b}Means in the same line with a different superscript differ ($P < .05$).

TABLE 2. DRY MATTER DIGESTIBILITY

Period	Bermudagrass Hay N=10	Ryegrass Pasture N=5	Ryegrass + $NaHCO_3$ N=5
Adaptation	38.5	-	-
Treatment	-	73.8^a	76.07^a

^{a,b}Means in the same line with a different superscript differ ($P < .05$).

In conclusion, the ryegrass diets resulted in a lower rumen digesta pH and greater DMD than the bermudagrass hay diet. The level of $NaHCO_3$ administered increased the pH of rumen digesta of steers grazing ryegrass, but did not alter DMD from steers not receiving $NaHCO_3$.

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PR-4218

Measurement of Potassium Status in Ruminants

J. H. Poe, L. W. Greene, G. T. Schelling, W. C. Ellis, and F. M. Byers

Summary

Two metabolism trials were conducted with 12 crossbred wether lambs to determine potassium (K) and magnesium (Mg) homeostasis and rate of potassium excretion in ruminants removed from high levels of dietary potassium and sodium (Na). The three dietary treatments were: (1) control (.6 percent K; .2 percent Na); (2) high potassium (3.0 Percent K; .2 percent Na); and (3) high potassium-high sodium (3.0 percent K; 1.0 percent Na). After a 15-day preliminary period in which lambs were fed their respective treatments, all lambs were fed the control diet for five days to monitor rate of potassium excretion. Magnesium absorption was not affected in animals removed from elevated levels of potassium or potassium and Sodium. During the last 5 days of the preliminary period, potassium retention was higher ($P < .05$) in lambs fed potassium. Urinary potassium excretion was 12.5 grams per day (g/day) when K was fed, as compared to 2.5 g/day when animals were fed the control diet. Urinary potassium excretion declined 127 percent and 188 percent between day 1 and day 2, following removal of supplementation, for the high potassium and high potassium-high sodium groups, respectively. There continued to be a significant decline between day 2 and day 3, and by day 4 both of the potassium-supplemented groups returned to normal potassium excretion patterns. In this study, urinary potassium excretion was closely related to potassium intake, and appeared to be an effective indicator of potassium intake.

Introduction

Increased levels of dietary potassium have resulted in increased animal performance in feedlot steers. Hutcheson et al. (4) concluded that a potassium level of 1.3 percent in the receiving diets of feedlot cattle not only increased weight gains, but also prevented death loss from stress. Greene et al. (1, 2) and Newton et al. (5) reported that when sheep and steers were fed elevated levels of potassium (4.8 percent), potassium absorption and retention increased significantly; however, there were minor changes observed in serum potassium. Erythrocytes contain 25 times as much potassium as plasma; therefore, measurement of erythrocyte potassium or urinary potassium excretion may provide a rapid and reliable measurement of body potassium status in the live animal.

The present study evaluated potassium homeostasis and a rate of potassium excretion in lambs removed from elevated quantities of potassium and sodium.

Experimental Procedure

Twelve crossbred wether lambs (average weight 27 kilograms) were used in two metabolism trials. Lambs were blocked according to weight and randomly assigned, within blocks, to one of three treatments. Treatments were designed to contain the following potassium and sodium ratios: 3:1 (control), 5:1 (high K); and 3:1 (high K, high Na). Potassium (potassium carbonate) and sodium (sodium chloride) were increased in the control diet by adding 30.54 g/day and 14.68 g/day, respectively. These supplements were added to the control diet (Table 1) and hand mixed prior to feeding. Animals were fed 400 grams of the control diet plus each corresponding treatment twice daily. The experiment consisted of a 15-day preliminary period in which lambs were fed their daily allottment of feed and corresponding treatment. During the last 5 days of the preliminary period, feed, feces and urine were collected and tested for potassium and magnesium balance. Following the 15-day preliminary period, treatments were removed and animals were maintained on the basal diet for a 5-day collection period. During this time, feed, feces, urine and blood samples were collected daily to monitor potassium and magnesium losses. All samples taken from the animals were analyzed for potassium and magnesium by atomic absorption spectrophotometry.

Results and Discussion

Potassium balance data for the last 5 days of the 15-day preliminary period are shown in Table 2. Lambs fed supplemental potassium showed greater ($P < .05$) quantities of potassium crossing the gut wall and subsequently excreting in the urine than the lambs fed the control diet. Potassium retention was increased 400 percent (.82 vs. 4.07 g/day) when potassium was

TABLE 1. COMPOSITION OF BASAL DIET FED TO LAMBS

Ingredient	% of Total[a]
Cottonseed hulls	30.00
Soybean meal	2.90
Ground corn	64.00
Urea	1.23
Trace mineralized salt	.50
Dicalcium phosphate	1.37

[a]As fed basis.

TABLE 2. POTASSIUM INTAKE, EXCRETION, ABSORPTION AND RETENTION IN LAMBS FED ELEVATED LEVELS OF POTASSIUM (K) AND SODIUM (Na)

Item	Control	High K	High K High Na
Intake, g/day	4.29[a]	17.50[b]	17.25[b]
Excretion, g/day			
Urine	2.49[a]	12.52[b]	12.88[b]
Absorption, g/day	3.26[a]	16.59[b]	16.28[b]
Retention, g/day	.82[a]	4.07[b]	3.40[b]

[a,b]Means within the same line with different superscripts differ significantly ($P < .05$).

included in the diet. The addition of sodium did not significantly alter potassium retention.

During the 5-day collection period, urinary potassium excretion (Table 3) ranged from 2.45 g/day to a low of 1.44 g/day in those lambs fed the control diet. There was a 15 percent decline (12.52 to 10.83 g/day) in potassium excreted in the urine the first day after removal of potassium from the diet. Urinary potassium excretion continued to decline until day 4, when urinary potassium excretion became similar to that of the control animals. Animals supplemented with potassium and sodium followed similar excretion patterns, and by day 4 following treatment removal, both potassium-supplemented groups exhibited similar urinary potassium ecretion patterns as the controls.

Potassium absorption for the 5-day period is shown in Table 4. It appears that immediately following removal of treatment, potassium was rapidly cleared from the gastro-intestinal tract and excreted in the urine in both the high potassium and high potassium-high sodium groups. Therefore, the quantity of potassium crossing the gut was similar to that of the control group from day 1 through day 5 following removal of supplemental potassium or potasssium and sodium.

Previous work indicates that animals fed high potassium diets exhibit little change in serum potassium (1). In the present study, there was no significant change in plasma potassium when animals were fed elevated potassium or sodium (Table 5).

Therefore, the high quantities of potassium being retained by those lambs fed the supplemental potassium during the preliminary period would seem to be a component of the cellular material. Erythrocyte potassium was measured (wet basis) in an attempt to assess the potassium status of these animals (Table 6).

TABLE 3. URINARY POTASSIUM EXCRETION (g/day) IN LAMBS FED ELEVATED LEVELS OF POTASSIUM (K) AND SODIUM (Na)

	DAY				
Diet	1	2	3	4	5
Control	2.45	2.45	2.11	1.44	1.44
High K	10.83[a]	4.78[b]	2.54[bc]	1.69[c]	1.80[c]
High K High Na	13.83[a]	4.80[b]	2.57[c]	1.49[c]	1.60[c]

[a,b,c]Means within the same line with different superscripts differ significantly ($P < .05$).

TABLE 4. POTASSIUM ABSORPTION (g/day) IN LAMBS FED ELEVATED LEVELS OF POTASSIUM (K) AND SODIUM (Na)

	Day				
Diet	1	2	3	4	5
Control	4.09	4.18	4.18	4.10	4.04
High K	3.94	3.66	3.81	3.76	3.79
High K High Na	3.82	3.49	3.76	3.88	3.87

TABLE 5. PLASMA POTASSIUM (Mg/dl) OF LAMBS FED ELEVATED LEVELS OF POTASSIUM (K) AND SODIUM (Na)

	Day				
Diet	1	2	3	4	5
Control	18.27	18.89	18.46	15.81	13.58
High K	20.09	18.54	17.89	15.94	18.55
High K High Na	18.75	18.58	17.55	18.03	17.25

TABLE 6. RED BLOOD CELL POTASSIUM (%) OF LAMBS FED ELEVATED LEVELS OF POTASSIUM (K) AND SODIUM (Na)

	Day				
Diet	1	2	3	4	5
Control	4.45	3.66	4.10	3.68	3.85
High K	3.51	3.76	3.82	3.33	3.58
High K High Na	3.52	3.87	3.78	3.74	3.51

However, in this study there was no significant change in erythrocyte potassium concentration in those animals previously supplemented with potassium or potassium and sodium. Cellular water retention probably increased, which would dilute any increase in cellular potassium.

The results of this study indicate that when ruminants are fed high quantities of potassium, the mechanisms responsible for maintaining normal potassium homeostasis will alter the rate of potassium excretion in an attempt to maintain normal body levels of potassium. In the present study, urinary potassium excretion was an effective indicator of potassium intake in animals consuming excess potassium. Measurement of erythrocyte potassium concentration gave no indication as to the potassium status of animals previously consuming diets high in potassium. After removal of excess potassium, animals returned to normal urinary potassium excretion patterns by day 4. This indicates that by day 4, normal potassium homeostasis was reached in those lambs previously fed the high potassium or high potassium-high sodium diets.

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PR-4219

Growth and Energy Retention in Steers Fed Chemically Treated Sorghum Silage

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Summary

Crossbred Hereford steers were used in growth and digestion experiments to evaluate the merit of chemically treating whole plant sorghum grain silage. Silage treatments used were anhydrous ammonia at 1.8 percent of silage dry matter (DM), sodium hydroxide (2.0 percent DM), sulfuric acid (1.8 percent DM), and an untreated control. Initial and final body composition of the steers were estimated. Digestibility of the silages was determined using chromic oxide as the marker. Fermentation characteristics of the silages were monitored throughout the experiment. Silage treated with anhydrous ammonia had 2.5 times more ($P < .05$) lactic and acetic acid than control silage. Steers fed the anhydrous ammonia treated silage gained weight more efficiently ($P < .05$) than those fed other silages. Digestibility of starch and energy were greater ($P < .01$ and $P < .1$, respectively) for the anhydrous ammonia and untreated silages than for other treatments. Energy retention was also higher ($P < .05$) for the anhydrous ammonia and untreated silages. Anhydrous ammonia extended fermentation, reduced soluble carbohydrate levels and increased hemicellulose digestion of the silages, resulting in improved energy utilization. These data indicate that treatment of whole plant sorghum grain silage with 1.8 percent anhydrous ammonia significantly extends the feeding value of the stover within the silage and also increases the stability of the silage when fed to cattle.

Introduction

One of the most efficient ways of harvesting and preserving fresh, whole plant sorghum grain is ensiling. Ensiling permits complete mechanization, is less dependent upon ideal weather at time of harvest than other harvesting alternatives, and results in larger quantities of harvested nutrients per hectare. The resulting silage may be stored successfully for extended periods. Research (8) has shown that ensiling the entire sorghum grain plant increases liveweight gains of cattle by almost one-third as compared to harvesting and feeding only the sorghum grain.

Silage additives are commonly used to increase silage stability and/or improve nutritional qualities. Numerous chemicals have been investigated for silages, but limited research has been conducted with whole plant sorghum grain silage.

This experiment was designed to evaluate three different chemical treatments of whole plant sorghum grain silage. Of special interest were the treatments' effects upon silage fermentation, rate and efficiency of growth, energy retention and nutrient digestibility in cattle.

Experimental Procedure

A commercial heteroyellow endosperm type sorghum grain hybrid (WAC 715) was used to evaluate the three chemical treatments. Whole plant sorghum grain silage was ensiled at approximately 40 percent dry matter in four 90 MT-capacity plastic bags. Anhydrous ammonia (1.8 percent), sodium hydroxide (2.0 percent) and sulfuric acid (1.8 percent) were added to three different silos as a percentage of silage dry matter. Application was made with spray nozzels situated in the throat of a Silopress unit. One silo with untreated silage served as the control.

Rations fed were composed of treated and control whole plant sorghum silages and premixes, as outlined in Table 1. Two premixes were used to provide similar crude protein and non-protein nitrogen content for all rations (Table 2).

Measures of fermentation (1,4) were recorded from the start of the ensiling process until the end of the growth trial. After 60 days of fermentation, the silages were fed in a 108-day growth trial with 84 Hereford crossbred steers randomly divided in three replicates of seven steers each. The steers were given routine vaccinations, implanted and identified upon arrival at the Texas A&M University Beef Cattle Research Facility. All cattle were weighed at the initiation, at 28-day intervals, and at the end of the growth phase. Weights were obtained on two consecutive days for initial and final liveweight. Final weight was adjusted to a common overall dressing percentage to eliminate the influence of differential gut fill. All cattle were fed once daily. To estimate body composition, eight steers were infused with deuterium oxide (3) at the start of the growth trial and at the end of the feeding period; five steers from each treatment were slaughtered to determine carcass specific gravity (6).

Four steers were individually fed with Calan gates to determine nutrient digestibility of the silages. Four

TABLE 1. COMPOSITION OF RATIONS[1]

Ration	Whole plant Sorghum grain silage IFN:3-07-962	Premix A	Premix B
Control	88.80	11.20	
Anhydrous ammonia	88.80		11.20
Sodium hydroxide	88.80	11.20	
Sulfuric acid	88.80	11.20	

[1]Diets were isonitrogenous (11 percent CP).

TABLE 2. COMPOSITION OF PREMIXES (DM BASIS)

Item	IFN	Premix A	Premix B
Cottonseed meal	5-01-621	82.08	85.10
Urea	5-05-070	4.48	
Calcium carbonate	6-02-632	5.60	5.78
Defluorinated phosphate	6-01-780	0.37	
Ammonium sulfate		3.74	4.59
Trace mineral salt	6-04-152	2.67	3.21
Vitamin premix		1.12	1.38

sampling periods of 21 days each (14 days of adaptation and 7 days of sampling) were performed in a Latin square design. Chromic oxide was added to the supplement before it was mixed with the silage to provide approximately 40 g/head/day. Rectal fecal grab samples were collected twice daily. Feed samples were obtained for 7 days, beginning 2 days before each collection period. Fecal and feed samples were composited by animal per period, and analyzed for chromic oxide, starch, energy and acid detergent fiber.

Analysis of variance and Duncan's New Multiple Range Test (7) were performed to compare treatment means.

Results and Discussion

Ensiling Characteristics. The addition of anhydrous ammonia increased ($P < .05$) silage organic acid levels (Table 3) above those observed for untreated, sodium hydroxide- or sulfuric acid-treated silages. Increases in acetic acid and lactic acid were the result of extended fermentation produced by the anhydrous ammonia, suggesting that the soluble carbohydrates were reduced in direct proportion to levels of organic acids formed (2). Silage temperature (Table 3) was highest ($P < .05$) with the sodium hydroxide treatment. None of the silages attained temperatures high enough to suggest heat damage. Acidity was least ($P < .05$) for the sodium hydroxide treatment, which is consistent with its higher temperature. Of the four silage treatments, anhydrous ammonia most consistently established near optimum fermentation. It also prolonged ($P < .05$) the bunk life of the silage as indicated by a lower temperature upon exposure of the silage to the atmosphere for 6 hours (Table 3).

Cattle Growth. Final adjusted weight, total gain and daily gain were greater ($P < .01$) for the untreated and anhydrous ammonia-treated silages than for the other treatments. Cattle fed treated silages consumed less ($P < .01$) dry matter than controls, and cattle fed ammoniated silage had the highest ($P < .01$) feed efficiency (Table 4).

The low pH of the sulfuric acid-treated silage was apparently responsible for the reduction in dry matter intake of steers (Table 4), which relates to their poorer performance. After 3 weeks on the experiment, sodium hydroxide was added to the sulfuric acid silage to increase silage pH to 4.2 to 4.3, after which consumption and gain improved. One steer consuming the sulfuric acid-treated silage died from acidosis during the third week of the experiment.

Digestibility. Dry matter digestibility averaged 52 percent and was not significantly influenced by silage treatment, while starch digestibility (average of 82

TABLE 3. SILAGE FERMENTATION CHARACTERISTICS.

	Chemical treatment (% of dry matter)				
Item	Control	Anhydrous ammonia 1.88%	Sodium hydroxide 2.07%	Sulfuric acid 1.53%	SEM
Dry matter, %[1]	40.52	38.80	42.54	44.82	3.00
Crude protein, % DM[2]	7.59	9.78	8.04	7.92	
Acid detergent[2] protein, % DM	5.90	8.70	6.02	6.19	
pH[1]	4.16[a]	4.35[a]	4.61[b]	3.71[a]	3.77
Acetic acid % DM[1]	2.77[a]	5.65[b]	1.72[a]	2.17[a]	0.60
Butyric acid, % DM[1]	0.30	0.83	0.47	0.41	0.17
Lactic acid, % DM[1]	5.45[a]	13.73[b]	5.46[a]	5.56[a]	0.91
Silage temperature[3] in silo, C	37.39[a]	39.00[a]	42.41[b]	39.90[a]	0.01
Silage temperature[4] in feed-bunks, C	37.00[a]	18.57[b]	26.14[c]	25.71[d]	0.01

[a,b,c,d]Means on the same line bearing different superscripts differ ($P < .05$).

[1]Mean of 6 samples collected per treatment after 2 months of fermentation were completed.

[2]Mean of 3 samples taken 1 month before start of experiment.

[3]Mean of 36 readings per treatment, obtained daily during the first 30 days and thereafter at 40, 45, 50, 55, 60 and 70 days.

[4]Mean of three temperature readings per treatment. Silage was fed at 14:00 hours, with temperatures taken 6 hours later.

TABLE 4. PERFORMANCE OF STOCKER CALVES

	Chemical treatment				
Item	Control	Anhydrous ammonia	Sodium hydroxide	Sulfuric acid	SEM
Days on feed	108	108	108	108	
Initial weight, kg	273	270	268	270	1.67
Adjusted final weight, kg[1]	363[a]	389[b]	330[c]	323[c]	5.08
Total gain, kg	90[a]	118[b]	61[c]	53[c]	4.41
Gain, g/day	832[a]	1096[b]	563[c]	495[c]	40.00
DM intake, kg/hd/day	10[a]	8[b]	9[b]	7[b]	1.00
Feed efficiency	12[a]	8[b]	16[a]	14[a]	1.26

[a,b,c]Means on the same line bearing different superscripts differ ($P < .01$).

[1]Final weight treatment dressing percent/mean dressing percent of 59.46.

percent) differed (P < .01) for the untreated and anhydrous ammonia silages as compared to the other treatments (Table 5). Acid detergent fiber digestibility was least (P < .1) for the sulfuric acid-treated silage and highest for the sodium hydroxide-treated silage. This suggests fiber hydrolysis. Energy digestibility averaged 50 percent and was least (P < .1) for the sulfuric acid-treated silage. Anhydrous ammonia silage had the highest energy digestibility, which may be associated with its higher lactic acid content (Table 3). The conversion of readily available energy sources in the form of soluble carbohydrates into lactic acid during ensiling may diminish the influence of low ruminal pH, which severely inhibits ruminal degradation of structural carbohydrates in forages. Thus, since the extended fermentation produced by anhydrous ammonia may lower the level of reaidly available soluble carbohydrates, energy in the structural carbohydrates of whole plant sorghum grain silage would be more efficiently utilized by rumen microbes.

Efficiency of Growth. After 108 days on feed the average final empty body weight was 317 kg, and empty body protein averaged 58 kg. These measurements were not influenced by silage treatments (Table 6). Empty body fat was greatest (P < .05) with the anhydrous ammonia (61 kg) silage, while the sodium hydroxide (42 kg) and sulfuric acid (40 kg) silages produced the least empty body fat compared to the control (52 kg) (Table 6).

Daily retention of energy was greatest (P < .05) for steers fed anhydrous ammonia silage (expressed as grams of fat or kg of energy), intermediate for steers fed control silage and least for steers in the sodium hydroxide and sulfuric acid treatments.

These results indicate that ammoniated silage had more digestible energy and lactic acid, resulting in more efficient weight gain for stocker calves, than the control, sodium hydroxide- or sulfuric acid-treated silages. Furthermore, the anhydrous ammonia-treated silage was higher in crude protein and more stable in the feedbunk compared to other silages.

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TABLE 5. DIGESTIBILITY OF SILAGES

Item	Chemical treatment: Control	Anhydrous ammonia	Sodium hydroxide	Sulfuric acid	SEM
Dry matter intake, kg/day	12	11	10	9	3.16
			Digestibility		
Dry matter,%	51	60	52	47	4.00
Starch, %	89^{a}	87^{a}	80^{b}	72^{c}	2.00
Acid detergent fiber, %	44^{ab}	46^{ab}	54^{a}	39^{b}	4.00
Energy, %	50^{ab}	59^{a}	48^{ab}	43^{b}	4.00
Digestible energy, Mcal/kg	2.07^{ab}	2.37	1.88^{b}	1.73^{b}	0.16

[a,b,c]Means on the same line bearing different superscripts (P < .05).

TABLE 6. COMPOSITION AND EFFICIENCY OF EMPTY BODY GROWTH

Item	Chemical treatment: Control	Anhydrous ammonia	Sodium hydroxide	Sulfuric acid	SEM
			Initial composition		
Number of steers	8				
Live weight, kg	270				
Empty body					
Weight, kg	235				
Protein, kg	43				
Fat, kg	38				
			Final Composition		
Number of steers	5	5	5	5	
Live weight, kg	364	366	344	321	46
Carcass weight, kg	213	230	197	190	27
Dressing percent	59^{a}	63^{b}	57^{a}	59^{a}	0.99
			Empty body composition, kg		
Weight	324	343	299	305	16
Protein	60	62	57	55	2
Fat	52^{ab}	67^{a}	42^{b}	40^{b}	6
			Rate and efficiency of growth		
Empty body, g/day	826	1003	590	647	155
Protein, g/day 24	163	175	130	116	24
Fat, g/day	133^{ab}	267^{a}	42^{b}	16^{b}	56
Retained energy[1] kcal/day	217^{ab}	350^{a}	114^{b}	82^{b}	63
Retained energy[2] Kcal/day	28^{ab}	42^{a}	15^{b}	12^{b}	7.50

[ab]Means on the same line bearing different superscripts differ (P < .05).

[1]((Protein growth * 5.686) + (fat growth * 9.367))/108 days.

[2](Retained energy)/(Empty body weight * $^{.75}$).

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PR-4220

The Effects of Rolling Grain Within Whole Plant Sorghum Silage on Growth Efficiency and Energy Retention of Cattle

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Summary

Crossbred Santa Gertrudis steers were individually fed three ratios of whole plant sorghum silage, with the grain within the silage fed whole or rolled. Grain was processed by separating the silage into grain and stover, rolling the grain, and then recombining the two immediately before feeding. Silage was fed at 85 (high silage), 40 (intermediate silage) and 5 percent of the dry matter (low silage). High and intermediate silage diets were fed either with processed or unprocessed grain. Steers fed intermediate silage-whole grain diet had lower ($P < .10$) total gain compared to the low silage-whole grain diet. Neither average daily gain, dry matter intake nor feed efficiency were significantly different among treatments. Acid detergent fiber digestibility was higher ($P < .001$) for the high silage-whole grain diet as compared to the other treatments. Dry matter, starch and energy digestibility, and composition and efficiency of body growth were not significantly different among treatments. These results suggest that rolling the grain within silage and combining silage with higher percentages of grain did not alter cattle performance.

Introduction

Sorghum silage is frequently processed and fed the same way as corn silage when intended for feeding cattle. Limited research suggests that post-ensile rolling of the silage (both grain and stover) significantly improves weight gain and feed efficiency (6) and starch digestibility (8) in cattle.

Therefore, an experiment was designed to determine whether selective rolling of the grain within sorghum silage would enhance silage digestibility, as well as rate, composition and efficiency of growth of cattle, when fed at three energy levels.

Experimental Procedure

A commercial heteroyellow endosperm type sorghum grain hybrid (WAC 715) was harvested and stored in large plastic bag silos for 4 months before initiating the feeding trial. The silage was processed by separating the grain from the stover with a mechanical shaker, rolling the grain and recombining both before feeding. The processed silage was then mixed with rolled reconstituted sorghum grain (23 percent moisture) to result in the following silage-added grain mixtures (percent of DM): 85-0 (high silage); 40-50 (intermediate silage), 5-90 (low silage) (Table 1). A supplement was added (Table 2) to produce isonitrogenous rations.

TABLE 1. COMPOSITION OF RATIONS[1]

Ingredient, %	IFN	Silage level: High	Interm.	Low
Whole plant sorghum grain silage	3-07-962	85	40	5
Reconstituted[2] sorghum grain	4-04-383		50	89
Cottonseed meal	5-01-621	11	6	2
Premix		4	4	4
Totals		*100*	*100*	*100*

[1]Means were adjusted to the nutritional requirements of the steers; given values are those of the finishing phase.
[2]Grain reconstituted to 23 percent moisture.

Santa Gertrudis crossbred steers were individually fed one of the five diets. Five steers were assigned to each of the following treatments: (a) high silage-whole grain; (b) high silage-rolled grain; (c) intermediate silage-whole grain; (d) intermediate silage-rolled grain; and (e) low silage-whole grain (Table 1). In treatments (a), (c) and (d) the grain within the silage was left intact; the added reconstituted grain was fed in the rolled form for the intermediate and low silage treatments.

Steers were given routine vaccinations and identified upon arrival at the Texas A&M University Beef Cattle Research Facility. Once the calves were trained to Calan gates[1], they were individually weighed and

TABLE 2. SUPPLEMENT COMPOSITION (DM BASIS)

Ingredient	IFN	%
Cottonseed meal	5-01-621	12.194
Ground sorghum grain	4-04-383	12.194
Calcium carbonate	6-02-632	39.021
Defluorinated phosphate	6-01-780	6.097
Ammonium sulfate		12.194
Salt	6-04-152	4.877
Potassium chloride	6-03-755	8.536
Trace mineral salt		4.268
Vitamin A (650 KIU/G)		0.034
Vitamin D (400 KIU/G)		0.004
Vitamin E (125 KIU/G)		0.079
EDDI (99%)	6-01-842	0.012
Mineral oil		0.487

[1]American Calan, Inc., Route 4, Northwood, N.H.

randomly assigned to the treatments. Cattle were weighed at 45-day intervals and at the end of the trial. Weight gain, feed intake and dry matter content of feed were used to calculate daily gain, dry matter intake and feed efficiency.

After 90 days on feed, chromic oxide was mixed with the supplement to provide 15 g/head/day to determine in vivo apparent digestibility of dry matter, starch, acid detergent fiber and energy. Diets containing chromic oxide were fed 7 days before sampling feed and feces for 7 days. Fecal and feed samples were composited on a per animal basis, dried at 50°C for 48 hours and ground through a Wiley mill with a 1 mm screen. Composited oven dried fecal samples were then analyzed for chromic oxide, energy, starch and acid detergent fiber. Digestion coefficients for dry matter, energy, starch and acid detergent fiber were calculated using indicator-nutrient ratios.

Body composition of the steers fed the whole grain diets was estimated at the start of the trial via deuterium oxide dilution (1, 3), while the initial composition of those cattle on the rolled diets was calculated by regressing composition on weight. At the end of the trial, body composition of all steers was estimated by carcass specific gravity (7).

Analysis of variance and least square means comparisons were performed to determine the effect of silage grain processing and silage to grain ratios upon rate and efficiency of growth, digestibility of nutrients, energy retention and carcass characteristics (9).

Results and Discussion

Cattle Performance. All steers (Table 3) were fed until similar estimated empty body weights were obtained. Total live weight gain was greater ($P < .10$) for the steers fed the low silage-whole grain treatment compared to other treatments. Rolling of the grain with the intermediate silage treatment improved ($P < .10$) total gain of the steers, but not of the steers in the high silage treatment. Average daily gain, dry matter intake and feed efficiency were not significantly influenced by treatments.

TABLE 3. PERFORMANCE OF STEERS

Silage level:	High		Intermediate		Low	
Item / *Grain Form:*	Whole	Rolled	Whole	Rolled	Whole	SEM
Days on feed	241	248	231	226	230	17.09
Initial weight, Kg	336	325	336	340	337	14.91
Adjusted final[1] weight, Kg	514	499	471	517	553	26.04
Total gain, Kg	179[ab]	175[ab]	1356[b]	177[ab]	217[a]	20.93
Gain, g/day	750	710	650	800	960	115.00
DM Intake, Kg/head/day	10	9	8	10	8	0.98
Feed conversion	14	18	16	14	9	2.06

[ab]Means on the same line bearing different superscripts differ significantly ($P < .01$).

[1]Weight adjusted with mean dressing percent of 59.88 percent.

Overall, these results suggest that feedlot performance of the steers was not improved by rolling the grain within whole plant sorghum silage at either high or intermediate silage levels. The fact that total gain was lower ($P < .10$) for cattle fed the intermediate silage-whole grain diet as compared to the high silage-whole grain diet supports the established concept that certain negative associative effects of feeds (2, 4) are present when grain and forage mixtures are fed. Rolling the grain within the intermediate silage level improved utilization of the feed, but not beyond the high silage or low silage treatments, indicating that even when the increase in ration energy content was linear, the utilization of the energy was not sufficient to support a linear increase in cattle performance (2). Another contributing factor to the apparent poor utilization of the added grain in the ration may be related to its relatively low moisture content (23 percent) upon reconstruction.

Digestibility of Rations. Dry matter, starch and energy digestibilities were not significantly influenced by treatments (Table 4). Acid detergent fiber digestibility was greatest ($P < .001$) for the high silage-whole grain treatment, and least for the low silage-whole grain treatment (33 vs. 6 percent). This suggests that rolling the grain and decreasing the silage content decreases fiber digestibility due to an increase in available soluble carbohydrates. These carbohydrates change the substrate available for fermentation in the rumen by shifting the microbial population to starch digesters and increasing ruminal acidity (4,5).

Post-ensile rolling of the grain did not alter either starch or energy digestibility, perhaps because the grain within whole plant sorghum silage gained moisture from the stover. This resulted in a softer grain which responded less to physical processing.

Body Composition. Neither final empty body composition nor rate and efficiency of growth were influenced by silage treatments. This indicates that there are no positive effects from rolling the grain within silage or by feeding mixed grain/forage diets (Table 5).

Carcass Characteristics. Dressing percent decreased ($P < .05$) and percent gut fill increased ($P < .05$) as silage content increased in the diets (Table 6). This is a typical response to high forage levels. Carcass quality characteristics were not significantly influenced by treatments, suggesting that whole plant sorghum silage will produce lean carcasses of good quality grade if fed the proper period of time (Table 6).

TABLE 4. DIGESTIBILITY OF SORGHUMS

Silage level:	*High*		*Intermediate*		*Low*	
Item / Grain Form:	Whole	Rolled	Whole	Rolled	Whole	SEM
Dry matter, %	48	42	49	46	56	3.81
Starch, %	82	81	77	69	76	4.15
Acid detergent fiber, %	33[a]	25[b]	24[b]	22[b]	6[c]	3.27
Energy, %	46	42	48	45	54	3.87
Digestible energy, Mcal/Kg	1.83	1.65	1.95	1.84	2.25	0.15

[a,b,c]Means on the same line bearing different superscripts differ significantly ($P < .001$).

TABLE 5. COMPOSITION AND EFFICIENCY OF EMPTY BODY GROWTH

Silage level:		High		Intermediate		Low	
Item	Grain Form:	Whole	Rolled	Whole	Rolled	Whole	SEM
	Initial empty body composition						
Weight, Kg		294	244	294	298	295	23.41
Fat, Kg		45	41	46	51	50	3.33
Fat, %		16	16	16	17	17	2.14
Protein, Kg		55	44	55	54	54	4.72
Protein, %		19	17	19	18	18	0.65
	Final empty body composition						
Weight, Kg		450	438	415	452	482	21.24
Fat, Kg		102	106	95	107	184	17.30
Fat, %		22	24	22	23	27	3.11
Protein, Kg		78	74	72	77	79	2.30
Protein, %		17	17	17	17	16	0.62
	Rate and efficiency of growth						
Empty body, g/day		648	782	522	684	813	103.88
Protein, g/day		96	92	74	102	109	12.17
Fat, g/day		234	229	210	245	353	82.00
Retained energy[1] Kcal/day		274	267	239	288	392	74.31
Retained energy[2] Kcal/day		28	28	24	28	38	7.09

[1]((Fat growth *9.367) + (protein growth *5.45))/days on feed.
[2](Retained energy/empty body weight.$^{.75}$)

These results indicate that whole plant sorghum grain silage is by itself a useful feedstuff for producing lean beef, and that no physical processing is required to enhance utilization of the silage. Also, the mixed grain/forage diets have no advantage over high silage or high grain diets for energy retention.

Acknowledgments

Appreciation is expressed to the National Council of Science and Technology of Mexico for financial support provided to J.E. Acosta and for support from the Texas A&M University Center for Energy and Mineral Resources.

TABLE 6. CARCASS CHARACTERISTICS

Silage level:		High		Intermediate		Low	
Item	Grain Form:	Whole	Rolled	Whole	Rolled	Whole	SEM
Hot carcass weight, Kg		308	359	275	311	332	33.70
Dressing,%		58[a]	59[ab]	60[ab]	61[bc]	62[c]	1.05
Gut fill, %		16[a]	13[ab]	12[bc]	11[bc]	10[c]	1.35
Skeletal maturity		30[a]	34[ab]	37[b]	38[b]	30[a]	2.25
Marbling score[1]		406	356	331	330	368	43.42
Rib eye area, sq. cm		77	77	77	71	77	0.63
Adjusted fat, cm		.91	1.04	.74	1.04	1.19	0.09
Kidney-heart-pelvic fat, %		2.50	2.50	2.33	3.00	2.76	0.33
Quality grade[2]		287	250	233	230	270	27.59
Yield grade		2.64	2.78	2.06	3.12	3.04	0.43

[a,b,c]Means on the same line bearing different superscripts differ significantly ($P < .05$).
[1]Marbling score: SL 300; SM 400; M+ 500; MD 600
[2]Quality grade: Standard 100; Good 200; Choice 300; Prime 400

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PR-4221

Stover Length and Rolling Effects on Digestibility, Rate of Passage and Ruminal Fermentation of Sorghum Grain Silage

J. E. Acosta and L. M. Schake

Summary

Intact and rumen- and duodenal-cannulated cattle (n=12) were fed six silage diets to determine the influence of stover length and post-ensile rolling of silage or grain upon nutrient digestibility and ruminal fermentation. Starch digestibility was increased ($P < .01$) with rolled silage or rolled grain compared to control silages. No effects of stover length were observed. Total volatile fatty acid concentrations were higher for those diets containing rolled grain; however ruminal fermentation patterns were not altered by post-ensile rolling of the grain or the silage, or the length of the stover. Rate of ingesta passage was not significantly different among treatments, suggesting that particle size of the stovers investigated did not influence digesta flow.

Introduction

The practice of feeding whole plant sorghum grain silage to cattle has often been questioned, since quantities of whole grain are visible in the feces. Research (4,5) indicates that post-ensile rolling of whole plant sorghum grain silage improves the digestibility of starch. However, little is known of the effects of silage stover length and selective post-ensile rolling of the grain or the silage upon nutrient digestibility and rumen fermentation. This experiment was designed to identify digestibility and rumen fermentation characteristics of whole plant sorghum grain silage harvested at two stover lengths, with the grain and stover rolled post-ensiling.

Experimental Procedures

A commercial heteroyellow endosperm sorghum grain hybrid (WAC 715) was harvested as whole plant silage by two procedures. Half of the silage was harvested by a conventional silage cutter to chopt he stover into 2.00-centimeter (cm) segments (theoretical cut). The remaining silage was harvested with a combine modified (9) to chop the stover into 5.00-cm segments (theoretical cut). Both short and long silages were stored in commercial oxygen-limiting silos.

Six silage treatments were investigated. Treatments that used short cut stover were fed 1) directly from the silo, 2) with both grain and stover rolled after removal from the silo, or 3) with only the grain rolled after removal. The remaining three treatments were the same as outlined above, except that silage with long stover segments was fed. Selective post-ensile rolling of the grain was accomplished by passing the silage over a series of vibrating screens to separate grain from stover, then rolling the grain before recombining it with the original stover. Before feeding, 97.3 percent of each silage was mixed with 2.7 percent premix (Table 1), producing isonitrogenous rations.

The six silage treatments were individually fed to twelve cattle divided into two groups: (a) six intact crossbred Hereford steers; and (b) six rumen- and duodenal-cannulated cattle (three Angus heifers and three Hereford steers). A Latin Square design was used to allow all six diets to be fed in each of six sequences to eliminate errors caused by individual animal digestive differences. Each experimental period consisted of 21 days, with 14 days allowed for adjustment to the diets and 7 days for a sampling period.

Fecal grab samples were collected from the intact steers for 5 days on a staggered schedule to overcome diurnal variation. Feed samples were taken 2 days before the start until 2 days before the end of the sampling period. The samples were grouped on a per animal per period basis and prepared for analysis (8). Sample groups were analyzed for indigestible neutral detergent fiber to serve as an internal marker (6) for determining digestibility of nutrients. Starch, acid detergent fiber, and energy content of the composited samples were determined by approved methods.

At the beginning of the sampling period, the six cannulated cattle were administered a single pulse dose of 6 grams of ytterbium nitrate per 100 grams of silage (dry matter basis) to establish the rate of ingesta passage (3). Samples were obtained from the duodenal cannula and rectum every 6 hours for 36 hours, and then every 12 hours for 72 hours. Samples were prepared for analysis (3), assayed (2) and statistically fitted to a one-compartment time-dependent model (7).

Ruminal fluid samples were obtained with a vacuum pump for 2 consecutive days at the end of the collection period. Ruminal fluid was withdrawn before the morning feeding and then at 2-hour intervals until six samples were obtained. The samples were frozen and prepared for analysis of volatile fatty acids (VFA) according to accepted techniques (1).

Analysis of variance and Duncan's new multiple range test (10) were performed to determine the digestibility of nutrients, the rate of ingesta passage and rumen fermentation characteristics.

TABLE 1. PREMIX COMPOSITION (DM BASIS)

Ingredient	IFN	%
Ground sorghum grain	4-04-383	72.69
Urea	5-05-070	9.68
Sulfur	6-04-705	1.09
Defluorinated phosphate	6-01-780	9.64
Vitamin A (650 KIU/G)		0.57
Salt	6-04-152	6.33
Total		100.00

Results and Discussion

Due to feed shortages, only four of the six sampling periods were completed. This forced us to adjust the experimental design to a 2 x 3 factorial arrangement.

Digestibility of rations. Dry matter intake, digestible dry matter, digestible acid detergent fiber and energy digestibility wre not significantly different among treatments. Only starch digestibility was increased ($P < .01$) in diets with rolled silage or grain (Table 2). These results agree with other published data (5) indicating that post-ensile rolling of silage or grain improves digestibility of the starch. No effects from

TABLE 2. DIGESTIBILITY AND RATE OF PASSAGE OF SILAGES

Item	Stover length: Long			Short			
Processing:	Control	Silage rolled	Grain rolled	Control	Silage rolled	Grain rolled	SEM
Dry matter intake, Kg	14	15	13	16	15	13	1.16
	Digestibility, %						
Dry matter	50	56	51	51	56	57	3.14
Starch[1]	84[a]	88[b]	89[b]	86[a]	90[b]	89[b]	1.18
Acid detergent fiber	40	38	28	37	32	32	4.10
Energy	48	52	48	41	53	54	4.27
Digestible energy, Mcal/Kg	1.92	2.08	1.86	1.53	2.16	2.25	0.17
	Ingesta rate of passage, %/hour						
Duodenal	3.90	4.59	4.32	3.84	4.16	3.48	1.17
Fecal	4.94	8.59	5.29	6.30	6.16	5.26	0.70

[1]Means on the same line bearing different superscripts are significantly different ($P < .01$).

varying stover lengths were detected, indicating considerable latitude in processing stover without altering carbohydrate digestion.

Rate of Passage. Duodenal and fecal flow were not significantly influenced by treatments (Table 2). These data suggest that the particle size of the stovers were too similar to influence the flow of digesta.

Ruminal Fermentation. Total volatile fatty acids (average of 95.02 micromoles/ml) were higher ($P < .01$) for those diets containing selectively rolled grain (Table 3). Neither acetic, propionic or butyric acid, nor acetic:propionic ratios were significantly different among treatments. These results suggest that ruminal fermentation patterns were not altered by post-ensile rolling of the grain or the silage, or the length of the stover in sorghum grain silages.

TABLE 3. RUMEN FERMENTATION PARAMETERS

Stover Length:	Long			Short			
Item Processing:	Control	Silage rolled	Grain rolled	Control	Silage rolled	Grain rolled	SEM
Total VFA's							
Micromoles/ml	93[a]	93[a]	113[b]	71[a]	93[a]	106[b]	7.64
Acetic, %	64	58	62	57	62	65	3.38
Propionic, %	22	23	22	21	21	20	2.19
Butyric, %	12	16	13	17	14	13	1.46
Others, %	3	3	3	4	3	3	0.40
C2:C3 Ratio	3.21	2.74	2.59	2.99	3.03	3.47	0.49
Rumen pH	6.62	6.36	6.61	6.48	6.42	6.9	0.007

[a,b]Means on the same line bearing different superscripts are significantly different ($P < .01$).

The increase in starch digestibility for rolled grain and rolled silages suggests that the grain underwent greater ruminal fermentation since more starch surface area was exposed to the ruminal microorganisms. Likewise, total production of microbial fermentation end-products (VFA's) increased due to rolling of the grain. However, rolling did not influence the amount of energy digested, except in the presence of the short stover treatment where energy digestibility was increased more than 10 percentage units compared to the control. This observation may indicate that post-ensile rolling of grain is more critical for sorghum silages with short stover.

Acknowledgments

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PR-4222

Factors Influencing Fermentation and Preservation of Sorghum Silages

L. M. Schake, R.E. Tolbert and R. E. Lichtenwalner

Summary

Two commercial hybrid sorghums, a tall grain variety and an intermediate height forage variety, were harvested at the early dough stage of maturity to determine the influence of variety, head to stover ratios, method of head and stover processing, and the addition of propionic acid at 2 percent weight/weight (w/w) upon preservation and ensiling characteristics. Dry matter ensiling loss during 30 days of fermentation increased ($P < .01$) as percentage of stover to grain in silage increased. Losses were six fold greater ($P < .01$) for rolled than for ground heads and were also greater ($P < .01$) when stover was coarsely chopped compared to a finer chop. Higher levels of non-protein nitrogen were associated with more extensive processing of the head than at lower head to stover ratios. The two sorghum varieties differed in most ensiling characteristics. Propionic acid reduced ($P < .01$) dry matter ensiling loss and increased ($P < .01$) titratible acidity suggesting its potential as a silage preservative. It was further concluded that much of the observed difficulty in successfully fermenting and preserving forage sorghums was related to their relatively low levels of soluble carbohydrates to initiate fermentation compared to grain sorghum varieties.

Introduction

Numerous factors are known to influence the success of ensiling crops (2). Sorghums are generally more difficult to manage as silage, and less published information is available for directing sorghum silage production compared to other crops, especially corn. Forage and grain type sorghums have exhibited considerable variation in their ability to ensile. Differences in grain to stover ratios and degree of processing imposed upon the pre-ensiled grain and stover are thought to be important variables. These factors further influence the responses observed during ensiling in the presence of various silage preservatives. This research was initiated to establish the influence of sorghum variety, grain to stover ratios, degree of grain and stover processing and organic acid preservation upon fermentation characteristics of sorghums.

Procedure

Two commercial hybrid sorghum varieties, ORO-T,a tall grain sorghum and FS-lb, an intermediate height forage sorghum, were cultured at the University Farm. Both varieties were harvested at the early dough stage of maturity at 6 cm above ground level, immediately separated into head and stover portions, then processed and ensiled in .946 liter (1) glass silos. The head plus 5 cm of stalk was either coarsely chopped, grain cracked by rolling or unprocessed as previously outlined (5). The stovers of each variety were chopped to two degrees of fineness as previously described (5). The resulting head and stover materials were recombined (w/w) into seven head to stover ratios, all head; 3:1, 2:1, 1:1, 1:2, 1:3; and all stover, respectively. Samples for both varieties and all combinations of processing at all head and stover ratios were ensiled in quadruplicate. Half of the samples were also treated with 2 percent (w/w) of propionic acid to evaluate its potential as a silage preservative. Each 400 gram sample was ensiled for 30 days at 4 c.

Samples were managed to determine dry matter loss during ensiling (DMEL), total nitrogen, non-protein nitrogen as a percent of total nitrogen, pH and titratible acidity by established laboratory procedures. Data were analyzed statistically by the least squares procedure for analysis of variance and the Student-Newman-Keuls test for mean separation. Only main effects are shown as least squares means with standard deviations in Tables 2 through 6.

Results and Discussion

Composition of freshly harvested sorghums were typical of other published values except for relatively high ash contents of stover for both varieties (Table 1). However, other data have been reported with ash in excess of 9 percent for stover of similar plant maturity and harvest conditions (4). The method of processing the head influenced ($P < .01$) all parameters measured (Table 2). Silage dry matter content was reduced with more extensive processing since more grain surface area was exposed to the atmosphere resulting in greater loss of moisture. Titratible acidity and pH both followed this same general trend with more extensive processing of the head. Dry matter ensiling loss was six fold greater ($P < .01$) for rolled than ground heads, possibly the result of partial grain disruption in the presence of poorly disrupted stalk segments resulting in entrapment of more oxygen into silos at time of filling. Total nitrogen content was greater ($P < .01$) for rolled heads compared to other processing treatments. This apparent increase in nitrogen content is a reflection of greater DMEL associated with this treatment indicating that a higher proportion of losses were represented by non-nitrogen containing compounds. Rolled and ground heads had higher ($P < .01$) non-protein nitrogen (NPN) levels than control heads suggesting a higher degree of soluble NPN compounds in these silages.

Stover processing also influenced most ensiling responses measured (Table 3). Coarsely processed stover resulted in a greater DMEL ($P < .01$), more titratible acidity ($P < .01$), and lower pH ($P < .10$) than intermediately processed stover. Ensiling was also influenced by sorghum variety (Table 4). The grain variety (ORO-t) had less DMEL ($P < .01$), a higher percent nitrogen ($P < 01$), and less NPN ($P < .05$) than the forage sorghum. This seems to be related to the higher proportion of grain present (3). The application of 2 percent (w/w) of propionic acid resulted in favorable responses ($P < .01$) for DMEL, NPN, and titratible

TABLE 1. COMPOSITION OF FRESH SORGHUMS, DRY MATTER BASIS

	Sorghum variety			
	ORO-t		FS-lb	
Item, %	Head	Stover	Head	Stover
Moisture	38.3	75.6	38.9	73.1
Crude protein	15.4	11.7	14.1	8.6
Crude fiber	5.1	27.4	4.7	30.4
Ether extract	3.8	6.4	4.1	4.7
Ash	3.0	11.3	2.5	9.5
Nitrogen free extract	72.6	43.2	74.6	46.8

TABLE 2. SILAGE CHARACTERISTICS AS EFFECTED BY SORGHUM HEAD PROCESSINGS

	Method of head processing		
Item	Whole	Rolled	Ground
Dry matter, %	41.4[a]	40.6[b]	39.3[c]
	(9.6)	(8.4)	(7.8)
Dry matter ensiling loss, %	5.5[a]	14.8[b]	2.4[c]
	(7.1)	(9.4)	(10)
Total nitrogen,%	1.09[a]	1.13[b]	1.06[a]
	(0.3)	(0.2)	(0.2)
Non-protein nitrogen, % of total nitrogen	27.1[a]	32.2[b]	32.3[b]
	(1.4)	(11.6)	(12.2)
pH	4.63[a]	4.40[b]	4.26[c]
	(0.4)	(0.5)	(0.2)
Titratible acid, ml of .1N KOH	1.33[a]	1.98[b]	1.89[c]
	(0.7)	(1.0)	(0.4)

[a,b,c]Means on the same line with different superscripts differ ($P < .01$). Standard deviations are presented with each mean ().

TABLE 3. SILAGE CHARACTERISTICS AS AFFECTED BY STOVER PROCESSING

Item	Stover processing	
	Intermediate	Coarse
Dry matter, %**	40.8 (7.8)	40.1 (8.0)
Dry matter ensiling, loss %**	5.4 (11.0)	6.5 (11.6)
Total nitrogen, %**	1.14 (0.2)	1.05 (0.3)
Non-protein nitrogen, % of total nitrogen	30.7 (13.5)	30.3 (12.2)
pH**	4.57 (0.5)	4.29 (0.2)
Titratible acid, ml of 0.1 N KOH*	1.64 (0.8)	1.83 (0.8)

**Significant influence ($P < .01$) due to processing.
*Significant influence ($P < .10$) due to processing.
Standard deviations are presented with each mean ().

TABLE 4. SILAGE CHARACTERISTICS AS AFFECTED BY SORGHUM VARIETY

Item	Sorghum variety	
	FS-lb	ORO-t
Dry matter, %**	39.1 (9.9)	41.7 (8.7)
Dry matter ensiling, loss %**	8.5 (14.8)	3.5 (5.8)
Total nitrogen, %**	0.93 (0.2)	1.26 (0.2)
Non-protein nitrogen, % of total nitrogen**	34.4 (13.5)	26.6 (11.4)
pH	4.45 (0.4)	4.41 (0.3)
Titratible acidity, ml of .1 N KOH*	1.59 (0.8)	1.87 (0.8)

**Significant influence ($P < .01$) due to variety.
*Significant influence ($P < .05$) due to variety.
Standard deviations are presented with each mean ().

TABLE 5. SILAGE CHARACTERISTICS AS AFFECTED BY PROPIONIC ACID PRESERVATION

Item	Preservative	
	Control	Propionic acid
Dry matter, %**	40.13 (9.7)	40.75 (8.9)
Dry matter ensiling loss, %	7.82 (11.8)	4.15 (11.3)
Total nitrogen, %**	1.11 (0.2)	1.07 (0.3)
Non-protein nitrogen, % of total nitrogen**	33.33 (12.5)	27.71 (12.9)
pH*	4.40 (0.3)	4.46 (0.4)
Titratible acid,** ml of .1 N KOH	1.33 (0.5)	2.14 (0.9)

**Significant influence ($P < .01$) due to preservation.
*Significant influence ($P < .10$) due to preservation.
Standard deviations are presented with each mean ().

TABLE 6. SILAGE CHARACTERISTICS AS AFFECTED BY RATIO OF HEAD TO STOVER

Item	Ratio of head to stover				
	3:1	2:1	1:1	1:2	1:3
Dry matter, %	49.2[a] (2.6)	46.4[b] (2.4)	40.2[c] (2.2)	34.5[d] (2.1)	31.6[e] (1.6)
Dry matter ensiling loss, %	3.4[a] (13.3)	4.1[a] (13.4)	6.4[b] (10.7)	7.8[c] (8.9)	8.2[c] (8.3)
Total nitrogen, %	1.23[a] (0.2)	1.20[a] (0.2)	1.08[b] (0.2)	0.99[c] (0.2)	0.97[c] (0.2)
Non-protein nitrogen, % of total nitrogen	23.0[a] (10.1)	23.9[a] (8.6)	31.6[b] (10.8)	34.3[b] (11.4)	39.6[c] (13.9)
pH	4.48 (0.3)	4.36 (0.6)	4.45 (0.3)	4.42 (0.2)	4.44 (0.3)
Titratible acid, ml of .1 N KOH	1.72 (0.9)	1.91 (0.2)	1.58 (0.6)	1.77 (0.6)	1.69 (0.6)

[a,b,c,d,e]Means on the same line with different superscripts differ ($P < .01$). Standard deviations are presented with each mean ().

acidity compared to control silage (Table 5). Total nitrogen was .04 percent less ($P < .01$) while pH was .06 units higher ($P < .01$) for propionic acid treated silage compared to control silage. These observations are consistent with reports on corn (1) and alfalfa silages (6).

Increasing amounts of stover resulted in a near linear increases ($P < .01$) in DMEL (Table 6), ranging from 3.4 to 8.2 percent for the 3:1 and 1:3, head to stover ratios, respectively. Total nitrogen and NPN levels were inversely related. As the proportion of stover to head increased, total nitrogen decreased ($P < .01$) from 1.23 to .97 percent, while percent NPN increased ($P < .01$) from 23 to 39.6 percent. These data suggest that greater proportions of grain (at the expense of stover) will reduce DMEL and minimize NPN levels. This relationship may largely explain why forage sorghums are generally less desirable for ensiling than grain sorghum varieties.

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Biological Efficiency of Growth

Brief PR-4223

The Fine Structure of the Endomysium and Intermyofibrillar Connections in Muscle

M. W. Orcutt, T. R. Dutson, S. B. Smith, and F. Y. Wu

One of the major determinants of meat tenderness is the structural arrangement of the proteins which bind together the various intracellular components of muscles. Collagen is one structural protein that influences tenderness. The filamentous proteins of collagen are deposited in an amorphous mass around the sarcolemma of muscle fibers, forming nets around muscle fibers. Several laboratories currently are investigating the influence of collagen content and solubility on meat tenderness.

Two other structural proteins that have not been investigated as thoroughly include reticular fibers, a class of filamentous proteins which connect adjoining muscle fibers, and intermyofibrillar fibers, which bind together myofibrils within the individual muscle fibers. Reticular fibers, the predominant type of connective tissue within the endomysium, are distinguished from collagen fibers by their extensive branching. Reticular fibers are arranged perpendicularly to the long axis of muscle fibers and are continuous with the amorphous collagen fibers.

In order to investigate the architecture of the reticular fibers, bovine sternomandibularis and rabbit semimembranosus muscles were fixed in a buffered hypertonic glutaraldehyde fixative. Freeze substitution methods minimized ice crystal damage within the tissue samples. Samples were prepared for both scanning and transmission electron microscopy.

Reticular fibers were shown to bind adjacent muscle fibers between the central region of the A-band of one fiber and the A-band/I-band junction, or Z-line, of adjacent fibers. The reticular fibers were arranged either perpendicularly or obliquely with respect to the long axis of the muscle fibers, depending on the degree of muscle shortening prior to preparation for electron microscopy. Scanning electron microscopy also indicated intracellular filaments interconnecting adjacent myofibrils in fixation-damaged myofibers. Since myofibrils are the intracellular structures that contain the contractile machinery of muscles, the interconnection of myofibrils byt hese fibers may play a role in maintaining the integrity of muscle structure during contraction. This was supported by transmission electron micrographs which indicated that the intermyofibrillar bridges were located at the Z-lines of the myofibrils. Scanning electron microscopy indicated that the interconnections occurred every 2.5 microns along the surface of the myofibrils in the rabbit muscle, and every 1.9 microns in the bovine sternomandibularis muscle. In bovine muscle that had been allowed to cold-shorten, the periodicity of the intermyofibrillar fibers was reduced to 1.4 microns. These measurements correspond to the dimensions of sarcomeres, the basic units of contraction which are bound at either end by the Z-lines.

The observation that intermyofibrillar bridges interconnect myofibrils at the Z-lines, while reticular fibers connect adjacent muscle fibers at somewhat different regions of the fibers, indicates that the two classes of fibers are not continuous with one another. However their connections to discrete regions of the muscle fibers suggest strongly that reticular and intermyofibrillar fibers have an important role in maintaining muscle integrity, and therefore are likely to have major effects on meat tenderness.

Brief PR-4224

Degradation of Gap Filaments During Postmortem Conditioning

M. W. Orcutt, T. R. Dutson, and S. B. Smith

Differences between tough and tender meat have been attributed to variations in intramuscular fat concentration, sarcomere length, extent of proteolytic degradation of muscle proteins and both connective tissue concentration and solubility. Recent research shows that intracellular structures called gap filaments may impart substantial tensil strength to muscle. Gap filaments join serially arranged Z-lines within myofibrils, and are composed of an elastic protein called titan or connectin. The way postmortem proteolysis of gap filaments tenderizes muscle during postmortem conditioning remains to be understood.

In order to investigate the influence of gap filaments on meat tenderness, super-stretch muscle fibers with sarcomere lengths greater than 4 microns were incubated at one of four combinations of pH and temperature (pH 5.5, 37°C; pH 5.5, 0 to 4°C; pH 7.4, 37°C; pH 7.4, 0 to 4°C) for 1 hour prior to fixation and embedding for transmission electron microscopy. These tissues were compared to controls, which were fixed immediately after stretching. Disruption of gap filament structure was greatest in those muscle bundles incubated at pH 5.5 and 37°C. This combination of pH and temperature is attained soon after slaughter in most steer carcasses. It was determined that pH had a greater influene upon gap filaments than did temperature, and that more gap filament disruption occurred at pH 5.5 than at pH 7.4.

This indicates that lysomal enzymes were responsible for greater proteolysis of gap filaments than were neutral proteases.

Other structural alterations of the stretched muscle included more glycogen granule disintegration at pH 7.4, independent of temperature. Pulling of alternate thick bands toward opposite Z-lines, as has been earlier reported, was not observed; instead, pulling of adjacent groups of thick filaments toward opposing Z-lines was observed. Gap filaments were found to eminate from the termini of all thick filaments and were oriented toward the Z-lines.

It was concluded that gap filament disruption may occur relatively eary during postmortem conditioning in muscles that attain an appropriately low pH while still at high temperature, and that these filaments therefore do not influence muscle tenderness to any great extent. It is apparent that lysosomal enzymes were primarily responsible for the degradation of the gap filaments.

Brief PR-4225

Factors Controlling Fat Accretion in Bovine Adipose Tissue

S. B. Smith and P. A. Ekeren

Recent studies have indicated that the amount of intramuscular fat (marbling) in beef carcasses is more highly correlated with meat palatability than is subcutaneous fat (back fat) thickness. These findings indicate that a highly acceptable meat product can be obtained from cattle that do not achieve 0.3 inches of backfat, as long as the animals are fed a diet rich in grain and produce carcasses with adequate levels of marbling fat. Obviously, this can be accomplished only if the factors that regulate the accumulation of subcutaneous fat differ markedly from those regulating intramuscular fat accretion. Unfortunately, little is known about the regulation of fat production at the cellular level in either fat depot. Therefore, studies were designed to demonstrate the processes responsible for the conversion of circulating lipids into stored fats in cattle.

Subcutaneous adipose tissue was obtained at slaughter from steers fed a finishing ration for a minimum of 110 days. Adipose tissue samples were transported to the laboratory and homogenized in 10 millimeters/mole (mM) phosphate: 154 mM KCl (pH 7.4) buffer at 0 to 4°C in a Teflon pestle homogenizer. High speed centrifugal fractions were obtained by centrifuging at 15,000 and 105,000 x g for 60 minutes. Portions of the supernate containing approximately 5 milligrams (mg) proteinw ere incubated at 25°C with 3 nmol palmitoyl-CoA and 0.020 μCi [1-^{14}C] palmitoyl-CoA. After incubating for approximately 15 minutes, the incubation mixture was eluted over a 2.7 x 45 centimeter (cm) Sephadex G-75 column at a flow rate of 1.0 milliliter per minute (ml/min). Fractions were collected and the absorbance at 280 nm and the cpm per fraction were measured.

Approximately 10 percent of the total cpm bound to protein was observed in the fractions corresponding to albumin (approximate MW = 64,000). The balance was observed as a sharp, well-defined peak corresponding to proteins of approximate MW of 12,000. These results were essentially identical to those obtained from rat and human adipose tissues, and provide strong evidence that a fatty acid binding protein of MW 12,000 exists in bovine adipose tissue. Fatty acid binding protein is required for maximal rates of fat synthesis in rat and human adipose tissues, and its presence in bovine adipose tissue suggests that it may have a regulatory function in cattle.

One of the enzymes responsible for the production of storage fats, phosphatidate phosphohydrolase (PPH), was measured in the centrifugal fractions of bovine subcutaneous adipose tissue homogenates. Phosphate release from phosphatidic acid was taken as a measure of PPH activity. On a per gram tissue basis, 15, 25 and 60 percent of the total PPH activity was observed in the mitochondrial, supernatant, and microsomal fractions, respectively. Contrary to the results observed for fatty acid binding protein, these percentages are quite deifferent than those observed for rat adipose tissue.

Brief PR-4226

Enzyme-Catalyzed Lipid Oxidation in Beef Muscle Microsomes

K. S. Rhee, T. R. Dutson and G. C. Smith

The development of undesirable flavor (rancidity) from the oxidation of lipids is a major quality problem in beef and beef products. It has been widely believed that heme iron of meat pigments and nonheme iron are responsible for accelerating lipid oxidation, and that oxidizing lipids, in turn, can accelerate the oxidation of meat pigments, causing the discoloration of fresh meat. Whereas both heme iron of meat pigments and nonheme iron are nonenzymic catalysts of lipid oxidation, recent studies showed the presence of enzyme-catalyzed lipid oxidation systems associated with fish and chicken muscle microsomes. The operational requirements of the system are dependent on species.

The present study was undertaken to: (1) determine if an enzyme-catalyzed lipid oxidation system exists in microsomal fractions of beef muscle; (2) determine its operational requirements; and (3) evaluate the magnitude of its activity in microsomes isolated from muscle samples stored for various lengths of time after removal from the carcass. The presence of an enzymic lipid oxidation system in microsomal fractions of beef skeletal muscle (*longissimus dorsi*) has been demonstrated in the study. Although the reaction required reduced nicotinamide adenine dinucleotide phosphate (NADPH), or reduced nicotinamide adenine dinucleotide (NADH), adenine diphosphate (ADP) and ferrous iron ($Fe^{2}+$) or ferric iron ($Fe^{3}+$), it was primarily dependent on NADPH or NADH. No enzymic activityw as shown without NADPH or NADH. The enzymic lipid oxidation took place without ADP or iron but at much lower rates thanw ith them; ADP enhanced the oxidative reaction more than did iron. The optimum pH of the reaction was approximately 6.5. Although the rate of the reaction was lower at pH 5.5 (a normal beef muscle pH reached at or after 24 hours postmortem) than at pH 6.5, the rate at pH 5.5 was still moderately high. The rate of oxidation was higher with NADPH than with NADH, and also higher with $Fe^{2}+$ than with $Fe^{3}+$. Prolonged storage of intact muscles at 4°C considerably reduced the oxidative enzymic activity of the isolated microsomes.

It is believed that microsomal enzymic lipid oxidation may cause quality deterioration of beef and beef products through its role in the initiation and/or acceleration of meat pigment oxidation and non-enzymic lipid oxidation. Since the color of lean is one of the most important factors influencing the acceptance of fresh beef, and the oxidation of lipids in fresh beef has adverse effects on the color of fresh beef and the flavor of heat-processed or cooked beef products, control of the enzymic lipid oxidation may be one of the first practical steps towards enhancing the quality of beef and beef products.

PR-4227

Anabolic Effects on Rate of Protein and Fat Deposition in Cattle Fed Silage and Grain Diets

P. G. Lemieux, F. M. Byers, G. T. Schelling, G. C. Smith and L. M. Schake

Summary

Santa Gertrudis cross steers (n=112) averaging 338 kg were used to assess the effects of anabolic implants and nutritional level on the rate of protein and fat deposition. Steers were group or individually fed one of three diets and either not implanted or implanted (initially and at 90 day intervals) with Ralgro or Synovex-S. One pen of eight and five individually fed cattle were assigned to each diet X implant combination. Sorghum grain silage and reconstituted sorghum grain were fed in three combinations (percent of diet, dry basis) 85-0 (forage), 40-50 (mixed) and 5-89 (grain) with cottonseed meal and premix. Empty body composition of individually fed cattle was determined initially and at mid-term via D_2O dilution, and final composition of all cattle was determined by carcass specific gravity. Initial empty body composition of group fed cattle was calculated from individually fed cattle by regressing composition on weight. Rate of empty body gain was increased ($P < .05$) from 699 g/d for non-implanted cattle to 802 and 846 g/day for Ralgro and Synovex implanted cattle. Anabolic implants increased ($P < .05$) daily empty body protein gain from 90.9 to 119.6 and 134.5 grams for Ralgro and Synovex, an increase of 31.6 and 48.0 percent, respectively. As a result, the percent of protein in empty body gain was increased ($P < .01$) from 13.8 percent to 15.6 and 15.9 percent. Rate of fat deposition averaged 318.3 g/day for non-implanted cattle and was reduced ($P > .05$) by 8.9 and 16.9 percent for Ralgro and Synovex implanted steers. These data indicate that anabolic estrogens increase protein growth by repartitioning energy from fat toward protein growth. Cattle fed the mixed diet had lower daily rates of empty body ($P < .01$), protein ($P < .05$) and fat ($P < .05$) gain than cattle fed either the silage or grain diets. Empty body gain was greater ($P > .05$) for grain vs. silage fed cattle (864 vs. 817 g/day) all of which was in the form of additional fat gain (350.3 vs. 297.8 g/day). Rates of protein growth were identical for silage-and grain-fed cattle.

Introduction

Mature size and genetic potential establish the upper limits of daily protein accretion (4) however, other factors such as nutritional level and the use of anabolic agents determine the extent to which these theoretical limits are achieved. Anabolic implants mimic endogenous estrogens and alter the physiological limits for protein growth, permitting an animal to deposit protein at rates closer to theoretical limits (5). While the mechanism of response is unclear, a consistant increase in protein growth has been observed in several studies. Implanted Hereford steers fed varying forage and grain levels deposited more protein and less fat at any rate of gain, indicating that anabolic agents altered the partitioning of dietary energy between protein and fat (5). Implanted cattle of four breeds fed a concentrate diet had less fat (27.3 vs. 28.7 percent final empty body fat) and deposited more protein (20 g/day empty body protein) than non-implanted cattle (3). The influence of nutritional level on protein growth has been reviewed by Byers (5). Nutritional level impacts composition of growth primarily through acceleration of rate of growth above daily limits for protein growth. Energy that is provided above maintenance and requirements for protein growth enhances rates of lipid deposition and accumulation of fat. Other factors that have been suggested as influencing composition of growth include intrinsic properties of grains vs. forages (9) and effects of specific carbon sources on lipogenesis (7).

The following study was conducted to assess the effects of anabolic implants on the rate of protein and fat deposition in cattle fed silage and grain diets.

Experimental Procedure

Crossbred steers (Santa Gertrudis X F1 Hereford Brahman; n=112) averaging 338 kg were stratified by weight and randomly allotted to a 2 x 3 x 3 factorial arrangement of treatments. Cattle were group or individually fed one of three diets (Table 1) and either not implanted or implanted with Ralgro (zeranol, 36 mg) or Synovex-S (estradiol benzoate, 20 mg and progesterone, 200 mg). Steers receiving an implant were implanted initially and at 90 day intervals. One pen of eight group fed cattle and five individually fed cattle were assigned to each diet X implant combination. Individually fed steers were fed in a Calan gate system[1] with one steer assigned to a gate. Five cattle were removed from the study for reasons not related to the research.

TABLE 1. DIET COMPOSITON[a]

Ingredient	Silage	Mixed	Grain
	Percent dry basis		
Sorghum grain silage (IFN 3-07-962)	85	40	5
Sorghum grain, reconstituted (IFN 4-04-383)	--	50	89
Cottonseed meal (IFN 5-01-621)	11	6	2
Premix	4	4	4

[a]Calculated crude protein content, 12 percent.

Empty body composition of individually fed steers was measured initially and at mid-term via D_2O dilution (1,2) and final composition of all steers was determined by carcass specific gravity (6). Initial empty body composition of group fed cattle was calculated from individually fed cattle by regressing composition on weight. Diets (Table 1) were composed of grain sorghum silage and reconstituted grain sorghum fed in three combinations. Silage was stored at 40 percent dry matter in silo bags. Grain was reconstituted by adding water to whole grain and storing the material in an oxygen limiting silo at 80 percent dry matter. Grain was rolled prior to feeding. Diets were formulated to contain 14 percent crude protein for the first 45 days and 12 percent thereafter. Diets were completely mixed and fed once daily. Digestibility of the diets was determined in individually fed cattle at mid-term using chromic oxide as a digestive tract marker.

Cattle were fed to similar expected empty body weights with group fed cattle slaughtered as a pen and individually fed cattle slaughtered singly. All cattle were slaughtered at the university meat laboratory. USDA quality and yield grade factors were evaluated 48 hours postmortem by Texas Agricultural Experiment Station personnel.

Data were subjected to an analysis of variance using the SAS general linear model procedure (SAS Institute Inc., 1982). Terms in the fixed effects model included the main effects of feeding system (group or individual), implant, diet, and their interactions. The Student-Newman-Keuls' test (10) was utilized to separate least-squares means when significant differences were detected.

[1]American Calan, Inc., Route 4, Northwood, NH

Results and Discussion

Initial empty body weight averaged 295.4 ± 2.4 kg with 18.19 ± .06 percent protein and 17.36 ± .28 percent fat. The use of anabolic implants significantly modified composition of gain and as a consequence final empty body composition (Table 2). Final empty body protein averaged 75.66 kg for non-implanted cattle and was increased by 2.6 ($P < .09$) and 5.8 kg ($P < .05$) for Ralgro and Synovex implanted cattle. The greater response to Synovex is due in part to a 3.3 percent heavier ($P > .05$) final weight than for Ralgro or non-implanted steers. Final empty body fat was reduced ($P < .12$) by 13.7 and 12.5 kg for Ralgro and Synovex implanted steers. This reduction was similar even though Synovex cattle had 15.6 kg additional empty body weight. Anabolic implants increased the percentage of protein ($P < .05$) and reduced the percentage of fat ($P < .05$) in the empty body.

Daily empty body gain (Table 2) averaged 699 grams for non-implanted cattle and was increased ($P < .05$) 14.7 and 21.0 percent for Ralgro and Synovex implanted cattle. Ralgro and Synovex implants increased ($P < .05$) daily empty body protein gain by 31.6 and 48.0 percent from 90.9 grams for non-implanted cattle to 119.6 and 134.5 grams for Ralgro and Synovex, respectively. As a result, percent protein in empty body gain was increased ($P < .01$) from 13.8 percent to 15.6 and 15.9 percent. Synovex implanted steers gained 14.9 grams more protein ($P < .05$) than cattle implanted with Ralgro, a difference that was reflected in total protein accretion. Rate of fat deposition averaged 318.3 g/day for non-implanted cattle and was reduced ($P > .05$) by 8.9 and 16.9 percent in Ralgro and Synovex implanted steers. As a consequence, the percent of fat in empty body gain was reduced ($P < .01$) from 42.0 percent for non-implanted cattle to 32.9 and 31.0 percent for Ralgro and Synovex cattle. These results are consistant with other published reports (3) and indicate the response to anabolic agents in repartitioning energy from fat to protein growth.

A comparison of tissue growth curves (figure 1) illustrates this regulatory response. Ralgro and Synovex implanted cattle deposited more protein and less fat at any rate of growth with the magnitude of response increasing with rate of growth. At an empty body growth rate of 200 g/day, comparable to a wintering program, Ralgro and non-implanted cattle were depositing similar quantities of fat (15 g/day) and protein (40 g/day). At an empty body growth rate of 600 g/day, comparable to gains for stocker cattle, Ralgro

TABLE 2. FINAL BODY COMPOSITION AND COMPOSITION OF GROWTH

Item	Anabolic agent			Diet			SEM[a]
	None	Ralgro	Synovex	Silage	Mixed	Grain	
Number of cattle	41	35	36	37	37	38	
Empty body composition							
Weight, kg	458.30	457.70	473.30	470.00^{b}	445.9^{c}	473.3^{b}	8.00
Protein, kg	75.66^{b}	78.26^{b}	81.44^{c}	79.98	76.75	78.63	1.08
Fat, kg	121.96	108.29	109.43	113.19^{bc}	102.96^{b}	123.52^{c}	5.25
Protein, %	16.61^{b}	17.16^{c}	17.25^{c}	17.05^{bc}	17.31^{b}	16.65^{c}	.17
Fat, %	26.10^{b}	23.38^{c}	22.93^{c}	23.92^{bc}	22.60^{b}	25.89^{c}	.84
Composition of growth							
Empty body gain, g/day	699.^{b}	802.^{c}	846.^{c}	817.^{e}	667.^{f}	864.^{e}	34.5
Protein gain, g/day	90.9^{b}	119.6^{c}	134.5^{d}	120.9^{b}	103.1^{c}	121.^{b}	5.1
Fat gain, g/day	318.3	289.9	264.5	297.8^{b}	224.5^{c}	350.3^{b}	25.7

[a]Standard error based on minimum group.
[b,c,d]Means in the same row and main effect with different superscripts differ, P.< 05.
[e,f]Means in the same row and main effect with different superscripts differ, P < .01.

and Synovex implanted cattle were depositing 86 g/day less fat and an additional 17 g/day of protein copared to non-implanted cattle gaining 234 and 86 g/day of fat and protein, respectively. At empty body growth rates of 1000 g/day, comparable to gains for finishing cattle, Ralgro and Synovex implanted steers were depositing 140 and 190 g/day less fat and an additional 30 and 40 g/day of protein compared to non-implanted cattle gaining 551 and 110 g/day of fat and protein, respectively. Use of Ralgro and Synovex increased the physio-

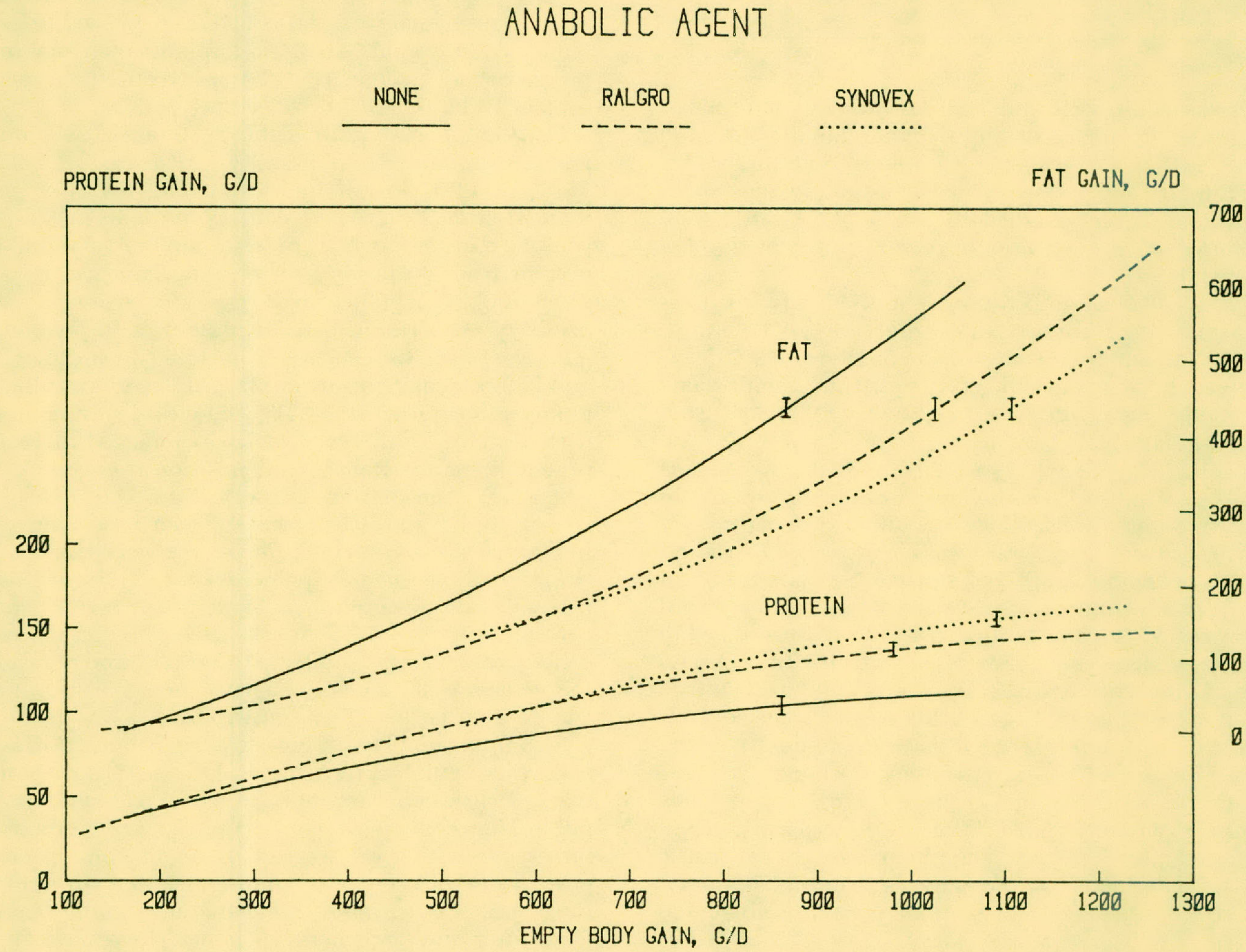

Figure 1. Effect of anabolic implants on modifying priorities for empty body protein and fat growth in steers growing at various rates.

logical limits for protein growth and modified the partitioning of energy from fat to protein deposition. This response is consistent with work reported by Byers (5).

Cattle fed the mixed diet did not reach the target empty body weight and as a consequence had the lowest ($P < .05$) final empty body weight and fat (Table 2). Empty body protein accretion was not affected by dietary treatment. Cattle fed the grain diet deposited 10.3 kg more ($P > .05$) empty body fat than cattle fed the silage diet. As a consequence of lighter slaughter weight, cattle fed the mixed diet and had more protein and less fat as a percent of empty body weight than cattle fed the grain diet ($P < .05$). Despite similar final empty body weights and days on feed (Table 3), cattle fed the forage diet tended ($P < .10$) to have more protein and less fat as percent of empty body weight than cattle fed the grain diet. Data of Prior and Scott (7) indicate that this is most likely due to differences in substrate absorption and use as acetate vs. use as propionate and glucose and the impact of these substrates on lipogenesis.

Cattle fed the mixed diet had lower rates of daily empty body ($P < .01$), protein ($P < .05$) and fat ($P < .05$) gain than cattle fed either the silage or grain diets. Empty body gain was greater ($P > .05$) for grain vs. silage fed cattle (864 vs. 817 g/day) all of which was in the form of additional fat gain (350 vs. 298 g/day). Rates of protein gain were identical for silage and grain fed cattle.

The differences in empty body fat were consistent with carcass data (Table 3). Adjusted fat thickness was reduced ($P > .05$) by 13.7 and 12.7 percent for Ralgro and Synovex implanted cattle from 1.16 cm for non-implanted cattle. Similarly, kidney, pelvic and heart fat was reduced ($P < .05$) 12.7 and 19.9 percent for Ralgro and Synovex steers from 2.72 percent for non-implanted steers. Carcass weight and ribeye area were not affected by anabolic treatment. Yield grades were reduced ($P > .05$) by 11.6 and 8.3 percent for Ralgro and Synovex implanted steers from 3.03 for non-implanted steers. Marbling scores and quality grades reflected the leaner carcasses of implanted cattle ($P < .01$) with all treatments averaging slight amounts of marbling and a USDA quality grade of good.

Anabolic implants increased rate of gain by 15.2 and 22.8 percent ($P < .01$) and as a result reduced the time required to reach similar target final weights by 8.9 and 9.7 percent ($P < .01$) for Ralgro and Synovex, respectively (Table 4). Dry matter consumption was similar for all groups and dry matter required per unit of gain was improved 13.7 percent ($P > .05$) for implanted cattle.

There were no differences in rate of gain or days on feed for cattle fed the silage or grain diets, however, cattle fed the mixed diet gained 21.5 percent more slowly ($P < .01$) and required 8.1 percent more ($P < .01$) time on feed. Dry matter intake was greatest for cattle fed the silage diet ($P < .01$). When dry matter per unit of gain was regressed on the silage content of the silage and grain diets, the conversion ratio of the mixed diet (12.2) was 23 percent less favorable than expected (9.9) indicating substantial negative associative effects.

In summary these data indicate that anabolic estrogens increase protein growth by repartitioning energy from fat toward protein production. The magnitude of this response is highly related to the overall rate of empty body growth. Despite similar final weights and rates of gain, cattle fed a grain diet deposited more fat than cattle fed a silage diet.

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TABLE 3. CARCASS CHARACTERISTICS

	Anabolic agent			Diet			
Item	None	Ralgro	Synovex	Silage	Mixed	Grain	SEM[a]
Number of cattle	41	35	36	37	37	38	
Hot carcass weight, kg	314.3	313.8	325.3	322.9[b]	305.1[c]	325.3[b]	5.9
Ribeye area, cm^2	75.4	77.8	76.8	78.5	75.6	75.8	1.6
Adjusted fat thickness, cm	1.16	.99	1.00	1.10	.86	1.19	.07
Kidney, pelvic and heart fat, %	2.72[b]	2.37[c]	2.17[c]	2.66[b]	2.22[c]	2.40[bc]	.11
USDA yield grade	3.03	2.68	2.78	2.87[bc]	2.55[b]	3.05[c]	.14
Marbling score[d]	SL[85e]	SL[36f]	SL[11f]	SL[60]	SL[30]	SL[42]	12.1
USDA quality grade[d]	Good[73e]	Good[37f]	Good[20f]	Good[55]	Good[32]	Good[44]	8.50

[a]Standard error based on minimum group.
[b,c]Means in the same row and main effect with different superscripts differ, $P < .05$.
[d]Means for electrically stimulated side. marbling: SL = Slight.
[e,f]Means in the same row and main effect with different superscripts differ, $P < .01$.

TABLE 4. RATE AND EFFICIENCY OF GROWTH

Item	Anabolic agent			Diet			
	None	Ralgro	Synovex	Silage	Mixed	Grain	SEM[a]
Number of cattle	41	35	36	37	37	38	
Initial weight, kg	338	333	338	337	336	334	4.6
Final weight, kg[b]	552	521	540	537[c]	507[d]	541[c]	9.7
Days fed	237[e]	216[f]	214[f]	218[e]	234[f]	215[e]	3.9
Gain, kg/day	.79[e]	.91[f]	.97[f]	.93[e]	.75[f]	.98[e]	.04
Number of cattle[g]	20	16	15	16	17	18	
DM intake, kg/day	8.81	8.86	9.62	10.70[e]	8.43[f]	8.16[f]	.48
DM/gain	11.92	10.33	10.25	11.85	12.17	8.49	1.02

[a]Standard error based on minimum group.
[b]Calculated as hot carcass weight divided by average dressing percent (60.18%).
[c,d]Means in the same row and main effect with different superscripts differ, $P < .05$.
[e,f]Means in the same row and main effect with different superscripts differ, $P < .01$.
[g]Pen of group fed cattle treated as one observation.

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PR-4228

Effects of Breed Groups and Growth Implants on Carcass Characteristics and Palatability of Feedlot Bulls

D. D. Johnson, J. W. Savell, G. C. Smith, D. R. Gill, D. E. Williams, L. E. Walters, and J. J. Martin

Summary

Ninety-six young bulls, 32 of each of three breed groups (Hereford, Hereford x Angus and Charolais-cross), were randomly assigned (within breed) to a control or to one of three growth stimulant implant treatments — Compudose, Ralgro or Synovex — and fed a high concentrate diet for 188 days. Bulls were implanted on day 1 of the test; Ralgro and Synovex groups were reimplanted on day 75. Charolais-cross bulls had less subcutaneous fat and larger ribeye areas, which resulted in lower numerical yield grades, than did either the Hereford or Hereford x Angus bulls. Synovex-implanted bulls had higher adjusted fat thickness at the twelfth rib and higher numerical yield grades than did bulls that were not implanted or those that were implanted with Ralgro. Carcasses from the Compudose-implanted bulls were intermediate in adjusted fatness and yield grade to the other groups. For the Hereford breed group, all nonimplanted bulls were classed as "bullock" carcasses. Implanted Hereford bulls more often produced carcasses that were classed as "steers." Neither growth implant nor breed group had any effect on palatability traits, shear force or cooking loss for loin steaks. The USDA sex class designations did denote differences in muscle fiber tenderness, overall tenderness, overall palatability and shear force values.

Introduction

The beef industry has renewed its interest in producing animals with more lean meat to meet the desires of consumers. Previous research (2, 9) generally has indicated that young bulls gain more rapidly on less feed per unit gain. In addition, young bulls produce carcasses with lower fat percentages than steers of the same weight. But performance advantages of young bulls are somewhat offset by behavorial problems, lower quality grades, lower consumer acceptance and a cooked product that is less tender and more variable in eating quality (9).

Some researchers have thought that exogenous hormone treatments might moderate the negative attributes of feeding intact males without retarding added growth and efficiencies of feedlot performance. Earlier studies by Baker and Arthaud (1) did not identify any consistent ways to improve traits found disadvantageous in feeding young bulls. However, more recent studies indicated that hormone treatment may increase the fatness of bulls (5,6) and increase the docility of implanted bulls (6). This study was initiated to further explore the effect of exogenous growth implants on the carcass characteristics and palatability traits of young feedlot bulls.

Materials and Methods

Ninety-six young bulls, 32 of each of three breed groups (Hereford, Hereford x Angus and Charolais-cross), were randomly assigned within breed to one of four groups. The first group received no implant. The other three received growth stimulant implant treatments with Ralgro, Synovex or Compudose. Bulls used in the various breed groups were selected for uniformity and predominance of breed group characteristics from a large group of bulls that had been pastured together. Each breed group x treatment combination was placed on feed in one of twelve pens at Panhandle State University, and fed ad libitum on a high concentrate diet for 118 days (3). The diet consisted of 89.0 percent whole shelled corn, 5.0 percent cottonseed hulls and 6.0 percent commercial supplement. Diet dry matter contained 12.3 percent protein, .53 percent calcium, .35 percent phosphorus, .66 percent potassium and calculated metabolizable energy (kcal/g) of 3.09. The bulls in the implant treatment groups were implanted on day 1 of the test; those in the Ralgro and Synovex implant treatment groups were reimplanted on day 75. Control bulls were processed in the same manner as were the implanted bulls, except no implants were applied. Control and Compudose bulls were not disturbed at reimplantation. Animals were transported to a commercial packing plant for slaughter and carcass evaluation.

Each carcass was electrically stimulated immediately after hide removal and before evisceration. Electrical stimulation (220 volts, 5 to 7 amps for approximately 12 continuous seconds) was administered by inserting a probe into the chuck region of the carcass, with the rail serving as the ground, using the existing electrical stimulation unit and variables of the packing plant.

Approximately 24 hours postmortem, Texas Agricultural Experiment Station personnel evaluated each carcass for USDA skeletal and lean maturity, USDA overall maturity, marbling score, USDA quality grade, USDA yield grade, and USDA sex class.

Immediately after carcass evaluation, a 2.5-inch section was removed from the anterior portion of the loin from one side of each animal. Samples were transported to the Texas A&M University Meat Laboratory and fabricated into two 1.25-inch steaks at 48 hours postmortem; one steak was used for shear force determinations and one steak was used for sensory panel evaluation. Each steak was vacuum packaged with a high oxygen-barrier, skin-type film and placed in a 34 ± 2°F cooler for 4 days. Steaks were then frozen (-10° F) until palatability determinations were made.

Each steak was removed from the freezer, thawed to 34° F and broiled on a Farberware Open-Hearth broiler to an internal temperature of 158°F. Steaks were served while warm to a trained, eight-member sensory panel. Steaks were scored for juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness and overall palatability using 8-point descriptive scales. Off-flavor was also evaluated on a 4-point descriptive scale (4= no off-flavor, 1=intense off-flavor). Sensory panel members were trained to detect those flavors not characteristic of beef ("liver-like," "acidy," etc.). Steaks for shear force determinations were cooled to room temperature (73°F) and as many .5-inch diameter cores as possible were removed parallel to the muscle fibers and sheared by a Warner-Bratzler shear machine. Cooking loss was an average of the difference between the uncooked and cooked weights of both the shear and sensory panel steaks, expressed as a percentage of their uncooked weight.

Data were analyzed according to variance and mean separation. This experiment was conducted in a 3 x 4 factorial design with three breed groups and four growth implant treatments as the two main effects. Interactions between main effects were tested, and only one trait (sex class) had significant interaction between main effects.

Results and Discussion

Main effect mean values for carcass characteristics of the young bulls are presented in Table 1. Carcasses from Hereford and Charolais-cross bulls were more youthful than Hereford x Angus bulls ($P < .05$) in skeletal and overall maturity. Carcasses from the Charolais-cross bulls had younger ($P < .05$) lean maturity than the carcasses from the Hereford x Angus bulls, with the carcasses from the Hereford bulls being intermediate in lean maturity values. Carcasses from Hereford x Angus and Hereford bulls had more ($P < .05$) marbling and higher ($P < .05$) USDA quality

TABLE 1. COMPARISONS OF MAIN EFFECT MEAN VALUES FOR CERTAIN CARCASS CHARACTERISTICS FROM THREE BREED GROUPS OF YOUNG BULLS

	Breed Group			
Trait[a]	Hereford x Angus	Hereford	Charolais-cross	SE
Skeletal maturity	A^{66b}	A^{50c}	A^{49c}	4.79
Lean maturity	A^{48b}	A^{43bc}	A^{40c}	2.33
Overall maturity	A^{59b}	A^{49c}	A^{45c}	3.30
Marbling	$Slight^{50b}$	$Slight^{32b}$	$Traces^{75c}$	10.98
USDA quality grade	$Good^{52b}$	$Good^{36b}$	$Standard^{95c}$	8.06
Fat thickness (12th rib), in	$.43^{b}$	$.39^{b}$	$.24^{c}$	.02
Adjusted fat thickness (12th rib), in	$.42^{b}$	$.40^{b}$	$.24^{c}$	.02
Hot carcass weight, lb	636.50^{b}	679.45^{c}	680.44^{c}	11.57
Estimated kidney, pelvic and heart fat, %	1.89^{b}	1.54^{c}	1.75^{c}	.18
Ribeye area, sq. in.	13.00^{b}	13.20^{b}	14.45^{c}	.27
USDA yield grade	2.19^{b}	2.17^{b}	1.38^{c}	.10

[a]Each carcass was quality and yield graded according to USDA (1975) grade standards. Superscript numbers refer to the relative position, from 00 to 100, within each trait, with higher values associated with more advanced maturity, higher marbling scores and higher grades.

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

grades than did carcasses from Charolais-cross bulls. Carcasses from Charolais-cross bulls had less ($P < .05$) actual and adjusted fat thickness measured at the twelfth rib than the Hereford x Angus and Hereford bulls. Hereford and Charolais-cross bulls had heavier ($P < .05$) hot carcass weights than did Hereford x Angus bulls. Carcasses from Hereford and Charolais-cross bulls had less ($P < .05$) estimated kidney, pelvic and heart fat than the carcasses from the Hereford x Angus bulls. Also, carcasses from Charolais-cross bulls had larger ($P < .05$) ribeye areas than carcasses from the other breed groups. The USDA yield grades for the carcasses from Hereford and Hereford x Angus bulls were very similar ($P > .05$), whereas the carcasses from Charolais-cross bulls were about .8 yield grade higher ($P < .05$) in cutability.

The main effect means for various carcass traits of the growth stimulant and control groups are presented in Table 2. There were no differences in skeletal, lean and overall maturity for carcasses from implanted bulls as compared to carcasses from nonimplanted bulls ($P > .05$). Also, growth implants had no effect ($P > .05$) on marbling score or USDA quality grade. The present data support the conclusion that cattle feeders should expect no improvement in USDA quality grade with implanted bulls. Carcasses from the Synovex-implanted bulls were significantly fatter than carcasses from the nonimplented or Ralgro-implanted bulls. When the actual fat thickness opposite the ribeye muscle was adjusted for variations in fatness in other areas of the carcass, similar results were noted, in that the carcasses from the Synovex-implanted bulls were the fattest ($P < .05$) and carcasses from the Ralgro and nonimplanted bulls were the leanest ($P < .05$).Carcasses from the Compudose-implanted bulls had higher adjusted fat thickness measurements at the twelfth rib than did the nonimplanted bulls.

When interactions between main effects were tested, only six class was found to be significant; therefore, interaction means for breed group x growth stimulant for sex class were tested but not presented in tabular form. These data indicate that for the Hereford x Angus or Charolais-cross bulls vs. the controls the various growth stimulants had no effect ($P > .05$). on sex classification (10) of the carcass as a "steer" or "bullock." For the Hereford breed group, all nonimplanted bulls were classed as "bullock" carcasses. Implanted Hereford bulls, regardless of the type of implant, more often ($P < .05$) produced carcasses classed as "steers."

There were no differences ($P > .05$) in any of the palatability traits, shear force or cooking loss for loin steaks from either Hereford x Angus, Hereford or Charolais-cross bull carcasses (Table 3). Also, when main effect means for loin steaks from nonimplanted or implanted bull carcasses were tested (Table 4), no differences ($P > .05$) were noted in any palatability traits, shear force or cooking loss. Research (4) has

TABLE 3. COMPARISONS OF SENSORY PANEL RATINGS AND COOKING LOSS MAIN EFFECT MEANS FOR LOIN STEAKS FROM CARCASS OF THREE BREED GROUPS OF YOUNG BULLS[a]

Trait	Breed group			SE
	Hereford x Angus	Hereford	Charolais-cross	
Juiciness[b]	5.56	5.43	5.67	.16
Muscle fiber tenderness[c]	5.90	5.58	5.93	.10
Connective tissue amount[d]	7.54	7.50	7.61	.05
Overall tenderness[c]	5.94	5.61	5.97	.16
Off-flavor[e]	3.91	3.87	3.88	.03
Overall palatability[f]	5.80	5.41	5.84	.14
Shear force, lb	8.82	9.20	8.91	.33
Cooking loss, %	28.16	27.38	27.93	.43

[a]None of the means were statistically different ($P > .05$).

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]4 = none; 1 = intense.

[f]8 = extremely palatable; 1 = extremely unpalatable.

TABLE 2. COMPARISONS OF MAIN EFFECT MEAN VALUES FOR CERTAIN CARCASS CHARACTERISTICS FOR GROWTH STIMULANT TREATMENT GROUPS

Trait[a]	Control	Growth stimulant			SE
		Ralgro	Synovex	Compudose	
Skeletal maturity	A^{52}	A^{60}	A^{57}	A^{53}	5.53
Lean maturity	A^{42}	A^{46}	A^{47}	A^{41}	2.69
Overall maturity	A^{49}	A^{53}	A^{53}	A^{48}	3.81
Marbling	$Slight^{22}$	$Slight^{06}$	$Slight^{32}$	$Slight^{17}$	12.68
USDA quality grade	$Good^{29}$	$Good^{19}$	$Good^{37}$	$Good^{25}$	9.31
Fat thickness (12th rib), in	$.31^{b}$	$.31^{b}$	$.43^{c}$	$.35^{bc}$	.03
Adjusted fat thickness (12th rib), in	$.31^{b}$	$.31^{bc}$	$.41^{d}$	$.37^{cd}$	.02
Hot carcass weight, lb	665.75	704.00	681.00	670.13	13.38
Estimated kidney, pelvic and heart fat, %	1.71	1.67	1.79	1.81	.08
Ribeye area, sq in	13.11	13.55	12.68	13.46	.31
USDA yield grade	1.72^{b}	1.77^{b}	2.23^{c}	1.94^{bc}	.12

[a]Each carcass was quality and yield graded according to USDA (1975) grade standards. Superscript numbers refer to the relative position, from 00 to 100, within each trait, with higher values associated with more advanced maturity, higher marbling scores and higher grades.

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

TABLE 4. COMPARISONS OF SENSORY PANEL RATINGS AND COOKING LOSS MAIN EFFECT MEANS FOR LOIN STEAKS FROM CARCASSES FROM GROWTH STIMULANT TREATMENT GROUPS[a]

	Growth stimulant				
Trait	Control	Ralgro	Synovex	Compu-dose	SE
Juiciness[b]	5.41	5.57	5.51	5.73	.12
Muscle fiber tenderness[c]	5.75	5.72	5.75	6.00	.19
Connective tissue amount[d]	7.52	7.54	7.55	7.59	.05
Overall tenderness[c]	5.76	5.76	5.81	6.03	.19
Off-flavor[e]	3.91	3.85	3.87	3.93	.03
Overall palatability[f]	5.57	5.60	5.59	5.97	.16
Shear force, lb	8.47	9.35	9.17	9.00	.40
Cooking loss, %	28.57	27.28	27.91	27.53	.50

[a]None of the means were statistically different ($P > .05$).

[b]8 = extremely juicy; 1 = extremely dry.

[c]8 = extremely tender; 1 = extremely tough.

[d]8 = none; 1 = abundant.

[e]4 = none; 1 = intense.

[f]8 = extremely palatable; 1 = extremely unpalatable.

reported no significant differences in palatability characteristics between steaks from bulls implanted with exogenous hormones vs. steaks from nonimplanted bulls.

Because these data indicated that neither breed group nor growth stimulants had an effect on the palatability of loin steaks from bulls, sex class means were tested to see if possibly the development ot secondary sexual characteristics of the carcass might influence palatability of loin steaks. Data (not presented in tabular form) indicated that sex class ("bullock" vs. "steer) had no effect on juiciness, incidence of off-flavor or connective tissue amount for loin steaks from bull carcasses. The taste panel scored loin steaks from "bullock" carcasses about .5 of a unit lower ($P < .05$) for muscle fiber tenderness, overall tenderness and overall palatability than loin steaks from carcasses designated as "steers." In addition, carcasses classed as "steers" had lower ($P < .05$) shear force values than carcasses classed as "bullocks" (8.36 lb. vs. 9.20 lb., respectively).

The lack of effect of growth implants on palatability traits in this study may be age-related. Although specific ages were not known, bulls were estimated to be about 1 year old and weighed about 600 lbs. at the beginning of the treatment; therefore puberty probably had occurred. Early implantation, before the development of puberty, could increase the likelihood of anabolic estrogens lessening the negative effects of secondary sex hormones on the attributes of beef palatability.

In summary, growth implants appear to have no effect on carcass quality factors (although slightly increased carcass fatness can be expected with some implants). In addition, growth stimulants had little effect on the palatability of loin steaks from carcasses of any of the three breed groups tested. The breed groups used in this study had different carcass characteristics, although these differences did not denote diferences in the palatability characteristics of the loin steaks. Sex class did cause differences in muscle fiber tenderness, overall tenderness, overall palatability and shear force.

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Tenderness of Major Muscles from Three Breed-Types of Cattle at Different Times-on-Feed

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Summary

Seventy-five steers (9 to 12 months old) of Angus (n=25), Brahman (n=25) and Brahman x Angus (n=25) breed-types and of known history were fed a high energy diet. Five steers from each breed-type were slaughtered after 0, 56, 112, 168 and 224 days. Steaks from Angus and Brahman x Angus steers were more tender than steaks from Brahman steers in 27 of 50 comparisons and 14 of 50 comparisons, respectively. Time-on-feed influenced the tenderness of steaks from all three breed-types: (a) Steaks from Brahman steers improved ($P < .05$) in tenderness with increasing time-on-feed for all muscles except the *psoas major* (tenderloin); (b) With the exception of the *longissimus* muscle (strip loin), the tenderness of steaks from Angus

steers did not change ($P > .05$) as time-on-feed increased; and, (c) For the Brahman x Angus steers, five of the ten muscles studied improved in tenderness with increasing time-on-feed. "Acceptable" tenderness (WBS values of less than 10.0 pounds) for most of the muscles was achieved at feeding periods from 112 to 224 days for Brahman, from 0 to 56 days for Angus, and from 56 to 168 days for Brahman x Angus.

Introduction

A number of studies have related breed-type to the tenderness of beef (3,7,8,9,10). Those studies reveal that Zebu and Zebu x European breed-types have higher Warner-Bratzler shear values and/or lower sensory panel tenderness ratings than steaks from European breed-types. It also has been suggested that time-on-feed is related to the tenderness of beef (1,2,4,5,12,13). Available data indicate that for cattle fed a conventional high-energy finishing diet, a feeding period of a determinate length (about 100 days in several studies) is sufficient to assure the production of beef with desirable tenderness and overall palatability. In most of those studies the time-on-feed necessary to achieve "acceptable" palatability is shorter than that currently employed by most cattle feeders.

The present study was conducted to compare the tenderness of some of the major muscles of carcasses from three breed-types of cattle fed for periods of 0 to 224 days.

Procedures

Seventy-five steers (9 to 12 months old) of purebred Angus (n=25), purebred Brahman (n=25) and F1 Brahman x Angus (N=25) breed-types, of known history and each weighing approximately 250 kilograms (kg), were fed for feeding periods of 0, 56, 112, 168 or 224 days. The animals were fed a high-energy finishing diet containing corn, sorghum, cottonseed hulls, cottonseed, alfalfa, molasses, salt and a vitamin and mineral premix; the diet had a dry matter content of 87.8 percent and a crude protein content of 13.7 percent.

Five steers of each breed-type were slaughtered at the end of each feeding period. Carcasses were chilled in a 33± 1°F cooler and ribbed at 24 hour postmortem. Quality and yield grade factors were evaluated by Texas Agricultural Experiment Station personnel.

Carcasses were stored for 6 additional days in the same 33± 1°F cooler. At 7 days postmortem, the left side of each carcass was fabricated into the major wholesale cuts and eight muscles or muscle groups were removed: shoulder clod, strip loin, tenderloin, top sirloin butt, knuckle, top round, bottom round, and eye of round. The following steaks with each muscle(s) studied listed parenthetially, were removed from each cut: clod (*triceps brachii* and *infraspinatus*); top loin *(longissimus)*, tenderloin *(psoas major)*; top sirloin *(biceps femoris* and *gluteus medius)*; top round *(semimembranosus)*; bottom round *(biceps femoris)*; eye of round *(semitendinosus)*; and knuckle *(vastus lateralis* and *rectus femoris)*. Warner-Bratzler shear (WBS) determinations were made on these steaks. A second steak was removed from the strip loin and from the bottom round and frozen before sensory panel evaluation.

Steaks for WBS determinations were removed from the freezer, thawed for 24 hours and oven-roasted to an internal temperature of 158°F. As many cores as possible were removed from each designated muscle for shear force determinations with a Warner-Bratzler shear machine. Steaks for sensory panel evaluation were removed from the freezer, thawed for 24 hours and cooked to an internal temperature of 158°F on a Farberware Open-Hearth Broiler. Eight experienced panelists evaluated each sample for flavor, amount of connective tissue, overall tenderness and overall palatability using 8-point descriptive rating scales.

Results

As time-on-feed (TOF) increased, overall maturity, marbling, weight and fat thickness of carcasses increased for all three breed-groups (Table 1). In comparison to carcasses from Angus steers, those from Brahman steers did not differ in overall maturity at four of five TOF periods, in marbling at four of five TOF periods, in carcass weight at five of five TOF periods and in fat thickness at four of five TOF periods. Brahman x Angus steer carcasses were not different from Angus steer carcasses in 20 of 20 comparisons (trait x TOF combinations), and were not different from Brahman steer carcasses in 17 of 20 comparisons (Table 1). Fed for the same periods of time on the same diet, steers of the three breed-types produced carcasses which differed very little in quality and yield grade factors when differences were tested for statistical significance.

The three breed-types did not respond in exactly the same manner to progressive increases in time-on-feed, but there were some general similarities in response for all four quality and yield grade factors (Table 1). All three breed-types increased most in overall maturity between 0 and 112 days, with little or no change thereafter. All three breed-types increased in marbling between 0 and 112 days and two of the breed-types (Brahman and Brahman x Angus) had further increases thereafter. Carcass weight increased between 0 and 56 days, 56 and 112 days, and 112 and 168 days for all three breed-types, and increased between 168 and 224 days for Brahman x Angus steers. All three breed-types increased in fat thickness between either 0 and 56 days or 0 and 112 days and again between 112 and 168 days, but not thereafter. Compared at the same TOF, the three breed-types showed few differences in terms of quality or yield grade.

Comparisons of WBS values (Tables 2 and 3) for the ten muscles or muscle groups show that TOF had more effect on the tenderness of steaks from Brahman steers than on tenderness of steaks from Angus steers. As compared to 0 days on feed, feeding for 56 days improved tenderness of 0 (Brahman), 0 (Angus) and 1 (Brahman x Angus) of 10 muscles; comparable data were 1, 0 and 2 muscles for 112 days, 4, 0 and 3 muscles for 168 days, and 6, 0 and 2 muscles for 224 days. As compared to feeding for 56 days, feeding for 112 days improved

TABLE 1. CERTAIN QUALITY AND YIELD GRADE FACTORS FOR CARCASSES FROM THREE BREED-TYPES OF CATTLE FED FOR EACH TIME-ON-FEED

Trait	Breed	Time-on-feed (days)					Time-on-feed comparison[c]				
		0	56	112	168	224					
	Brahman	A^{22a}	A^{48a}	A^{50a}	A^{44a}	A^{71a}	0	168	56	112	224
Overall maturity[d]	Angus	A^{11b}	A^{37a}	A^{41a}	A^{45a}	A^{48a}	0	56	112	168	224
	Brahman x Angus	A^{23ab}	A^{36a}	A^{41a}	A^{50a}	A^{48a}	0	56	112	224	168
	Brahman	PD^{84a}	Tr^{30a}	Tr^{74a}	Sl^{82a}	Sl^{70a}	0	56	112	224	168
Marbling[e]	Angus	Tr^{04a}	Tr^{76b}	Sl^{00a}	Sl^{78a}	Sl^{62a}	0	56	112	224	168
	Brahman x Angus	Tr^{14a}	Tr^{58ab}	Sl^{30a}	Sl^{78a}	Sm^{62a}	0	56	112	168	224
	Brahman	320.5^{a}	443.5^{a}	536.2^{a}	633.7^{a}	661.7^{a}	0	56	112	168	224
Carcass weight (lb)	Angus	313.2^{a}	425.0^{a}	518.9^{a}	645.2^{a}	700.8^{ab}	0	56	112	168	224
	Brahman x Angus	360.7^{a}	503.2^{a}	572.0^{a}	683.5^{a}	766.3^{b}	0	56	112	168	224
	Brahman	0.02^{a}	0.06^{a}	0.15^{a}	0.35^{a}	0.33^{a}	0	56	112	224	268
Fat thickness (in)	Angus	0.04^{ab}	0.20^{b}	0.20^{ab}	0.40^{a}	0.50^{a}	0	56	112	168	224
	Brahman x Angus	0.08^{b}	0.13^{ab}	0.39^{b}	0.42^{a}	0.50^{a}	0	56	112	168	224

[a,b] Means in the same column and for the same carcass trait bearing a common superscript letter are not different ($P > .05$).

[c] Means underscored by a common line are not different ($P > .05$).

[d] A^{00} and A^{100} in USDA maturity score represents a range in chronological age from about 9 months to 30 months.

[e] Marbling score: Sm=small; Sl=slight; Tr=traces; PD=practically devoid.

tenderness of 3 (Brahman), 1 (Angus) and 0 (Brahman x Angus) of 10 muscles; comparable data were 7, 2 and 3 muscles for 168 days and 7, 2 and 0 muscles for 224 days. As compared to feeding for 112 days, feeding for 168 days improved tenderness of 4 (Brahman), 1 (Angus) and 2 (Brahman x Angus) of 10 muscles; comparable data were 5, 1 and 0 muscles for 224 days. Feeding steers for 224 days rather than 168 days improved tenderness of one muscle in Brahman steers and none in either of the other breed-types. In summary, feeding for progressively longer periods of time improved tenderness of muscles in 33 of 100 comparisons for Brahman, 7 of 100 comparisons for Angus, and in 13 of 100 comparisons for Brahman x Angus (Tables 2 and 3).

Comparisons of the three breed-types within specific feeding periods (Tables 2 and 3) showed that steaks from Angus steers had lower WBS values than steaks from Brahman steers in 27 of 50 comparisons (e.g., *longissimus* at days 0, 112 and 168; *psoas major* at days 0 and 224; *etc.*). Steaks from Brahman x Angus carcasses had lower WBS values than Brahman steers in 14 of 50 comparisons (e.g., *longissimum* at days 0 and 168; *triceps brachii* and infraspinatus at day 112; *etc.*). Steaks from Angus steers had lower WBS values than steaks from Brahman x Angus steers in 5 of 50 comparisons. Differences in WBS values between breed-types were more evident at early TOF periods (0, 56 and 112 days) than at later TOF periods (168 and 224 days). There were breed-type differences in WBS values for 6 of 10 muscles at day 0, 7 of 10 muscles at day 56, 8 of 10 at day 112, 3 of 10 at day 168, and 3 of 10 at day 224. As time-on-feed increased beyond 112 days, differences in muscle tenderness of different breed-types were seldom statistically significant.

In comparisons of sensory panel ratings for steaks at each of five times-on-feed, those from Angus steers were only more desirable than those from Brahman steers in flavor, amount of connective tissue, overall tenderness and overall palatability in few comparisons of strip loins (Table 4) and in few comparisons of bottom round steaks (Table 5). Steaks from Angus steers were not more desirable than those from Brahman x Angus steers in palatability for strip loin steaks (Table 4) at any time-on-feed, but bottom round steaks (Table 5) were more desirable only at day 0. When steers of the three breed-types were fed for the same periods of time (and for 56 days or longer) on the same diet, they produced strip loin and bottom round steaks which differed very little in the four sensory categories.

Discussion

Data from this study generally concur with results of previous research. Kincaid (6) and Palmer (9) reported that beef from steers of Brahman breed-types was less tender than that from steers of European breed-types, while beef from European x Brahman steers was intermediate to the other two breed-types in tenderness. In the present study, effects of time-on-feed on palatability of cooked beef also appeared to be associated with differences in breed-type. Time-on feed did not seem to affect tenderness in steaks from Angus steers. But with the exception of the *psoas major*, all muscles of the Brahman steers increased in tenderness as time-on-feed increased.

The different responses to time-on-feed among steers of different breed-types may involve breed differences in subcutaneous fat thickness. Using regression data, Brahman, Angus and Brahman x Angus steers required approximately 179, 126 and 118 days of feeding, respectively, using the diet and feeding conditions invol-

TABLE 2. WARNER-BRATZLER SHEAR FORCE VALUES (LB) FOR SOME OF THE MAJOR MUSCLES FROM THE CHUCK AND LOIN FROM THREE BREED-TYPES OF CATTLE FED FOR EACH TIME-ON-FEED

Cut (muscle)	Breed	Time-on-feed (days) 0	56	112	168	224	Time-on-feed comparison[c]				
	Brahman	16.7^{a}	17.4^{a}	15.8^{a}	10.9^{a}	11.2^{a}	56	0	112	224	168
Strip loin (*Longissimus*)	Angus	10.7^{b}	13.7^{a}	10.6^{b}	8.1^{b}	8.4^{a}	56	0	112	224	116
	Brahman x Angus	12.3^{b}	13.6^{a}	12.7^{ab}	8.3^{b}	9.9^{a}	56	112	0	224	168
	Brahman	8.1^{a}	8.8^{a}	8.8^{a}	8.3^{a}	8.9^{a}	224	56	112	168	0
Tenderloin (*Psoas major*)	Angus	6.6^{b}	8.0^{a}	7.7^{a}	7.5^{a}	7.5^{b}	56	112	168	224	0
	Brahman x Angus	7.9^{ab}	8.3^{a}	8.2^{a}	8.0^{a}	8.5^{a}	224	56	112	168	0
	Brahman	8.4^{a}	11.2^{a}	11.0^{a}	9.2^{a}	8.9^{a}	56	112	168	224	0
Clod	Angus	7.8^{a}	8.6^{b}	8.1^{b}	8.2^{a}	9.0^{a}	224	56	168	112	0
(*Triceps brachii* and Infraspinatus)	Brahman x Angus	8.7^{a}	9.3^{ab}	8.7^{b}	8.3^{a}	9.3^{a}	224	56	112	0	168
	Brahman	11.7^{a}	11.4^{a}	10.6^{a}	7.8^{a}	7.6^{a}	0	56	112	168	224
Top sirloin	Angus	7.0^{b}	6.4^{b}	6.6^{b}	7.9^{a}	6.2^{a}	168	0	112	56	224
(*Biceps femoris*)	Brahman x Angus	10.4^{a}	8.9^{ab}	6.2^{b}	6.4^{a}	7.3^{a}	0	56	224	168	112
	Brahman	14.3^{a}	14.9^{a}	11.0^{a}	11.3^{a}	10.0^{a}	56	0	168	112	224
Top sirloin	Angus	9.9^{a}	8.2^{b}	8.3^{b}	6.5^{a}	7.8^{b}	0	168	112	56	224
(*Gluteus medius*)	Brahman x Angus	12.7^{a}	8.5^{b}	8.9^{b}	8.8^{a}	9.3^{ab}	0	224	112	168	56

[a,b]Means in the same column and for the same muscle bearing a common superscript letter are not different (P > .05).

[c]Means underscored by a common line are not different (P > .05).

TABLE 3. WARNER-BRATZLER SHEAR FORCE VALUES (LB) FOR SOME OF THE MAJOR MUSCLES OF THE ROUND FROM THREE BREED-TYPES OF CATTLE FED FOR EACH TIME-ON-FEED

Cut (muscle)	Breed	Time-on-feed (days) 0	56	112	168	224	Time-on-feed comparison[c]				
	Brahman	10.7^{a}	12.7^{a}	11.7^{a}	10.0^{a}	9.9^{a}	56	112	0	168	224
Round	Angus	9.8^{a}	9.7^{b}	9.3^{b}	8.8^{a}	8.6^{a}	0	56	112	168	224
(*Semimembranosus*)	Brahman x Angus	10.6^{a}	10.5^{b}	10.6^{ab}	8.9^{a}	9.7^{a}	0	112	56	224	168
	Brahman	12.4^{a}	14.2^{a}	11.2^{a}	11.7^{a}	11.4^{a}	56	0	168	224	112
Round (*Semitendinosus*)	Angus	9.2^{b}	11.0^{b}	12.7^{a}	12.7^{a}	10.6^{a}	112	56	168	224	0
	Brahman x Angus	10.5^{b}	12.0^{b}	10.9^{a}	10.9^{a}	10.2^{a}	56	112	0	224	168
	Brahman	12.5^{a}	11.7^{a}	11.4^{a}	10.0^{a}	10.3^{a}	0	56	112	224	168
Round (*Biceps femoris*)	Angus	8.8^{b}	8.8^{b}	9.6^{b}	10.6^{a}	11.3^{a}	224	168	112	0	56
	Brahman x Angus	10.5^{b}	10.8^{a}	10.5^{ab}	9.6^{a}	9.9^{a}	56	112	0	224	168
	Brahman	12.9^{a}	14.5^{a}	13.4^{a}	12.7^{a}	11.6^{a}	56	112	0	168	224
Tip, cap-off	Angus	10.2^{a}	11.3^{b}	9.5^{b}	9.5^{b}	9.5^{b}	56	0	224	168	112
(*Vastus lateralis*)	Brahman x Angus	12.8^{a}	11.2^{b}	10.9^{ab}	9.8^{b}	11.3^{ab}	0	224	56	112	168
	Brahman	12.0^{a}	10.3^{a}	10.0^{a}	10.0^{a}	8.8^{a}	0	56	112	168	224
Tip, cap-off	Angus	6.7^{c}	8.8^{a}	7.4^{b}	7.9^{c}	8.8^{a}	56	224	168	112	0
(*Rectus femoris*)	Brahman x Angus	10.7^{b}	9.8^{a}	8.9^{ab}	9.0^{b}	10.0^{a}	0	224	56	168	112

[a,b,c]Means in the same column and for the same muscle bearing a common superscript letter are not different (P > .05).

[d]Means underscroed by a common line are not different (P > .05).

TABLE 4. SENSORY PANEL RATINGS FOR *LONGISSIMUS* MUSCLES FROM EACH OF THREE BREED-TYPES OF CATTLE AT EACH TIME-ON-FEED

Sensory panel reading	Breed	Time-on-feed (days) 0	56	112	168	224	Time-on-feed comparison[c]				
Flavor[d]	Brahman	5.0^{a}	5.1^{a}	5.4^{a}	5.4^{a}	5.4^{b}	224	168	112	56	0
	Angus	4.9^{a}	5.2^{a}	5.7^{a}	5.9^{a}	5.9^{a}	224	168	112	56	0
	Brahman x Angus	5.2^{a}	5.2^{a}	5.4^{a}	6.1^{a}	6.0^{a}	168	224	112	56	0
Amount of connective tissue[e]	Brahman	6.3^{b}	6.7^{a}	7.0^{a}	7.6^{a}	7.4^{a}	168	224	112	56	0
	Angus	7.2^{a}	6.8^{a}	7.5^{a}	7.3^{a}	7.3^{a}	112	224	168	0	56
	Brahman x Angus	6.8^{ab}	6.9^{a}	7.4^{a}	7.5^{a}	7.2^{a}	168	112	224	56	0
Overall tenderness[f]	Brahman	1.7^{a}	2.3^{a}	3.8^{a}	5.3^{a}	4.6^{a}	168	224	112	56	0
	Angus	3.8^{a}	3.1^{a}	5.4^{a}	5.1^{a}	5.4^{a}	224	112	168	0	56
	Brahman x Angus	3.5^{a}	3.8^{a}	3.5^{a}	6.2^{a}	4.5^{a}	168	224	56	112	0
Overall palatability[g]	Brahman	2.0^{a}	2.6^{a}	3.9^{a}	4.8^{a}	4.6^{a}	168	224	112	56	0
	Angus	3.8^{a}	3.2^{a}	5.2^{a}	5.2^{a}	5.5^{a}	224	168	112	0	56
	Brahman x Angus	3.5^{a}	3.8^{a}	3.7^{a}	5.7^{a}	4.5^{a}	168	224	56	112	0

[a,b]Means in the same column and for the same sensory panel rating bearing a common superscript letter are not different ($P > .05$).

[c]Means underscored by a common line are not different ($P > .05$).

[d]8 = extremely desirable flavor; 1 = extremely undesirable flavor.

[e]8 = no detectable connective tissue; 1 = abundant detectable connective tissue.

[f]8 = extremely tender; 1 = extremely tough.

[g]8 = extremely desirable in palatability; 1 = extremely undesirable in palatability.

TABLE 5. SENSORY PANEL RATINGS FOR *BICEPS FEMORIS* MUSCLES FROM EACH OF THREE BREED-TYPES OF CATTLE AT EACH TIME-ON-FEED

Sensory panel rating	Breed	Time-on-feed (days) 0	56	112	168	224	Time-on-feed comparison[c]				
Flavor[d]	Brahman	5.1^{b}	4.9^{a}	5.0^{a}	5.5^{a}	4.8^{b}	168	0	112	56	224
	Angus	5.2^{a}	5.3^{a}	4.9^{a}	5.5^{a}	5.5^{a}	224	168	56	0	112
	Brahman x Angus	4.6^{b}	5.1^{a}	5.2^{a}	5.2^{a}	5.2^{a}	224	168	112	56	0
Amount of connective tissue[e]	Brahman	4.2^{a}	3.7^{a}	3.9^{a}	4.4^{a}	4.1^{a}	168	0	224	112	56
	Angus	5.0^{a}	4.8^{a}	4.7^{a}	4.2^{a}	4.1^{a}	0	56	112	168	224
	Brahman x Angus	2.8^{b}	4.0^{a}	4.0^{a}	4.0^{a}	3.9^{a}	168	112	56	224	0
Overall tenderness[f]	Brahman	3.3^{b}	3.1^{a}	3.4^{a}	4.1^{a}	3.9^{a}	168	224	112	0	56
	Angus	4.9^{a}	4.7^{a}	4.6^{a}	4.3^{a}	4.0^{a}	0	56	112	168	224
	Brahman x Angus	2.7^{b}	3.7^{a}	3.8^{a}	4.0^{a}	4.3^{a}	224	168	112	56	0
Overall palatability[g]	Brahman	3.4^{b}	3.2^{b}	3.6^{a}	4.2^{a}	3.9^{a}	168	224	112	0	56
	Angus	4.9^{a}	4.6^{a}	4.3^{a}	4.2^{a}	4.2^{a}	0	56	112	168	224
	Brahman x Angus	2.9^{b}	3.7^{ab}	3.9^{a}	4.1^{a}	4.3^{a}	224	168	112	56	0

[a,b]Means in the same column and for the same sensory panel rating bearing a common superscript letter are not different ($P > .05$).

[c]Means underscored by a common line are not different ($P > .05$).

[d]8 = extremely desirable flavor; 1 = extremely undesirable flavor.

[e]8 = no detectable connective tissue; 1 = abundant detectable connective tissue.

[f]8 = extremely tender; 1 = extremely tough.

[g]8 = extremely desirable in palatability; 1 = extremely undesirable in palatability.

ved in the present study, to achieve fat thickness of 0.76 centimeters (cm).

Assuming that a shear force value of less than 10 lb. is required for "acceptable" tenderness, the point in feeding time at which that shear force was attained for individual muscles could be used to identify the desired time-on-feed for each breed-type. With the exception of *psoas major* ("acceptable" at all times-on-feed) and *semitendinosus* ("unacceptable" at all times-on-feed) muscles, the time required for acceptable tenderness in Brahman steaks was 112 to 224 days of feeding. *Longissimus* and *vastus lateralis* muscles from Angus steers required feeding periods of 168 and 56 days, respectively, to attain "acceptable" WBS values; all other muscles, aexcept the *semitendinosus* ("unacceptable" at all times-on-feed) and the *biceps femoris* (which behaved peculiarly in that shear force increased as time-on-feed increased), were "acceptable" at 0 days of feeding and at all other times-on-feed. For Brahman x Anugs steers, WBS values for *triceps brachii, infraspinatus* and *psoas major* were "acceptable" with 0 days of feeding; those for *biceps femoris* — sirloin, *gluteus medius* and *rectus femoris* were "acceptable" after 0 to 56 days of feeding; and WBS values were "acceptable" for the *biceps femoris* — round, *longissimus, semimembranosus* and *vastus lateralis* after 112 to 168 days of feeding (Tables 2 and 3).

Using similar logic for categorizing sensory panel ratings, with 4.5 being the minimum "acceptable" mean rating, Brahman steers required 112 to 168 days of feeding to produce strip loin steaks of "acceptable" overall tenderness and overall palatability. Angus steer required 56 to 112 days of feeding to produce strip loin steaks of "acceptable" overall palatability, and Brahman x Angus steers requires 112 to 168 days of feeding to produce strip loin steaks of "acceptable" overall tenderness and overall palatability. Bottom round steaks from Brahman and from Brahman x Angus steers did not achieve "acceptable" ratings for amount of connective tissue, overall tenderness and overall palatability ratings at any of the times-on-feed; bottom round steaks from Angus steers were "acceptable" in amount of connective tissue, overall tenderness and overall palatability after 0 and 56 days of feeding, but not at either 168 or 224 days. The flavor of both *longissimus* and *biceps femoris* steaks was "acceptable" at all times-on-feed for steers from all three breed-groups (Tables 4 and 5).

Data from this study support the theorty that time-on-feed can be used to predict the tenderness of the major muscles of the beef carcass for different breed-groups of cattle.

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Effects of Electrical Stimulation on Carcass Quality and Meat Palatability of Charolais Crossbred Bulls and Steers

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Summary

Forty-four Charolais crossbred bulls and steers from a common background and commercial feedlot were slaughtered. The right side of each carcass was electrically stimulated while the left side served as a control. Electrical stimulation lowered lean maturity scores (more youthful) and lean firmness scores (softer lean), but had no effect on marbling, lean texture, "heat-ring" or iridescence scores. A relatively rapid pH decline, coincidental with a slow temperature decline, indicated that electrical stimulation may have caused a slight pale, soft and exudative condition that might account for the lower firmness scores. Electrical stimulation reduced shear force values but had no effect on sensory panel scores for juiciness, muscle fiber tenderness, overall tenderness, off-flavor or overall palatability of loin steaks. Electrical stimulation had a greater influence in improving the palatability of steaks from bulls than from steers.

Introduction

There has been extensive research into the effects of electrical stimulation on beef carcass lean quality and meat palatability. Electrical stimulation has been shown to improve lean maturity scores (more youthful), decrease the incidence and/or severity of "heat-ring" (depression and discoloration of the lean in the exposed ribeye due to differential chilling rates), and increase lean firmness and texture scores (1,8,9,10,12). These studies have included a wide range of carcass weights (400 to 660 pounds) of steers and heifers, but limited data has been reported regarding the influence of electrical stimulation on lean quality and cooked meat palatability in meat from young bulls.

Because bull carcasses have a coarse texture and dark lean color, and because cooked steaks from bulls are often less tender than those from steers, electrical stimulation may enhance the marketability of beef from young bulls. Savell et al. (11) reported more youthful lean color, finer-textured lean, higher marbling scores and higher quality grades for electrically stimulated sides from Santa Gertrudis bulls. Other studies (3,4,5) have shown that electrical stimulation brightened lean color of bull carcasses. However, softer, coarser-textured lean in electrically stimulated sides from bulls vs. those from control sides have been reported (3).

Of studies involving the effects of electrical stimulation on palatability of meat from bulls, three showed increased tenderness (3,6,11), one indicated decreased flavor (3) and one showed no differences in palatability traits (2) attributable to electrical stimulation. This study was designed to further investigate the effects of electrical stimulation on carcass quality and beef palatability in meat from bulls and steers.

Procedures

Forty-four 1/2 blood Charolais and 3/4- to 7/8-blood Charolais bulls and steers from a common herd were commercially fed for 172 days. Cattle were then held by sex-breed group (n=11) overnight with water, and transported to the plant on the morning of slaughter. Within 2 hours of arrival, the cattle were slaughtered.

The right side (n=44) of each carcass was electrically stimulated (550 volts AC; 2 to 2.5 amps; 15 impulses for a duration of 1.8 seconds) within 45 minutes of bleeding, using a Lector-Tender™ experimental unit. The left sides (n=44) were not electrically stimulated and served as controls. Temperature and pH declines were monitored at 2, 4, 6, 8, 10, 12 and 24 hours postmortem.

At 24 hours postmortem, Texas Agricultural Experiment Station personnel evaluated both sides for USDA beef carcass quality and yield grade factors, lean firmness (8=very firm, 1=very soft), texture (8=very fine, 1=very coarse), "heat-ring" (5=none, 1=extremely severe) and iridescence (3=none, 1=evident).

Sides were fabricated at the plant and bone-in strip loins were vacuum packaged, boxed and shipped to College Station. At 12 days postmortem, strip loins were boned, faced and cut into 1.25-inch loin steaks. Loin steaks for sensory panel evaluation and shear force determination were the second and third steaks removed, respectively. Each steak was individually double-wrapped with polyethylene-coated freezer paper, frozen at -30°F and stored at 0°F for 6 to 8 weeks prior to the evaluations.

Loin steaks were thawed for 14 to 16 hours and broiled on Farberware Open-Hearth broilers to internal temperatures of 158°F. Steaks designated for shear force determinations were cooled to ambient temperature and trimmed of exterior fat. Six to eight cores were removed parallel to the orientation of the muscle fibers and sheared once. Steaks designated for sensory panel evaluations were trimmed of exterior fat and cut into 0.5-inch cubes. Two cubes from each steak were served, while warm, to each person in an eight-member, experienced sensory panel. Eight-point descriptive scales were used to score juiciness, connective tissue amount and overall palatability. In addition, panelists were asked to score off-flavor and to indicate why overall palatability was rated less than 5 (i.e., due to dryness, toughness, off-flavor, etc.).

Means for carcass lean attributes, shear force, sensory panel evaluations and cooking loss were analyzed by paired t-tests using the Statistical Analysis System (7). Frequencies were calculated for the reasons that overall palatability was rated less than 5 ("slightly undesirable" or lower).

Results and Discussion

To characterize the sample population, means and standard deviations for certain carcass characteristics are presented in Table 1. Paired comparisons, across sex and breed groups (Table 2), indicate that electrical stimulation lowered lean maturity scores (more youthful) and lowered lean firmness scores (softer lean), but had no effect on marbling, texture, "heat-ring" or iridescence scores. The effect of electrical stimulation on lean maturity scores concurs with previous research; however, the lower lean firmness scores in electrically stimulated sides was not expected.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR LIVE WEIGHT AND CARCASS CHARACTERISTICS OF CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	Steers (n=22)		Bulls (n=22)	
Live weight, lb	1123	(99)	1197	(106)
Age at slaughter, days	422.6	(18.8)	424.1	(16.2)
Carcass weight, lb	720	(71)	771	(72)
Adjusted fat thickness, 12th rib, inches	0.36	(0.1)	0.24	(0.1)
Ribeye area, sq. inches	12.7	(1.6)	15	(1.6)
Kidney, pelvic and heart fat, %	2.2	(0.5)	1.5	(0.4)
USDA Yield Grade	2.5	(1.8)	1.5	(0.6)

When paired comparisons were made within sex classes (Table 3), lower lean maturity scores were observed in electrically stimulated sides from both steers and bulls than in control sides. For steer carcasses, lower firmness and "heat-ring" scores were found for electrically stimulated sides than for control sides; no differences in these traits were noted for bull carcasses. In general, the mean longissimus muscle pH and temperature data within sex class (not illustrated) indicate similar rates of pH and temperature decine for both steers and bulls that were not electrically stimulated. However, bulls had higher pH values at 10 and 24 hours and higher temperatures at each measurement time than did steers. The slower temperature declines for bull carcasses may be attributed to their heavier carcass weights.

TABLE 2. EFFECTS OF ELECTRICAL STIMULATION ON LEAN QUALITATIVE CHARACTERISTICS FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS COMBINED

Lean Trait	Not electrically stimulated (n=44)	Electrically stimulated (n=44)	Level of Probability[a]
Lean maturity[b]	A^{30}	A^{23}	P < .0001
Marbling[c]	Sl^{72}	Sl^{75}	NS
Firmness[d]	6.5	6.2	P < .01
Texture[e]	6.2	6.2	NS
"Heat-ring"[f]	4.6	4.4	NS
Iridescence[g]	2.8	2.8	NS

[a]Means compared by paired t-tests.

[b]Lean maturity scores from A^{00} to A^{100} reflect lean color typical of cattle slaughtered at 9 to 30 months of age, respectively.

[c]Marbling: Sl=slight, Sm=small, with 00 equal to the minimum amount and 100 equal to the maximum amount within a degree.

[d]Firmness: 8=very firm, 1=very soft.

[e]Texture: 8=very fine, 1=very coarse.

[f]"Heat-ring": 5=none, 1=extremely severe.

[g]Iridescence: 3=none, 2=slight amount, 1=evident.

TABLE 3. EFFECTS, BY SEX CLASS, OF ELECTRICAL STIMULATION ON CERTAIN LEAN QUALITATIVE CHARACTERISTICS OF CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Lean Trait	Not electrically stimulated	Electrically stimulated	Level of probability[a]
Steers			
Lean maturity[b]	A^{24}	A^{18}	P < 0.001
Marbling[c]	Sm^{17}	Sm^{14}	NS
Firmness[d]	6.8	6.4	P < 0.008
Texture[e]	6.5	6.6	NS
"Heat-ring"[f]	5.0	4.5	P < 0.009
Iridescence[g]	3.0	2.9	NS
Bulls			
Lean maturity[b]	A^{53}	A^{44}	P < 0.001
Marbling[c]	Sl^{35}	Sl^{29}	NS
Firmness[d]	6.2	6.0	NS
Texture[e]	5.8	5.8	NS
"Heat-ring"[f]	4.3	4.4	NS
Iridescence[g]	2.7	2.8	NS

[a]Means within sex class compared by paired t-tests; n=22 per sex class.

[b]Lean maturity scores from A^{00} to A^{100} reflect lean color typical of cattle slaughtered at 9 to 30 months of age, respectively.

[c]Marbling: Sl=slight, Sm=small, with 00 equal to the minimum amount and 100 equal to the maximum amount within a degree.

[d]Firmness: 8=very firm,1=very soft.

[e]Texture: 8=very fine, 1=very coarse.

[f]"Heat-ring": 5=none, 1=extremely severe.

[g]Iridescence: 3=none, 2=slight amount, 1=evident.

It has been suggested that electrical stimulation is of greatest benefit on sub-populations of cattle with inherent tendencies to have less tender meat if not given postmortem conditioning. Table 4 presents paired comparisons of palatability characteristics, across sex and breed groups, of loin steaks from control and electrically stimulated sides. Electrical stimulation reduced shear force values but had no effect on sensory panel evaluations of juiciness, muscle fiber tenderness, overall tenderness, off-flavor or overall palatability of cooked loin steaks. Only 11.4 and 11.9 percent of the overall palatability scores were less than 5.0 for steaks from controls and stimulated sides, respectively (Table 4). Sensory panelists indicated (data not in tabular form) that the main reason for the low rating was tenderness (59.0 percent for steaks from control sides and 46.2 percent for steaks from electrically stimulated sides). But the lower percentage for electrically stimulated sides indicates that this treatment does improve tenderness.

Table 5 contains the palatability data for electrically stimulated and control sides within sex class. The only

TABLE 4. EFFECTS OF ELECTRICAL STIMULATION ON SENSORY PANEL RATINGS, COOKING LOSS AND SHEAR FORCE VALUE FOR STRIP LOIN STEAKS FROM CHAROLAIS CROSSBRED BULLS AND STEERS COMBINED

Trait	Not electrically stimulated (n=44)	Electrically stimulated (n=44)	Level of probability[a]
Sensory panel evaluations[b]			
Juiciness	5.6	5.4	NS
Muscle fiber tenderness	6.1	6.3	NS
Connective tissue amount	7.7	7.8	P < .04
Overall tenderness	6.2	6.3	NS
Off-flavor	3.9	3.8	NS
Overall palatability	5.9	5.9	NS
WBS, lbs.	8.6	7.5	P < .001
Cooking loss, %	26.5	27.3	NS

[a]Means compared by paired t-tests.

[b]Sensory panel evaluations: 8=extremely juicy, extremely tender, no connective tissue, extremely tender and extremely palatable; off-flavor, 4=none, 1=intense; 1=extremely dry, extremely tough, abundant amount of connective tissue, extremely tough, intense off-flavor and extremely unpalatable.

[c]Warner-Bratzler shear force: the pounds of force necessary to shear a 1/2-inch diameter core.

difference detected between steaks from steer carcasses was for shear force value; steaks from electrically stimulated sides were lower in shear force than steaks from control sides. For steaks from bull carcasses, muscle fiber tenderness and connective tissue amount scores were higher (more tender and less connective tissue, respectively) and the shear force was much lower in electrically stimulated sides than in control sides.

In general, paired comparisons of electrically stimulated sides vs. control sides revealed that electrical stimulation increased lean youthfulness, decreased firmness and had no effect on marbling, texture, "heat-ring" or iridescence. Over-stimulation (a too-rapid pH decline while temperatures were high) may have caused a pale, soft and exudative condition resulting in a softer lean in electrically stimulated sides. Sensory panel evaluations were not different but shear force was reduced for steaks from electrically stimulated sides vs. steaks from control sides. Electrical stimulation had a greater effect on palatability of steaks from bulls than from steers.

Since research on the effects of electrical stimulation is inconsistent, especially as it affects meat from young bulls, we need to better define the mechanism(s) by which electrical stimulation influences tenderness. In addition, we must determine more precisely the optimum amount and method of applciation for electrical stimulation.

Acknowledgments

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TABLE 5. EFFECTS, BY SEX CLASS, OF ELECTRICAL STIMULATION ON SENSORY PANEL RATINGS, COOKING LOSS AND SHEAR FORCE VALUE FOR STRIP LOIN STEAKS FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	Not electrically stimulated	Electrically stimulated	Level of probability[a]
Steers			
Sensory panel evaluations[b]			
Juiciness	5.6	5.5	NS
Muscle fiber tenderness	6.5	6.5	NS
Connective tissue amount	7.8	7.8	NS
Overall tenderness	6.5	6.5	NS
Off-flavor	3.9	3.9	NS
Overall palatability	6.3	6.0	NS
WBS, lbs	7.9	6.6	P < .02
Cooking loss, %	26.6	25.1	NS
Bulls			
Sensory panel evaluations[b]			
Juiciness	5.5	5.3	NS
Muscle fiber tenderness	5.8	6.2	P < .04
Connective tissue amount	7.6	7.8	P < .04
Overall tenderness	5.8	6.1	NS
Off-flavor	3.8	3.8	NS
Overall palatability	5.6	5.7	NS
WBS, lbs	9.2	7.9	P < .001
Cooking loss, %	26.4	29.4	P < .01

[a]Means within sex class compared by paired t-tests; n=22 per sex class.

[b]Sensory panel evaluation: 8=extremely juicy, extremely tender, no connective tissue, extremely tender and extremely palatable; off-flavor 4=none, 1=intense; 1=extremely dry, extremely tough, abundant amount of connective tissue, intense off-flavor and extremely unpalatable.

[c]Warner-Bratzler shear force: the pounds of force necessary to shear a 1/2-inch diameter core.

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Palatability Characteristics of Loin Steaks from Charolais Crossbred Bulls and Steers

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Summary

Loins from 1/2-blood and 3/4- to 7/8-blood Charolais bulls (n=60) and steers (n=64) were obtained after carcasses were evaluated for USDA Quality and Yield Grade factors and secondary sex characteristics. Shear force values were higher (less tender) and sensory panel evaluations of tenderness and overall palatability were lower (less desirable) for steaks from bulls than from steers. No differences in connective tissue amount or off-flavor were detected in steaks from bulls and steers. No differences in sensory panel evaluations, shear force or cooking loss were attributable to breed or to sex X breed interactions (except for juiciness). Palatability evaluations were significantly related to characteristics such as lean maturity, marbling and quality grade.

Introduction

Most research comparing young bulls and steers has shown that meat from young bulls is less tender and more variable in tenderness than that from steers (1,2,5,10). But some studies have indicated no palatability differences in meat from young bulls vs. steers (4,6). Conflicting results may have been due to differences in age at slaughter (9,18), to unlike feeding regimens (3,8,16) or to differences in breed types (11,12). Crouse et al. (7) and Riley et al. (14) used electrical stimulation to reduce variability and enhance tenderness of young bull and steer beef.

The present study used cattle from a common genetic and management background which were handled alike from weaning through slaughter. The purpose was to investigate further the palatability differences of cooked loin steaks from young bulls and steers and to assess the relationship between secondary sex characteristics and certain palatability indicators.

Procedures

General

One hundred twenty-eight 1/2-blood or 3/4- to 7/8-blood Charolais bulls (n=60) and steers (n=64) from a common background were fed alike in a commercial feedlot and then slaughtered. Within 30 minutes of bleeding, carcasses were electrically stimulated (550 v; 2-2.5 amps; 15 impulses of 1.8-second duration). At 24 hour postmortem, USDA Quality and Yield Grade factors and carcass secondary sex characteristics were evaluated by Texas Agricultural Experiment Station personnel. Secondary sex characteristics included pizzle eye size (7=small; 1=very large), pizzle muscle characteristics (7=small, fine and light; 1=very large, coarse and dark), jump muscle and crest development (6=none; 1=very prominent) and overall masculinity (4=steer; 1=very masculine).

Loins were obtained from electrically stimulated sides from 60 bulls (30 each from the 1/2-blood and 3/4- to 7/8-blood groups) and 64 steer (32 each from the 1/2-blood and 3/4- to 7/8-blood groups) carcasses. It was not possible to obtain loins from two, "dark-cutting" bull carcasses (1/2-blood group), and two bulls (3/4- to 7/8-blood group) died during the feedlot phase of the study. Thus sample sizes were unequal.

At 12 days postmortem, loins were boned, faced and cut into 1.25-inch thick steaks. Sensory panel and shear force determinations wer made on the second and third steaks removed from the anterior end of the loins, respectively. Steaks were double-wrapped in freezer paper, frozen and stored for 6 to 8 weeks prior to shear force determinations and sensory panel evaluations.

Shear force determination

Loin steaks were thawed for 14 to 16 hours prior to cooking. Thawed steaks were weighed and then broiled in Farberware Open-Hearth broilers to internal temperatures of 158°F. Cooked steaks were weighed and then cooled to ambient temperature before being trimmed of exterior fat. Six to eight cores (0.50-inch) were removed parallel to the muscle fibers with a mechanical coring machine. Each core was sheared once using a Warner-Bratzler shear machine.

Sensory panel evaluations

Loin steaks for sensory panel evaluations were cooked as previously described for shear force steaks. After cooking, steaks were trimmed of exterior fat, cut into 0.50-inch cubes and served warm to an eight-member, experienced sensory panel.

Eight-point descriptive scales were used to evaluate juiciness, muscle fiber and overall tenderness, connective tissue amount and overall palatability. In addition, panelists were asked to score off-flavor and to describe the character of off-flavor (i.e., "liver-like," "metallic," "fish-like," "acid," "old," "other"). When panelists rated overall palatability less than 5.0, they were asked to indicate why (i.e., due to dryness, toughness, off-flavor, etc.).

Data analysis

Shear force, cooking loss and sensory panel evaluation means were subjected to analysis of variance with sex, breed and sex x breed as sources of variation. Frequencies for the reasons given as to why overall palatability scores were less than 5.0 were calculated. All data were analyzed using the Statistical Analysis System (15).

Results and Discussion

Mean slaughter weight, age, and quantitative and qualitative carcass data were presented in Table 1. Ages of the cattle at slaughter were in the range (between 400 and 500 days) where tenderness differences between bulls and steers become greater than for younger cattle (9).

Sensory panel evaluations, shear force determinations and percentage cooking losses are presented in Table 2. Loin steaks from bulls were less tender (muscle fiber, overall tenderness and shear force values) than were those from steers. However, if panel tenderness scores of 5± 0.2 rating scale units and shear force values of 10.0 lbs or less are considered acceptable, then steaks from bulls in this study would be likely acceptable to most consumers. The sex x breed interaction noted for juiciness has no clear-cut interpretation. No differences were noted for connective tissue amount or off-flavor. Lower cooking losses were observed for steaks froms teers as compared to those from bulls.

Sensory panelists indicated that they were able to detect an off-flavor in the cooked steaks less than 14 percent of the time. In those samples in which an off-flavor was detected, panelists characterized the flavors as "old" and "liver-like" 36 percent and 20 percent of the time, respectively. For overall palatability, 12 percent of the panelists' evaluations were in the "less than 5.0" category. About half (49.6 percent) of these low (< 5.0) overall palatability ratings were assigned because panelists were dissatisfied with the tenderness of the sample. Because of the limited numbers contained in these data, sex and breed comparisons were not made.

It has been suggested that the degree of masculinity of bull carcasses may be related to muscle tenderness (13). When young bull carcasses are officially graded by

TABLE 2. MEAN SENSORY PANEL EVALUATIONS, SHEAR FORCE AND COOKING LOSS VALUES FOR CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Trait	(n=32)	(n=30)	(n=32)	(n=30)	Probability level		
Juiciness rating[a]	5.4	5.7	5.5	5.4	NS	NS	.05
Muscle fiber tenderness rating[a]	6.6	6.1	6.4	5.8	.001	NS	NS
Connective tissue amount rating[a]	7.8	7.7	7.8	7.6	NS	NS	NS
Overall tenderness rating[a]	6.6	6.1	6.4	5.8	.001	NS	NS
Off-flavor rating[a]	3.8	3.8	3.9	3.8	NS	NS	NS
Overall palatability rating[a]	6.1	5.8	6.0	5.5	.01	NS	NS
WBS, kg[b]	3.3	3.9	3.3	4.1	.001	NS	NS
Cooking loss, %	26.6	29.7	26.8	30.2	.001	NS	NS

[a]Sensory panel ratings based on 8-point scales with 8=extremely juicy, extremely tender, no connective tissue, extremely tender and extremely palatable; off-flavor, 4=none, 1=intense; 1=extremely dry, extremely tough, an abundant amount of connective tissue, extremely tough, intense off-flavor and extremely unpalatable.

[b]Warner-Bratzler shear force: kg of force necessary to shear a 0.50-inch diameter core of cooked muscle.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR SLAUGHTER WEIGHT, AGE, QUANTITATIVE AND QUALITATIVE CARCASS DATA FOR CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood				3/4- to 7/8-blood			
Trait	Steers (n=32)		Bulls (n=30)		Steers (n=32)		Bulls (n=30)	
Slaughter wt., lb	1061	(85)	1154	(90)	1121	(99)	1121	(122)
Age at slaughter, days	420.6	(17.3)	422.8	(16.4)	434.9	(19.8)	436.9	(21.9)
Carcass wt., lb	674	(62)	739	(67)	709	(69)	769	(84)
Adjusted fat thickness, 12th rib, in.	.44	(.11)	.3	(.1)	.33	(.09)	.19	(.09)
Ribeye area, sq. in.	12.1	(1.1)	13.9	(1.4)	12.9	(1.7)	15.2	(1.9)
Kidney, pelvic and heart fat, %	2.3	(0.5)	1.6	(0.4)	2.3	(0.5)	1.5	(0.5)
USDA Yield Grade	2.8	(0.5)	1.9	(0.6)	2.4	(0.5)	1.4	(0.5)
Skeletal maturity[a]	A^{25}	(7)	A^{40}	(9)	A^{25}	(7)	A^{36}	(12)
Lean maturity[b]	A^{25}	(10)	A^{40}	(53)	A^{23}	(9)	A^{42}	(16)
Marbling[c]	Sm^{72}	(72)	Sl^{74}	(67)	Sm^{31}	(78)	Sl^{36}	(61)
USDA Quality Grade[d]	Ch^{21}	(30)	Gd^{62}	(57)	Ch^{01}	(39)	Gd^{29}	(65)

[a]Skeletal maturity scores from A^{00} to A^{100} reflect skeletal maturity characteristics typical of cattle slaughtered at 9 to 30 months of age, respectively.

[b]Lean maturity scores from A^{00} to A^{100} reflect lean color typical of carcasses from 9- to 30-month old cattle, respectively.

[c]Marbling: Sl=slight, Sm=small, with 00 equal to the minimum amount and 100 equal to the maximum amount without a degree.

[d]Quality grade; Gd=Good, Ch=Choice, with 00 equal to the minimum and 100 equal to the maximum of a grade.

USDA graders, the standards (17) require the grade designation to include the work "bullock." Application of the grade standards for determining whether the sex-class "bullock" should be used largely depends on subjective evaluation of secondary sex characteristics (jump muscle, pizzle eye, pizzle muscle, crest development, etc.). Means for certain masculinity characteristics are presented in Table 3. As expected, sex was the major determinant in variation of carcass masculinity characteristics. On the average, bull carcasses were rated lower (more masculine) for secondary sex characteristics than steer carcasses. However, significant breed effects also were observed for jump muscle development, crest development and overall masculinity. The sex x breed interactions (crest development and overall masculinity) reflect the earlier maturing characteristics of the 1/2-blood Charolais breed group.

When simple correlations between certain carcass characteristics and sensory panel evaluations were examined across (Table 4) and within (Table 5) sex class, marbling score and quality grade were significantly related to overall tenderness and overall palatability. Across sex class (Table 4), lean maturity was highly related to muscle fiber tenderness, connective tissue amount and overall tenderness. However, within sex class (Table 5), lean maturity was significantly related only to juiciness and connective tissue amount for bulls. Actual and adjusted fat thicknesses were related to muscle fiber tenderness, overall tenderness and overall palatability across sex class, but were not correlated to the palatability factors within sex class. Thus, in this study, the characteristics such as lean maturity score, marbling score and quality grade, which currently are used to segment carcasses, were significantly related to sensory panel palatability evaluations of loin steaks.

In summary, these data revealed that loin steaks from Charolais crossbred steers were more tender and more palatable than those from bulls, and that electrical stimulation of carcasses did not removed the sex-class difference. Also, shear force values and cooking losses were lower for steaks from steers than for those from bulls. Significant correlations (across sex class) of masculinity characteristics with muscle fiber tenderness, connective tissue amount and overall tenderness were noted. However, within sex class, the only significant correlations found were between masculinity characteristics and connective tissue amount. In addition, significant correlations were observed for certain quality-indicating characteristics and sensory panel scores for muscle fiber tenderness, connective tissue amount, overall tenderness and overall palatability. However, these correlations were not high enough to predict muscle tenderness and palatability.

TABLE 3. MEAN MASCULINITY CHARACTERISTICS OF CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
	(n=32)	(n=30)	(n=32)	(n=30)	Probability level		
Pizzle eye size[a]	5.7	3.5	5.6	3.4	.001	NS	NS
Pizzle muscle characteristics[b]	6.0	3.5	5.8	3.3	.001	NS	NS
Jump muscle development[c]	5.0	3.6	4.5	3.0	.001	.001	NS
Crest development[d]	5.1	3.2	5.0	2.5	.001	.01	.05
Overall masculinity[e]	4.0	2.8	3.9	2.2	.001	.001	.05

[a]Pizzle eye size: 7=very small; 1=very large.

[b]Pizzle muscle characteristics: 7=very small, fine and light; 1=very large, coarse and dark.

[c]Jump muscle development: 6=none; 1=very prominent.

[d]Crest development: 6=none; 1=very prominent.

[e]Overall masculinity: 4=steer; 1=very masculine.

Acknowledgments

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TABLE 4. SIMPLE CORRELATION COEFFICIENTS (ACROSS SEX AND BREED) FOR SENSORY PANEL EVALUATIONS AND CARCASS CHARACTERISTICS FOR CHAROLAIS CROSSBRED BULLS AND STEERS

Sensory panel evaluation[b]	Carcass secondary sex characteristic[a]				
	Pizzle eye	Pizzle muscle	Jump muscle	Crest development	Overall masculinity
Juiciness	.05	-.03	.11	.01	.06
Muscle fiber tenderness	.21*	.28***	.27**	.34***	.31***
Connective tissue amount	.18	.22**	.24**	.32***	.31***
Overall tenderness	.23**	.29***	.28**	.36***	.33***
Off-flavor	-.02	.08	.04	.10	.04
Overall palatability	.19	.22**	.23	.30	.29***

n=24

*P < .05; **P < 0.01; ***P < 0.001.

[a]Pizzle eye size (7=small, 1=very large); pizzle muscle characteristics (7=small, fine and light, 1=very large, coarse and dark); jump muscle and crest development (6=none, 1=very prominent); overall masculinity (4=steer, 1=very masculine).

[b]Juiciness (8=extremely juicy, 1=extremely dry); muscle fiber and overall tenderness (8=extremely tender, 1=extremely tough); connective tissue amount (8=none, 1=abundant amount); off-flavor (4=none, 1=intense); overall palatability (8=extremely palatable; 1=extremely unpalatable).

TABLE 5. SIMPLE CORRELATION COEFFICIENTS, BY SEX CLASS, FOR SENSORY PANEL EVALUATIONS AND CARCASS MASCULI—NITY CHARACTERISTICS FOR CHAROLAIS CROSSBRED BULLS AND STEERS

	Carcass secondary sex characteristic[a]				
Sensory panel evaluation[b]	Pizzle eye	Pizle muscle	Jump muscle	Crest development	Overall masculinity
Steers (n=64)					
Juiciness	.18	-.11	.14	.03	.03
Muscle fiber tenderness	-.10	.04	.01	-.01	-.00
Connective tissue amount	-.05	-.03	.06	.15	.19
Overall tenderness	-.10	.04	.08	-.01	-.02
Off-flavor	-.22	.13	.04	-.12	-.03
Overall palatability	-.04	-.00	.12	.02	.05
Bulls (n=60)					
Juiciness	.04	.16	.20	.11	.22
Muscle fiber tenderness	.01	-.03	.08	.22	.14
Connective tissue amount	.21	.33**	.26*	.44***	.36**
Overall tenderness	.04	-.01	.08	.22	.14
Off-flavor	.02	-.06	-.03	.18	-.01
Overall palatability	.05	.01	.07	.23	.18

*P < 0.05; **P < .01; ***P < 0.001.

[a]Pizzle eye size (7=small, 1=very large); pizzle muscle characteristics (7=small fine and light, 1=very large, coarse and dark); jump muscle and crest development (6=none, 1=very prominent); overall masculinity (4=steer, 1=very masculine).

[b]Juiciness (8=extremely juicy, 1=extremely dry); muscle fiber and overall tenderness (8=extremely tender, 1=extremely tough); connective tissue amount (8=none, 1=abundant amount); off-flavor (4=none, 1=intense); overall palatability (8=extremely palatable; 1=extremely unpalatable).

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PR-4232

Consumer Acceptance of Steaks and Roasts from Charolais Crossbred Bulls and Steers

C. L. Griffin, D. M. Stiffler, G. C. Smith, and J. W. Savell

Summary

Forty-eight 1/2-blood or 3/4- to 7/8-blood Charolais bulls (n=24) and steers (n=24) from a common background were commercially fed and slaughtered. Subprimals were distributed to three retail stores. Steaks and roasts were cut and a questionnaire was placed in each package. Consumers detected differences in tenderness for steaks from the rib, loin and top sirloin of bulls and steers; but, with few exceptions, they did not detect differences for steaks or roasts from the round and chuck of bulls and steers. However, 91.7 percent and 86.8 percent of the consumers of steaks from steers and bulls, respectively, indicated that they would purchase similar steaks again, while 92.3 percent and 93.2 percent of the consumers of roasts indicated they would purchase similar roasts from steers and bulls, respectively.

Introduction

Studies of the palatability of young bull and steer meat usually have been based on the evaluations of trained sensory panelists sampling rib or loin steaks. Few studies have ascertained consumer acceptance of meat from bulls vs. steers. Field et al. (2) and Sumwalt et al. (7) reported that consumers rate loin steaks from bulls lower in taste and tenderness than loin steaks from steers. Jacobs et al. (3) reported that only 45 percent of the consumers in their study rated retail cuts from young bull rounds less tender thatn those that they would normally buy (i.e., round cuts from Choice steers). Thus, consumer research has been inconclusive; one reason may be the small numbers of animals and consumer responses included in previous studies.

The present study was conducted to assess consumer acceptance of a variety of cuts from bull and steer carcasses from cattle with common genetic backgrounds and handling.

Procedures

General

One hundred twenty-eight 1/2-blood or 3/4- to 7/8-blood Charolais bulls and steers from a common breeding and management background were commercially fed (195 days) and slaughtered. Cattle were fed by sex-breed group (n=32) and were not mixed prior to slaughter. Within 30 minutes of bleeding, carcasses were electrically stimulated (550 volts; 2-2.5 amps; 15, 1.8-second impulses). Sides from 24 bulls (12 each from the 1/2-blood and 3/4- to 7/8-blood groups) and 24 steers (12 each from the 1/2-blood and 3/4- to 7/8-blood groups) were selected from among those carcasses grading low Good to low Choice.

At 24 hours postmortem, sides were fabricated into boneless subprimals which were vacuum-packaged and boxed at the commercial packing plant. The subprimals included clods, ribs, strip loins, top sirloin butts, knuckles (sirloin tips) and cushion rounds. At 6 days postmortem, the boxed subprimals were transported by refrigerated truck to College Station, where they were stored for 4 days. At 11 days postmortem, subprimals were sorted and equally distributed to three retail stores (representing low-, middle- and high-income areas) in the Bryan-College Station, Texas area. From each subprimal, steaks and/or roasts were prepared for retail sale by the meat market personnel in each store.

Consumer survey

A questionnaire was placed beneath the soaker pad of each package of meat. A brightly colored identification label (coded for animal number, sex, breed, cut, etc.), which was to be returned with the questionnaire, was placed on the outside of each package. The questionnaire was designed to evaluate consumer response to: (1) color of lean; (2) lean-to-fat ratio of the cut; (3) flavor; (4) tenderness; (5) juiciness; (6) overall desirability; and (7) consumer desire to buy similar meat again. These responses represented one or more person's opinions, depending on the number of people served. Questions, with their exact wording, are presented the footnotes of the appropriate tables.

There was no indication to the consumers that sex-breed groups were being evaluated in this study. Consumers were informed that the meat was from experimental cattle and that no use of chemicals or additives was associated with the study.

The meat was packaged, presented and priced in the same way as all other meat being sold simultaneously. However, an incentive of $2.00 per package was offered for return of the completed questionnaire.

Data analysis

Frequencies of consumer responses were determined and Chi-square tests were used when appropriate. Consumer sensory data were analyzed by analysis of variance with sex, breed and sex x breed as sources of variation. The Statistical Analysis System (5) was used to analyze all data.

Results and Discussion

Means and standard deviations for slaughter and carcass data were presented in Table 1 to characterize the animals included in the study. The subprimal cuts were typical of those fabricated and sold in the retail stores.

Of the 2855 questionnaires distributed, consumers returned 1479 of them or 51.8 percent of those placed in the packages at the three retail stores. In most cases, a majority of the animals included in the study (n=48) were represented by the returned questionnaires.

Palatability scores for steaks and roasts followed similar trends in all stores, suggesting that, regardless of income level, the consumers' preferences were very similar. Therefore, the data presented here represent the combined information from all returned questionnaires.

Table 2 shows the responses to questions on color, lean-to fat ratio and purchasing for all steaks in the study. More than 90 percent of the consumers indicated that the color of lean steaks was acceptable. Other research (1,6) has indicated that packers and retailers discriminate against meat from young bulls because of a perceived high incidence of objectionably dark lean. In this study, only 3.7 percent of the consumers indicated that steaks from bulls were darker than they preferred.

In response to the questions regarding the amount of lean and fat, 88.6 percent and 87.2 percent of the consumers indicated that steaks from steer and bull carcasses, respectively, were "about right" in the amount of lean and fat (Table 2). Of the consumers, 91.7 percent and 86.8 percent indicated that they would purchase similar steaks from steers and bulls, respectively (Table 3). The fact that 164 of the 1243 consumers (13.2 percent) who responded to the question on purchasing of the bull steaks said "no" (they would not buy similar steaks) may be of economic importance to retailers and a deterrent to the retailing of steaks from bull carcasses.

Table 3 gives sensory evaluations for all steaks from steers and bulls. Mean value differences for these traits were not large (with the exception of tenderness), and fall into the "slightly juicy" to "juicy" and "slightly desirable" to "desirable" ranges. These data concur with research comparing steers and bulls in which tenderness usually was rated lower for steaks from bulls than for those from steers. Despite these differences, the steaks were rated in the "acceptable" range ("slightly tender" to "tender") by consumers, and a high percentage of those who responded were willing to purchase similar steaks again.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR SLAUGHTER WEIGHT, AGE, AND QUANTITATIVE AND QUALITATIVE CARCASS DATA FOR CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	1/2-blood				3/4- to 7/8-blood			
	Steers (n=12)		Bulls (n=12)		Steers (n=12)		Bulls (n=12)	
Slaughter wt., lb	1037.5	(84.5)	1131.4	(57.8)	1057.5	(69.9)	1143.3	(112.5)
Age at slaughter, days	422.5	(14.3)	425.5	(16.8)	430.3	(21.8)	438.6	(24.9)
Carcass wt., lb	659.3	(54.5)	714.9	(44.1)	674.1	(41.2)	712.	(67.7)
Adjusted fat thickness, 12 rib, in	.48	(1.0)	.33	(1.0)	.33	(1.0)	.2	(1.0)
USDA Yield Grade	2.8	(0.4)	2.3	(0.4)	2.3	(0.7)	1.6	(0.5)
Marbling[a]	SM[39]	(60)	Sl[82]	(57)	Sm[32]	(46)	Sl[22]	(69)
USDA Quality Grade[b]	Ch[08]	(28)	Gd[74]	(46)	Ch[06]	(24)	Gd[32]	(56)

[a]Marbling: Sl=slight, Sm=small, with 00 equal to the minimum amount and 100 equal to the maximum amount within a degree.

[b]Quality grade: Gd=Good, Ch=Choice, with 00 equal to the minimum and 100 equal to the maximum of a grade.

TABLE 2. PERCENTAGE CONSUMER RESPONSE FOR ALL STEAKS[a] TO QUESTIONS ON COLOR, LEAN-TO-FAT RATIO AND PURCHASING INTENTION

Trait	Options	Steers (n=593)	Bulls (n=650)
Color[b]	Light	4.9	5.7
	Acceptable	92.2	90.6
	Dark	2.9	3.7
Fat[c]	Too lean	5.8	8.1
	About right	88.6	87.2
	Too fat	5.6	4.6
Buy[d]	No	8.3	13.2
	Yes	91.7	86.8

[a]Steaks: loin, ribeye, top butt (sirloin), sirloin tip (knuckle), top round (inside), bottom round (outside), eye of round, full-cut round and clod.

[b]Percentage response to the question — "Was the color of the lean (at the time of purchase): lighter than you prefer; acceptable; darker than you prefer?"

[c]Percentage response to the question — "Was the meat: too fat; about right in amount of lean and amount of fat; or too lean?"

[d]Percentage response to the question — "Would you buy beef like this again? Yes or No."

TABLE 3. LEAST-SQUARES MEANS FOR CONSUMER SENSORY EVALUATIONS OF STEAKS[a] FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
					Probability level		
Juiciness[b]	4.7	4.5	4.6	4.5	.02	NS	NS
Flavor[c]	4.9	4.5	4.8	4.6	.0001	NS	NS
Tenderness[d]	4.8	4.4	4.8	4.4	.0001	NS	NS
Overall desirability[e]	5.1	4.9	5.0	4.9	.0001	NS	NS

[a]Steaks: loin, ribeye, top butt (sirloin), sirloin tip (knuckle), top round (inside), bottom round (outside), eye of round, full-cut round and clod.

[b]Mean response to the question — "Was the meat: (6) very juicy, (5) juicy, (4) slightly juicy, (3) slightly dry, (2) dry, or (1) very dry?"

[c]Mean response to the question — "How was the flavor of the meat: (6) excellent, (5) very good, (4) good, (3) fairly good, (2) fair, or (1) poor?"

[d]Mean response to the question — "Was the meat: (6) very tender, (5) tender, (4) slightly tender, (3) slightly tough, (2) tough or (1) very tough?"

[e]Mean response to the question — "All things considered (appearance, leanness, flavor, tenderness and juiciness) was the meat: (6) very desirable, (5) desirable, (4) slightly desirable, (3) slightly undesirable, (2) undesirable, or (1) very undesirable?"

To compare consumer responses to results obtained under controlled conditions, mean values for experienced sensory panel ratings of cooked loin steaks from opposite sides of those carcasses used in the consumer acceptability study are presented in Table 4.

Sex was a significant source of variation for juiciness, muscle fiber tenderness and overall tenderness. Cooked loin steaks from bull carcasses were rated higher for juiciness than were those from steers; however, steaks from steers had higher scores for muscle fiber tenderness and overall tenderness than did those from bulls. No differences were observed for connective tissue amount, off-flavor or overall palatability. Breed and sex x breed were not significant sources of variation for cooked loin steaks.

Table 5 gives the response to questions on appearance and purchasing for all roasts. Consumers indicated that the color of the lean at the time of purchase was generally acceptable (89.2 percent and 97.2 percent for steers and bulls, respectively). The majority felt that the roasts were "about right" in the amount of lean-to-fat; however, more consumers thought that roasts from steers were "too fat" (6.1 percent) than thought that roasts from bulls (2.7 percent) were "too fat." The majority of consumers (92.3 percent for steers and 93.2 percent for bulls) said they would purchase similar roasts again. These data indicate a high degree of consumer acceptance of roasts regardless of sex class. And, interestingly, the roasts from the bulls were more acceptable than those from steers (perhaps because bull roasts were less fat).

The acceptability of roasts to the consumer is further illustrated by sensory responses (Table 6). No differences in these characteristics were detected due to sex, breed or sex x breed, maybe because moist heat cookery was predominantly used. McKeith et al. (4) reported that electrical stimulation improved tenderness of not only the *longissimus dorsi* but also of the

TABLE 4. MEANS FOR EXPERIENCED SENSORY PANEL EVALUATIONS OF STRIP LOIN STEAKS FROM OPPOSITE SIDES OF CARCASSES FROM CHAROLAIS CROSSBRED STEERS AND BULLS ALLOCATED TO THE CONSUMER STUDY

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Trait					Probability level		
Juiciness[a]	5.1	5.9	5.3	5.5	.01	NS	NS
Muscle fiber tenderness[b]	6.3	6.0	6.5	5.5	.05	NS	NS
Connective tissue amount[c]	7.7	7.6	7.8	7.7	NS	NS	NS
Overall tenderness[b]	6.3	6.0	6.6	5.5	.02	NS	NS
Off-flavor[d]	3.9	3.8	3.9	3.8	NS	NS	NS
Overall palatability[e]	5.8	5.9	6.0	5.4	NS	NS	NS

[a]Juiciness: 8=extremely juicy, 1=extremely dry.

[b]Muscle fiber and overall tenderness: 8=extremely tender, 1=extremely tough.

[c]Connective tissue amount: 8=none; 1=abundant amount.

[d]Off-flavor: 4=none; 1=intense.

[e]Overall palatability: 8=extremely palatable, 1=extremely unpalatable.

TABLE 5. PERCENTAGE CONSUMER RESPONSE FOR ALL ROASTS[a] TO QUESTIONS ON COLOR, LEAN-TO-FAT RATIO AND PURCHASING INTENTION.

Trait	Options	Steers (n=66)	Bulls (n=74)
Color[b]	Light	6.2	0.0
	Acceptable	89.2	97.2
	Dark	4.6	2.8
Fat[c]	Too lean	4.5	6.8
	About right	89.4	90.5
	Too fat	6.1	2.7
Buy[d]	No	7.7	6.8
	Yes	92.3	93.2

[a] Roasts: rump, sirloin tip (knuckle), top round (inside), eye of round, heel of round and chuck (clod).

[b] Percentage response to the question — "Was the color of the lean (at the time of purchase): lighter than you prefer; acceptable; darker than you prefer?"

[c] Percentage response to the question — "Was the meat: too fat; about right in amount of lean and amount of fat; or too lean?"

[d] Percentage response to the question — "Would you buy beef like this again? Yes or No."

muscles in the round and chuck. Perhaps physiological conditions associated with the postmortem temperature decline (mass affect) and the use of electrical stimulation increased the tenderness of muscles from the rounds and chucks of bulls enough to equal that of muscles from steers.

From these data it appears that consumers detected differences in tenderness and overall desirability for steaks from the middle meats (rib, loin, top butt) of steers and bulls, but not for most of the steaks or roasts from the round and chuck of steers and bulls. Despite the differences previously noted, 91.7 percent and 86.8

TABLE 6. LEAST-SQUARES MEANS FOR CONSUMER SENSORY EVALUATIONS FOR BEEF ROASTS[a] FROM CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Trait					Probability level		
Juiciness[b]	4.8	4.7	4.5	4.6	NS	NS	NS
Flavor[c]	4.9	5.0	4.9	4.9	NS	NS	NS
Tenderness[d]	4.8	4.9	4.9	5.0	NS	NS	NS
Overall desirability[e]	5.1	5.2	5.2	5.2	NS	NS	NS

[a]Roasts: rump, sirloin tip (knuckle), top round (inside), eye of round, heel of round and chuck (clod).

[b]Mean response to the question — "Was the meat: (6) very juicy, (5) juicy, (4) slightly juicy, (3) slightly dry, (2) dry, or 91) very dry?"

[c]Mean response to the question — "How was the flavor of the meat: (6) excellent, (5) very good, (4) good, (3) fairly good, (2) fair, or (1) poor?"

[d]Mean response to the question — "Was the meat: (6) very tender, (5) tender, (4) slightly tender, (3) slightly tough, (2) tough, or (1) very tough?"

[e]Mean response to the question — "All things considered (appearance, leanness, flavor, tenderness and juiciness) was the meat: (6) very desirable, (5) desirable, 94) slightly desirable, (3) slightly undesirable, (2) undesirable, or (1) very undesirable?"

percent of consumers of steaks and 92.3 percent and 93.2 percent of consumers of roasts from steers and bulls, respectively, indicated that they would purchase similar steaks and roasts again. The fact that 13.2 percent of the consumers of bull steaks were not willing to purchase similar steaks may be of economic importance.

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Cutability Comparisons of Charolais Crossbred Bulls and Steers

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Summary

In this study, seventy-two sides (18 sides from each sex-breed group) from carcasses of 1/2-blood or 3/4- to 7/8-blood Charolais bulls or steers of known history and age were used. Animals were handled alike from weaning through slaughter. All cattle were fed in a commercial feedlot (average days-on-feed was 186) and slaughtered at a commercial packing plant. Comparisons among sex-breed groups were made for percentage yields of wholesale, primal and retail-ready cuts at various stages of fabrication and processing. Bulls had higher percentages than steers of chuck and round at all stages of trim. Steers had higher percentages than bulls of untrimmed, wholesale loin and partially boneless shortloin (3/4 inch of fat), but steer percentages of shortloin cuts trimmed to 3/8 inch of fat did not differ from those of bulls. Bulls averaged 48.05 percent, while steers averaged 45.45 percent, major boneless, closely trimmed retail-ready cuts. After the lean trim was adjusted to 25 percent chemical fat, bulls had 27.70 percent lean trim and 5.65 percent fat trim while steers had 24.30 percent lean trim and 12.15 percent fat trim. No differences in the percentage of retail-ready cuts were attributable to breed. However, the 3/4- to 7/8-blood Charolais group had a lower percentage of standardized fat trim and a slightly higher percentage of bone than the 1/2-blood group.

Introduction

Several studies (1,2,3,4,5 and 6) have indicated that bull carcasses yield higher percentages of lean and lower percentages of waste fat than do carcasses from steers. However, these studies generally involved few cattle or carcasses, with unknown history or uncommon feeding and handling. In addition, the majority of these studies did not use cattle fed under commercial conditions.

This study was conducted to determine the differences in yields of certain components from carcasses of Charolais crossbred bulls and steers of known history and age from a common background, which were fed and slaughtered under commercial conditions.

Materials and Methods

General

One hundred twenty-six 1/2-blood or 3/4- to 7/8-blood Charolais bulls or steers were fed and slaughtered commercially. Seventy-two carcasses were randomly selected (18 per sex-breed group) for cutability studies from among electrically stimulated sides that did not have excessive hide pulls, trim or other major defects. Following a 24-hour chill, carcasses were ribbed and evaluated for USDA quality and yield grade. Selected right sides were shipped by refrigerated truck to College Station, Texas at 6 days postmortem.

Upon arrival, all carcasses were fabricated within 3 days. Each side was trimmed of heart fat, channel fat and hanging tender before the chilled side's weight was recorded. Cutting procedures were developed by Texas A&M University personnel in general accordance with the Institutional Meat Purchase Specifications (IMPS) of USDA. Sides were cut into standard wholesale cuts (chuck, rib, loin, round, flank, short plate, brisket, foreshank, kidney knob and pelvic fat) and each was weighed. Then, each major wholesale cut (chuck, rib, loin and round) was processed, by stages, into: (1) partially boneless subprimals trimmed to 3/4 inch of fat; (2) partially boneless retail-ready cuts trimmed to 3/8 inch of fat; and (3) boneless retail-ready cuts trimmed to 3/8 inch of fat. The brisket was first boned and trimmed of fat in excess of 3/4 inch and then trimmed of fat in excess of 3/8 inches. The foreshank was boned and trimmed to 3/8 inch of fat. The short plate and flank (flank steak removed) were boned (no fat removed). At each stage for each cut, weights were recorded for the cut, lean trim, fat trim (except for the flank and short plate) and bone. Lean trimmings from the major cuts (chuck, rib, loin and round) and from the minor cuts (brisket, foreshank) were ground separately and sampled for fat analysis. The percentage of lean standardized to 25 percent fat was calculated.

Component data (as percentages of side weights) were analyzed by variance using sex (bulls vs. steers), breed (1/2-blood vs. 3/4- to 7/8-blood) and sex x breed as sources of variation.

Results and Discussion

To characterize those carcasses used in the cutability studies (n=72), quantitative (Table 1) and qualitative (Table 2) carcass data are presented. Mean percentage yields of untrimmed wholesale cuts are shown in Table 3. The interaction of sex and breed was not a significant source of variation for yield of any of the wholesale cuts. Carcasses from bulls had higher percentage yields of chuck, round and foreshank, but a lower ($P < .0001$) percentage of kidney and pelvic fat, than did carcasses from steers. Carcasses from steers had high percentages of untrimmed wholesale loin, plate and flank. No differences were detected in percentage yields of untrimmed rib or brisket from carcasses of bulls or steers. In this study, major wholesale primals accounted for 79.00 percent and 77.05 percent of carcass weight for bulls and steers, respectively.

With two exceptions, untrimmed wholesale cut yields from carcasses of cattle in the 1/2-blood group (across sex) were not different than those from carcasses of cattle in the 3/4- to 7/8-blood group (Table 3). The 1/2-blood group had a higher percentage of side weight as flank but a lower percentage of foreshank than did the 3/4- to 7/8-blood group.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR SLAUGHTER WEIGHT, AGE AND QUANTITATIVE CARCASS DATA OF CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	1/2-blood				3/4- to 7/8-blood			
	Steers (n=18)		Bulls (n=18)		Steers (n=18)		Bulls (n=18)	
Slaughter wt., lb.	1070	(91)	1125	(69)	1095	(102)	1162	(122)
Age at slaughter, days	417	(19)	422	(18)	435	(18)	432	(22)
Dressing percentage	63.1	(1.4)	63.8	(2.1)	63.6	(1.8)	62.9	(1.8)
Carcass wt., lb.	679	(63)	718	(54)	696	(66)	732	(78)
Adjusted fat thickness, 12th rib, in.	.41	(.1)	.32	(.1)	.33	(.1)	.22	(.1)
Ribeye area, sq. in.	12.3	(1.2)	13.5	(1.3)	12.9	(1.9)	14.2	(1.4)
Kidney, pelvic and heart fat, %	2.3	(0.5)	1.7	(0.4)	2.4	(0.5)	1.6	(0.4)
USDA Yield Grade	2.6	(0.5)	2	(0.4)	2.3	(0.7)	1.6	(0.5)

TABLE 2. MEANS AND STANDARD DEVIATIONS FOR QUALITATIVE CARCASS DATA OF CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Trait	1/2 Blood				3/4- to 7/8-blood			
	Steers (n=18)		Bulls (n=18)		Steers (n=18)		Bulls (n=18)	
Skeletal maturity[a]	A^{25}	(8)	A^{40}	(10)	A^{25}	(7)	A^{32}	(11)
Lean maturity[b]	A^{28}	(11)	A^{43}	(16)	A^{23}	(9)	A^{39}	(14)
Marbling[c]	Sm^{40}	(63)	Sl^{83}	(69)	Sm^{33}	(85)	Sl^{44}	(75)
USDA Quality grade[d]	Ch^{08}	(29)	Gd^{68}	(54)	Ch^{01}	(41)	Gd^{29}	(79)
Firmness[e]	6.4	(0.8)	6.3	(0.9)	6.6	(0.9)	6.3	(0.6)
Texture[f]	6.4	(0.5)	5.7	(0.5)	6.2	(0.6)	5.6	(0.6)
"Heat-ring"[g]	4.8	(0.5)	4.8	(0.4)	4.9	(0.3)	4.4	(0.5)
Iridescence[h]	2.9	(0.2)	2.7	(0.5)	2.9	(0.2)	2.8	(0.4)

[a]Skeletal maturity scores from A^{00} to A^{100} reflect skeletal maturity characteristics typical of cattle slaughtered at 9 to 30 months of age, respectively.

[b]Lean maturity: scores from A^{00} to A^{100}reflect lean color and texture typical of carcasses from 9- to 30-month old cattle, respectively.

[c]Marbling: Sl=slight, Sm=small, with 00 equal to the minimum amount within a degree and 100 equal to the maximum amount within a degree.

[d]Quality grade: Gd=good, Ch=choice, with 00 equal to the minimum and 100 equal to the maximum within a grade.

[e]Firmness: 8=very firm, 1=very soft.

[f]Texture: 8=very fine, 1=very coarse.

[g]"Heat-ring": 5=none, 1=extremely severe.

[h]Irridescence: 3=none, 2=slight amount, 1=evident.

TABLE 3. MEAN PERCENTAGE YIELDS[a] OF UNTRIMMED WHOLESALE CUTS FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

Wholesale cut	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers (n=18)	Bulls (n=18)	Steers (n=18)	Bulls (n=18)	Sex	Breed	SXB
					Probability level		
Chuck	26.7	28.4	26.5	28.9	.0001	NS	NS
Rib	8.9	9.1	9.0	8.8	NS	NS	NS
Loin	17.2	16.1	17.2	16.3	.0001	NS	NS
Round	24.2	25.0	24.4	25.6	.001	NS	NS
Brisket	4.0	4.1	4.1	4.0	NS	NS	NS
Foreshank	3.2	3.4	3.4	3.6	.02	.01	NS
Plate	7.8	7.2	7.7	6.8	.0001	NS	NS
Kidney knob and Pelvic fat	2.7	2.0	2.8	1.8	.0001	NS	NS

[a]Mean percentages of right side weights.

When major subprimals were trimmed of fat in excess of 3/4 inches, no interactions of sex x breed were noted (Table 4). The only significant breed effect found was for bone from the round; the 3/4- to 7/8-blood group had a higher percentage of pelvic and shank bone from the round than did the 1/2-blood group. Bull carcasses yielded higher percentages of bone-in blade chuck and bone-in neck and partially boneless round, but a lower percentage of shortloin, than did steer carcasses. Fat trim percentages from the chuck, loin and round were lower for carcasses from bulls than from steers.

In Table 5, mean percentage yields of major, partially boneless, retail-ready cuts trimmed to 3/8 inch fat are presented. As with wholesale and major subprimal percentages, no sex x breed interactions were noted. Percentage yields of blade chuck inside (top) round and gooseneck (bottom) round were higher for bulls than for steers. Carcasses from bulls also had

TABLE 4. MEAN PERCENTAGE YIELDS[a] OF MAJOR SUBPRIMALS FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS (TRIMMED OF 3/4 INCH OF FAT)

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Cut	(n=18)	(n=18)	(n=18)	(n=18)	Probability level		
Chuck							
Arm	10.7	10.6	10.4	10.8	NS	NS	NS
Blade	8.7	9.6	8.7	9.9	.0001	NS	NS
Neck	7.3	8.1	7.4	8.2	.0001	NS	NS
Fat Trim	0.1	0.0	0.02	0.0	.001	NS	NS
Rib							
Rib, short cut	5.9	6.5	6.4	6.3	Ns	NS	NS
Short rib	2.1	2.0	2.0	1.9	NS	NS	NS
Fat trim	0.01	0.01	0.01	0.0	NS	NS	NS
Bone[b]	0.6	0.5	0.6	0.6	NS	NS	NS
Loin							
Shortloin	8.2	7.6	8.1	7.6	.001	NS	NS
Sirloin	6.6	6.4	6.7	6.6	NS	NS	NS
Lean trim	0.4	0.4	0.5	0.5	NS	NS	NS
Fat trim	1.0	0.7	0.9	0.6	.002	NS	NS
Bone[c]	1.0	1.0	1.0	1.0	NS	NS	NS
Round							
Round	19.3	20.2	19.3	20.7	.0001	NS	NS
Lean trim	1.8	1.8	1.8	1.9	NS	NS	NS
Fat trim	0.8	0.7	0.8	0.6	.002	NS	NS
Bone[d]	2.3	2.3	2.4	2.5	NS	.02	NS

[a] Mean percentages of right side weights.

[b] Chine bone was sawed from the short cut rib.

[c] Chine and hip bones were removed from the shortloin and sirloin, respectively.

[d] Pelvic and shank bones were removed from the round.

less fat trim from the chuck, rib, loin and round.

The only significant breed effects (Table 5) for major, partially boneless, retail-ready cuts were for fat trim. Carcasses from the 3/4- to 7/8-blood group had less fat trim from the chuck, rib and loin than carcasses from the 1/2-blood group.

Mean percentage yields of major, boneless, retail-ready cuts trimmed of fat in excess of 3/8 inch are shown in Table 6. Again, sex x breed effects were not significant sources of variation for any of the retail-ready cuts, lean trim, fat trim or bone. For the chuck, carcasses from bulls had a higher percentage of blade chuck, lean trim and one, but a lower percentage of fat trim, than carcasses from steers. Bulls also had a lower percentage of fat trim from the rib, loin and round than steers. The inside (top) and gooseneck (bottom) round comprised higher percentages of side weight for carcasses from bulls than for carcasses from steers.

Breed was not a significant source of variation for percentages of major, boneless, retail-ready cuts trimmed of fat in excess of 3/8 inch (Table 6). However, carcasses of cattle from the 1/2-blood group had higher percentages of fat trim and lower percentages of bone from the chuck, rib and loin than did carcasses of cattle in the 3/4- to 7/8-blood group.

Mean percentage yields of boneless brisket, flank steak, lean trim and fat trim from the minor primal cuts are presented in Table 7. The lean and fat trim percentages for the plate and flank are calculated values after

TABLE 5. MEAN PERCENTAGE YIELDS[a] OF MAJOR, PARTIALLY BONELESS, RETAIL-READY CUTS (TRIMMED TO 3/8 INCH OF FAT) FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Cut	(n=18)	(n=18)	(n=18)	(n=18)	Probability level		
Chuck							
Arm	8.6	8.6	8.4	8.9	NS	NS	NS
Blade	8.6	9.6	8.6	9.9	.0001	NS	NS
Lean trim	0.6	0.8	0.6	0.8	.01	NS	NS
Fat trim	1.8	1.2	1.5	1.0	.0001	.02	NS
Rib							
Rib, short cut	6.2	6.4	6.3	6.3	NS	NS	NS
Short rib	2.0	2.0	2.0	1.9	NS	NS	NS
Fat trim	0.2	0.1	0.1	0.03	.0002	.02	NS
Bone[b]	0.6	0.5	0.6	0.6	NS	NS	NS
Loin							
Shortloin	5.4	5.3	5.4	5.4	NS	NS	NS
Butt tender	1.0	1.0	1.0	1.0	NS	NS	NS
Top sirloin	3.2	3.3	3.4	3.4	NS	NS	NS
Bottom sirloin	1.8	1.7	1.8	1.8	NS	NS	NS
Lean trim	2.0	1.9	2.0	2.0	NS	NS	NS
Fat trim	2.2	1.5	2.0	1.2	.0001	.03	NS
Bone[c]	1.0	1.0	1.0	1.1	NS	NS	NS
Round							
Inside	5.9	6.2	6.0	6.4	.0001	NS	NS
Gooseneck	7.8	8.4	7.7	8.6	.0001	NS	NS
Knuckle	2.9	3.0	3.0	3.1	NS	NS	NS
Lean trim	1.8	1.8	1.8	1.9	NS	NS	NS
Fat trim	1.7	1.4	1.4	1.3	.0001	NS	NS
Bone[d]	4.1	4.0	4.2	4.3	NS	NS	NS

[a] Mean percentages of right side weights.

[b] Chine bone was sawed from the short cut rib.

[c] Chine and hip bones were removed from the shortloin and sirloin, respectively.

[d] All bones were removed.

the lean trim was standardized to 25 percent chemical fat; those from the brisket and foreshank are based upon lean trim and fat trim weights after the lean was trimmed to 3/8 inches of fat. No sex x breed interactions were noted for these data. Lean trim percentages from the foreshank, plate and flank were higher for bulls than for steers. Percentages of fat trim from the brisket, plate and flank were lower for bull carcasses than for steer carcasses. Percentages of bone trim from the minor primals were not different for carcasses from bulls and steers.

Lean trim percentage (adjusted to 25 percent chemical fat) in the plate was greater for carcasses from the 3/4- to 7/8-blood group than for those from the 1/2-blood group (Table 7). Fat trim percentages from the brisket, plate and flank were lower for carcasses from the 3/4- to 7/8-blood group than from 1/2-blood group. The only significant difference in percentage bone of carcasses from the two breed groups was detected for the foreshank; the 3/4- to 7/8-blood group had carcasses with 0.10 percent higher foreshank bone than did carcasses from 1/2-blood group.

In Table 8, the cutability data are summarized. No interactions between sex and breed were noted. Carcasses from bulls had an average yield of 48.05

TABLE 6. MEAN PERCENTAGE YIELDS[a] OF MAJOR, BONELESS, RETAIL-READY CUTS (TRIMMED TO 3/8 INCH OF FAT) FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Cut	(n=18)	(n=18)	(n=18)	(n=18)	Probability level		
Chuck							
Arm	6.6	6.6	6.4	6.8	NS	NS	NS
Blade	7.1	8.0	7.1	8.2	.0001	NS	NS
Lean trim	7.3	8.5	7.5	8.6	.0001	NS	NS
Fat trim	1.9	1.2	1.5	1.0	.0001	.01	NS
Bone	3.9	4.0	4.0	4.3	.05	.03	NS
Rib							
Rib, short cut	4.9	5.2	5.0	5.0	NS	NS	NS
Lean trim	2.2	2.2	2.2	2.1	NS	NS	NS
Fat trim	0.2	0.1	0.1	0.03	.001	.02	NS
Bone	1.6	1.6	1.6	1.7	NS	.02	NS
Loin							
Strip loin	3.1	3.1	3.2	3.2	NS	NS	NS
Short tender	1.0	1.0	1.1	1.1	NS	NS	NS
Top sirloin	3.3	3.3	3.4	3.4	NS	NS	NS
Bottom sirloin	1.8	1.7	1.8	1.8	NS	NS	NS
Butt tender	1.0	1.0	1.0	1.0	NS	NS	NS
Lean trim	2.0	1.9	2.0	2.0	NS	NS	NS
Fat trim	2.9	2.0	2.7	1.7	.0001	.04	NS
bone	2.0	2.0	2.1	2.1	NS	.04	NS
Round							
Top (inside)	5.9	6.2	6.0	6.4	.0001	NS	NS
Bottom (gooseneck)	7.8	8.4	7.6	8.6	.0001	NS	NS
Knuckle (tip)	2.9	3.1	3.0	3.1	NS	NS	NS
Lean trim	1.8	1.8	1.8	1.9	NS	NS	NS
Fat trim	1.7	1.4	1.7	1.3	.0001	NS	NS
Bone	4.1	4.0	4.2	4.3	NS	NS	NS

[a]Mean percentages of right side weights.

TABLE 7. MEAN PERCENTAGE YIELDS[a] OF MINOR, BONELESS, RETAIL-READY CUTS (TRIMMED TO 3/8 INCH OF FAT) FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Cut	(n=18)	(n=18)	(n=18)	(n=18)	Probability level		
Brisket							
Brisket	2.2	2.6	2.4	2.6	.0001	NS	NS
Lean trim	0.3	0.3	0.3	0.3	NS	NS	NS
Fat trim	1.0	0.7	0.9	0.6	.0001	.03	NS
Bone	0.5	0.5	0.5	0.5	NS	NS	NS
Foreshank							
Lean trim	1.7	1.9	1.8	2.0	.01	NS	NS
Fat trim	0.04	0.05	0.04	0.04	NS	NS	NS
Bone	1.4	1.4	1.5	1.5	NS	.001	NS
Plate							
Lean trim[b]	4.9	5.4	5.2	5.5	.0001	.02	NS
Fat trim[b]	1.7	0.7	1.3	0.3	.0001	.01	NS
Bone	1.1	1.1	1.1	1.1	NS	NS	NS
Flank							
Flank steak	0.5	0.5	0.5	0.5	NS	NS	NS
Lean trim[b]	2.7	2.8	2.6	2.7	.02	NS	NS
Fat trim[b]	1.8	1.1	1.4	0.7	.0001	.02	NS
Bone	0.3	0.3	0.3	0.3	NS	NS	NS

[a]Mean percentages of right side weights.

[b]Lean trim and fat trim percentages remaining after the lean trim was standardized to 25 percent chemical fat.

TABLE 8. MEAN PERCENTAGE YIELDS[a] OF MAJOR, BONELESS, CLOSELY TRIMMED (TRIMMED TO 3/8 INCH OF FAT), RETAIL-READY CUTS, LEAN TRIM, FAT TRIM AND BONE FOR CARCASSES FROM CHAROLAIS CROSSBRED BULLS AND STEERS

	1/2-blood		3/4- to 7/8-blood		Source of variation		
	Steers	Bulls	Steers	Bulls	Sex	Breed	SXB
Cut	(n=18)	(n=18)	(n=18)	(n=18)	Probability level		
Boneless, closely trimmed major primals[b]	45.4	47.6	45.5	48.5	.0001	NS	NS
Brisket	2.2	2.6	2.4	2.6	.0001	NS	NS
Flank steak	0.5	0.5	0.5	0.5	NS	NS	NS
Lean trim[c]	23.9	27.3	24.7	28.1	.0001	.05	NS
Fat trim[c]	13.0	6.9	11.3	4.4	.0001	.01	NS
Bone	14.8	14.9	15.4	15.7	NS	.01	NS
Kidney	0.2	0.2	0.2	0.2	NS	NS	NS

[a]Mean percentages of right side weights.

[b]Major primals include: arm chuck section (rib portion removed); blade chuck section (neck removed); short cut rib; strip loin; sirloin (top and bottom); tenderloin, and round (inside gooseneck and knuckle).

[c]Lean trim and fat trim percentages remaining after the lean trim was adjusted to 25 percent chemical fat.

percent major closely trimmed, boneless, retail-ready cuts, while those from steers had an average of 45.45 percent. The advantage in percentage of major, closely trimmed, boneless, retail cuts for bulls compared to steers resulted from a significant advantage in percentage yields of the chuck. Bulls yielded, on the average, 2.35 percent more cuts from the major, boneless, retail-ready chuck (Table 6). The percentage of the carcass as edible portion (non-tabular data) was 6.3 percent higher for bulls than steers. Percentage fat trim (after lean trim was adjusted to 25 percent chemical fat) for bull carcasses averaged 5.65 percent, while that average for steer carcasses was 12.15%. Sex effect was not a significant source of variation for percentage of bone.

The 1/2- blood and 3/4- to 7/8-blood groups did not differ in percentages of major, closely trimmed, boneless, retail-ready cuts, brisket or flank steak. Lean trim percentage was 0.80 percent higher, bone trim was 0.70 percent higher and fat percentage was 2.10 percent lower for carcasses from the 3/4- to 7/8-blood group than for carcasses from the 1/2-blood group. However, it should be reemphasized that the sex effect was a greater source of variation (i.e., more highly significant) for these data (Table 8) than was the breed effect.

In this study, Charolais crossbred bulls and steers of a common background were handled alike through feeding and slaughtering. Bulls yielded higher percentages of wholesale cuts, trimmed subprimals and edible portion than steers. These data further suggest that sex influences percentage yields more than breed for the cattle included in this study. However, it should be emphasized that the advantage in percentage yields of major, closely trimmed, boneless, retail cuts resulted from the increased proportionate weights and/or percentages of cuts of the chuck (primarily) and the round.

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Young Bulls in Today's Marketplace: A Review

H. Russell Cross

Summary

There are many advantages to using intact males in red meat production systems. Young bulls grow more rapidly and efficiently and produce leaner carcasses at a younger age than do steers. However, several critical problems must be solved before bulls can be fully exploited for beef production. These problems are addressed in the following review.

Introduction

Consumers ultimately determine the type of beef produced in this country. Today's consumers demand a leaner, boneless product, free of excess fat. This trend will become more pronounced as the costs of production and ultimate cost to the consumer increase. Castration of the young bull has long been practiced in the United States. This practice is intended to produce an animal more acceptable to current management systems and a more desirable carcass for marketing. During the past four decades, numerous studies have been conducted to assess the relative performance and meat characteristics of castrates and noncastrates. Results indicate that young bulls grow more rapidly, utilize feed more efficiently and produce a higher-yielding carcass with less fat and more edible product than do steers.

Increased production efficiency with young bulls has often offset management problems caused by behavior. But meat from noncastrates has encountered strong resistance from meat packers, in part because of the price difference between carcasses from bulls and steers. This price difference is due to the lower USDA quality grade for bulls, and the belief that intact male beef has a lower consumer acceptance at the retail level because of differences in color, texture and fat distribution. In addition, cooked meat from young bulls is often less tender than that from steers. Processors have also cited numberous problems with the slaughtering and dressing of young bull carcasses (4).

The objective of this discussion is to discuss current research concerning the production of young bulls for the retail and block beef trade.

Preslaughter handling of young bulls

It is often reported that meat from bulls is darker in color and coarser in texture than meat from steers (5,11,20,21). Field (11) suggested that, because of their temperament, bulls may be more easily stressed than steers, and that this may cause the darker meat. Under controlled preslaughter conditions no differences are usually reported between bulls and steers. Kousgaard (15) reported that more than 18 percent of young bulls studied had a 24-hour pH value greater than 6.0, resulting in a significantly darker color lean than steers.

Price and Tennessen (20) investigated the influence of social interactions among bulls before slaughter on the incidence of dark-cutting. Their design used 12-month-old bulls taken off a 140-day feedlot performance test. The bulls were placed in pens of 7 or 21 per pen for a period of 12 to 14 weeks, during which time stable social structures developed within each pen. At the end of this period, bulls were trucked, in groups of 21 or 7 bulls in either mixed or unmixed lots, 150 kilometers to the slaughter plant. At the plant, the groups were held together overnight and slaughtered the next day. Price and Tennessen (20) reported that during loading, transport and holding at the plant, the regrouped bulls were observed to be continually active. Fighting and mounting occurred frequently. The authors concluded that the most disturbing part of the marketing process for these bulls was not the unfamiliar surroundings or handling procedures, but the presence of strange bulls.

The incidence of dark-cutters among carcasses from the Price and Tennessen (20) study is outlined in Table 1. Of the 119 bulls in the study, 42 were judged to have dark-cutter carcasses. The effect of load size on the incidence of dark-cutting was not significant, but the effect of regrouping before slaughter was significant.

Workers in Denmark have investigated the influence of preslaughter feeding on the incidence of dark-cutting bull carcasses. Kousgaard (15) investigated the effects of conventional handling (animals kept overnight were fed hay and water). Results showed that this method of feeding did not improve the state of the animals. After one night in the holding pens, the animals had an 18 percent incidence of dark-cutters, and after two nights 23 percent were dark-cutters.

Sorenson (23) investigated the use of a highly digestible feed for young bulls prior to slaughter, to deter-

TABLE 1. THE INCIDENCE OF DARK-CUTTING AMONG THE CARCASSES OF YOUNG BULLS SHIPPED TO THE PACKING PLANT IN LARGE (21) OR SMALL (7) GROUPS DRAWN FROM SEVERAL PENS (MIXED) OR SINGLE PENS (UNMIXED) IN THE FEEDLOT

	Large loads (21 bulls)	Small loads (7 bulls)	Individually shipped bulls	Total
Mixed				
Number	42	14	--	56
Dark cutters‡	29 (69%)	12 (86%)		41 (73%)[a]
Unmixed				
Number	42	14	--	56
Dark cutters‡	1 (2%)	0 (0%)		1 (2%)[b]
Total				
Number	84	28	7	119
Dark cutters‡	30 (36%)[c]	12 (48%)[c]	0 (0%)	42 (35%)

‡As defined in the Canadian Beef Carcass Grading Regulations.

[a,b]Numbers in the same column having different letters are significantly different (P < .01).

[c]Numbers in the same row having the same letter are not significantly different (P > .05).

Source: (20)

mine if it would raise the muscle glycogen content prior to death. Results indicated that the high energy diet could increase the glycogen content, produce a lower ultimate postmortem muscle pH and a lower incidence of dark-cutting.

In conclusion, it appears that:

a) Young bulls are more susceptible to the dark-cutting condition than steers, mainly because of their activity prior to slaughter;
b) Group size is unlikely (within limits) to affect the incidence of dark-cutters provided all the bulls within the group are familiar with each other;
c) Feeding diets high in energy prior to slaughter can reduce the incidence of dark-cutting.

Additional research is needed to evaluate the proper means of handling and feeding young bulls prior to slaughter. The high incidence of dark-cutting in young bulls serves as a continuing disincentive to potential bull-beef producers. The dark-cutting, high pH meat presents serious marketing problems with regard to quality grade, consumer acceptance, and microbial shelf-life.

Slaughtering and processing

Many meat packers have negative reactions to the young bulls because of increased processing costs. Many of these costs are associated with the difficulty of removing the bull hide and the often heavier carcasses. Cook (7) conducted an informal survey among several packers regarding the problems with slaughtering young bulls vs. steers. The main conclusions are summarized in Table 2.

There is almost no research data available as to why the bull hide is more difficult to remove. Industry comments (4,7) indicate that these problems may be related to slaughter weight, age or breed. Cross et al. (8) investigated the influence of age, breed and sex on the biosynthesis of muscle collagen. Their results indicate that near puberty, bulls have an accelerated production of testosterone and muscle collagen. The endocrine influence on collagen synthesis in the bull hide should be studied to see if it affects hide removal.

TABLE 2. INDUSTRY OPINION REGARDING PROCESSING PROBLEMS WITH BULLS

Kill Floor

1. More difficult to stun due to head hide and skull thickness.
2. Bull heads often must be manually skinned on the kill floor because the dehider will not remove the hides from the head. This occurs because of the extreme thickness of the hides over the heads as compared to steers and heifers.
3. The extra pressure needed to pull bull hides from the carcass often results in damaged carcasses, i.e., fat pulls and torn hock tendons (which drops animals), reducing carcass value.
4. Bull bone is more dense and can cause problems with saws and hock clippers.

Hide Room

1. Bull hides are usually wider and thicker than hides from steers and heifers of comparable weights. This causes breakdowns of fleshing equipment and increases downtime.
2. Because of the extra thickness, bull hides may need to be passed through the fleshing machine two or three times, increasing labor requirements.
3. Bull hides are extremely heavy and may weigh 80 to 90 pounds after curing.
4. Bull hides may not cure completely in a commercial operation bcause length of cure time is based on the majority of hides which are from steers and heifers.
5. Bull hides must be sorted from others and are usually worth less money to the packer.

Source: (7)

Carcass weight (size of primal and retail cut) and minimum external fat thickness are other problems associated with the marketing of young bulls. The boxed beef and retail segment of the meat industry places price constraints on bulls with too little fat (less than 0.2 inch) and carcasses that are too large (more than 800 pounds (lbs.)). The maximum acceptable carcass weight has tended to gradually increase over the years, but packer and retail resistance to extemely heavy weights is still prevalent. Thus, steers may be more efficient than bulls because they likely will reach the minimum fat endpoint sooner than bulls, and be in the feedlot for less time. The bull carcass may also be too heavy by the time it reaches the fat endpoint. Research is needed to investigate the breed and breed cross effects on the economics of fat and muscle deposition in bulls.

Carcass characteristics

Carcass characteristics of bulls vs. steers are outlined in Table 3. Data from selected studies were used to illustrate differences in carcass traits. These findings are covered in more detail in reviews by field (10) and Seideman et al. (22). Generally, bulls produce heavier carcasses with less outside fat, larger rib-eye areas, more desirable USDA yield grades, less intramuscular fat (marbling), lower USDA quality grades, and darker lean color. Also, bulls usually have a lower dressing percent than steers since they have less fat and heavier hides. The literature indicates that these differences are small.

TABLE 3. CARCASS CHARACTERISTICS OF BULLS AND STEERS

	Carcass wt. kg		Dressing %		Fat depth, cm		Rib-eye area, cm^2		USDA yield grade		Lean color[a]		Marbling		USDA quality grade	
Reference	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*	*B*	*S*
Hedrick et al. (1969)	317	282	60.8	61.6	1.70	1.90	75.6	64.3	---	---	---	---	SL+	SM°	G+	Ch-
Climp et al. (1971)	286	263	61.1	58.5	.94	1.37	82.9	65.6	---	---	---	---	PD	SM-	S°	Ch-
Gortsema et al. (1974)	291	291	61.2	62.3	.60	1.80	88.4	71.4	1.7	3.9	3.9	2.8 (+)	Sl+	MT°	G+	Ch
Albaugh et al. (1975)	227	207	---	---	1.09	1.30	76.1	66.7	---	---	---	---	Sl°	SM-	G°	Ch-
Carroll et al. (1975)	253	244	60.4	60.7	1.80	2.10	73.5	63.9	---	---	---	---	SM-	MT-	Ch-	Ch-
Jacobs et al. (1975)	648	627	63.3	63.9	.24	.61	13.5	11.7	1.5	3.1	4.3	3.1(+)	SM-	MT°	Ch-	Ch°
Jacobs et al. (1976)	676	667	64.4	64.7	.26	.59	13.0	11.4	2.1	3.5	---	---	SL+	MT-	G+	Ch-
Landan et al. (1978)	---	---	60.7	63.2	.59	1.12	85.6	83.0	1.8	2.9	---	---	TR+	SM-	S+	Ch-
Crouse et al. (1982)	175	143	---	---	.81	1.21	87.9	69.4	2.6	3.4	5.8	5.3(+)	SL-	SL+	G-	G+

[a]Since the various studies used different scoring systems, the (+) indicates the advantage in that particular trait.

A comparison of percentage retail yield and percentage separable lean and bone in bull and steer carcasses is presented in Table 4. The advantage in boneless round, loin, rib and chuck for bulls exceeds 2.6 percent according to the Murphey et al. (18) estimating equation. However, Champagne et al. (6), Gorstsma et al. (12) and Jacobs et al. (14) found differences of more than 9 percent using actual cutout data. It is difficult to determine if the need to use different prediction equations for estimating bull composition is due to differences in sex or to the lack of variation in outside fat in the bull carcass.

Percentage separable bone in the carcasses (Table 4) averaged 15.4 percent for the bulls and 15.2 percent for steers. Differences in percent bone are small, but bulls have much higher muscle-bone ratios in their carcasses than steers.

In conclusion, if young bulls are to be more prevalent in the marketplace, more cutability data will be needed in order to test the accuracy of the USDA prediction equation on bull carcasses. It could be necessary to have a separate equation for bulls. It's obvious from the available literature that bulls have a tremendous advantage over steers in yield of edible lean product.

TABLE 4. COMPARISON OF PERCENT RETAIL YIELD, PERCENT SEPARABLE LEAN AND BONE IN BULL AND STEER CARCASSES

Reference	Bulls	Steers
Boneless chuck, rib, loin and round %		
Field et al. (11)	50.2	46.3
Matsushima et al. (17)	52.7	49.5
Anthony and Starling (1)	52.7	51.3
Martin et al. (16)	50.7	48.3
Champagne et al. (6)	55.5	50.7
Gortsema et al. (12)	53.5	46.3
Jacobs et al. (14)	62.3	53.1
Separable lean or boneless closely trimmed carcass, %		
Nichols et al. (19)	63.5	60.4
Arthaud et al. (2)	66.5	60.8
Hedrick et al. (13)	67.9	62.0
Separable bone in carcass, %		
Nichols et al. (19)	18.0	17.0
Champagne et al. (6)	14.6	14.6
Hedrick et al. (13)	12.9	13.2

Source: (10)

USDA quality grades

Since the United States meat industry relies heavily on USDA grades as a marketing tool, the lower USDA quality grades of bulls results in a serious disadvantage to the meat packer. Due to greater variability in tenderness of young bulls, USDA has a separate classification system for the quality grade. Those carcasses indentified as bulls are graded as "bullocks." Because of this "class" distinction, known bullocks are never graded and rolled as such. The majority of the young bull beef marketed today is sold unbranded or under a commercial "house-brand."

The USDA recently proposed a change in the quality grade standards to lower the marbling requirements for the various grades (24). Their proposal did not include a revision of the "bullock" classification. Data in Table 5 give comparisons of bull and steer carcasses graded according to various proposals. It is obvious that with any of the new proposals, bull carcasses will have quality grades similar to steer carcasses. As USDA continues to reduce the emphasis on marbling, the differences between bull and steer carcass quality grades will decrease. The question of class designation for bulls remains. Recent experience indicates that industry will not use USDA grades for bulls if the "bullock" designation still exists. As bull and steer carcasses become more alike in marbling characteristics, do they also become more alike in tenderness? That question must be answered before USDA can reevaluate their bullock standards.

It may be necessary to control the tenderness variability in young bulls through some postmortem means. Generally, the literature indicates that bulls are lower in tenderness and more variable than steers or heifers (10,22). The cause of the tenderness problem has not been fully documented, but appears to be related to the state of muscle contraction or cold-shortening and the amount and strength of the connective tissue in the muscle. Scientists in France (3) and in the U.S. (8) have reported that connective tissue toughness in bulls may be linked to sexual development, and may be subject to some endocrine function in the animal.

The cold-shortening effects on tenderness in bulls

TABLE 5. COMPARISON OF PRESENT AND PROPOSED GRADING SYSTEMS ON BULL AND STEER CARCASSES

Source	Fat thickness (inches)		Marbling		USDA present grade		USDA proposal[a]		NCA proposal[b]		AMI proposal[c]	
	Bulls	Steers	Bulls	Steers	Bulls	Steers	Bulls	Steers	Bulls	Steers	Bulls	Steers
Field et al. (11)	.34	.67	SL	MT	Gd°	Ch°	Ch-	Ch+	Ch-	Ch+	Ch-	Ch+
Matsushima et al. (17)	.36	.61	SM	MD	Ch-	Ch+	Ch°	Pr-	Ch-	Pr-	Ch°	Pr-
Nichols et al. (19)	.10	.13	TR+	SL	Std+	Gd°	Gd+	Ch-	G+	G+	Gd+	Gd-
Anthony and Starling (1)	.10	.20	TR+	SM	Std+	Ch-	Gd+	Ch°	G+	Ch°	Gd+	Ch°
Martin et al. (16)	.54	.82	MT	MD	Ch°	Ch+	Ch+	Pr-	Ch°	Pr-	Ch+	Pr-
Arthaud et al. (2)	.35	.55	SM	MD	Ch-	Ch+	Ch°	Pr-	Ch°	pr-	Ch°	Pr-
Champagne et al. (6)	.25	.40	SL	SM	Gd°	Ch-	Ch-	Ch°	G+	Ch°	Ch-	Ch°
Hedrick et al. (13)	.66	.85	SL	SM	Gd°	Ch-	Ch-	Ch°	Ch-	Ch°	Ch-	Ch°
Crouse et al. (9)	.32	.47	SL-	Sl+	Gd-	Gd+	Gd+	Ch-	Ch-	Ch-	Ch-	Ch-

[a]USDA proposed change for Choice: minimum Choice = SL^{50}.

[b]National Cattleman's Association: minimum Choice = SL zero coupled with 0.3 in fat thickness or greater.

[c]American Meat Institute: minimum Choice = SL zero.

could be related to the rate of postmortem chill and its effects on muscle contraction. This condition may be helped with postmortem electrical stimulation (ES). The use of ES by beef slaughterers is widespread, and it is well known that ES improves the palatability of beef steaks. Furthermore, it is becoming increasingly apparent that subcutaneous fat thickness is related to beef tenderness through its effect as an insulator which reduces the rate of chilling. If ES could eliminate some of the variation in tenderness from young bulls, and/or some minimum fat thickness could assure that beef from young bulls would have "acceptable" tenderness, their use would become more widespread.

Meat scientists from Texas A&M (21) have found the greatest benefit of ES is on tenderness in young bulls with less than 0.30-inch fat thickness, which is likely related to cold shortening. In contrast, Crouse et al. (9) found no ES tenderness effects on bull carcasses, but did find that high temperature aging did improve tenderness (9). In the latter study, the fat thickness was greater than 0.30 inch, suggesting that tenderness improvement was likely related to the connective tissue component. It is likely that the cause is a combination of two or more factors. Major research efforts are needed in this area to learn to control the tenderness variability in young bulls.

Conclusions

Since the consumer likely will continue to demand a leaner product, young bull beef may have a larger role in our future production systems. A review of the literature shows that there are numerous advantages to producing young bulls, since they grow more rapidly and efficiently, and produce leaner carcasses at a younger age. Several critical problems remain, however, and must be solved before bulls can be fully exploited for beef production. These include the need to:

1. Develop preslaughter handling systems to reduce the incidence of dark-cutting muscle.
2. Develop more efficient and effective hide removal systems.
3. Develop more accurate classification systems for yield.
4. Develop antemortem and postmortem means to reduce the variability in tenderness.

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Carcass Fatness Evaluations: Sex-Related Differences in the Deposition of External Fat — Steer vs. Heifer

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Summary

A cutability prediction equation derived from data on 129 steer and 80 heifer carcasses, and based on the factors included in the USDA beef carcass yield grade equation, underestimated the cutability of steer carcasses by .19 percent and overestimated the cutability of heifer carcasses by .31 percent. However, this difference was essentially eliminated by substituting "carcass percentage of external fat trim" for "adjusted thickness of fat over the ribeye" in that equation. While the steer and heifer carcasses had similar patterns of fat deposition on their various parts, heifer carcasses had greater ($P < .05$) percentages of external fat trim in 9 of 10 carcass areas than did steers. Thus, any subjective carcass evaluation procedure aimed at eliminating the external fat trim sex-bias between steer and heifer carcasses would have to include an arbitrary adjustment reflecting that, in comparison with steer carcasses, heifer carcasses are fatter than indicated by their appearance.

Introduction

It is important to develop the best possible procedures for evaluating the fatness of beef carcasses, especially in applying USDA beef yield grade standards. Those grades, which identify carcasses for their cutability, are widely used in trading, and adjusted thickness of fat over the ribeye muscle at the twelfth rib is the most important factor affecting cutability (1,2,3,4).

Beef yield grade standards (5) were developed on an unverified assumption that, among steer, heifer and cow carcasses, sex has no effect on cutability (4). However, Abraham et al. (2) reported that equations containing the same independent variables as the USDA equation predicted the cutability of steer carcasses quite accurately but underestimated the cutability of heifer carcasses. Wholesale prices for steer and heifer carcasses tend to support these differences in predicted cutability. For example, during 1983, 273- to 318-kilogram (kg) Choice, Yield Grade 3 steer carcasses sold for an average of 14.60 per 100 kg more than did heifer carcasses of the same weight and grade.

The objective of this study was to report the various findings as to how sex and degree of fatness affect the deposition of external fat.

Experimental Procedure

In the study (2) which provided the data for this article, 280 beef carcasses (129 steers, 80 heifers, 71 cows) were selected from seven packing plants in three states. The experimental design used in selecting carcasses was based on sex, hot carcass weight, fat thickness over the ribeye at the twelfth rib and overall muscling. Within each sex, the carcasses selected represented an extremely wide range in fatness, muscling and weight.

At the time of selection, three evaluators — one from Texas A&M University and two from the Meat Quality Division, Food Safety and Quality Service, USDA (currently the Livestock, Meat, Grain and Seed Division, Agricultural Marketing Service, USDA) — made various measurements and visual evaluations of each carcass as described by Abraham et al. (2). Two of the evaluators also made independent evaluations of the external fatness of each of ten carcass areas on the left side of each carcass: rump/sirloin, hereafter referred to as "rump"; inside round; outside round; short loin; cod or udder; flank; rib; plate; brisket; and chuck. One of the evaluators determined the fatness of these areas in terms of the thickness of fat over the ribeye, based on his perception of a carcass with "normally" distributed fat; the other evaluator considered the weight of fat in each area, expressed as a percentage of side weight.

After the carcasses were evaluated, each of the left sides was shipped to the meat warehouse of a large retailer for cutting. Cutting was conducted according to procedures developed by USDA and Texas A&M University personnel. The sides were first broken into wholesale cuts. Then, in successive steps, the round, loin, rib, chuck and brisket were made into boneless cuts that were trimmed of external and intermuscular fat to a maximum thickness of 1.3 centimeters (cm). Each of these cuts was further trimmed of all external and seam fat. References herein to percentage of external fat trim on each of the ten locations, or to the total percentage of external fat trim, will relate to all of the external fat trimmed from the round, loin, rib, chuck and brisket, as applicable, and to the fat removed from the plate, flank and cod or udder.

The distribution of the 280 carcasses in this study by sex and actual thickness of fat over ribeye is shown in Table 1. However, because the cow carcasses were so unevenly distributed throughout the overall fatness range, and because cow carcasses make up such a small proportion of our block beef, it was felt that only the results for the steer and heifer carcasses should be reported.

Results and Discussion

Table 2 shows the means and standard deviations of the carcass yield grade factors and actual carcass cutability, by sex. These data reveal that the heifer carcasses had a slightly greater actual and adjusted thickness of fat over the ribeye and slightly more kidney, pelvic and heart fat than did the steer carcasses, but that the steer carcasses were heavier and also had larger ribeye areas and slightly higher cutability than did the heifers.

According to Abraham et al. (2), a substantial increase in the R^2 value (.83 vs. .91) for predicting the cutability of all 280 carcasses occurred when fat trim percentage was substituted for adjusted fat thickness in an equation also containing the other three yield grade factors. Therefore, we postulated that much of the difference in accuracy of predicting the cutability of steer vs. heifer carcasses might be due to the accuracy with which adjusted fat thickness values explained variations in the percentages of external fat trim. We explored that possibility by using the USDA yield grade factors to derive a cutability prediction equation from the 209 steer and heifer carcasses in this study. We applied that equation (Equation 1, Table 3) to each steer and heifer carcass to predict its cutability; then, by determining the difference between the actual and predicted cutability of each carcass, we demonstrated that the equation usually overestimated the cutability of the heifer carcasses by .31 percent and underestimated the cutability of the steer carcasses by .19 percent (Table 3) — a total difference of .50 percent. We then followed the same procedure using a cutability prediction equation (Equation 2, Table 3) in which the total percentage of the external fat trim from the ten carcass areas was substituted for adjusted fat thickness over the ribeye. The use of that equation, as shown in Table 3, essentially eliminated the difference in the accuracy of predicting cutability of the steer vs. the heifer carcasses, and verified that this sex difference was due to inaccuracies with which adjusted fat thickness values reflected differences in percentage of external fat trim.

That finding led to a further exploration of the data

TABLE 1. FREQUENCY DISTRIBUTION OF CARCASSES BY SEX AND ACTUAL FAT THICKNESS OVER THE RIBEYE[a]

Actual fat thickness, cm	Steers	Heifers	Cows
0.00 and 0.13	8	1	23
0.25 and 0.38	15	7	14
0.51 and 0.64	14	4	4
0.76 and 0.89	16	10	8
1.02 and 1.14	11	7	6
1.27 and 1.40	9	8	5
1.52 and 1.65	7	10	2
1.78 and 1.90	10	6	3
2.03 and 2.16	8	7	2
2.29 and 2.41	8	4	1
2.54 and 2.67	9	5	2
2.79 and 2.92	5	2	--
3.05 and 3.18	2	5	1
3.30 and 3.43	2	2	--
3.56 and 3.68	2	1	--
3.81 and 3.94	3	1	--
Total	129	80	71

[a]A single thickness of fat at a point over the *longissimus* muscle three-fourths of its length from the chine bone end, where this surface was exposed by a cut between the twelfth and thirteenth ribs.

TABLE 2. MEANS AND STANDARD DEVIATIONS OF CARCASS YIELD GRADE FACTORS, STRATIFIED BY SEX

	Steers		Heifers	
Yield grade factor	Mean	Standard deviation	Mean	Standard deviation
Actual fat thickness, cm	1.51	1.05	1.66	.91
Adjusted fat thickness, cm	1.54	1.03	1.72	.83
Ribeye area, cm^2	75.39	11.27	71.97	12.39
Kidney, pelvic and heart fat, %	3.73	.96	3.91	.96
Carcass weight, kg	331.10	58.91	265.32	51.55
Actual cutability, %[a]	51.33	3.49	50.49	3.82

[a]Carcass yield of boneless, closely trimmed, retail cuts from the round, loin, rib and chuck.

TABLE 3. DIFFERENCES IN THE ACCURACY OF TWO EQUATIONS FOR PREDICTING THE MEAN CUTABILITY OF STEER AND HEIFER CARCASSES

			Equation 1		Equation 2	
Sex	n	Actual mean cutability	Predicted mean cutability[a]	Difference[b]	Predicted mean cutability[c]	Difference
		%				
Steers	129	51.33	51.14	+.19	51.31	.02
Heifers	80	50.49	50.80	-.31	50.52	-.03
Overall	209	51.01	51.01	.00	51.01	.00

[a]Based on an equation which included adjusted fat thickness over the ribeye; percentage kidney, pelvic and heart fat; carcass weight and ribeye area.

[b]Actual cutability minus predicted cutability.

[c]Based on an equation which included the same factors as listed in footnote [a], except that external fat trim percentage was submitted for adjusted fat thickness over the ribeye.

to identify (a) the locations at which steer and heifer carcasses having the same predicted cutability differed in their predicted percentages of external fat trim, (b) the magnitude of those differences, and (c) the extent to which those differences were affected by differences in overall degree of fatness.

Table 4 shows (a) the percentage external fat trim in each of the ten areas expressed in absolute terms and (b) the difference in those percentages between steers and heifers. For the steer carcasses, Table 4 shows that, based on its predicted percentage of fat trim, each carcass area could be assigned to one of four groupings. The grouping with the highest percentage of predicted fat trim included the flank (1.59 percent), chuck (1.56 percent) and the short loin (1.53 percent). A second grouping included the rib (1.27 percent), rump (1.19 percent) and cod (1.17 percent); a third grouping included the brisket (1.10 percent) and plate (1.07 percent). The inside round (.94 percent) and outside round (.58 percent) had the lowest percentages.

The data in Table 4 indicate that the same four general carcass area groupings which charaterized fatness in steers also applied to heifers. However, the rank order of the predicted percentage of fat trim on each of the ten carcass areas was different for heifers than for steers. This is further evidence that steers and heifers deposit fat at different rates on their different parts. For example, in steers, the flank had more predicted external fat trim than the chuck, but in heifers that order was reversed. Differences also were noted among the areas in the second grouping (udder, rump, rib) and between the brisket and plate in the third grouping.

Data in Table 4 also show that for each of the ten carcass areas except the inside round, the heifers had more ($P < .05$) predicted external fat trim than did the steers; for the inside round there was no ($P > .05$) sex difference. This consistent sex bias indicates that more accurate estimates of the fatness and cutability, of carcasses could be made by considering sex.

This sex difference was greatest for the chuck (.41 percent), cod or udder (.34 percent) and rump (.24 percent); it was least for the outside round (.11 percent and intermediate (.14 to .20 percent) for the other carcass areas. Data in Table 4 indicate that at the same predicted cutability (based on an equation derived from the steers and heifers, combined), the heifer carcasses had a higher percentage of external fat trim in 9 of the 10 carcass areas evaluated (there was no sex difference for fat trim from the inside round). These differences in percentage fat trim amount to a total difference of .50 percent between the actual and predicted cutability of the steers and heifers. Since differences in fatness of the steer and heifer carcasses were not recognized by the highly qualified evaluators, it is obvious that such differences can be eliminated only by applying arbitrary, sex-related modifications to the adjusted fat thickness evaluations. In this study, based on the beta value for adjusted fat thickness (-2.373) in the cutability prediction equation developed from the steers and heifers combined, the .31 percent cutability overestimate of the heifer carcasses would have been eliminated if their adjusted fat thickness had been increased by .13 cm, from 1.72 to 1.85 cm ($.13 \times -2.373 = -.31$). The .19 percent cutability underestimate of the steers would have been eliminated if their adjusted fat thickness value had been decreased by .08 cm, from 1.54 to 1.46 cm ($-.08 \times -2.373 = .19$).

This study of the different rates at which steers and heifers deposit external fat on their various parts should be of value to animal and meat scientists interested in carcass and live animal composition. It also could be very useful to the USDA in making improved adjusted fat thickness evaluations and in applying the official beef carcass yield grade standards. The industry might use this information to facilitate trading on live cattle and carcasses.

TABLE 4. COMPARISON OF MEAN PREDICTED PERCENTAGE[a] OF EXTERNAL FAT TRIM ON TEN CARCASS AREAS WITH MEAN PREDICTED CUTABILITY[b], STRATIFIED BY SEX AND CARCASS AREA

Carcass area	Steer %	Heifer %	Difference[cd]
Rump	1.19	1.43	.24
Outside Round	.58	.69	.11
Inside round	.94	.94	.00
Cod or udder	1.17	1.51	.34
Flank	1.59	1.76	.17
Short loin	1.53	1.73	.20
Plate	1.07	1.23	.16
Rib	1.27	1.41	.14
Brisket	1.10	1.25	.15
Chuck	1.56	1.97	.41

[a]Based on side weight.

[b]Mean cutability (51.01 percent) of steer and heifer carcasses combined.

[c]Percentage for heifers minus percentage for steers.

[d]Difference for inside round $P > .05$; all other differences $P < .05$.

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PR-4236

Performance and Carcass Characteristics of Cattle Fed Different Levels of Whole Cottonseed

N. J. ADAMS AND J. L. ARNOLD

Summary

Twenty-two yearling steers and heifers, progeny of Brangus sires and Angus x Hereford dams, were allotted to three treatment groups. Treatments consisted of diets containing 20 percent whole cottonseed and 80 percent milo, 35 percent whole cottonseed and 65 percent milo, and 50 percent whole cottonseed and 50 percent milo. Cattle were slaughtered as they reached USDA Yield Grade 2, as evaluated subjectively. There were no differences in performance or carcass traits due to the level of whole cottonseed in the ration. With the exception of weight, there were no differences between steers and heifers slaughtered after an average feeding period of 107 and 80 days, respectively. Feed utilization improved as the percentage of whole cottonseed in the ration increased. There were no unfavorable effects on carcass fat color or the aroma of cooked fat samples caused by levels of whole cottonseed in the ration.

Introduction

Carcass specifications in the locker plant meat industry are rather precise. Preferred carcasses are from young animals with high cutability and acceptable eating qualities. Most plants require carcasses weighing less than 500 pounds (lbs.), with most orders being for sides from 200 to 300 pounds. These specifications favor cattle, particularly heifers, fed shorter lengths of time. Carcass requirements also favor feedlots which can sort and slaughter animals at short intervals for maximum efficiency.

Whole cottonseed is often an inexpensive source of high quality protein and energy. Recent prices for whole cottonseed have made this product very attractive for use in fattening rations. The amount of whole cottonseed which can be fed in finishing rations without causing digestive disturbances to the animals or undesirable effects on their carcasses is not well documented.

It was reported (3) that cattle fed 50 percent cottonseed (12 lbs. per head per day for 800-pound cattle) in a finishing ration scoured after 68 days. With a reduction to 40 percent the cattle showed no ill effects for the remainder of the 112-day feeding trial. In this same study cattle fed 25 percent cottonseed consumed an average of 5.63 lbs. of seed per head daily, and made the highest gain on the least amount of feed per pound of gain. In early feedlot trials (2) cottonseed fed at an average daily amount of 3.63 lbs. (average 630-pound yearlings) seemed to reduce voluntary intake. There was evidence that increases in the amount of seed were made too rapidly. Results of these studies (1,2) indicated whole cottonseed was cost effective as a protein source and useful as a replacement for a portion of the grain.

In all-concentrte rations (4), cottonseed as a source of protein produced the greatest gain and required the least amount of feed per pound of gain of all protein sources tested. But information on the effect of high cottonseed rations on carcass characteristics is limited.

The objective of this study was to determine the performance of cattle fed diets containing various levels of whole cottonseed, and the effect these levels had on certain carcass characteristics.

Procedures

Twenty-two yearling steers and heifers were used in this study. These were progeny of Brangus bulls and Angus x Hereford cows. The yearlings encompassed the full range of the USDA medium framed feeder cattle grade. They all possessed USDA No. 1 feeder cattle grade thickness. The yearlings were stratified by sex and randomly assigned to one of three treatment groups. The treatments consisted of diets containing 20 percent whole cottonseed and 80 percent ground milo, 35 percent whole cottonseed and 65 percent ground milo, and 50 percent whole cottonseed and 50 percent ground milo. All treatment groups were provided low quality sudan hay and salt. Sudan hay was in large round bales (approximately 1100 pounds per bale) and was fed free choice from a feeding frame. Animals had consumed a limited amount of whole cottonseed during the wintering maintenance period prior to this trial. The cattle were individually weighed at the beginning and at 2-week intervals throughout the trial.

Cattle were slaughtered at 2-week intervals at the earliest date their carcasses would be USDA Yield Grade 2 or better and have acceptable eating quality (USDA good). This was determined by subjective evaluation. Carcasses of this type often are referred to in the meat industry as "no-rolls." These specifications fit the locker beef trade for which these cattle were fed.

The cattle were slaughtered at a local custom kill plant over a 6-week period. Weight, quality and yield grade factors were recorded for each carcass. Fat samples were frozen for later analysis of fat off-odor. The data were studied using analysis of variance with samples of unequal size.

Results and Discussion

Table 1 shows means for cattle performance and feed consumption. The average daily gains of steers and heifers were similar. There were no significant differences between steers and heifers within treatment groups, nor differences among treatment groups when sexes were combined. The feed utilization data shows an improvement in feed conversion as the percentage of whole cottonseed in the ration increased. This resulted in a lower cost per pound of gain for the concentrate portion of the ration at the prevailing feed prices. Each treatment group was given approximately the same amount of low quality sudan hay. However, due to considerable wastage from the round bales, no accurate

TABLE 1. PERFORMANCE OF CATTLE FED THREE LEVELS OF WHOLE COTTONSEED

Treatment:[1]	Initial weight	Final weight	Average Days on feed	Average gain per head (lbs.)	Average daily gain (lbs.)	Concentrate Feed: Lbs. per animal	Concentrate Feed: Lbs. per lb. gain	Concentrate Feed: Cost per lb. gain[2]
Group 1								
Steers (4)	658	912	108	254	2.35			
Heifers (4)	610	798	81.5	188	2.31			
Combined	634	855	95	221	2.33	1577	7.14	0.35
Group 2								
Steers (3)	672	919	104.5	247	2.36			
Heifers (4)	583	768	77	185	2.40			
Combined	621	833	89	212	2.38	1497	7.06	0.33
Group 3								
Steers (3)	693	952	107	259	2.42			
Heifers (4)	592	784	81.5	192	2.36			
Combined	635	856	93	221	2.38	1427	6.46	0.29

[1]Group 1 — 20 percent whole cottonseed and 80 percent ground milo
Group 2 — 35 percent whole cottonseed and 65 percent ground milo
Group 3 — 50 percent whole cottonseed and 50 percent ground milo
All groups had free choice low quality sudan hay.
[2]Ingredient costs: cottonseed — $75 per ton (Fall 1982)
milo — $5.25 per cwt (Spring 1983)
no other charges included

hay consumption figures can be provided.

The same comparisons are shown in Table 2 for carcass traits. Again, there were no differences among feed treatment groups. With the exception of carcass weight, there were no significant differences between steers and heifers within treatment groups. All carcasses, regardless of sex, brought the same price of $1.08 per pound.

These data indicate that cattle perform equally well and carcass traits are similar on rations varying from 20 percent to 50 percent whole cottonseed. There were no apparent digestive disturbances in the cattle receiving 50 percent cottonseed in their rations. However, individuals in group 3 did have looser fecal material for the first 10 to 14 days of the trial. The condition was not considered serious enough to reduce the amount of seed in the ration.

High levels of whole cottonseed produced no unfavorable effects on carcass fat color or aroma of cooked fat.

Table 3 compares performance and carcass traits of steers and heifers of uniform age and breeding. Carcasses of heifers showed slightly higher values for fat measures and indicators of quality than carcasses of steers. In this study steers and heifers had similar performance and carcass characteristics when fed for an average of 107 and 80 days, respectively.

TABLE 2. CARCASS CHARACTERISTICS FROM CATTLE FED THREE LEVELS OF WHOLE COTTONSEED

Treatment:[1]	Hot carcass weight,lb.	Dressing percent	Fat thickness, in.	Ribeye area sq in/cwt	Kidney & pelvic fat, %	USDA grade yield	Marbling score	USDA quality grade[2]	Fat color[3]	Fat off-odor[4]
Group 1										
Steers (4)	511	58.5	.20	1.9	1.25	2.15	SL^{70}	$Good^{70}$	3.75	5.6
Heifers (4)	445	58.4	.26	2.0	1.50	2.16	SL^{80}	$Good^{80}$	3.75	5.9
Combined	478	58.4	.23	1.9	1.37	2.15	SL^{75}	$Good^{75}$	3.75	5.8
Group 2										
Steers (3)	504	57.0	.17	1.8	1.5	2.17	SL^{50}	$Good^{50}$	3.0	5.9
Heifers (4)	416	56.4	.30	2.0	1.6	2.46	SL^{60}	$Good^{60}$	3.0	6.7
Combined	454	56.7	.24	1.9	1.6	2.34	SL^{55}	$Good^{55}$	3.0	6.4
Group 3										
Steers (3)	519	56.8	.19	1.8	1.3	2.26	SL^{50}	$Good^{50}$	3.0	5.9
Heifers (4)	424	56.3	.27	2.0	1.6	2.36	SL^{80}	$Good^{80}$	3.0	5.9
Combined	465	56.5	.24	1.9	1.5	2.32	SL^{70}	$Good^{70}$	3.0	5.9

[1]Group 1 — 20 percent whole cottonseed and 80 percent ground milo
Group 2 — 35 percent whole cottonseed and 65 percent ground milo
Group 3 — 50 percent whole cottonseed and 50 percent ground milo
All groups had free choice low quality sudan hay
[2]All carcasses possessed A- maturity (yearlings were 14 to 18 months of age at slaughter)
[3]Fat color was scored on a 10-point scale (1=white, 10=extremely yellow)
[4]Fat off-odor rating was based on an 8-point scale (8=extremely weak, 1=extremely strong)

TABLE 3. COMPARISON OF PERFORMANCE AND CARCASS CHARACTERISTICS OF STEERS AND HEIFERS

	Steers (10)	Heifers (12)
Initial weight, lb	673	595
Final weight, lb	926	783
Average days on feed	107	80
Average gain per head, lb	253	188
Average daily gain, lb	2.36	2.35
Hot carcass weight, lb	511	428
Dressing percent	57.6	57
Fat thickness, in	.19	.28
Kidney & pelvic fat, %	1.35	1.58
USDA yield grade	2.19	2.32
Marbling score	SL^{60}	SL^{75}
USDA quality grade	$Good^{60}$	$Good^{75}$
Fat color score[1]	3.3	3.1
Fat off-odor score[2]	5.8	6.2

[1]Fat color was scored on a 10-point scale (1=white, 10=extremely yellow)
[2]Fat off-odor rating was based on an 8-point scale (8=extremely weak, 1=extremely strong)

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PR-4237

Mineral and Energy Balance in Rats Fed Different Levels of Phosphorus

L. W. GREENE, F. M. BYERS, G. T. SCHELLING, AND D. J. KIRK

Summary

Eighteen mature female Sprague-Dawley rats were used in a randomized block design to evaluate calcium (Ca), phosphorus (P), nitrogen (N) and energy utilization in phosphorus-deficient animals. All animals were fed a purified diet containing .05 or .44 percent phosphorus in the following three treatment combinations: a) phosphorus adequate (.44 percent, ad libitum intake; b) phosphorus deficient (.05 percent), ad libitum intake; and c) phosphorus adequate, pair-fed with deficient diet. Apparent phosphorus absorption was decreased ($P < .05$) from 58.8 to 27.8 percent when animals were fed the phosphorus-deficient diet. Animals fed .44 percent phosphorus retained more phosphorus than those fed .05 percent phosphorus (29.8 vs. .9 milligrams per day (mg/d)). Serum phosphorus was 51 percent lower when animals were fed the low phosphorus diet. Apparent calcium absorption and retention and serum calcium were greater ($P < .05$) when rats were fed .05 vs. .44 percent phosphorus. Nitrogen balance and biological value were not affected by the level of dietary phosphorus. The level of heat production and fecal, digestible and retained energy in rats appeared to be a direct reflection of energy intake. These data suggest that animals consuming phosphorus-deficient diets have altered calcium and phosphorus utilization, and the change in energy retention appears to be primarily a function of digestible energy.

Introduction

Phosphorus is a component of many vital compounds in the body, and is involved in virtually every metabolic event. This element is important in the form of adenosine triphosphate (ATP) and other energy-carrying compounds.

Phosphorus deficiency is recognized as a cause of several systemic disorders, and is widely accepted as one of the major nutritional factors in limiting reproductive efficiency. Ovarian dysfunction and reduced fertility in females are symptoms of phosphorus deficiency. Although rebreeding efficiency decreases when females are phosphorus-deficient, the precise physiological role of phosphorus in reproduction has not been identified. However, it may be related to a complicated phosphorus deficiency involving protein and energy (1).

Henry et al. (2) have suggested that low dietary phosphorus depresses appetite and energy intake by decreasing the amount of energy-carrying compounds. Gartner et al. (3) indicated that a dietary phosphorus deficiency decreased the efficiency of energy utilization. Ozanne and co-workers (4) reported that increasing dietary phosphorus from .07 to .23 percent in sheep increased feed intake and weight gain. It is well documented that phosphorus-deficient cows are normally thin when entering the breeding season. Therefore, the reproductive inefficiency of phosphorus-deficient females could be indirectly associated with an energy deficiency. The objectives of this research were to determine the effect of phosphorus deficiency on energy utilization and mineral balance.

Materials and Methods

Eighteen, mature, Sprague-Dawley female rats were used in a randomized block design to evaluate calcium, phosphorus and energy utilization in phosphorus deficient rats. Animals were fed a purified diet containing two levels of phosphorus, .44 and .05 percent (Table 1), beginning at 45 days of age. Diets were formulated to contain the full phosphorus requirement and 10 percent of the requirement, respectively. Rats were fed the diets ad libitum and in a paired feeding arrangement to yield the following three treatments: a) phos-

TABLE 1. COMPOSITION OF DIETS FED TO RATS[a]

Ingredient, g/kg	Phosphorus adequate	Phosphorus deficient
Corn Starch	729.4	743.3
Egg White Spray, Dried	150.0	150.0
a — Cellulose	50.0	50.0
Corn Oil	26.0	26.0
Vitamin Mix[b]	10.0	10.0
Mineral Mix[c]	20.7	20.7
Meta-phosphoric Acid	13.9	--

[a]Dry matter basis.

[b]Teklad Vitamin Fortification Mix

[c]Mineral mix prepared with reagent grade minerals. SeO_2, 2.7 mg/kg; KI, 10.0 mg/kg; $Fe(NH_4)_2(SO_4)_2 \times 12H_2O$, 16.7 g/kg; K_2CO_3, 170 g/kg; $CaCO_3$, 675.4 g/kg; $ZnCl_2$, 1.3 g/kg; NaCl, 73.7 g/kg; $MnSO_4 \times H_2O$, 4.8 g/kg; $CuSO_4 \times 5H_2O$,1.1 g/kg; MgO,49.3 g/kg.

phorus adequate (.44 percent), ad libitum intake; b) phosphorus deficient (.05 percent), ad libitum intake; and c) phosphorus adequate (.44 percent), pair fed with b. Rats were fed their respective diets at 7:30 a.m. daily, and the previous day's consumption was recorded. Animals were maintained in stainless steel wire bottom cages in an environmentally controlled room at 25°C. They received 14 hours of light daily. The experimental period consisted of a 10-day total collection of feces and urine followed by a 24-hour indirect calorimetry period. Two milliliters of a 50:50 sulfuric acid:water solution were added to the urine collection containers daily. Following the fecal and urine collection period, rats were moved to 1-gallon calorimetry chambers for a 6-day period. Rats were maintained in calorimetry chambers for 24 hours then their oxygen consumption and carbon dioxide production was measured for 24 hours.

All feces were collected by animal and ground through a 40-mesh screen. Urine was collected and diluted to 500 ml with distilled-deionized water. Calcium and phosphorus contents were determined for wet digested feed, feces, and urine. A parr oxygen bomb calorimeter was used to determine gross energy content of feed, feces, and urine.

Results and Discussion

Phosphorus balance data are shown in Table 2. Rats fed the deficient phosphorus diet (.05 percent) consumed 4.9 mg phosphorus per day in comparison to the 65.3 and 43.4 mg phosphorus per day consumed by those fed .44 percent phosphorus. For rats on the deficient diet, phosphorus decreased ($P < .05$) from 27.3 to 3.5 mg per day and apparent absorption decreased ($P < .05$) from 38.1 to 1.4 mg per day. Animals fed .44 percent phosphorus excreted 65.3 mg per day and absorbed 43.4 mg per day. Apparent phosphorus availability was lower ($P < .05$) when the phosphorus-deficient diet was fed. The decrease in phosphorus availability probably reflected the contribution of endogenous fecal phosphorus excretion. All animals remained in a positive phosphorus balance during the collection period; however, rats fed the phosphorus-deficient diet retained less ($P < .05$) phosphorus than those fed .44 percent. There were no differences in phosphorus retention expressed as a percent of intake or absorbed phosphorus.

Calcium intake (Table 3) was similar for rats fed .44 percent and .05 percent phosphorus and ad libitum. Calcium intake was 50 percent lower for rats fed .44 percent phosphorus, restricted intake, than those fed ad libitum. Fecal calcium excretion was similar for all rats. Urinary calcium excretion increased 117 percent when rats were fed .05 percent phosphorus. Calcium retention was greater (mg/day) in rats fed .05 percent phosphorus as compared to those fed 44 percent phosphorus.

Serum calcium was 17.5 percent higher ($P < .05$) and phosphorus was 52 percent lower when rats were fed .05 percent phosphorus (Table 4).

Energy balance data are presented in Table 5. Fecal and digested energy values appear to be directly asso-

TABLE 2. PHOSPHORUS BALANCE IN RATS FED DIFFERENT LEVELS OF PHOSPHORUS AND ORGANIC MATTER

Feeding level	Ad libitum		Restricted
Phosphorus, %	.44	.05	.44
Intake, mg/day	65.3[a]	4.9[b]	43.4[c]
Excretion, mg/day			
Feces	27.3[a]	3.5[b]	20.8[a]
Urine	8.3	.5	5.5
Absorption			
mg/day	38.1[a]	1.4[b]	22.6[c]
% of intake	58.8[a]	27.8[b]	51.1[a]
Retention			
mg/day	29.8[a]	.9[b]	17.13[a]
% of intake	45.4	17.6	38.0
% of absorbed	77.2	63.0	72.0

[a,b,c]Means within the same line with different superscripts differ ($P < .05$).

TABLE 3. CALCIUM BALANCE IN RATS FED DIFFERENT LEVELS OF PHOSPHORUS AND ORGANIC MATTER

Feeding level	Ad libitum		Restricted
Phosphorus, %	.44	.05	.44
Ca intake, mg/d	63.2[a]	68.3[a]	42.0[b]
Ca excretion, mg/d			
Feces	46.0	31.0	36.3
Urine	17.2[a]	37.3[b]	5.7[a]
Ca absorption			
mg/d	1.7[ab]	15.6[a]	.61[b]
% of intake	15.6	21.7	5.08
Ca retention			
mg/d	27.0[a]	55.0[b]	12.6[a]
% of intake	24.2	34.0	11.0
% of absorbed	87.1	56.8	55.4

[a,b]Means within the same line with different superscripts differ ($P < .05$).

TABLE 4. SERUM CALCUM AND PHOSPHORUS IN RATS FED DIFFERENT LEVELS OF PHOSPHORUS AND ORGANIC MATTER

Feedling level	Ad libitum		Restricted
Phosphorus, %	.44	.05	.44
Calcium, mg/dl	9.7[a]	11.4[b]	10.2[a]
Phosphorus, mg/dl	7.3[a]	4.8[b]	7.6[a]

[a,b]Means within the same line with different superscripts differ ($P < .05$).

TABLE 5. ENERGY BALANCE IN RATS FED DIFFERENT LEVELS OF PHOSPHORUS AND ORGANIC MATTER

Feeding level	Ad libitum		Restricted
Phosphorus, %	.44	.05	.44
Intake, Kcal	65.2[a]	58.5[ab]	43.3[a]
Excretion			
Feces, Kcal	18.7[ab]	22.1[a]	14.8[b]
Urine, Kcal	9.2	.98	8.9
Digestible			
Kcal/day	46.4[a]	36.5[ab]	28.5[b]
% % of intake	71.0	61.8	65.4
Metabolizable			
Kcal/day	37.3[a]	26.7[b]	19.5[b]
% of intake	57.3[a]	45.5[ab]	44.2[b]
% of digestible	80.8[a]	73.7[ab]	67.3[b]
Heat Production, Kcal	41.0[a]	38.3[ab]	36.7[b]
Net Energy, Kcal	-3.8[a]	-11.6[ab]	-17.1[b]

[ab]Means within the same line with different superscripts differ ($P < .05$).

ciated with energy intake, although digestible energy, expressed as percent of intake, tended to be lower when rats were fed lower quantities of energy. Metabolizable energy was lowest in rats fed the lower quantities of energy. Expressed as a percentage of intake and digestible energy, metabolizable energy values decreased when animals were fed lower amounts of total and digestible energy. Heat production and energy retention were a direct function of energy intake.

These data suggest that the inefficiency in energy utilization of animals fed phosphorus-deficient diets is a direct reflection of feed and digestible energy intake. Furthermore, the reproductive inefficiency of phosphorus-deficient females could be an indirect response to a depressed energy metabolism.

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Marketing Options

Brief PR-4238

Future Alternatives for South Texas Cattle Feeding and Beef Marketing Systems

L. M. Schake, D. E. Farris, J. W. Savell, E. E. Davis, D. M. Stiffler, D. P. Hutcheson, and G. C. Smith

In 1982, cattle feeders in South Texas expressed concern for the future economic viability of their industry. Four survey instruments were used to determine the current status of the cattle feeding, cattle slaughter and beef merchandising industries in order to provide future alternatives for cattle feeders.

Lightweight heifers (initially 300 to 500 pounds) represented 65 percent of the cattle fed in South Texas. Costs of gain and feed conversion for lightweight heifers fed in South Texas were found to be competitive with feeding of larger heifers in the Texas Panhandle. However, traditionsl marketing structures were perceived to be shifting away from the use of lightweight carcass beef and more toward heavier beef, in particular, boxed beef.

Suggested alternatives formulated from these surveys for cattle feeders in South Texas were:

1. Feed heifers to heavier slaughter weights due to prospects (1983) of cheaper feed and the demand for carcasses that would cost-effectively fit into the boxed beef trade.
   a) Purchase heavier feeder heifers.
   b) Sort cattle at time of receiving by outcome potential (frame size, genetic potential, condition and weight). It is critical to identify heifers with ability to gain.
   c) Attempt to develop heifers with more growth potential for short intervals (30 to 50 days) before finishing.
   d) Purchase and feed some steers suitable for boxed beef trade to spread the risk.
   e) Emphasize improved feeding efficiency of all cattle.
2. Promote lightweight, grain-finished heifer beef. Key on uniformity, leanness and value (cost per serving) in merchandising.
   a) Target on mid- to low-income groups.
   b) Consider a market association to work with or without the packer, wholesaler or retailer (custom processing).
   c) Organize export trade to Mexico (key on tourist markets and plan beyond the current financial crises).
3. Anticipate higher feeder cattle prices due to lower feed grain prices for the next year.
   a) Explore the potential for backgrounding and backgrounding contracts with Panhandle feeders.
4. Forward contract for specific carcass grade and weight to assist with market outlets and reduce the risk of producing a carcass of lower demand. The price may be set by a pre-arranged formula tied to Texas Panhandle Choice steers.

PR-4239

Evaluation of Trading Techniques for Live Cattle Futures

D. M. Pluhar, C. E. Shafer, and T. L. Sporleder

Summary

Managing the price risk of cattle feeding can be attempted in a number of ways. One method is to hedge price risk by using the futures market. It has been said that technical trading techniques detect price trends. This study evaluates a controversial trading technique, first identified by Helmuth, in comparison with other hedging techniques, to provide cattle feeders with current information concerning price risk management.

Helmuth's live cattle futures trading technique (HTT) predicts that prices will drop when the futures price exceeds the projected monthly average of Corn Belt cattle feeders' costs plus a midwestern basis adjustment. Four versions of HTT generated "gross profits" in live cattle futures during the January 1978 to January 1981 period.[1] Restricting each version by simply eliminating trading in April futures contracts 90 days after the first of the placement month (October or November) resulted in gross profits in all three placement periods, i.e., the entire July 1974 to December 1982 time span. Between 54 and 64 percent (depending on the version) of the futures prices over that 8.5-year period reached the level where HTT was triggered. Trades were profitable, in terms of gross profit, from 92 to 100 percent of the time.

In spite of the potential for price risk management using the futures market, previously defined hedging strategies have shown a low probability of continued success. Strategies developed by Purcell and Riffe, Shafer et al., and Gorman et al. did not perform well after the time period from which they were developed. A successful hedging strategy must be continually

[1]Commission and interest costs have not been deducted from gross profits.

updated and revised to improve the probability of profit. Franzmann and Shields, by refining Merrill Lynch's 7- and 13-day moving average combination (the most consistent live cattle futures price indicator over the 1970-76 period), produced the highest average per trade profit over the 1975-79 period. Their strategy also yielded the highest profit over the 1975-82 period.

While certain moving average strategies have performed well over certain periods, there is no guarantee these strategies will be profitable hedging indicators for a later time period. How can cattle feeders have confidence in such devices? This study suggests that hedgers should be aware of and evaluate Helmuth's trading technique as a useful addition to technical trading indicators.

Introduction

Price risk has been a problem facing cattle feeders for decades. As a result of bolatility in the feed grain sector, the cyclical liquidation of cattle and cyclical hog prices, variability in cash cattle prices has increased dramatically since 1972 (9). Thus, understanding the futures market and hedging strategies can help cattle feeders improve their risk management ability.

Several studies have reported success with cattle feeding hedging strategies using various combinations of moving averages and filter devices. Purcell and Riffe found a 4-day weighted, 5-day, and 15-day moving average combination successfully signaled short hedges for fed cattle during the feeding period from 1965 to 1977. Shafer and colleagues evaluated short cattle hedges triggered by a 10- and 15-day moving average combination over both a 2-month planning period and the feeding period, accompanied by long corn and feeder cattle hedges (set during the 2-month planning period), by moving average combinations and filter devices. Although not tested as a hedging strategy, Franzmann and Shields showed a 2-day weighted, 7-day, and 13-day moving average combination (plus a $.13/hundredweight (cwt) penetration rule) yielded the highest average profit per trade, and fewest trades, of all live cattle futures trading techniques tested over the 1975-79 period.

Finally, Gorman and colleagues used 3- and 10-day moving averages to set and lift initial short hedges during the feed-outs based on $5 per hundredweight (cwt) objectives.

Studies using moving averages, such as those mentioned above, have at least two major limitations. The moving average strategies have little or no theoretical foundation and have not been tested beyond the period from which they were developed. Thus, it is not known why the moving average strategies work and whether they perform well beyond the period from which they are developed.

Previous studies suggest three important research objectives; ; (1) to evaluate Helmuth's trading technique (HTT) over out-of-sample periods; (2) to evaluate the performance of the four previously developed moving average strategies over the more recent 1975-82 period; and (3) to synthesize new hedging strategies for cattle feeding.

The Helmuth Controversy

Unlike the aforementioned moving average indicators, Helmuth's trading technique (HTT) has at least a modest theoretical foundation, since it defines a natural short hedging point. In the 1978-81 congressional study headed by Helmuth, simulated trading with HTT was successful each of 29 times that the futures price reached the basis of adjusted cost of feeding (14). Having isolated the signal, Helmuth used additional information to suggest that 32 large traders had made disproportionate profits using the technique.

Helmuth's reports spawned special investigations by the Commodity Futures Trading Commission, the National Cattlemen's Association, and Palme and Graham. These studies were primarily concerned with the allegation that 32 traders had acted in concert, rather than with the technique used (1,6,7). However, Palme and Graham offered three methodical criticisms of HTT: (1) use of a combination of unrevised and revised USDA data did not test whether the technique would work had it been executed solely with currently available data; (2) the basis adjustment was inappropriate; and (3) the test period was too brief.

Given the importance of HTT for cattle futures trading and the criticisms thereof, it was reevaluated using unrevised USDA reported breakeven prices, two sets of bases, and two closing rules over three time periods spanning July 1974 through December 1982. If the HTT consistently yielded significant trading profits under these alternatives, it could be considered useful as a short hedging tool.

Methods

Four alternatives determined from two basis adjustments and two closing rules were applied to unrevised breakeven prices in evaluating the HTT:

Method 1. 1968-78 Basis Adjustments, Day or Overnight Trades

Method 2. 1968-78 Basis Adjustments, Overnight Trades Required

Method 3. 1972-81 Basis Adjustments, Day or Overnight Trades

Method 4. 1972-81 Basis Adjustments, Overnight Trades Required

Data used were the unrevised breakeven selling prices per hundredweight required by Corn Belt cattle feeders to cover all costs (16, 17, 18), and the average 1968-78 Interior Iowa-Southern Minnesota and 1972-81 Interior Iowa basis adjustments (8,11). HTT established a short position once the daily high live cattle futures price equalled or exceeded the signal value, consisting of the unrevised USDA reported Corn Belt cost of feeding per hundredweight, plus a basis adjustment (4). The short position was offset when the daily closing price dropped below the signal level. The closing rule used by Helmuth (Methods 1 and 3) allowed a trade to be offset whenever the daily close declined below the signal level, i.e., a day or overnight trade. Alternatively, the closing rule associated with

Methods 2 and 4 required at least overnight presence in the market. Each of the four versions were simulated over the 8.5-year period from July 1974 through December 1982, or 102 cattle placement months.[2] This period encompasses the January 1978-January 1981 period used by Helmuth, as well as considerable time spans before and after.

Previous hedging strategies, as well as those synthesized herein, were evaluated for 96 feed-outs from 1975 to 1982 with a pen of 200 cattle marketed each month. For each of the 96 marketings, a pen of 630-pound feeder steers was purchased and placed on feed 168 days prior to the marketing. Feed sufficient to meet nutritional requirements to feed out the pen was purchased at time of placement. Cash prices for feeder cattle, fat cattle, and all feed ingredients, as well as all other costs, were those reported in the Great Plains Custom Cattle Feeding Table (16, 17, 18).

Live cattle and feeder cattle futures prices from the Chicago Merchantile Exchange (CME), and corn futures prices on the Chicago Board of Trade (CBT), were used in the futures market transactions. Standard commissions and interest expenses were included in hedging fat cattle, feeder cattle, and corn. Hedges were placed in futures contracts nearest to the delivery month.

Eight marketing strategies were evaluated over the 1975-82 period:

1. Cash Market Operation
2. Purcell and Riffe Hedging Strategy
3. Shafer et al. Integrated Hedging Strategy
4. Franzmann and Shields Hedging Strategy
5. Gorman et al. Hedging Strategy
6. Helmuth Hedging Strategy
7. Synthesized 32-Week Integrated Hedging Strategy
8. Synthesized 50-Week Integrated Hedging Strategy

The naive Cash Market Operation used for the comparison is self-explanatory. Strategies 2 through 5, based on moving averages and filter devices, are from the studies discussed earlier. Strategy 6 is Helmuth's trading technique using the 1968-78 basis adjustments and the closing rule allowing day or overnight trades. Strategy 7 was designed to protect against (1) input cost increases over a 2-month planning period, and (2) output price decines over that same 2-month period plus a 24-week feeding period. Feeder cattle and corn hedging strategies, as discussed in the Shafer et al. Integrated Hedging Strategy, were used to protect against input price increases. The Franzmann-shields Hedging Strategy and Helmuth's trading technique were used together to protect against a decline in fed cattle prices. Strategy 8 is equivalent to Strategy 7, with the planning period for both inputs and fed cattle lengthened to 6 months.

Mean-variance analysis for both (1) average per head return over only feed and feeder costs, and (2) average per head profit above all costs, was used to gauge the performance of the various strategies. The performance of each hedging strategy was tested against the cash marketing alternative. The evaluation assumes that hedging strategies which increase per head profitability without jointly increasing the variance, or which decrease the variance without decreasing the mean per head profitability, are superior.

Results

Helmuth's Trading Technique

HTT provided positive mean gross profits for all four methods, but only during the January 1978 to January 1981 time span used by Helmuth (8). Only three to five of the 65 trades signaled in each method were losers, but these losses were sufficient to provide negative mean gross profits during the periods before and after the January 1978 through January 1981 period. Higher average gross profits during the Helmuth study period may have been because the cattle cycle was in the deceleration stage in 1978 and the turn-around stage in 1979-81 (15).

Each of the three to five losing trades generated by Helmuth's technique were associated with April contract trades opened after 90 days. It is theorized that the losing trades occurred in a consistent pattern due to the seasonality of live cattle prices, since price usually moves upward from January through April. Adding the restriction that trading could not occur in the April futures contract 90 days after the first of the placement month (October or November) eliminated all losing trades and yielded positive mean gross profits for each method in each period (Table 1). Thus, Helmuth's trading technique may be used as a hedging tool.

Previous Strategies

The Cash Market Operation yielded an average per head return above feed and feeder costs of $25.52 (profit above all costs of $-37.33) for the 96 pens over the 8-year period. The cattle feeder would have had a substantial number of unprofitable pens and extended periods of negative feeding margins (Figure 1). Only one of the four previously developed hedging strategies proved superior to the cash marketing alternative over the entire 8-year period (Table 2). The Franzmann and Shields Hedging Strategy both increased per head profitability by $7.35 and reduced profitability variation by 18 to 20 percent. Profitability was increased or the variance was reduced in each of the 8 years analyzed.

The Purcell and Riffe Hedging Strategy reduced profit variability, but per head profitability was $4.19 less than the Cash Market Operation over the 1975-82 period. With the Shafer et al. Integrated Hedging Strategy, per head profitability was $4.15 less than the cash marketing alterntive and the variance was greater. Long hedges for feeder cattle and corn added small amounts to per head profitability. The Gorman et al.

[2] The monthly average USDA breakeven Corn Belt selling prices used in Helmuth's trading technique are distinguishable by cattle placement months. To stay current between the quarterly issues of the *Livestock and Poultry Outlook and Situation,* a trader would need to substitute 20-day moving averages of current cash feeder cattle and corn prices available in the *Wall Street Journal* in calculating the most recently published placement month's breakeven selling price. The one transaction allowed per placement month had to occur between the first trading day of the placement month and the last trading day before the delivery month.

TABLE 1. COMPARISON OF THE MEAN-VARIANCE RESULTS FROM FOUR METHODS BASED ON THE RESTRICTED HELMUTH TECHNIQUE USING THE UNREVISED PER HUNDREDWEIGHT BREAKEVEN SELLING PRICES, 102 PLACEMENT PERIODS, JULY 1974 TO DECEMBER 1982

Placement Months	Criterion	Measure	Trading results			
			Method 1	Method 2	Method 3	Method 4
Jul., 1974 - Dec., 1977	Trades	Number[a]	22(22,0)/42	22(22,0)/42	22(22,0)/42	22(22,0)/42
	Gross Profit[b]	Mean	145.09****	211.27****	118.00****	176.55****
		S.D.[c]	119.10	169.69	86.88	132.35
		Range	(4.00,316.00)	(8.00,708.00)	(4.00,296.00)	(4.00,564.00)
	Days Traded	Mean	3.27	5.23	3.77	5.59
		S.D.[c]	3.69	6.00	5.84	6.70
		Range	(1,16)	(2,27)	(1,25)	(2,25)
Jan., 1978- Jan., 1981	Trades	Number[a]	32(32,0)/37	32(32,0)/37	32(32,0)/37	32(32,0)/37
	Gross Profit[b]	Mean	289.13****	337.25****	292.88****	342.38****
		S.D.[c]	265.59	243.79	276.49	283.81
		Range	(12.00,1012.00)	(32.00,1012.00)	(28.00,1148.00)	(20.00,1148.00)
	Days Traded	Mean	2.09	2.78	2.03	2.91
		S.D.[c]	1.55	1.26	1.58	1.51
		Range	(1,7)	(2,7)	(1,7)	(2,7)
Feb., 1981- Dec., 1982	Trades	Number[a]	5(5,0)/23	5(5,0)/23	5(5,0)/23	5(5,0)/23
	Gross Profit[b]	Mean	157.60**	196.00**	94.40**	147.20*
		S.D.[c]	122.30	119.53	46.70	122.45
		Range	(16.00,256.00)	(16.00,296.00)	40.00, 140.00)	40.00,320.00)
	Days Traded	Mean	2.00	2.60	1.20	3.20
		S.D.[c]	1.73	1.34	.45	1.30
		Range	(1,5)	(2,5)	(1,2)	(2,5)
Jul., 1974- Dec., 1982	Trades	Number[a]	59(59,0)/102	59(59,0)/102	59(59,0)/102	59(59,0)/102
	Gross Profit[b]	Mean	224.27****	278.31****	210.85****	264.00****
		S.D.[c]	221.25	217.67	227.81	240.61
		Range	(4.00,1012.00)	(8.00,1012.00)	(4.00,1148.00)	(4.00,1148.00)
	Days Traded	Mean	2.53	3.68	2.63	3.93
		S.D.[c]	2.60	3.93	3.81	4.39
		Range	(1,16)	(2,27)	(1,25)	(2,25)

[a] Actual number of trades that were triggered. Numbers in parentheses indicate the number of trades producing positive and negative gross profits, respectively. / Potential number of trades that could have been triggered.

[b] Gross profit is on a dollars per trade basis. Mean gross profit level of significance indicated by *=10%, **=5%, ***=1%, ****=.1%.

[c] Standard Deviation.

Hedging Strategy had minor impact on cattle feeding profitability. Only six hedges were triggered over the 8-year period, due to the high profit targets. Three of those were unprofitable. Thus, three of the four previously successful hedging strategies did not fare well when tested beyond the time spans from which they were developed.

New Strategies

Hedging strategies based on previously successful strategies and HTT proved more profitable than the cash marketing alternative (Table 2). The synthesized 50-Week Integrated Hedging Strategy (combining Strategies 3, 4, and 6) produced a $16.09 mean per head profitability over cash marketing, highest of all strategies evaluated for this period. Profitability was enhanced in 5 of the 8 years studied, and the variance was decreased in 4 years. However, only 51 percent of the 606 hedges triggered over 1975-82 were profitable.

The Synthesized 32-Week Integrated Hedging Strategy was $11.50 more profitable per head than was the Cash Market Operation. Profitability variance was 12 to 13 percent lower than that of cash marketing. Profitability increased in 6 years, whereas the variance decreased in 4 years. In addition, 56 percent of the 344 trades triggered were profitable.

The Helmuth Hedging Strategy triggered 61 hedges, of which 80 percent were profitable. Profitabiity was enhanced in 6 years and the variance was decreased in 4 years. Mean per head profitability exceeded that of the Cash Market Operation by only $1.50.

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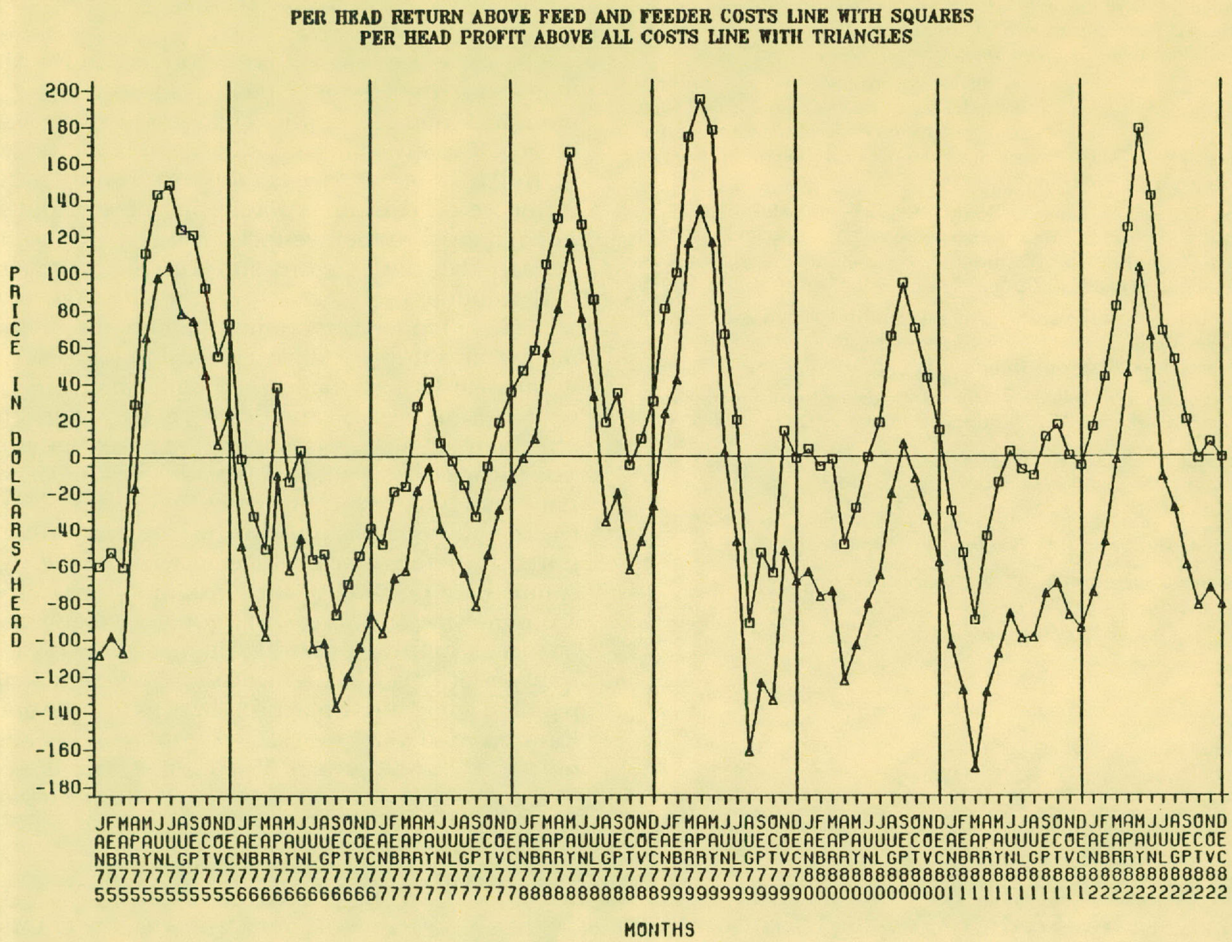

Figure 1. Cattle feeding profitability from cash market operation (1975-82).

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TABLE 2. OVERALL EIGHT-YEAR COMPARISON OF THE MEAN-VARIANCE RESULTS AMONG EIGHT MARKETING STRATEGIES, 96 PENS, TEXAS HIGH PLAINS, 1975-82

	Return Per Head Above Feed and Feeder Costs				Profit Per Head Above All Costs			
Strategy	Mean	Standard Deviation	C.V.[a]	Range	Mean	Standard Deviation	C.V.[a]	Range
1. Cash Marketing Operation	$25.52	$67.41	264.12	($-91.24,$194.41)	$-37.33	$70.35	-188.46	($-169.91,$134.32)
2. Purcell and Riffe Hedging	21.33	60.86	285.34	(-93.52,183.18)	-41.52	64.62	-155.64	(-173.99,132.60)
3. Shafer et al. Integrated Hedging	21.37	73.48	343.85	(-123.29,207.78)	-41.48	76.83	-185.21	(-203.65,148.75)
4. Franzmann and Shields Hedging	32.87	55.37	168.42	(-77.77,178.25)	-29.98	56.11	-187.20	(-147.68,102.64)
5. Gorman et al. Hedging	25.79	68.12	264.12	(-91.24,200.46)	-37.06	71.29	-192.35	(-169.91,156.22)
6. Helmuth Hedging	27.02	67.08	248.27	(-87.99,206.46)	-35.83	69.78	-194.77	(-167.46,146.37)
7. Synthesized 32-Week Integrated Hedging	37.02	59.58	160.92	(-98.18,224.51)	-25.83	61.24	-237.10	(-178.55,148.90)
8. Synthesized 50-Week Integrated Hedging	41.61	63.79	153.31	(-140.76,269.49)	-21.24	68.54	-322.70	(-221.12,223.77)

[a]Coefficient of Variation = (Standard Deviation ÷ Mean) x 100.

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Brief PR-4240

Interregional Competition in the U.S. Cattle Feeding/Fed-Beef Economy

G. M. CLARY, R. A. DIETRICH, AND D. E. FARRIS

Summary

Cattle feeding and slaughtering firms in the Southern and Central Plains, especially in West Texas, West Oklahoma, Kansas and Nebraska, enjoy competitive advantages due to the proximity of feed grain and feeder cattle supplies, access to major fed beef markets, and the size of the feeding and slaughtering industries. Research indicates that feeders in the Southern and Central Plains and Corn Belt will continue to account for more than 75 percent of all cattle fed in the U.S.

Increased energy costs, which could result in less irrigation in the Southern and Central Plains states, would have little or no effect on the optimum location and levels of cattle feeding in the area. A 50 percent decline in feed grain production in West Texas and West Oklahoma would cause no change in the optimum location or level of cattle feeding in that region, based on 1980 regional competitive alignments and competitive factors. Nor would production be affected by decreases in feeder cattle supplies from Southeastern states, due to resource reallocation, shifts in farm enterprises, etc. This research suggests that the Southern Plains cattle feeding and slaughter industries will maintain their competitive position in the U.S. cattle feeding/fed-beef economy, with increased competition likely from the Central Plains and Western Corn Belt.

Introduction

The cattle feeding/fed-beef economy in the United States has undergone wide-spread structural, technological and economic changes during the last decade. Rapidly changing energy and labor costs, fluctuating livestock and feed grain prices, inflation and its influence on consumer purchasing power, and structural changes in the livestock-meat sector, make it imperative that cattle feeding and slaughter firms continually analyze such aspects of production as location and size of operation, source and levels of inputs, marketing strategies, and distribution patterns.

The cattle feeding/fed-beef industry likely will remain a high-risk, capital-intensive industry that is often slow in adjusting to changing economic conditions. Dietrich (3) showed that the Texas-Oklahoma Panhandle had a competitive advantage in cattle feeding and beef packing during the early 1970's. The purpose of this study was to determine the current competitive position of this area, and to examine the economic implications of regional changes in such factors as supplies of feed grain and feeder cattle, and transportation and slaughter costs. This study analyzed regional competitive positions by determining optimal location and size of cattle feeding and slaughter operations, and optimal distribution of feeder cattle, feed grains, fed slaughter cattle, and fed-beef in the U.S.

Experimental Procedure

This study used a multiproduct transshipment model of the U.S. cattle feeding and fed-beef economy to examine interregional economic relationships based on industry conditions in 1980. The basic coefficients and mathematical programming procedures used in this study were updates and modifications of the methodology developed by Dietrich (3) and are available in Clary (1). The Mathematical Programming System (MPS/360), which employs a linear programming technique, was used to distribute feeder cattle, feed grains, fed slaughter cattle, and fed-beef among 26 regions in the contiguous 48 states (Figure 1). so that total costs in the industry are minimized. Basic regional data depicting annual feedlot capacity, slaughter capacity, feed grain supplies, feeder cattle supplies, and fed-beef consumption for 1980 were developed from data published by the U.S. Department of Agriculture and the U.S. Department of Commerce (8,15,7,14,11,13,16,10,17,19,20). Regional transportation cost data were adapted from Dietrich (3) and updated with current highway and rail mileages (4). Regional slaughter costs were developed from U.S. Department of Labor Statistics (21). Details concerning methodology and data estimating techniques developed for this study are available in Clary, Dietrich and Farris (2).

Six scenarios were designed to provide insights and guidelines for decision making in the cattle feeding, cattle slaughtering and related industries. The base model was designed to depict the 1980 cattle feeding/fed-beef sector with respect to regional feeding and slaughter levels, industry costs, regional levels and

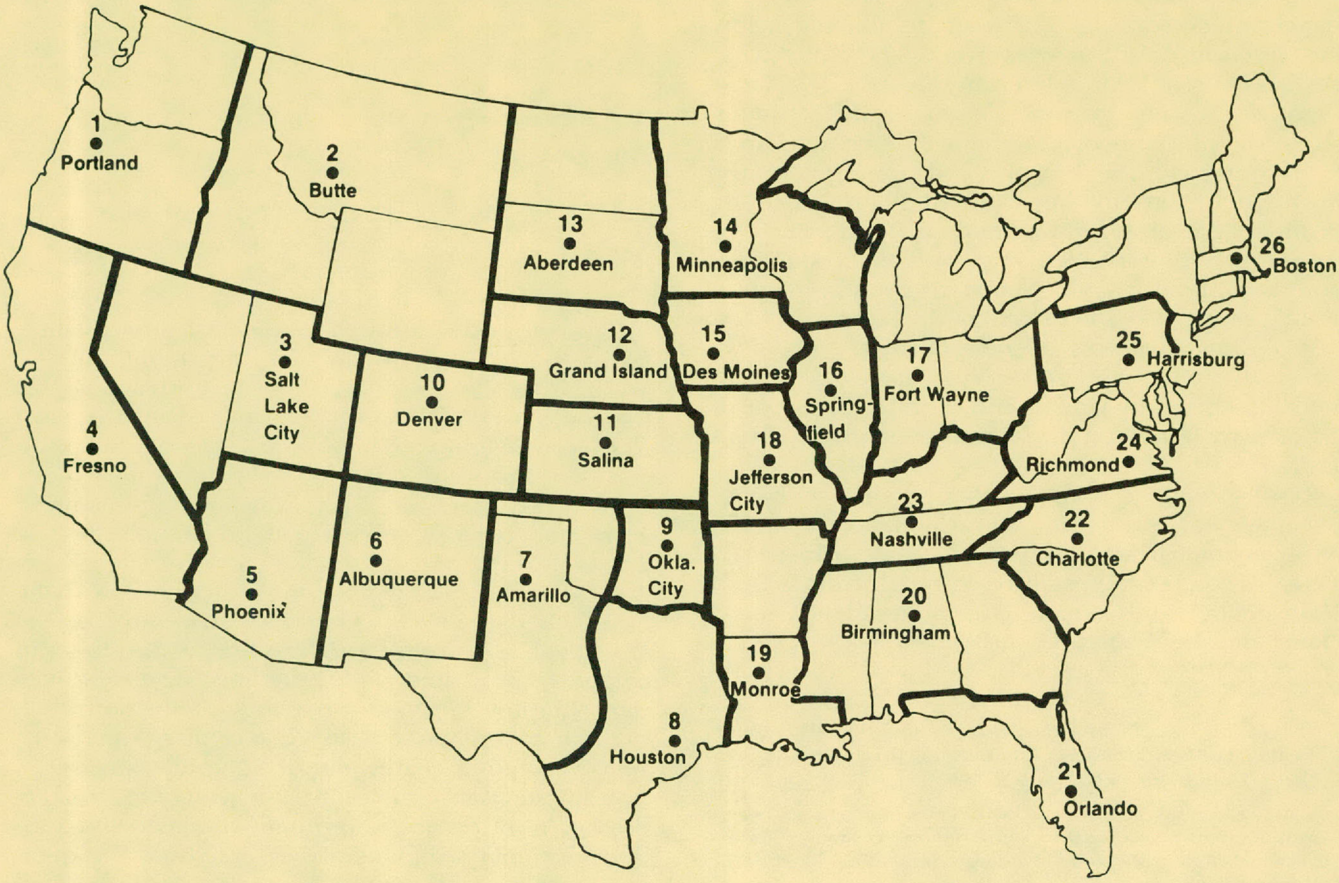

Figure 1. Regional demarcation and regional shipping and receiving points.

sources of supplies, and fed-beef consumption. Additional scenarios were designed to measure the impact of: (1) a declining water table in the Central and Southern High Plains on projected feed grain supplies; (2) an assumed 50-percent decline in Texas' feed grain production; (3) an assumed 30-percent decrease in feeder cattle supplies from the Southern States; (4) increases in regional variable slaughter costs of 50 percent; and (5) increases in regional variable slaughter and transportation costs of 50 percent.

Results and Discussion

The 1980 Base Model revealed that cattle feeding and slaughter firms in the Southern and Central Plains and the Corn Belt enjoy considerable competitive advantage over other regions, and that they would continue to account for more than 75 percent of all cattle fed in the U.S. However, West Texas and West Oklahoma have been importing increasing volumes of feed grain from regions to the North. The 1980 Base Model also revealed that slaughter would generally remain production oriented, as slaughter firms are able to minimize cattle acquisition costs by locating near large sources of fed slaughter cattle.

Fed-beef distribution costs were minimized when fed-beef was distributed to the West from plants in Colorado, Montana, Idaho, Wyoming and the Southwest. Fed-beef markets in the East relied primarily on plants in the Central Plains, the Corn Belt, and the Southern Plains. West Texas and West Oklahoma were the only regions shipping fed beef both east and west.

Projected regional feed grain supplies to 1990, considering changing irrigation practices due to declining water tables and energy costs, did not reduce the current levels of cattle feeding in West Texas and West Oklahoma (Table 1). Further, assumptions of a

TABLE 1. FED CATTLE MARKETED AS A PERCENT OF THE 23-STATE TOTAL CATTLE ON FEED, SELECTED FEEDING AREAS, 1980-90

Region	1980[1] (Actual)	1980[2] (Estimated)	1990[2] (Estimated)
		Percent	
Southern Plains[3]	22.2	26.6	26.6
Central Plains[4]	37.9	37.1	38.4
Corn Belt[5]	18.7	18.0	17.9
Western[6]	12.5	8.2	5.6
Other States	8.7	10.1	11.5
TOTAL	100.00	100.00	100.0

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[3] West Texas, West Oklahoma and New Mexico.

[4] Kansas, Nebraska and Colorado.

[5] Iowa, Missouri, Illinois, Indiana and Ohio.

[6] Arizona, California, Idaho, Oregon and Washington.

50-percent decrease in feed grain production below 1980 levels in West Texas and West Oklahoma did not alter the current feeding levels in this area. If the latter hypothetical scenario were to occur, total costs in the cattle feeding/fed-beef economy would be minimized by shipping additional surplus feed grain from nearby Northern regions to the Southern Plains. If future feeding cattle supplies were to decrease 30 percent in the South, feedlots in West Texas and West Oklahoma, Colorado, Kansas and Nebraska would maintain feeding levels near 100 percent at the expense of Corn Belt feedlots. Increases in transportation costs of 50 percent or more, while other costs remained at base model levels, would tend to shift cattle feeding towards the primary feed grain production areas, given current feeding practices.

Results suggest that the Southern Plains area has an advantage in cattle feeding, in cattle slaughter, and in shipment of fed beef both east and west. However, increased competition is likely, especially from Central Plains feedlots and from slaughter plants in the Central Plains and the Western Corn Belt.

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PR-4241

A Computerized Decision Aid for Range Cow-Calf Enterprises

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Summary

Cattlemen may use microcomputers to improve their business management practices, depending on the availability of appropriate software (instructions for the computer). Computers can be used in two main ways in managing a ranch — for keeping accounting and performance records, and for helping make decisions. This article deals with using computers to make economic decisions and evaluate production (2). The Texas Agricultural Extension Service and Texas Agricultural Experiment Station joined forces with the Soil Conservation Service to produce a group of Range Livestock Economic and Productive Evaluation computer programs. The programs are to evaluate range improvements and livestock production practices on an economic basis. The computer performs time-consuming mathematical computations necessary for such an evaluation. The programs generate breakeven prices, cost, profit, investment and productivity analyses. This article descrribes the capabilities of one of these programs, the Cow-Calf Economic and Production Evaluation program.

Introduction

The objective of the Beef Cow-Calf program is to guide the user through data entry using values for his individual ranch. The program then completes the calculations and displays or prints useful information for making decisions about the ranching enterprise. Modifications can easily and quickly be made by the user, so that the computer gives "what if" type analyses. The information also can be stored for later use. Information for the program can be obtained from production records, a current balance sheet and income statement, the IRS depreciation schedule, and the farm income and expense schedule F.

This aid can facilitate the evaluation of different production, management, marketing and investment alternatives. It can be used to evaluate a specific production period or for forward planning. This program is designed to be combined with other livestock and forage production and range improvement enterprise budgets for a whole ranch analysis.

Data Inputs

Data inputs for the program are for a breeding cow unit (BCU). A BCU includes the breeding cow, her calf, a portion of a bull and horse, and a portion of a replacement heifer. Because a replacement heifer is not a producing unit, she is considered a supporting unit such as a bull. A heifer is classified as a replacement heifer from the time she is selected at weaning until the time she is placed with a bull for breeding, or until she is artificially inseminated (AI). When a replacement heifer enters the breeding program, she is considered a breeding cow because the costs of a bull or AI begin at the first breeding.

The user will need access to production and financial records of the ranch to answer the input questions required by the program (Table 1). The first section of questions deals with production coefficients including calf crop, death and replacement rates of cows and heifers, calving and weaning ages, number of bulls and horses used and useful life of bulls and horses.

The next section requires the payweights of the calves, cows, replacement heifers and bulls when sold, and the prices expected when sold (Table 2). Capital investment values are then entered for bulls, horses, replacement heifers, cows and purchased breeding cows. Animal unit equivalents for the cattle and horses also are required.

Production costs can then be entered on a per BCU basis or on a total herd basis, depending on the user's preference (Table 3). Production costs include marketing costs (including hauling and commission), hired labor and management costs, owner-operator management and labor return, veterinarian fees (non-breeding), veterinary drugs and supply costs, AI breeding costs (including semen cost), miscellaneous ranch cash overhead costs (such as phone, advertisement, etc.), and costs of vehicle and livestock equipment used for the cattle enterprise (investment, operating and maintenance, insurance, license, tax and depreciation). Up to six supplemental feeds may be entered. Information requested for each supplemental feed is feed name, amount and price, either on a per unit basis or on a total feed fed basis.

TABLE 1. PRODUCTION INPUTS

PRODUCTION COEFFICIENTS		
PERCENT CALF CROP:	(%)	90
REPLACEMENT RATE OF COWS & HEIFERS IN BREEDING HERD FOR AGE, DEATH LOSS, FERTILITY, ETC.	(%)	15
PORTION OF REPLACEMENT HEIFERS CULLED BEFORE BREEDING:	(%)	10
PORTION OF REPLACEMENT COWS THAT ARE PURCHASED:	(%)	50
DEATH RATE OF BREEDING COWS:	(%)	3
DEATH RATE OF REPLACEMENT HEIFERS BEFORE BREEDING:	(%)	2
AVERAGE AGE AT WEANING:	(MONTHS)	7.5
AVERAGE CALVING AGE OF REPLACEMENT HEIFERS:	(MONTHS)	25
NUMBER OF BREEDING COWS PER BULL:	(HEAD)	25
USEFUL LIFE OF BULL:	(YEAR)	5
NUMBER OF BREEDING COWS PER HORSE:	(HEAD)	150
USEFUL LIFE OF HORSE:	(YEAR)	10
PAYWEIGHT PRODUCTION COEFFICIENTS		
PAYWEIGHT OF STEER OR BULL WEANER CALVES:	(LB/HD)	500
PAYWEIGHT OF HEIFER WEANER CALVES:	(LB/HD)	475
PAYWEIGHT OF CULLED COWS:	(LB/HD)	900
PAYWEIGHT OF REPLACEMENT HEIFERS CULLED BEFORE BREEDING:	(LB/HD)	650
PAYWEIGHT OF CULLED BULLS:	(LB/HD)	1400

TABLE 2. PAYWEIGHT SELLING PRICE, CAPITAL INVESTMENT AND ANIMAL UNIT INPUTS

PAYWEIGHT SELLING PRICE		
PAYWEIGHT SELLING PRICE OF STEER & BULL WEANER CALVES:	($/CWT)	70
PAYWEIGHT SELLING PRICE OF HEIFER WEANER CALVES:	($/CWT)	65
PAYWEIGHT SELLING PRICE OF CULL COWS:	($/CWT)	45
PAYWEIGHT SELLING PRICE OF CULL REPLACEMENT HEIFERS:	($/CWT)	50
PAYWEIGHT SELLING PRICE OF CULL BULLS:	($/CWT)	48
HORSE SALVAGE VALUE:	($/HD)	400
THE DIFFERENCE BETWEEN THE PRICE OF BULL AND STEER AND HEIFER CALVES WILL BE THE PRICE DIFFERENTIAL USED IN THE BREAKEVEN ANALYSIS.		
CAPITAL INVESTMENT IN LIVESTOCK		
AVERAGE BULL INVESTMENT VALUE:	($/HD)	1200
AVERAGE HORSE INVESTMENT VALUE:	($/HD)	1000
REPLACEMENT HEIFERS ONE YEAR TO BREEDING AGE:	($/HD)	400
AVERAGE BREEDING COW VALUE:	($/HD)	650
COST OF PURCHASED BREEDING COW OR PAIR	($/HD)	650
WEIGHT OF PURCHASED BREEDING COW WITHOUT CALF:	(LB/HD)	950
ANIMAL UNIT EQUIVALENTS PER COW UNIT		
REPLACEMENT HEIFERS WEANING TO ONE YEAR:	(AU)	.5
REPLACEMENT HEIFERS ONE YEAR TO BREEDING AGE:	(AU)	.7
BREEDING COW AND CALF:	(AU)	1
BULL:	(AU)	1.1
HORSE:	(AU)	1.2

TABLE 3. PRODUCT COST INPUTS

PRODUCTION COSTS LIVESTOCK COSTS ON A PER UNIT BASIS		
MARKETING COSTS INCLUDING HAULING AND COMMISSION:	($/HD)	8
HIRED LABOR AND MANAGEMENT COSTS:	($/HD)	10
OWNER-OPERATOR MANAGEMENT AND LABOR RETURN:	($/HD)	10
VETERINARIAN FEES PAID (NON-BREEDING):	($/HD)	1
VETERINARY DRUGS AND SUPPLY COSTS:	($/HD)	5
AI BREEDING COSTS (INCLUDING SEMEN COST):	($/HD)	0
MISCELLANEOUS RANCH CASH OVERHEAD COSTS:	($/HD)	12
TOTAL INVESTMENT IN VEHICLE AND LIVESTOCK EQUIPMENT:	($/HD)	90
OPERATING AND MAINTENANCE COST FOR VEHICLE AND LIVESTOCK EQUIPMENT:	($/HD)	10
INSURANCE, LICENSE, AND TAX COST FOR VEHICLE AND LIVESTOCK EQUIPMENT:	($/HD)	2
ANNUAL DEPRECIATION OF VEHICLE & LIVESTOCK EQUIPMENT:	($/HD)	15
INTEREST RATE ON LIVESTOCK AND FORAGE EQUIPMENT, VEHICLE, AND LIVESTOCK INVESTMENT:	(%)	11

SUPPLEMENTAL FEED REQUIREMENT AND COSTS

SUPPLEMENT TYPE	UNITS	QUANTITY PER HEAD	PRICE/UNIT
RANGE CUBES	CWT	2	$10.00
SALT & MINERAL	LBS	15	$0.20

TOTAL LBS OF SUPPLEMENT PER COW UNIT: 215 LBS/BCU
TOTAL COST OF SUPPLEMENT PER COW UNIT: 23 $/BCU

Inputs for forage can be entered directly or retrieved from stored data from a separate Forage and Land Improvement Cost Calculator program (Table 4).

The other information required to complete the analysis is the number of breeding cow units in the herd if the output on a total herd basis is desired. After all of the input questions have been answered, the computer will perform the calculations and the outputs will be displayed and/or printed.

Outputs

The program generates a breakeven price, cost, profit, investment and productivity analyses. A summary of information for evaluating forage and land improvement investments also are generated per animal unit, and on a total herd basis, for livestock and forage.

The selling prices of calves necessary to cover variable costs and total costs are calculated (Table 5). This information is useful in selecting alternative marketing strategies.

The cost analysis breaks down the total costs into cash variable, cash fixed, total cash, non-cash fixed and total costs. Cash costs are important for short-term economic and financial planning (Table 5). Non-cash fixed costs (primarily land and capital returns) are of particular importance in a range cow-calf operation, since these costs are generally very high and not as easily recognized as out-of-pocket cash costs.

The profit analysis calculates several things. Gross income is the value of all sales from the cattle enterprise

TABLE 4. FORAGE INPUTS

FORAGE REQUIREMENTS AND COSTS PER BREEDING COW UNIT

NAME OF FORAGE TYPE #1:		RANGE
TOTAL ACRES GRAZED OF FORAGE TYPE #1 :	(AC)	10000
FORAGE ACRES PER ANIMAL UNIT:	(AC/AU)	15
CASH VARIABLE MAINTENANCE COST (HERB., FERT., ETC):	($/ACRE)	0.25
CASH FIXED COST (TAX, INS., CASH LEASE IF LEASING):	($/ACRE)	1
NON-CASH COST (INTEREST, ETC.):	($/ACRE)	0.6
DEPRECIATION: FORAGE MACHINERY & IMPROVEMENTS:	($/ACRE)	0.25
FORAGE MAINTENANCE MACHINERY AVERAGE INVESTMENT:	($/ACRE)	2.5
MARKET VALUE OF LAND, IMPROVEMENTS, WILDLIFE INVEST.:	($/ACRE)	400
OWNER-OPERATOR MANAGEMENT AND LABOR RETURN:	($/ACRE)	0.5
FIXED LAND COST OR RETURN: (OPPORTUNITY COST)	($/ACRE)	5

FORAGE REQUIREMENTS AND COSTS PER BREEDING COW UNIT

NAME OF FORAGE TYPE #2:		PASTI
TOTAL ACRES GRAZED OF FORAGE TYPE #2 :	(AC)	5000
FORAGE ACRES PER ANIMAL UNIT:	(AC/AU)	10
CASH VARIABLE MAINTENANCE COST (HERB.,FERT.,ETC):	($/ACRE)	1.1
CASH FIXED COST (TAX, INS., CASH LEASE IF LEASING):	($/ACRE)	0.6
NON-CASH COST (INTEREST, ETC.):	($/ACRE)	2.51
DEPRECIATION: FORAGE MACHINERY & IMPROVEMENTS:	($/ACRE)	2.51
FORAGE MAINTENANCE MACHINERY AVERAGE INVESTMENT:	($/ACRE)	5
MARKET VALUE OF LAND, IMPROVEMENTS, WILDLIFE INVEST.:	($/ACRE)	600
OWNER-OPERATOR MANAGEMENT AND LABOR RETURN:	($/ACRE)	0.95
FIXED LAND COST OR RETURN: (OPPORTUNITY COST)	($/ACRE)	5

FORAGE REQUIREMENTS

FORAGE TYPE	ACRES	% OF TOTAL ACRES	AU	AC/AU
1. RANGE	10000.00	66.66%	666.67	15.00
2. PASTI	5000.00	33.33%	500.00	10.00
TOTAL	15000.00	100.00%	1166.67	12.85 (AVE)

TABLE 5. BREAKEVEN PRICE, COST AND PROFIT ANALYSIS REPORTS

BREAKEVEN ANALYSIS

NECESSARY SELLING PRICE OF CALVES TO COVER COST OF FEED AND OTHER VARIABLE COSTS ADJUSTED FOR VALUE OF CULL COWS AND HEIFERS		
FOR HEIFER CALVES	($/CWT)	3.63
FOR STEER AND BULL CALVES	($/CWT)	8.63
NECESSARY SELLING PRICE OF CALVES TO COVER TOTAL COST PER COW UNIT ADJUSTED FOR VALUE OF CULL COWS AND HEIFERS (BREAKEVEN PRICE)		
FOR HEIFER CALVES	($/CWT)	58.44
FOR STEER AND BULL CALVES	($/CWT)	63.44

*** PRICE DIFFERENTIAL IS EQUAL TO PAYWEIGHT PRICE INPUT DIFFERENTIAL ***

COST ANALYSIS

CASH VARIABLE COSTS	($/BCU)	76.75
CASH FIXED COSTS	($/BCU)	14.6
TOTAL CASH COSTS	($/BCU)	91.35
NON-CASH FIXED COSTS	($/BCU)	204.04
TOTAL COSTS	($/BCU)	295.39

PROFIT ANALYSIS

GROSS INCOME	($/BCU)	321.54
NET CASH RETURN	($/BCU)	230.19
PROFIT	($/BCU)	26.15
PROFIT & RETURN TO OWNER-OPERATOR MANAGEMENT AND LABOR	($/BCU)	45.6
PROFIT & RETURN TO OWNER-OPERATOR MANAGEMENT, LABOR AND CAPITAL	($/BCU)	102.54
PROFIT & RETURN TO OWNER-OPERATOR MANAGEMENT LABOR, CAPITAL, LAND, IMPROVEMENTS,& WILDLIFE INVEST.	($/BCU)	175.24

(Table 5). Taking cash costs from the gross income gives the net cash return, which is the amount that can be used to meet debt payments and for reinvestment, savings and family living. Profit is gross income minus all costs of production, including returns to all resources used in production such as land, owner-operator management and labor, capital, etc. The profit analysis is also shown recalculated with land costs, owner-operator management and labor costs, and return to capital included. The last enterprise return value is for an owner-operator who is debt free and takes no return on his own labor and management. This would be the amount of income available for reinvestment, savings and family living.

The investment analysis shows the total capital invested per breeding cow unit (Table 6). The rate of return to this capital also is shown.

A productivity summary displays the beef produced and sales of beef per breeding cow unit (Table 6). The difference betwen these values reflects the death losses and the number of animals kept for replacements.

The next output section, composition of a breeding cow unit, shows the actual number of cattle and animal units associated with a BCU (Table 6). This report also can be viewed on a total herd basis for actual numbers of cattle in a herd described by the production coefficients, as compared to the actual ranch inventory.

The last sections of output information are for evaluating forage and land improvements on both an animal unit and a total herd basis (Tables 7 through 9).

Programs being developed are for other livestock species, wildlife enterprises and Rangeland Improve-

TABLE 6. INVESTMENT ANALYSIS, PRODUCTIVITY SUMMARY AND HERD COMPOSITION REPORTS

INVESTMENT ANALYSIS

TOTAL INVESTMENT	($/BCU)	7351.06
RETURN TO CAPITAL	($/BCU)	155.79
RATE OF RETURN	(%)	2.12

PRODUCTIVITY SUMMARY

WEANER CALF PRODUCTION	(LB/BCU)	438.75
CULL COW AND REPLACEMENT HEIFER PRODUCTION	(LB/BCU)	115.38
TOTAL BEEF PRODUCTION	(LB/BCU)	554.13
TOTAL BEEF SALES	(LB/BCU)	511.73

HERD COMPOSITION PER BREEDING COW UNIT

	HD/BCU	AU/BCU
BREEDING COW AND CALF	1.000	1.000
REPLACEMENT HEIFER WEANING TO ONE YEAR	0.084	0.016
REPLACEMENT HEIFER ONE YEAR TO BREEDING AGE	0.084	0.064
PURCHASED REPLACEMENT FEMALES	0.075	*
BULL	0.040	0.044
HORSE	0.007	0.008
TOTAL ANIMAL UNITS REQUIRED PER BREEDING COW UNIT (AU/BCU)		1.131

* PURCHASED FEMALE AU INCLUDED WITH BREEDING COW AND CALF AU

TABLE 7. LIVESTOCK AND FORAGE INVESTMENT REPORT ON AN ANIMAL UNIT BASIS

SUMMARY OF INFORMATION FOR EVALUATION OF FORAGE AND LAND IMPROVEMENTS INVESTMENT ON THE BASIS OF AN ANIMAL UNIT FOR LIVESTOCK

GROSS INCOME	($/AU)	284.18
CASH VARIABLE COSTS (HIRED LABOR, VET, ETC.)	($/AU)	40.66
CASH FIXED COSTS (INSURANCE, LICENSE, TAX, ETC.)	($/AU)	1.77
DEPRECIATION OF LIVESTOCK	($/AU)	6.52
DEPRECIATION OF VEHICLE AND LIVESTOCK EQUIPMENT	($/AU)	13.26
VEHICLE AND LIVESTOCK EQUIPMENT INVESTMENT	($/AU)	79.54
LIVESTOCK INVESTMENT	($/AU)	377.98
OWNER-OPERATOR MANAGEMENT AND LABOR RETURN	($/AU)	8.84

SUMMARY OF INFORMATION FOR EVALUATION OF FORAGE AND LAND IMPROVEMENTS INVESTMENT ON THE BASIS OF AN ANIMAL UNIT FOR FORAGE

FORAGE ACRES PER ANIMAL UNIT	(AC/AU)	12.85
CASH VARIABLE MAINTENANCE COSTS (HERB, FERT, ETC)	($/AU)	6.85
CASH FIXED COSTS (TAX,INS.,CASH LEASE IF LEASING)	($/AU)	11.14
NON-CASH COSTS (INTEREST, ETC.)	($/AU)	15.89
DEPRECIATION OF FORAGE MACHINERY AND IMPROVEMENTS	($/AU)	12.89
FORAGE MACHINERY INVESTMENT	($/AU)	42.83
MARKET VALUE OF LAND,IMPROVEMENTS,WILDLIFE INVEST	($/AU)	5996.67
OWNER-OPERATOR MANAGMENT AND LABOR RETURN	($/AU)	8.35
FIXED LAND COST OR RETURN (OPPORTUNITY COST)	($/AU)	64.25

TABLE 8. TOTAL HERD COMPOSITION REPORT

TOTAL HERD COMPOSITION

	TOTAL HEAD	TOTAL AU
BREEDING COW AND CALF	1000.00	1000.00
REPLACEMENT HEIFER WEANING TO ONE YEAR	84.00	15.75
REPLACEMENT HEIFER ONE YEAR TO BREEDING AGE	84.00	63.70
PURCHASED REPLACEMENT FEMALES	75.00	*
BULL	40.00	44.00
HORSE	6.67	8.00
TOTAL ANIMAL UNITS OF GRAZING REQUIRED TO SUPPORT 1000 BREEDING COW UNITS (AU)		1131.45

* PURCHASED FEMALE AU INCLUDED WITH BREEDING COW AND CALF AU

TABLE 9. LIVESTOCK AND FORAGE INVESTMENT REPORT ON A TOTAL NUMBER BASIS

SUMMARY OF INFORMATION FOR EVALUATION OF FORAGE AND LAND IMPROVEMENTS INVESTMENT ON A TOTAL BASIS FOR LIVESTOCK

GROSS INCOME	($)	321540
CASH VARIABLE COSTS (HIRED LABOR, VET, ETC.)	($)	46000
CASH FIXED COSTS (INSURANCE, LICENSE, TAX, ETC.)	($)	2000
DEPRECIATION OF LIVESTOCK	($)	7380.25
DEPRECIATION OF VEHICLE AND LIVESTOCK EQUIPMENT	($)	15000
VEHICLE AND LIVESTOCK EQUIPMENT INVESTMENT	($)	90000
LIVESTOCK INVESTMENT	($)	427665.63
OWNER-OPERATOR MANAGEMENT AND LABOR RETURN	($)	10000

SUMMARY OF INFORMATION FOR EVALUATION OF FORAGE AND LAND IMPROVEMENTS INVESTMENT ON A TOTAL BASIS FOR FORAGE

TOTAL ACRES OF FORAGE REQUIRED	(AC)	14539.13
CASH VARIABLE MAINTENANCE COSTS (HERB, FERT, ETC)	($)	7754.2
CASH FIXED COSTS (TAX,INS.,CASH LEASE IF LEASING)	($)	12600.58
NON-CASH COSTS (INTEREST, ETC.)	($)	17980.06
DEPRECIATION OF FORAGE MACHINERY AND IMPROVEMENTS	($)	14587.6
FORAGE MACHINERY INVESTMENT	($)	48463.78
MARKET VALUE OF LAND,IMPROVEMENTS,WILDLIFE INVEST	($)	6784928.5
OWNER-OPERATOR MANAGMENT AND LABOR RETURN	($)	9450.44
FIXED LAND COST OR RETURN (OPPORTUNITY COST)	($)	72695.66

ment and Forage Cost Analysis, so that an overall view of a ranch business can be evaluated. When used in the Whole Ranch Summary Program, this information helps compare economic returns between species, including cows, stocker cattle, deer, feeder lambs, sheep, angora and spanish goats. Long-term ranch planning easily can be facilitated by a computer.

The program is available throught he computer operations unit of the Texas Agricultural Extension Service.

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Reproductive Efficiency

Brief PR-4243

The Role of Ca++ in GnRH-Induced LH Release

J. P. KILE AND M. S. AMOSS, JR.

For the past decade scientists have known that GnRH from the hypothalamus induces the release of LH from the anterior pituitary gland, and that this action probably is mediated by the second messenger cAMP. There is increasing evidence that Ca++ is important in the release of LH. In vitro studies using dispersed pituitary cells from calves were designed to increase our understanding of the mechanism(s) which produce either pulsatile LH release or the ovulatory surge of LH, or both.

Pituitaries were collected as rapidly as possible after slaughter at local abattoirs. They were minced and vigorously stirred in 0.2 percent collagenase for 1 hour to disperse the cells. Cells were then grown in Dulbecco's Modified Eagles Medium in an atmosphere of 5 percent CO_2 and 95 percent air for 4 to 5 days prior to stimulation. Immediately before the experiment, cells were washed thoroughly and treated with agents known to induce LH release or mediate hormone release from other endocrine cells. These included potassium chloride ($10\text{-}50 \times 10^{-3}$ M); theophylline ($1\text{-}4 \times 10^{-3}$ M); estradiol ($2\text{-}40 \times 10^{-8}$ M); prostagland in E_2 (10^{-7}M-10^{-4}M); and GnRH (10^{-9} - 10^{-6} M). Experiments were carried out with 300,000 cells/well in a volume of 1 ml. Each treatment was replicated six times.

GnRH was found to cause a dose-dependent increase in LH release over 6 hours, with 10^{-7} M producing a maximal response (2.5-4 fold increase over controls). The amount of LH release both with and without GnRH also was found to be time dependent. No difference in response to GnRH was found between cells from mature animals and those from young calves.

Cells treated with KCl released much greater amounts of LH than the control cells (medium alone); 25 mM and 50 mM KCl induced greater LH release than GnRH ($P < 0.01$). Both prostagland in E_2 and estradiol also produced dose-dependent rises in LH; 10^{-6} - 10^{-5}M PGE_2 and 2×10^{-7} M estradiol produced LH levels much higher than in control cells, but not higher than the maximum dose of GnRH (10^{-7} M). Theophylline at 1 mM also released greater amounts of LH. Treatment with the highest concentrations of all agents tested, except KCl, decreased the response as compared to the dose of the secretagogue that produced maximum LH release.

Brief PR-4244

Long Term Culture of Bovine Hypothalamic Cells

L. A. RUND, S. MCCONNELL AND M. S. AMOSS, JR.

It is generally accepted that the brain has a pronounced effect on such endocrine-mediated phenomena as growth and reproduction. To increase our understanding of the mechanisms by which the brain communicates with the endocrine system, studies were initiated using cells of the hypothalamus placed in long-term tissue culture. The hypothalamus was chosen because it appears to be the final common pathway betweent he brain and endocrine system. Stimuli to or from this area of the brain may be responsible for the pulsatile hormone release that seems so important in maintaining the integrity of the endocrine system. Long term culture of the peptidergic neurons appeared to be one way of isolating these messages and investigating the effect of various stimuli.

The hypothalamus was removed from the bovine brain and the cells dispersed by the enzymes collagenase and trypsin. These cells were placed into flasks and kept tightly sealed at 37°C. Some of these cultures were maintained for as long as 5 months. The normal procedure was to feed the cells at approximately 4-day intervals and subculture them every 2 weeks. Some of the cells were frozen in liquid nitrogen both as primary cultures and as subcultures; both were viable upon thawing.

The first experiment was intended to show that some of the cells treated in this manner were peptidergic neurons containing GnRH, the hypothalamic peptide responsible for the release of LH. Use of a cytohistochemical technique for GnRH revealed the presence of peptidergic neurons containing GnRH.

It will be necessary to maintain these hypothalamic cells in long-term culture in order to: a) increase the percentage of peptidergic neurons; and b) stabilize the biological response of these cells in order to study the role of neurotransmitters in the control of hormone secretion rates. This type of investigation provides a precisely controlled cellular environment for the study of specific mechanisms. It must be realized, however, that the response of the system in the living animal is dependent upon signals from many organs.

In vitro and in vivo studies of neurotransmitters will help us determine how the central nervous system regulates pulsatile LH release and ovulatory LH surge during the estrous cycle. This knowledge will lead to more efficient treatment of reproductive problems related to the central nervous system, and help improve the reproductive capacity of healthy cattle.

PR-4245

The Role of Serotonin in LH Release in Steers

L. A. RUND AND M. S. AMOSS, JR.

Summary

The administration of 150 micrograms (μg) of serotonin (5-HT) directly into the third ventricle of the brain caused marked changes in the pattern of pulsatile LH release in steers. The average time between LH pulses more than doubled during the first 2 hours after 5-HT injection, and returned to preinjection values within the next 2 hours. Saline-injected steers exhibited no change. The response to 5-HT was most pronounced during the first 60 to 90 minutes post injection when there were virtually no pulses generated and the baseline concentration of plasma LH was the lowest. The baseline concentration of plasma LH fell an average of 44 percent, while the saline controls remained at 83 percent of preinjection values. Compared to controls, the LH peak heights were elevated in 7 of 9 of the 5-HT treated animals. This suggests a rebound phenomenon due to the decrease in pulse frequency. Average LH concentration decreased from 6.2 nanograms per milliliter (ng/ml) to 3.8 ng/ml during the first hour following 5-HT injection, and returned to 6.5 ng/ml by 4 hours after treatment. These data suggest that 5-HT decreases plasma LH concentration and that a reduction in the activity of a hypothalamic pulse generator may be responsible for the observed decrease (1).

Introduction

For many years it has been known that environmental stimuli, monitored by the central nervous system (CNS), can affect reproduction: day-night cycles influence the length of estrous cycles; pheromones enhance reproduction; and stress inhibits reproduction. The link between the CNS and hormone secretion was not known until recently, when neurotransmitters and neuromodulators were found to be responsible for alterations in the secretion rates of many hormones.

Neurotransmitters are water soluble chemicals with low molecular weights, which have a localized and short-lived effect on nerve cells. These neurotransmitters affect LH release at the junction of nerve cells connecting the CNS to the hypothalamus. The hypothalamus then secretes releasing or inhibiting hormones, which in turn stimulate the secretaion of LH and folicule stimulating hormone (FSH) from the anterior pituitary.

The differential effects of the various neurotransmitters on LH release are unknown. This problem is complicated by the changing LH pulse patterns which occur during development, during different phases of the estrous cycle, and following removal of the gonads. The frequency and magnitude of LH release varies significantly during these physiological states (2,3). In fact, there may be two diferent control mechanisms — one for pulsatile LH release and another for the ovulatory LH surge. For this reason castrated males, which have a consistent pulsatile pattern, were chosen for study. When the neurotransmitter's function in these animals is understood, it can be tested in more diverse situations such as in cycling females.

The neurotransmitter chosen for intensive studies was 5-HT because results of preliminary tests of many neurotransmitters indicated 5-HT did alter LH patterns in cattle. In addition, other investigators have shown 5-HT to alter LH release in other species (4,5,6).

Experimental Procedures

At 300 pounds, young bull calves were castrated and implanted with permanent third ventricular cannulas. The placement of these cannulas was done following the procedure of Stewart and Bailey (7). This procedure is based on the fact that a plane perpendicular to the frontal bone and three-quarters of the distance between the poll and the caudal border of the orbit of the eye passes through the rostral border of preoptic nuclei. Placement of the cannula into the third ventricle is determined by moving 12.6 millimeters (mm) from the three-quarter point toward the poll. Proper cannula placement is verified by withdrawing cerebral spinal fluid.

Experiments were not done until at least 1 month after surgery. A catheter was placed in the jugular vein the day before each experiment. Blood was collected through this catheter every 10 minutes for 4 hours prior to and 4 hours after injection. Either 100μl saline or 150 μg 5-HT in 100 μl saline was injected directly into the third ventricle.

The blood samples (10 ml) were immediately mixed with 10 milligrams (mg) of Ethylenedinitrilo Tetraacetic Acid (EDTA) and placed in an ice bath. The plasma was separated and stored at -20°C until assayed. The validated LH radioimmunoassay described by Niswender et al. (8) was used to measure LH.

Results and Discussion

The data obtained in these experiments were analyzed for the following parameters: LH pulse frequency; the magnitude of the LH pulse; baseline concentration of plasma LH; and mean plasma LH concentration. An LH pulse was identified on the basis of two parameters: (1) there must be a minimum increase of 2 ng in plasma LH; and/or (2) the peak must have occurred at the proper time (that is the interval between the immediately preceding pulse and the pulse in question, and the interval between the pulse in question and the succeeding pulse are similar). These pulses ae identified by a star in the following figures. Figure 1 demonstrates that in a typical response to 100 μl saline the pulse frequency, pulse height, and mean plasma LH concentration did not change. The response to 150μg 5-HT was a decrease in pulse frequency to 66 percent of preinjection levels (Figure 2) (Table 1).

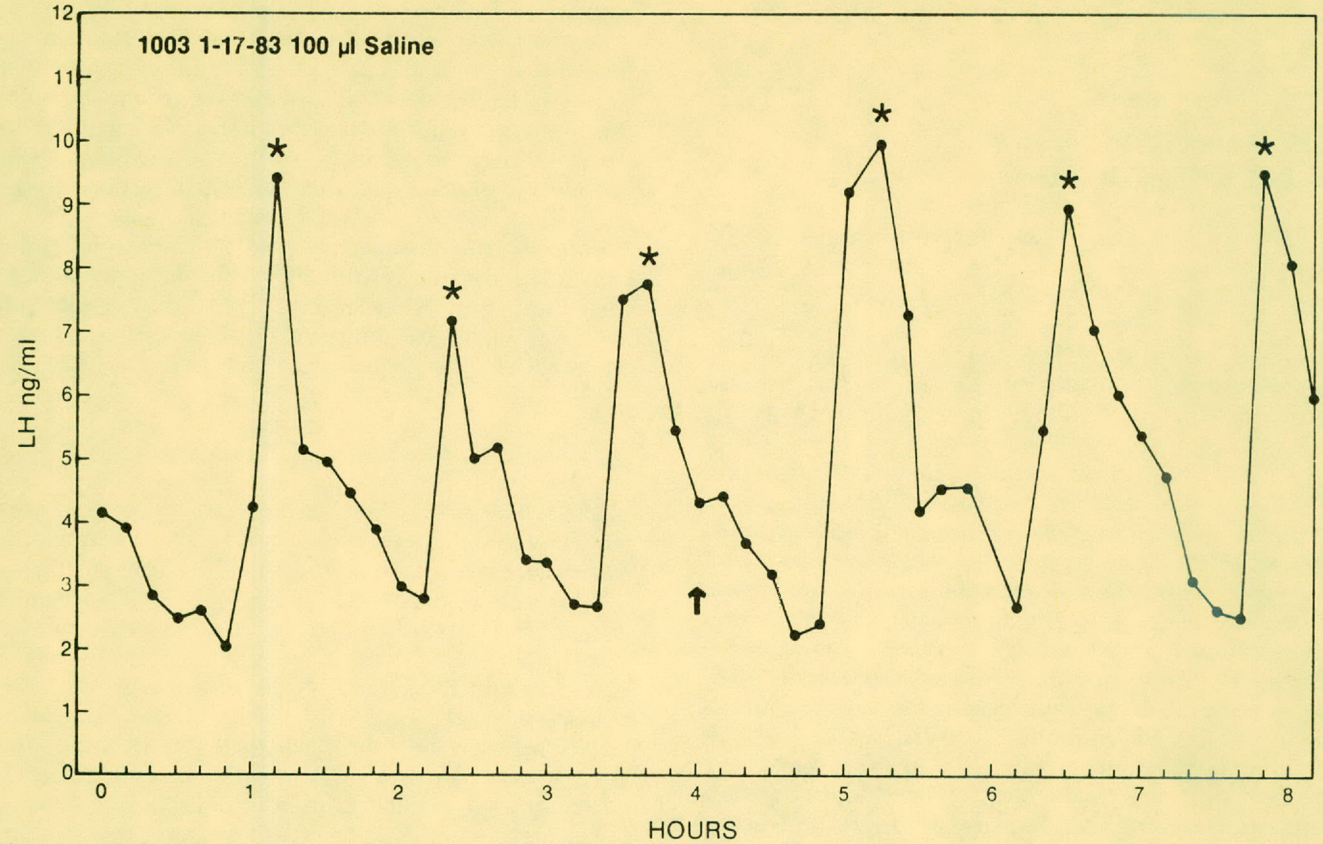

Figure 1. Pulsatile LH release following ventricular injection of 100 ul saline.
**Indicates an LH pulse as defined in text.*

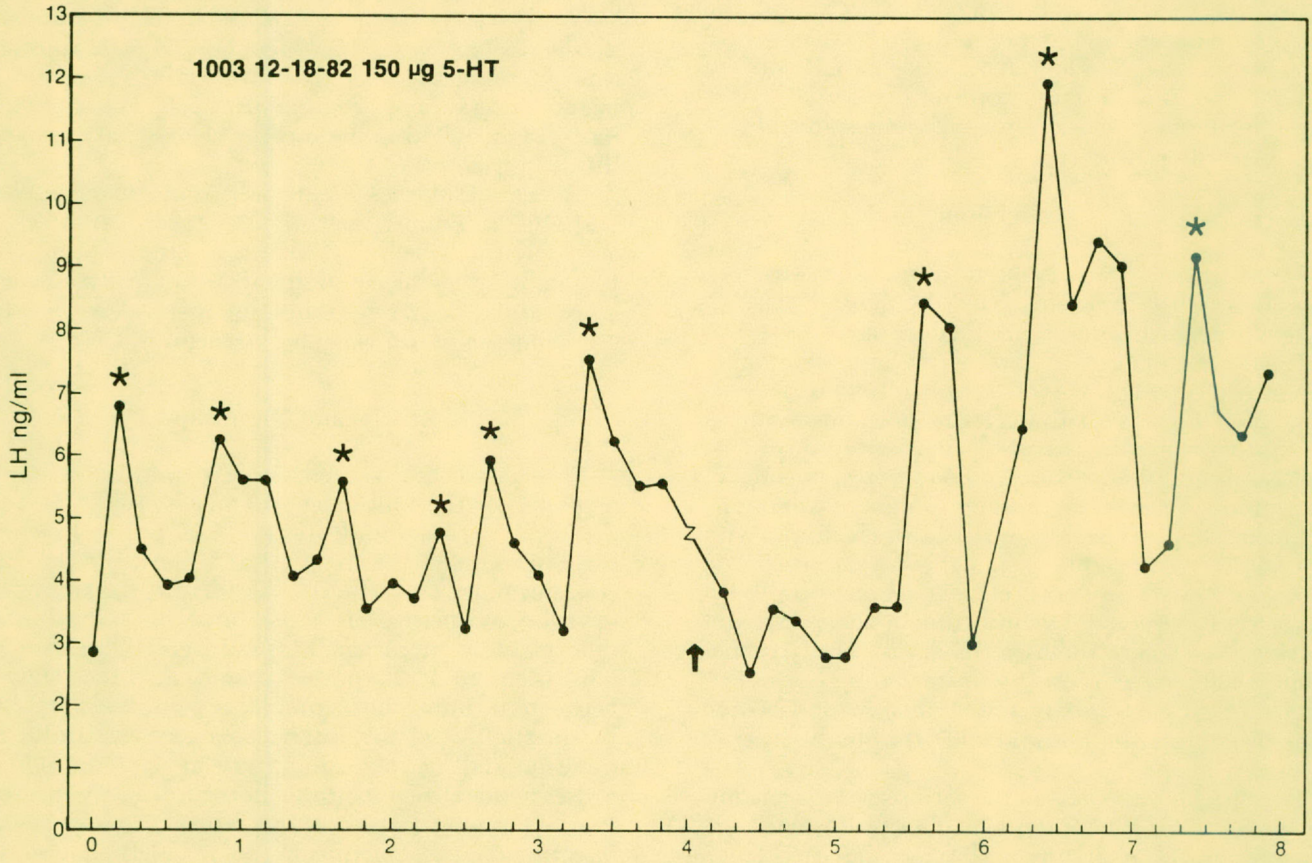

Figure 2. Pulsatile LH release following ventricular injection of 150 ug of serotonin.

TABLE 1. FREQUENCY RESPONSE OF LH PULSES FOLLOWING INJECTION OF EITHER SALINE OR SEROTONIN

		Frequency response Pulses/hour	
Treatment	N	Preinjection	Postinjection
Saline Control	3	1.24 ± 0.74	1.04 ± 0.26 (84% Preinjection)
150 μg 5-HT	8	1.56 ± 0.36	1.03 ± 0.14 (66% Preinjection)

Note that following the injection of 5-HT, there were almost no LH pulses for approximately 90 minutes. During this time the baseline concentration of LH fell to 56 percent of the preinjection level, but returned to within 25 percent of control values by 4 hours post injection. After saline injection, baseline plasma LH concentrations remained at 80 to 90 percent of the levels found before injection (Table 2). The mean plasma LH concentrations were lowest during the first hour following adminsitration of 5-HT; these concentrations fell to 68 percent of levels observed during the control or preinjection period in the 5-HT treated animals, whereas the change in the saline treated animals was only 14 percent and was not statistically significant (see Table 3).

These data suggest that a pulse generator for LH secretion exists in the brain. The exact location of this generator is unknown, but it is thought that the signals coming from the generator and signals that influence the generator are neurotransmitters. In these experiments it would appear that serotonin, a neurotransmitter, when injected directly into the brain, can decrease the signals coming from the LH pulse generator for a period of time corresponding to its biological half-life. The fall in frequency of the LH pulses probably accounts for the decreases in baseline concentrations of LH and mean plasma LH concentrations. This same phenomenon has been shown to occur in castrated male sheep (4). In vitro experiments can help to isolate the specific area of the brain that is the hypothalamic pulse generator, and determine how or where 5-HT affects this generator. It should be noted that this experimental design does not rule out the possibility that the serotonin may be acting on the brain or anterior pituitary gland.

TABLE 2. CHANGES IN BASELINE CONCENTRATIONS OF LH FOLLOWING INJECTION OF SALINE OR SEROTONIN

		Baseline Concentration of LH (ng/ml				
		Pre-	Postinjection			
Treatment	N	injection	1 hr	2 hr	3 hr	4 hr
Saline Control	3	3.63±1.4	3.06±.95	3.32±.63	2.99±1.1	2.9±1.2
% Change			84	91	82	80
5-HT	8	6.23± .88	3.48±.87	4.4±1.1	4.02±1.1	4.75±1.1
% Change			56	71	65	76

TABLE 3. MEAN PLASMA LH CONCENTRATIONS FOLLOWING INJECTION OF SALINE OR SEROTONIN

		Mean Plasma LH concentration (ng/ml)				
		Pre-	Postinjection			
Treatment	N	injection	1 hr	2 hr	3 hr	4 hr
Saline	3	5.07±1.4	4.34±1.1	4.4±1.1	4.4±2.9	4.4±1.4
% Change			86	88	88	88
150 μg 5-HT	8	7.25±1.1	4.95±.95	5.59±1.4	5.5±1.6	5.99±.87
% Change			68	77	76	83

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PR-4246

Growth and Pubertal Characters of Straightbred and F2 Heifers

W. H. McELHENNEY, C. R. LONG, AND G. A. POSADA

Summary

Data from 468 straightbred and F2 heifers were analyzed to estimate breed and heterotic effects on growth and pubertal characters. The heifers were produced by mating cows of five breeds — Angus (A), Brahman (B), Hereford, (He), Holstein (Ho) and Jersey (J) — and their crosses (reciprocals pooled) to bulls of the same breedtype. Breedtype means and average heterosis estimates are reported via weights and heights at 1 year and at 18 months, as well as age, weight and height at puberty. Crossbred heifers were 5.9 and 4.3 percent heavier than straightbreds at 12 and 18 months, respectively. Heterosis estimates of 1.3 and 1.6 percent for height indicate that the crossbreds were sightly taller than straightbreds at these ages. Crossbred heifers were also younger (by 26.7 days), lighter (by 2.6

pounds) and taller (by .3 inches) at puberty than straightbred heifers. Since the F2 heifers were reared by F1 dams, these estimates reflect a combination of F1 maternal and F2 direct heterosis effects.

Introduction

Crossbreeding has become a widely accepted technique for increasing the efficiency of beef production. In order to use this tool effectively, characterization of existing breeds and their crosses is necessary for designing effective breeding systems. Also, the use of crossbreeding to develop new breeds has increased; information relating to early generations of such breed formation is needed.

This study was conducted to quantify breed and heterosis effects on growth and pubertal characters of straightbred and F2 heifers. Since the F2 heifers were reared by F1 dams, heterosis estimates contain a maternal heterosis component and an individual or direct heterosis component. A similar situation exists in early generations of composite breed formation.

Experimental Procedure

Data for this study were collected as part of TAES project H-1936: "Evaluation of Hybrid Systems for Total Efficiency of Beef Production." The project was conducted as a modified five breed diallel involving Angus (A), Brahman (B), Hereford (He), Holstein (Ho) and Jersey (J) and their crosses (reciprocals pooled. Females were mated to bulls of the same breedtype to produce second generation straightbred and F2 crossbred calves. Further details concerning the origin and management of the foundation animals have been given in previous reports (1,2).

Heifers produced by these matings were allocated to three management groups at weaning: individual pen feeding; pasture with supplementation; or pasture with supplementation until one year of age, followed by individual pen feeding. The distribution of heifers by breedtype and type of management is presented in Table 1. Twelve- and 18-month weights and heights were calculated by interpolation between monthly measures of the heifers. Puberty was defined as the first ovulatory estrus. This was determined by examining the ovaries of non-pubertal heifers for ovarian activity when the heifers were ridden by a marker bull or showed other signs of estrus. At puberty, the date, weight and hip height were recorded.

A statistical model with breedtype, management, birth month and parity of dam was used to analyze the data. Breedtype was a significant source of variation for all of the data reported. The analyses provided adjusted (least squares) means for each of the 15 breedtypes for the characters included in this report. Heterosis in units is estimated as the crossbred mean minus the straightbred mean; percentage heterosis is obtained by dividing heterosis in units by the straightbred mean and multiplying the quotient by 100.

TABLE 1. DISTRIBUTION OF HEIFERS BY BREEDTYPE AND TYPE OF MANAGEMENT FOR CHARACTERS ASSOCIATED WITH 270 DAYS OF AGE

	Type of management		
Breedtype	Pasture	Pasture-pen	Pen
Angus (A)	23	4	4
Brahman (B)	11	2	5
Hereford (He)	53	3	5
Holstein (Ho)	17	4	4
Jersey (J)	7	3	2
A X B	22	4	4
A X He	18	2	2
A X Ho	31	3	3
A X J	15	3	4
B X He	27	4	3
B X Ho	9	3	3
B X J	22	6	3
He X Ho	38	3	3
He X J	49	3	3
Ho X J	24	4	3

Results and Discussion

Least squares means by breedtype for 12- and 18-month weight and height are presented in Table 2. Among the straightbreds, Holsteins were the heaviest and tallest and Jerseys were the lightest at both ages. Hereford calves weighed less than Angus and Brahman, but were similar in height to the Angus. Among the crossbreds, Holstein and Jersey crosses were heavier and lighter, respectively, than their counterparts. Brahman-Holstein crosses were the heaviest and tallest of the crossbreds. These results are in general agreement with those reported for the first generation of this experiment (1,2).

Average heterosis estimates for 12- and 18-month weight (Table 2) indicate that the crossbreds were heavier and taller thant he straightbreds at both ages. However, these heterosis estimates are lower than those reported for the first generation (1,2).

In many beef production systems, age at puberty is important in choosing which breed or cross to use. For

TABLE 2. YEARLING AND 18-MONTH WEIGHT AND HEIGHT

	Yearling		18-Month	
Breedtype	Weight (lb)	Height (in)	Weight (lb)	Height (in)
Angus (A)	533	42	725	45
Brahman (B)	528	47	739	49
Hereford (He)	502	42	718	45
Holstein (Ho)	619	48	872	51
Jersey (J)	474	44	698	46
AB	535	45	763	48
AHe	558	43	772	46
AHo	605	46	824	48
AJ	515	43	721	46
BHe	575	46	810	49
BHo	631	49	880	52
BJ	528	47	735	49
HeHo	592	47	822	50
HeJ	507	44	718	46
HoJ	571	46	784	49
Means:				
Straightbreds	531.3	44.7	750.4	47.5
Crossbreds	561.7	45.3	782.9	48.2
Heterosis:				
Units	30.4	0.6	32.4	0.8
%	5.9	1.3	4.3	1.6

a heifer to calve at 2 years of age, she must reach puberty by 15 months of age. Among the straightbreds in this study, Holsteins and Jerseys were the youngest at puberty (Table 3), while the Brahman heifers were the oldest. Among the crossbreds, Brahman crosses were the oldest, while Holstein and Jersey crosses were the youngest. The two measures of size at puberty included in this experiment — weight and height — indicate that there are considerable variations among breed-types.

TABLE 3. AGE, WEIGHT AND HEIGHT AT PUBERTY

Breedtype	Age (days)	Weight (lb)	Height (in)
Angus (A)	421	606	44
Brahman (B)	539	754	50
Hereford (He)	468	627	44
Holstein (Ho)	284	553	46
Jersey (J)	257	381	42
AB	444	638	46
AHe	409	613	44
AHo	294	546	44
AJ	303	468	42
BHe	474	703	48
BHo	441	726	51
BJ	413	576	47
HeHo	353	606	46
HeJ	293	471	42
HoJ	246	469	44
Means:			
Straightbred	393.6	584.2	45.2
Crossbred	366.9	581.8	45.5
Heterosis:			
Units	-26.7	-2.6	0.3
%	-6.8	-0.4	.7

The average heterosis estimates (Table 3) indicate that crossbred heifers were younger, lighter and slightly taller at puberty than the straightbreds. The heterosis estimate for age at puberty was considerably larger in absolute terms than estimates for the first generation (1,3). This is probably because F_2 heifers were reared by F_1 dams and all other heifers by straight-bred dams. It is thought that the effect of maternal heterosis on age at puberty was a major factor in this study.

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Infectious, Nutritional, and Toxic Diseases

Brief PR-4247

The Effects of Extracts of Fescue Grass on Plasma Prolactin Levels of Cattle

L. V. SHEELER, G. R. BRATTON, AND M. S. AMOSS, JR.

Tall fescue grass is a cool season forage that occupies more than 35 million acres of pasture in the southeastern United States. During the last two decades, many cattle grazing fescue pastures have exhibited reproductive problems, agalactia, decreased weight gains, and dry gangrene of the hooves. If these problems can be eliminated, more fescue may be planted in Texas. At present, the compound(s) responsible for the toxic effects of fescue has not been identified.

It is known that fescue can alter plasma concentrations of prolactin (PRL), a hormone involved in several reproductive mechanisms. In order to define the biological actions of the fescue toxin, the effects of fescue grass extracts on plasma prolactin concentrations in cattle were studied.

Six-month-old bull calves were administered either saline or a 50 percent ethanol extract of fescue forage. The extract dosages were 3.6 gram equivalents, 36.3 gram equivalents or 363 gram equivalents. One hour following I.V. injection of the extract, 150 grams (g) of TRH were given by I.V. in order to assess pituitary PRL response. Blood samples were taken at 10-minute intervals throughout the experimental period. Plasma PRL levels were determined by Radio Immune Assay (RIA) using antiserum supplied by Dr. D. Bolt of USDA, Beltsville Station.

Data indicate that the cationic fraction of the extract significantly elevated plasma PRL within 20 minutes of the injection at a dose of 36.3 grams of grass equivalents. No change in the TRH-induced PRL release was observed at any of the doses tested. the data from an alkaloid fraction of this extract appeared to have little effect, but the results are not conclusive.

Brief PR-4248

Magnesium Availability in Dry, Non-Pregnant, Mature Cows of Five Breeds and their Crosses

J. C. SOLIS, L. W. GREENE, F. M. BYERS AND G. T. SCHELLING

Both scientists and livestock producers have suggested that cattle breed may play an important role in susceptibility to grass tetany. The disease is characterized by low serum magnesium (Mg) concentrations that can result from low availability of Mg in the digestive tract. Field observations suggest that cattle containing at least one-eighth Brahman breeding are more tolerant to factors that depress Mg availability. The objective of this study was to determine Mg availability in dry, non-pregnant, mature cows of different breeds and crosses. Sixty dry, non-pregnant cows more than 10 years of age, of five breeds (Angus, Brahman, Hereford, Holstein and Jersey) and their crosses, were used in a 51-day experiment to determine apparent magnesium digestibility. Animals were fed one of four levels of a 70 percent roughage diet during four consecutive 12-day periods. During each period, cows were fed 50, 83, 117 and 150 percent of their estimated nutrient maintenance requirement. Four cows per breed group were assigned to one of the four intake levels each period, with one cow per level per period. Feeding levels rotated as 50 → 117 → 83 → 150 → 50 for periods 1 to 4. Each period consisted of a 7-day adjustment followed by a 5-day collection of fecal samples at randomly assigned times. Feed samples were obtained for 5 days beginning 2 days prior to fecal collection. Indigestible neutral detergent fiber was determined on feed and feces and used as a digestive tract marker.

There were no significant interactions ($P > .05$) between breed and level of feeding. Apparent Mg digestibility increased ($P < .05$) from 15 to 39.9 percent as level of feeding increased from 50 to 150 percent of estimated maintenance. This increase in apparent digestibility was most likely due to a shift in the relative proportion of endogenous Mg present in the feces at different levels of Mg intake. Apparent Mg digestibility tended to be higher for brahmans (34.0 percent) and lower for Herefords (17.7 percent). Angus, Holstein and Jersey breeds had similar ($P < .05$) Mg digestibilities of 29.8, 29.9 and 26.0 percent, respectively. Magnesium digestibility in all Brahman crossbred cows was equal to or greater ($P > .05$) than the Mg digestibility in straightbred Brahmans.

In summary, it appears that Brahman and Brahman cross cattle may be less susceptible to grass tetany than other breeds due to an increased efficiency of Mg digestibility.

PR-4249

The Effects of Fresh Forage, Hay, Acetate, Propionate, Monensin, Grain, and pH on the Production of 3-Methylindole by Rumen Microbes in Continuous Culture

A. B. Clark, B. B. Boren, G. T. Schelling, L. W. Greene and J. J. Nagyvary

Summary

The metabolism of tryptophan (TRP) to 3-methylindole (3MI) by rumen microbes is associated with acute bovine pulmonary edema and emphysema (ABPE) in cattle, and was studied in a series of in vitro studies using continuous culture fermentation flasks. Treatments were imposed to create various microbial environments to study 3MI production. There were only trace amounts (< 0.1 g/ml) of indole and indoleacetic acid (IAA) detected in the five trials. The infusion of propionate and acetate caused a significant ($P < .05$) increase in 3MI concentration. There was no difference in 3MI production when a low level (1.5 ppm) of monensin was administered. However, when the level of monensin was increased to 88 ppm, there was a significant ($P < .05$) decrease int he production of 3MI. The concentration of TRP was significantly ($P < .05$) higher and the level of 3MI decreased ($P < .05$) drastically with a 90 percent grain diet even when the pH was controlled. There was a decrease ($P < .05$) in 3MI production when a hay diet was used and the pH was lowered from 7.1 to 5.0 or below. Feeding some grain or monensin would appear to aid in the prevention of ABPE in cattle on pasture.

Introduction

Acute bovine pulmonary edema and emphysema (ABPE), or fog fever as it is called in Europe, is the most prevalent, acute, non-infectious, respiratory disease found in pastured cattle (3). The annual losses due to the syndrome are as high as several million dollars in many states, including Texas. ABPE symptoms typically occur within 3 to 10 days after cattle are switched from a dry pasture to a succulent, improved pasture.

While the cause of the disease is not entirely known, the disease can be experimentally induced by intraruminal administration of L-tryptophan (TRP). TRP is metabolized in the rumen by one of two major pathways to produce either indole or 3MI. Indoleacetic acid (IAA) is an intermediate in the 3MI pathway. The absorption of 3MI, and its subsequent metabolism, appears to be the cause of the disease.

It has been discovered that increasing concentrations of glucose and decreasing the pH (5), or feeding a grain diet (1) will decrease the level of 3MI produced. Several ruminal bacteria are capable of converting TRP to IAA (4), and a Lactobacillus species is capable of decarboxylating IAA to 3MI (6). Monensin will inhibit most lactate-producing bacteria (2) and reports show that when 60 ppm of monensin is fed to cattle there is a decrease in ruminal IAA levels (1).

Experimental Procedures

Five trials were conducted using eight continuous culture flasks. McDougall's buffer (pH 6.7 except where noted) was constantly infused. The effluent was collected for 24-hour periods. After a three-day adjustment period, pH and volume of effluent were measured on day 4 through 8. Representative samples were frozen for subsequent analyses. The diets were administered at 0800 and 1600 hours daily.

Trial I was designed to determine the effects of acetate, propionate, and fresh forage on TRP metabolism and 3MI production. Fermentation flasks were administered a ground alfalfa hay diet or fresh frozen forage with 2.5 percent TRP. The forage was lush, rapidly growing Coastal Bermudagrass which had been cut and rapidly frozen. The acetate and propionate treatments involved the addition of these acids to the McDougall's buffer at levels of 31 and 21 μmol/ml respectively.

Trials II and III were conducted to determine the effect of monensin on 3MI production when a basal hay (plus 2.5 percent TRP) diet was used. Levels of 0 or 1.5 ppm of monensin were used in the diet in Trial II. For Trial III, higher levels of 0, 22, 44 and 88 ppm of monensin in the diet were chosen.

Trial IV consisted of four dietary treatments of ground corn (0, 30, 60 and 90 percent) and hay rations with 2.5 percent TRP to determine the effect of grain feeding on 3MI production. Trial V was conducted to determine whether pH alone was influencing 3MI production. The pH of McDougall's buffer was adjusted with hydrochloric acid in an attempt to produce fermentation flask pH values of 6.7, 6.1, 5.5 and 4.9. The actual resulting pH values in the fermentation flasks are given in Table 4.

The effluent samples taken from the fermentation flasks were analyzed for indole, 3MI, TRP and IAA by reverse phase high pressure liquid chromatography. Duplicate samples taken from each flask were assayed and the results were statistically analyzed using analysis of variance and Tukey's HSD for all five trials.

Results and Discussion

In each of the five trials, the concentration of IAA and indole were negligible (< 0.1 μg/ml). The turnover rates (averaging 1.2 x per day) and pH values were stable by the third day of the trial and did not differ due to treatment except when imposed as a treatment (Trial V).

The average effluent concentrations of TRP of Trial I (Table 1) were not significantly different. However, the 3MI concentrations (10.18 and 10.28) were significantly greater ($P < .05$) in the flasks provided with additional propionate or acetate in the buffer than for the hay control or fresh frozen forage (6.37 and 4.23). There was no significant difference between the hay and fresh frozen treatments, thus indicating that "fresh" forage

TABLE 1. CONCENTRATIONS OF TRP AND 3MI IN TRIAL I

Treatment	µg/ml TRP	µg/ml 3MI
Hay + Control buffer	18.22	6.37[1]
Hay + Propionate buffer	14.23	10.18[2]
Hay + Acetate buffer	10.61	10.28[2]
Fresh frozen forage + Control buffer	16.22	4.23[1]

[1,2]Values with different superscripts are significantly different ($P < .05$).

is not a major factor influencing 3MI production by the rumen microbes.

No significant differences were observed in the TRP or 3MI concentrations between the 1.5 ppm and 0 ppm monensin treatments of Trial II. The average TRP concentraions were 3.16 and 4.21 µg/ml for the hay with 0 and 1.5 ppm monensin, respectively. The average 3MI concentrations were 7.43 and 8.42 µg/ml for the hay with 0 and 1.5 ppm monensin, respectively. Thus, a low level of monensin had no effect on 3MI production. However, the higher levels of monensin used in Trial III did have an effect. The average effluent concentrations of TRP (Table 2), ranged from 15.11 to 25.55 µg/ml for the hay with 0 and 88 ppm monensin, respectively. Although none of the TRP differences were significant, the data tended to suggest an increase in TRP concentrations as the monensin level was increased. Conversely, the average 3MI concentrations displayed a negative correlation with the monensin level. There was a significant reduction ($P < .05$) in 3MI concentrations for the hay with 88 ppm compared to 0 ppm monensin. Thus, higher levels of monensin decrease 3MI production by rumen microbes.

TABLE 2. CONCENTRATIONS OF TRP AND 3MI IN TRIAL III

Monensin Treatment	µg/ml TRP	µg/ml 3MI
Hay + 0 ppm	15.11	9.23[1]
Hay + 22 ppm	19.85	5.89[1 2]
Hay + 44 ppm	19.43	6.49[1 2]
Hay + 88 ppm	25.55	3.81[2]

[1 2]Values with different superscripts are significantly different, ($P < .05$).

A significant reduction ($P < .05$) in 3MI was observed as the percentage of grain increased from 0 to 90 percent in the diet in Trial IV (Table 3). The levels of 3MI in the effluent were 7.30, 2.60, 0.90 and < 0.10 g/ml for the 0, 30, 60 and 90 percent grain diets, respectively. As shown in Table 3, there was a tendency for the expected inverse relationship between the TRP and 3MI levels. There was a significant increase ($P < .05$) in the level of TRP with 90 percent grain in the diet as compared to the 100 percent and 70 percent hay diets. The addition of grain to the hay diet caused a significant decrease ($P < .05$) in the concentration of 3MI to near trace amounts in the 90 percent grain diet. Thus, feeding grain is an extremely effective method of decreasing 3MI production by rumen microbes.

TABLE 3. CONCENTRATIONS OF TRP AND 3MI IN TRIAL IV

Dietary Treatment	µg/ml TRP	µg/ml 3MI
100% Hay	1.03[1]	7.30[1]
70% Hay, 30% Grain	4.56[1]	2.60[2]
40% Hay, 60% Grain	5.98[1 2]	0.90[2]
10% Hay, 90% Grain	11.94[2]	.10[2]

[1 2]Values in a column with different superscripts are significantly different, ($P < .05$).

The fermentation flask pH values of 7.1, 6.2, 5.0 and 4.6 in Trial V (Table 4) were the result of the infusion of increased acidity into the flasks in order to assess the pH effect. The effluent concentration of TRP increased from 1.12 to 3.02 µg/ml as the pH decreased. Conversely, the 3MI concentrations decreased as pH decreased. There was a significant reduction ($P < .05$) in the 3MI concentrations when the pH's were lowered to 5.0 and 4.6. The extremely low 3MI concentrations of .44 and .08 at these low pH values are of about the same magnitude as when a 90 percent grain diet is fed. Since a 90 percent grain diet would produce pH values of about 5, it may be that rumen pH is an important factor of grain diets that decreases 3MI production.

TABLE 4. CONCENTRATION OF TRP AND 3MI IN TRIAL V

pH Treatment	µg/ml TRP	µg/ml 3MI
pH 7.1	1.12	1.95
pH 6.2	1.68	2.77[1]
pH 5.0	2.95	0.14[2]
pH 4.6	3.02	0.08[2]

[1 2] Values with different superscripts are significantly different, $P < .05$).

The results indicate that monensin partially inhibits the breakdown of TRP to decrease 3MI production, but monensin may not completely control ABPE. The effect of grain and pH on 3MI production were more pronounced than that of monensin. Nevertheless, monensin might significantly reduce the incidence of the disease while still providing the benefits of increased feed efficiency and rate of gain in pastured cattle.

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Role of Beef in Human Nutrition and Health

Brief PR-4250

Cholesterol Content of Beef Patties as Affected by the Amounts of Beef, Fat and Soy Protein

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Textured soy protein (TSP) products are widely used as ground beef extenders, and the sensory quality of ground beef patties containing TSP has been studied extensively. However, there have been no studies on the cholesterol content of ground beef mixed with TSP. This study was undertaken to determine the effect of cooking on the cholesterol content of beef patties extended with TSP, and the interaction between TSP and fat levels on cholesterol content of cooked patties.

Ground beef patties (115 grams (g), 9.2 centimeters (cm) diameter, 1.7 cm thickness) were prepared to contain 0, 10, 20 or 30 percent rehydrated TSP and 8, 16 or 27 percent fat. Patties were cooked from the frozen state on a rack in a preheated oven at 177°C to an internal temperature of 75°C.

Cholesterol content of raw ground beef patties decreased as the amount of TSP increased, and also decreased as the fat content decreased from 27 to 16 or 8 percent. There was no significant difference between patties containing 8 percent fat and those containing 16 percent fat. The amount of cholesterol per cooked patty tended to decrease as the amount of TSP increased when initial fat levels were 8 and 16 percent. At an initial fat level of 27 percent, however, cholesterol levels in cooked patties did not decrease with an increase in the amount of TSP. No consistent trend was observed as to the effect of the initial fat level on the cholesterol content of cooked patties. However, among patties containing no TSP, those with an initial fat level of 27 percent had less cholesterol per patty when cooked than did those with an initial fat level of 8 percent. The patties with 27 percent fat initially might have lost a substantial amount of fat (with accompanying loss of cholesterol) as drippings during cooking.

The percentage retention (per-patty basis) of cholesterol during cooking was computed to determine the effect of TSP level on cholesterol retention. The addition of different amounts of TSP to patties did not result in significant differences in cholesterol retention at initial fat levels of 8 and 16 percent. However, at an initial fat level of 27 percent, patties containing TSP retained substantially higher amounts of cholesterol. At the high fat level (27 percent), the binding effect of TSP on the fat present in patties became obvious.

It was concluded that the cholesterol content of cooked beef patties can be decreased by incorporating TSP in raw patties if the fat content of raw ground beef is low (66.8 milligrams (mg) per cooked patty with 0 percent rehydraded TSP vs. 46.8 mg per cooked patty with 30 percent rehydrated TSP at the initial fat level of 8 percent). However, patties containing TSP may retain more cholesterol on a per-patty basis when cooked if the fat content of the raw ground beef is high (58.1 mg per cooked patty with 0 percent rehydrated TSP vs. 59.4 mg per cooked patty with 30 percent rehydrated TSP at the initial fat level of 27 percent).

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