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# BEEF CATTLE RESEARCH IN TEXAS, 1990



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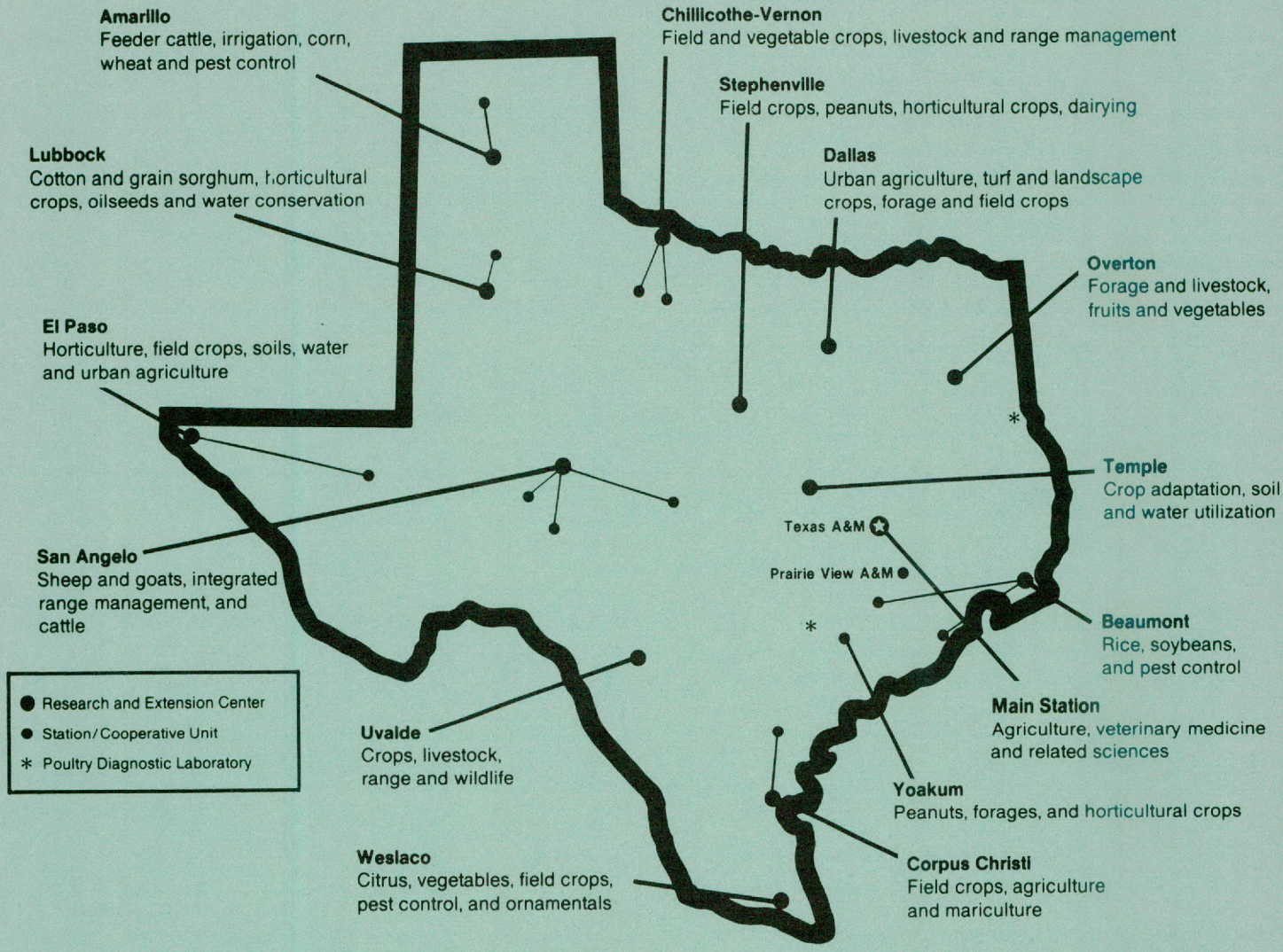
# Texas Agricultural Experiment Station
# Research and Extension Centers





## Acknowledgments

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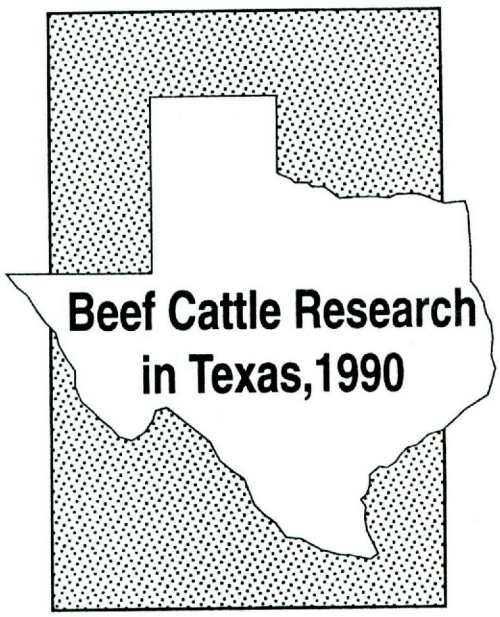
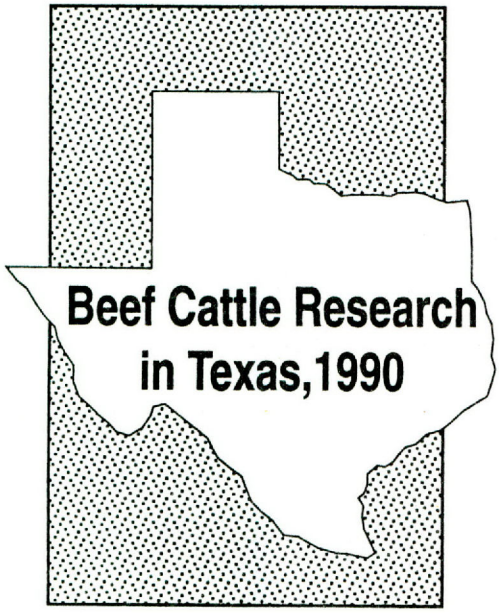
# Preface




Texas has an approximate land area of 168.4 million acres (254 counties), or about 263,000 $mi^2$, and an 800-mi span between its east-west and north-south extremities (94 to 107 degrees west longitude; 26 to 37 degrees latitude). A wide range of climate, vegetation and soils exists. According to similarity of soils, topography, climate and vegetation, the state is divided into 16 land resource areas. Annual rainfall exceeds 56 inches at the Louisiana border in the east but is less than 8 inches at El Paso, the state's westernmost city. The elevation extends from sea level along the Gulf of Mexico to 3,000 - 4,000 ft on the High Plains of the Panhandle in the northwestern part of the state. The Tran-Pecos area, in the far western part, has an elevation ranging from 2,500 to 8,751 ft, the highest point in Texas (Guadalupe Peak in Culberson County). The frost-free period ranges from about 180 days at the Panhandle's north end to 340 or more days at the State's southern tip. Of the 168.4 million acres total land area, about 88 million, or 52 percent, are classified as arable, but only about 40 million acres, or 24 percent, are used for crop production. About 8 million acres, or 20 percent of the land used for crop production, are irrigated. Approximately 26 million acres are classified as forest land, which provides timber and grazing for ruminant livestock and game animals. More than 100 million acres are used as rangeland by cattle, sheep, goats and game animals.

Texas holds a position of major responsibility in the beef industry. Despite the magnitude of the industry, there are major constraints to development of its full potential. The Texas Agricultural Experiment Station carries out a comprehensive beef cattle research program oriented toward developing technology for optimizing the conversion rate of production resources into highly nutritious, palatable beef. Research is conducted at 15 locations across the State because of the wide variations in soil, climate, elevation and other environmental and economic conditions. Research centers and stations are located in major agricultural areas to best serve them. Work at these locations is complemented by scientists working at Texas A&M University at College Station. All research, ranging from biochemical, genetic and physiological processes at the cellular level through breeding, nutrition and meats to feeding and management utilizing field demonstrations, is reported in this publication.

# Foreword




The single most important contributor to Texas agricultural cash receipts is beef cattle. 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 to 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 marketplace, the beef industry must become more efficient. Recent estimates reveal that the U.S. beef industry has over $12 billion in "lost opportunities" or inefficiencies from conception to consumption. Excess production of fat costs the U.S. beef industry over $4.4 billion each year. The Department of Animal Science and the Texas Agricultural Experiment Station have 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.

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. Research to identify genetic markers for carcass merit and disease resistance is ongoing at our department's research centers at McGregor and Angleton. 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 in order that we continue to produce a consumer-desired product.

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

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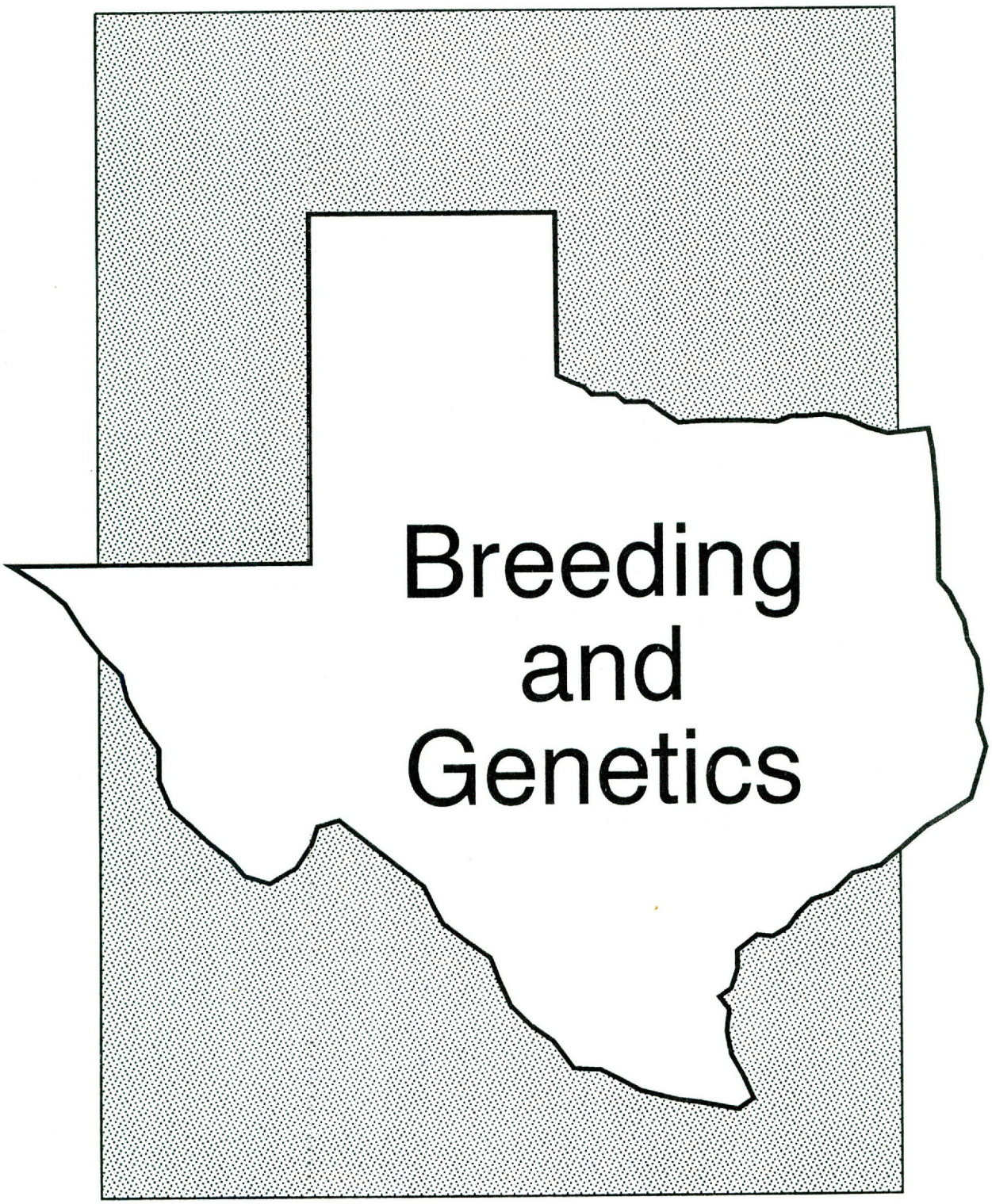

Breeding
and
Genetics

# A Descriptive Evaluation of Ultrasonic Ribeye Area Measurements in Young Beef Bulls

S.A. Bormann and J.W. Turner


## Summary

Age, weight, ultrasound ribeye area, and fat thickness measures of young bulls (300 to 450 days) from two data sets were used to assess the value of weight, fat thickness, and age as single predictors of ribeye area, establish breed differences, and determine heritability estimates. A Hereford data set containing 2,026 observations in a multiple regression model to predict ribeye area indicated the effects of quadratic age, quadratic fat thickness, and weight as significant sources of variation accounting for 71 percent of the variability in ribeye area. Ribeye area was predicted from singular measures of weight, age, or fat thickness, considering either linear or quadratic terms. Weight accounted for 69 percent of the variation in ribeye area while age and fat thickness accounted for 57 percent and 54 percent of the variation in ribeye area, respectively. The effects of year, herd, and sire:herd were included in the prediction models for ribeye area in the Hereford data set.

Five hundred ninety-nine bulls representing eight different breeds on performance test at nine various stations were used to estimate breed effects for ribeye area within station. Prediction equations for ribeye area were developed within each breed. Weight was the best predictor of ribeye area, accounting for 43 percent of the variation across all breeds. Age and fat thickness as single predictors accounted for 27 and 28 percent of the variability in ribeye area, respectively, across all breeds. The effect of test station was included in all breed models. Breed effects in ribeye area were observed within station. Average ribeye area size across all breeds was 8.26 $cm^2$ per 45.4 kg of live body weight.

Genetic parameters were obtained using the Hereford data set, resulting in heritability estimates of 0.47±0.09 for ribeye area, 0.51±0.09 for fat thickness and 0.65±0.10 for weight. Phenotypic correlations were reported as 0.09 for fat and ribeye area and 0.43 for weight and ribeye area. Estimates of genetic correlations were obtained and are 0.67±0.08 for ribeye area and weight, 0.20±0.15 for ribeye area and fat thickness and 0.55±0.10 for weight and fat thickness.


## Introduction

In recent years the economic pressure to produce beef more efficiently plus consumer demands for less fat and more lean have led to widespread industry changes. Increasingly, selection based on carcass merit at all levels of the industry is surfacing as an issue. Ribeye area, fat thickness, and marbling are the carcass traits the beef industry has deemed most important.

The increased industry awareness of consumer preferences in beef has merged with the need to identify sires capable of producing progeny with desirable carcass qualities. Ultrasonics represents a viable alternative to progeny tests or records on sibs for estimating carcass traits of live breeding animals. In the early 1960s, ultrasonic measures of ribeye area and fat thickness on the live animal were shown to be related to their respective carcass traits (2,3). Correlations between actual fat and ribeye measures and ultrasonic measures of recent literature sources provide a range of 0.76 to 0.94 for fat and 0.43 to 0.94 for ribeye area (4,8,11,13,14,15). The questions concerning the accuracy of ultrasound continue to be discussed and debated (10). However, ultrasound is still more accurate than the majority of producers who use visual appraisal.

Realizing that ultrasonics can serve as a viable tool in estimating carcass traits, the application of ultrasonic measures of young breeding animals continues to demand consideration. The role of ultrasound in the production of genetic values for carcass traits is still in the infant stages and a large amount of descriptive research remains.

It was the specific purpose of this study to evaluate the sources of variation in ribeye area of young beef bulls and to estimate the value of weight, age, and ultrasonic fat thickness as predictors of ribeye area. Breed differences in ultrasonic ribeye area measures were also evaluated as breed group has been found to be a significant source of variation for many carcass traits including ribeye area (1,5,6,7,8,12). Finally, heritability estimates of weight, ultrasonic ribeye area, and fat thickness were obtained.

## Data and Procedures

Field data for this study were supplied by the Live Animal Carcass Evaluation Service of the Texas Agricultural Extension Service. Carcass measures from 1988 to 1990 of ribeye area and average fat thickness opposite the twelfth and thirteenth rib were taken using an Aloka 210 DXII real time linear array ultrasound unit equipped with a 3.0 $Mh_z$ probe. Fat thickness measures along with age and weight were recorded at the time of data collection, while ribeye area was later estimated using a split-image

video tape recording. Records with missing data were deleted as an individual record so that only individuals with complete data were used.

Upon editing, two data sets were subsequently created to reflect bulls between 300 to 450 days of age based upon expected use of ultrasound data for selection in yearling bulls. A cross-classified data set containing 2,026 records of Hereford bulls from 12 herds in each of 2 years was constructed. Sire was defined as nested within herd for statistical analysis. Heritability estimates were obtained by creating a hierarchical arrangement of sire within herd.

Data from young bulls on performance test programs at nine stations comprised the data set utilized to establish and estimate breed differences. A total of 599 records reflecting bulls between 300 to 450 days of age were represented with breed considered nested within station. Individual breed data sets were created in order to generate within breed prediction equations for ribeye area.

## Results and Discussion

Linear and quadratic regressions of weight, age, and fat thickness were calculated since only single data points were available. Quadratic effects for weight, age, and fat thickness were included (as muscle growth is linear up to 350 kg of empty body weight, while fat deposition is slow and slightly curvilinear (9)).

In the Hereford data set, statistical analysis demonstrates that weight, quadratic age, and quadratic fat thickness were all significant sources of variation in ribeye area. Herd and sire within herd were also significant sources of ribeye area variation. The resulting model accounted for 71 percent of the variation in ribeye area.

Considering either linear or quadratic effects, the value of weight, age, and fat thickness as single predictors of ribeye area was determined. Weight was the best predictor accounting for 69 percent of the variation in ribeye area. Muscle growth exhibits a linear relationship to weight (Figure 1). Age accounted for 57 percent of the variation in ribeye area. Significance of the quadratic age term demonstrates that muscle growth continues but at a decreasing rate as the animal matures (Figure 2). Fat thickness accounted for 54 percent of the variation in ribeye area. The relationship between ribeye area and fat thickness is slightly curvilinear (Figure 3). As the animal matures, ribeye area increases at a decreasing rate as compared to fat thickness. The shift from low to rapid fat deposition occurrs more quickly in small breeds as maturity occurs at a lighter weight.

From the performance bull test data, breed was defined as a significant source of variation in ribeye area. In order to more accurately obtain breed estimates, individual breed data sets were created for statistical analysis. Resulting statistical analysis indicates weight as the dominant predictor of ribeye area across all breeds as reflected in Table 1. Prediction equations using significant effects were developed. Since weight is the driving prediction factor of ribeye area, prediction equations using weight as the single regressor variable are displayed in Table 2. Estimates of breed differences in ribeye area using weight as a single predictor are reflected in Table 3 (based on 45.4 kg of body weight). The average ribeye area size across all breeds was 8.26 $cm^2$ per 45.4 kg of live body weight.

Weight accounted for an average of 45 percent of the variability in ribeye area across all breeds with a range of 7.6 percent to 78.1 percent. Again, as results from the Hereford data set indicate, age and fat thickness are similar in value as single predictors of ribeye area, but neither is as good as weight. Age accounted for an average of 27 percent of the variability in ribeye area across all breeds, while fat thickness accounted for an average of 28 percent.

Genetic parameter estimates for weight, ultrasonic ribeye area, and fat thickness are displayed in Table 4. Heritabilities of this magnitude indicate that selective pressure can be effective. The phenotypic correlation for ribeye area and weight was .57, indicating that heavier bulls tend to have larger ribeye areas. The genetic correlation between the same traits demonstrates the prediction of ribeye area is essentially weight driven.

## Literature Cited


1. Crockett, J.R., F.S. Baker, Jr., J.W. Carpenter, and M. Koger. 1979. Preweaning, feedlot and carcass characteristics of calves sired by continental, Brahman and Brahman-derivative sires in subtropical Florida. J. Anim. Sci. 49:900.
2. Davis, J.K., and R.A. Long. 1962. Ultrasonic and other methods of estimating fatness in beef cattle. J. Anim. Sci. 21:970 (Abstr.).
3. Hedrick, H.B., W.H. Meyer, M.A. Alexander, S.E. Zobrisky, and H.D. Naumann. 1962. Estimation of ribeye area and fat thickness of beef cattle. J. Anim. Sci. 21:362.
4. Houghton, P.L. 1988. Application of ultrasound in commercial feedlots and beef breeding programs. *In*: Proc. Beef Improvement Federation Annual Convention, Albuquerque, NM. p. 89.
5. Koch, R.M., and M.E. Dikeman. 1977. Characterization of biological types of cattle. V. Carcass wholesale cut composition. J. Anim. Sci. 45:30.
6. Koch, R.M., M.E. Dikeman, D.M. Allen, M. May, J.D. Crouse, and D.R. Campion. 1976. Characterization of biological types of cattle. III. Carcass composition, quality and palatability. J. Anim. Sci. 43:48.
7. Koch, R.M., M.E. Dikeman, and J. D. Crouse. 1982. Characterization of biological types of cattle (cycle III). III. Carcass composition, quality and palatability. J. Anim. Sci. 54:35.
8. Koch, R.M., M.E. Dikeman, R. Jerry Lipsey, D.M. Allen, and J.D. Crouse. 1979. Characterization of biological types of cattle - cycle II: III. Carcass composition, quality and palatability. J. Anim. Sci. 49:448.
9. Mendel, V.E. 1980. Growth and body composition. *In*: H.H. Cole and W.N. Garrett (Ed.) Animal Agriculture (2nd Ed.). W.H. Freeman and Company, San Francisco. P. 424.
10. Recio, H.A., J.W. Savell, H.R. Cross, and J.M. Harris. 1986. Use of realtime ultrasound for predicting beef cutability. J. Anim. Sci. 63 (Suppl. 1):260.

11. Smith, M.T., J.W. Oltjen, H.G. Dolezal, D.R. Gill, and B.D. Behrens. 1989. Evaluation of ultrasound for prediction of carcass fat thickness and ribeye area in feedlot steers. Anim. Sci. Res. Rep. 291. Oklahoma State Univ., Stillwater, OK.
12. Swortzel, M.A., T.J. Marlowe, D.R. Notter, R.F. Kelly, and E.A. Tolley. 1984. Sire breed effects in matings with Angus cows: II. Carcass characteristics of steer progeny. J. Anim. Sci. 59:23.
13. Tatum, J.D., R.L. Baird, T.G. Field, D.J. Stade, C. Probert, and S.E. Williams. 1990. Evaluation of ultrasound and visual appraisal for estimation of fat thickness and ribeye area in live cattle. *In*: Beef Program Report. Colorado State Univ., Ft. Collins, CO. p. 99.
14. Turner, J.W., L.S. Pelton, H.R. Cross, and S.G. May. 1989. Correlation of beef carcass fat thickness and ribeye area measurements with live animal ultrasonic measurement. J. Anim. Sci. Southern Section Abstracts. p. 65.
15. Wilson, D.E., G. Rouse, R.L. Willham, D.A. Duello, and P. Houghton. 1989. Predicting Genetic Differences in Beef Cattle Body Composition. *In*: Proc. for the Third Genetic Prediction Workshop, Kansas City, MO P. 66.

TABLE 1. RELATIVE SIGNIFICANCE PROBABILITY RANK OF REGRESSOR VARIABLES BY BREED

| | Regressor Variable[b] | | | | | | |
|---|---|---|---|---|---|---|---|
| Breed[a] | WT | $WT^2$ | FAT | $FAT^2$ | AGE | $AGE^2$ | $R^2$ |
| Angus | 1*** | 3 | 5 | 2 | 6 | 4 | .38 |
| Beefmaster | 1** | 5 | 4 | 6 | 3 | 2 | .53 |
| Charolais | 1*** | 5 | 4 | 3 | 6 | 2* | .82 |
| Hereford | | | | | | | |
| Bull test | 1 | 4 | 3*** | 2** | 6* | 5* | .17 |
| Herd[c] | 1t[d]*** | 6 | 1t*** | 3** | 4* | 5* | .71 |
| Saler | 1*** | 2 | 4 | 5 | 6 | 3 | .48 |
| Santa Gertrudis | 1*** | 4 | 2*** | 5 | 6 | 3* | .56 |
| Simbrah | 6 | 3 | 4 | 5 | 2 | 1 | .33 |
| Simmental | 1** | 5 | 6 | 3 | 2 | 4 | .54 |

[a] The effect of station is included in each breed model.
[b] Abbreviations: WT = linear weight, $WT^2$ = quadratic weight, FAT = linear fat thickness, $FAT^2$ = quadratic fat thickness, AGE = linear age, $AGE^2$ = quadratic age.
[c] The effects of year, herd and sire within herd are included in the model.
[d] t denotes tied.
* P<.05
** P<.01
*** P<.001

TABLE 2. PREDICTION EQUATIONS FOR RIBEYE AREA BY BREED USING WEIGHT AS A REGRESSOR VARIABLE

| Breed[a] | Prediction Equation[b] | Standard Error of Estimate | $R^2$ |
|---|---|---|---|
| Angus | 86.77 + .0782(WT - 417.8)** | 7.090 | .33 |
| Beefmaster | 72.65 + .1081(WT - 435.5)*** | 7.213 | .48 |
| Charolais | 87.16 + .1124(WT - 513.4)*** | 5.321 | .78 |
| Hereford | | | |
| Bull test | 76.32 + .0512(WT - 478.7) | 6.242 | .11 |
| Herd[c] | 79.23 + .0939(WT - 455.2)*** | 5.443 | .69 |
| Saler | 89.15 + .0981(WT - 443.9)*** | 7.348 | .46 |
| Santa Gertrudis | 79.19 + .0996(WT - 411.3)*** | 7.322 | .51 |
| Simbrah | 82.97 + .0256(WT - 540.3) | 5.954 | .08 |
| Simmental | 100.8 + .0839(WT - 577.4)*** | 6.277 | .43 |

[a] The effect of station is included in each model.
[b] Abbreviation: WT = weight (kg).
[c] The effects of year, herd, sire within herd are included in the model.
** P<.01
*** P<.001

TABLE 3. BREED PREDICTION FACTORS OF RIBEYE AREA BASED ON 45.4 kg OF BODY WEIGHT FOR BULLS 300 TO 450 DAYS OF AGE

| Breed | Ribeye Area ($cm^2$) per 45.4 kg of Body Weight |
|---|---|
| Angus | 8.96 |
| Beefmaster | 7.46 |
| Charolais | 8.05 |
| Hereford | |
| Bull test | 7.51 |
| Herd | 7.91 |
| Saler | 9.01 |
| Santa Gertrudis | 8.34 |
| Simbrah | 8.08 |
| Simmental | 9.05 |
| Average | 8.26 |

TABLE 4. ESTIMATES OF HERITABILITY, GENETIC AND PHENOTYPIC CORRELATIONS FOR RIBEYE AREA, FAT THICKNESS AND WEIGHT.[a]

| | Ribeye Area ($cm^2$) | Fat Thickness (cm) | Weight (kg) |
|---|---|---|---|
| Ribeye Area | .47 ± .09 | .09 | .57 |
| Fat Thickness | .20 ± .15 | .51 ± .09 | .43 |
| Weight | .67 ± .08 | .55 ± .10 | .65 ± .10 |

[a] Heritability and standard errors on the diagonal, phenotypic and genetic correlations above and below the diagonal respectively.

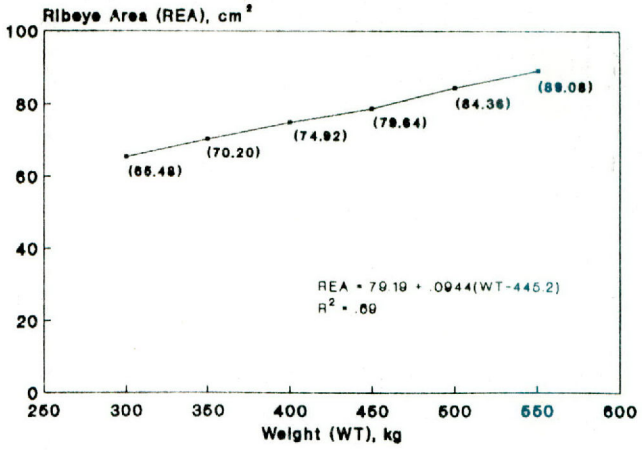



Figure 1. Regression response of ribeye area on weight.

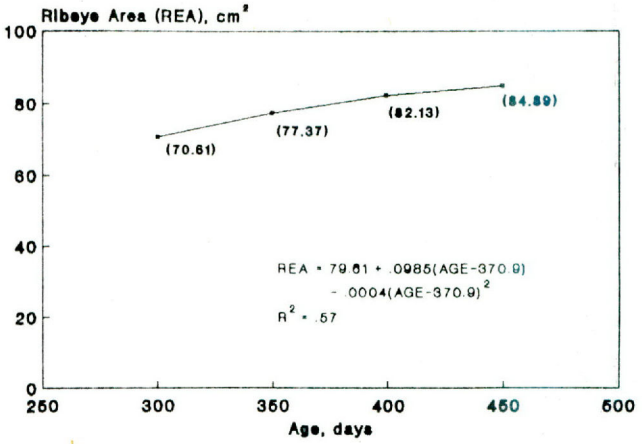



Figure 2. Regression response of ribeye area on age.

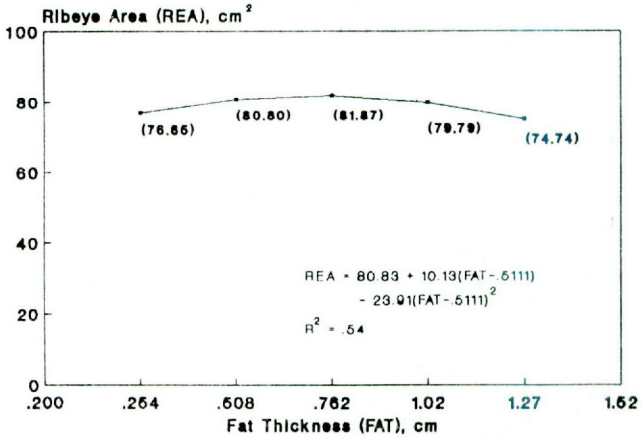



Figure 3. Regression response of ribeye area on fat thickness.

# Season of Birth and Stocking Rate Effects on Preweaning Traits of Simmental-Sired Calves from Brahman x Hereford (F1) Dams

S.J. Gaertner, F.M. Rouquette, Jr., J.W. Turner and C.R. Long


## Summary

Birth weight and weaning weight data from 1,911 records collected over 15 years on Simmental-sired calves from Hereford x Brahman (F1) dams at the Texas A&M Research Center, Overton, were used to estimate effects of dam's stocking rate and seasons of birth: fall, winter, and spring. Cool and warm season forages were utilized with stocking rates of high, medium, low and creep-fed calves within specific seasons. Year, sex, age of dam, dam's previous stocking rate and season of birth were significant effects for birth weight (P<.05). Main effects were not significant among spring-born calves. In the fall and winter calving seasons, respectively, dams weaning calves under a high stocking rate had the lightest subsequent birth weights (33.3, 33.0 kg), whereas, dams weaning creep-fed calves had the heaviest subsequent birth weights (35.6,37.7 kg). Year, sex, age of dam, stocking rate, and season of birth plus a regression on age at weaning were significant for weaning weight (P<.01). Dams on low stocking rate weaned heavier calves than those on pastures with either high or medium stocking rates (296.2, 236.7, 282.5 kg, respectively). Fall-born calves grazing cool season annual pastures were heavier at weaning than either winter- or spring-born calves (280.1, 246.2, 200.3 kg, respectively). A stocking rate x season of birth interaction was observed for birth weight and weaning weight (P<.01). Sex x season of birth and sex x stocking rate were significant interactions for weaning weight (P<.05). Results from this study indicated that weaning weights of Simmental-sired calves can be maximized by optimizing stocking rate of fall-born calves grazing cool season annuals.


## Introduction

Beef cattle consume the greatest portion of their feed, approximately 80 percent (3), as forage. Because the forage must provide adequate energy to meet the cattle's requirements to perform the intended productive function, seasonal availability and quality should influence the calving season in a cow-calf operation. Traditionally, cow-calf producers in East Texas have allowed bulls to remain with the cow herd on a year-round basis with a high percentage of the calves born in the late spring. Calving in the late spring reflects the utilization of warm-season perennial grasses; however, climatic conditions in East Texas are also conducive to the production of higher quality, cool-season annuals. Utilizing cool-season annuals would improve cow and calf performance; thus, a fall calving season could be more advantageous to East Texas cow-calf producers.

In order to appropriately assess the relative influence of season of birth, as dictated by forage species, on calf performance in East Texas, preweaning traits of the Brahman x Hereford (F1) dam should be considered. Pre-weaning characteristics have been evaluated for the Brahman and Hereford breeds independently (6,7) and direct and maternal heterotic effects when crossing them have been quantified (11). Considering the widespread importance and influence of the F1 dam in the East Texas beef cattle industry, this study was designed to identify the major components influencing calf performance of the F1 dam, such as year, season of birth, age of dam, weaning age, sex of calf, and dam's stocking rate. In particular, this study documented the relative influence of forage availability on birth weights and weaning weights of fall versus spring born Simmental-sired calves with F1 dams.

## Experimental Procedure

Brahman x Hereford (F1) cows have been utilized to evaluate the influence of grazing pressure on forage attributes and animal performance at the Texas A&M Agricultural Research and Extension Center at Overton since 1970. Calving cows in the fall and the late winter facilitated the utilization of cool-season and warm-season forages, respectively. Nutrient requirements of the cows and their calves within calving seasons were reconciled with the production of the forage species. Cows calving in the fall were assigned to ryegrass-bermudagrass or clover-bermudagrass test pastures with their calves during February. Cows and calves remained on the test pastures until mid-June when the calves were weaned. In mid-June, cows calving in late winter were assigned to bermudagrass test pastures with their calves. They remained on the test pastures until the calves were weaned in mid-October.

Data for this study were compiled from 1,911 records of Simmental-sired calves born to these F1 dams in 1975 and from 1977 to 1990. Data originally recorded for each calf included dam identification, year of birth, sex, breed of sire, age of dam, date of birth, birth weight, weaning date, weaning weight, stocking rate code, and grazing trial status. A data set for this analysis was derived from the data as follows:

A. All calves were classified with regard to age of dam from 1 to 17 years. These ages were calculated assuming a March 1 birthdate for every dam. March 1 represented the average calving date among F1 replacement heifer suppliers producing replacements for the Research Center. In order to reduce the nunber of class levels within dam age, dam's ages were grouped as follows: less than 3.5 years, 3.5 to 12 years, and older than 12 years.
B. Calf birth dates were used to determine their season of birth as follows: fall, September 1 to December l5; winter, December 16 to March l5; and spring, March 16 to May 31.
C. Weaning date was recorded as the day the calf was physically separated from the cow, even though some calves on pastures with high stocking rate were weaned earlier. Weaning age was calculated from the birthdate of the calf to weaning date in days.
D. A stocking rate code was assigned to every calf based on its pasture assignment. Stocking rate codes included high, medium, low stocking rate and "grazer". Additionally, several calves in the fall and winter were assigned a stocking rate code of creep fed.
E. Since a variable (put and take) method of stocking was used to implement the grazing research trial, cows were stratified into testers and grazers based on cow and calf parameters. Although pairs that were not assigned to a particular stocking rate received a stocking rate code of "grazer", grazers that remained on a specific stocking rate 60 days prior to weaning were assigned the same stocking rate code as a tester.
F. Every calf was assigned a previous stocking rate code based on the stocking rate code assigned to its dam's calf in the previous year. If the dam did not have a previous calving record because she was a first calf heifer, dry, or had been recently purchased, a previous stocking rate code of "grazer" was assigned to the calf.

Two separate files were created from these records to analyze birth weights and weaning weights independently. Analysis was completed between and within seasons of birth. For weaning weight, bull calves, represented only in the spring, and creep fed calves, represented in the fall and winter, were excluded from the analysis between seasons of birth. Similarly, for the between season analysis of birth weight, those calves in the fall and winter that were assigned to a previous stocking rate of creep fed were excluded. Least-square means for birth weight and weaning weight were calculated to compare the data since unequal subclass number were present.

## Results and Discussion

### *Birth Weight*

In the fall and winter calving seasons, respectively, bull calves weighed 1.2 and 1.9 kg more than heifer calves. Although these results are supported by the findings of Ahunu and Makarechian (1) and Roberson et al. (11), they reported differences of greater magnitude among Hereford cattle, 2.12 and 2.5 kg, respectively.

Ahunu and Makarechian (1) also reported that age of dam had a significant effect on birth weight. In accordance with their study, first calf heifers, represented by the 2.5 and 3 year olds, had the lightest birth weights of 31.6 and 34.0 kg for fall and winter, respectively. Although Ahunu and Makarechian (1) also found some evidence that preweaning performance began to decline in dams 9+ years of age, in this study birth weights from the 3.5 to 12 year olds (35.9 and 34.8 kg) were not significantly different from the 12-17 years olds (35.2 and 36.2 kg) for the fall and winter, respectively.

Although differences in birth weight due to sex of calf, age of dam, and year of birth are well documented, the effect of the dam's previous stocking rate on birth weight is somewhat questionable. In the fall and winter calving seasons, respectively, dams weaning calves under a high stocking rate had the lightest subsequent birth weights (33.3, 32.5 kg); whereas dams weaning creep-fed calves had the heaviest subsequent birth weights (35.6, 37.9 kg), respectively (Table 1). This contradicts Godfrey et al. (9) findings that dam's weight loss due to forage availability during the first two trimesters of pregnancy did not affect calf's birth weight. However, previous studies conducted by Tudor (12), Laster (10), and Bellows and Short (4) had indicated that decreasing precalving feed level during the last trimester resulted in decreased birth weights.

### *Weaning Weight*

In the fall and winter, steers weighed 24.2 and 18.7 kg more at weaning than heifer calves. Bradley et al. (5) reported that Hereford-Red Poll steers weighed 17 kg more at weaning than heifer calves. Numerous other studies have documented the superiority of steer calves over female calves with regard to weaning weight (1,2).

First calf heifers weaned lightest calves in the fall and winter, respectively (281.5 and 264.5 kg). These results supported the findings of Ahunu and Makarechian (1) which concluded that weaning weight increased with increasing age of dam for 2 to 4 years old in Hereford calves as well as cross bred calves ($P<.01$). Although Ahunu and Makarechian (1) also found that weaning weight performance began to decline in dams 9 years and older, there was no apparent difference in weaning weights of 3.5 to 12 year olds (301.1 and 279.6 kg ) and 12 to 17 year olds (300.2 and 283. 5 kg), respectively, for fall and winter.

The availability and quality of forage was undoubtedly an important contributor to the heavier weaning weights obtained by fall-born calves. Fall-born calves grazing cool-season annual pastures were heavier at weaning than either winter- or spring-born calves (280.1, 246.2, 200.3 kg, respec-

tively) grazing predominantly bermudagrass. In addition to grazing higher quality forage, fall-born calves were weaned at an older average age (258 days) than either winter-born (225 days) or spring-born (172 days) calves. Least-square means for stocking rates are presented in Table 2. Dams on low stocking rate weaned heavier calves than those on pastures with either high or medium stocking rates (296.2, 236.7, 282.5 kg, respectively). Creep fed calves present only in the fall and winter were favored with regard to weaning weight. Nutrient consumption by the brood cow is important in terms of energy required for lactation and reproduction; however calves clearly can benefit from levels of protein and energy beyond what their dams require (8). Furr and Nelson (8) demonstrated that creep fed calves, with dams on a low feeding level, weighed 11 kg more at weaning than calves, from dams on a high feeding level, that did not receive creep feed.

A stocking rate by season of birth interaction was also observed for weaning weight (P<.01). This provides further evidence of the calves' ability to utilize high quality forage. Being older at weaning, fall-born calves were able to effectively utilize the higher quality, cool-season forages available to them. Fall-born calves on a low and medium stocking rate out performed all winter-born calves (Figure 1). In conclusion, results from this study indicate that weaning weight of Simmental-sired calves can be maximized by optimizing stocking rate of fall-born calves grazing cool season annuals.

## Literature Cited


1. Ahunu, B., and M. Makarechian. 1986. Influence of birth date on preweaning performance of range beef calves. Can. J. Anim. Sci. 66:381.
2. Bair, L.G., L.L. Wilson, and J.H. Ziegler. 1972. Effects of calf sex and age of dam on pre- and post-weaning performance of calves from an Angus-Holestein crossbred herd. J. Anim. Sci. 35:1155.
3. Barnes, R.F. 1985. Grassland agriculture and ecosystem concepts. *In*: M.E. Heath, R.F. Barnes, D.S. Metcalfe (Ed.) Forages: The Science of Grassland Agriculture (4th Ed.) . Iowa State University Press, Ames, Iowa.
4. Bellow, R.A., R.E. Short, and G.V. Richardson. 1982. Effect of sire, age of dam and gestation feed level on dystocia and postpartum reproduction. J. Anim. Sci. 55:18.
5. Bradley, N.W., L.V. Cundiff, J.D. Kemp, and T.R. Greathouse. 1966. Effects of sex and sire on performance and carcass traits of Hereford and Hereford-Red poll calves. J. Anim. Sci. 25:78.
6. Cartwright, T.C., G.F. Ellis, Jr., W.E. Kruse, and E. K. Crouch. 1964. Hybrid vigor in Brahman Hereford crosses. Texas Agr. Exp. Sta. Tech. Monogr. 1.
7. Ellis, G.F., Jr., T.C. Cartwright, and W.E. Kruse. 1965. Heterosis for birth weight in Brahman-Hereford crosses. J. Anim. Sci. 24:93.
8. Furr, R.D., and A.B. Nelson. 1964. Effect of level of supplemental winter feed on calf weight and on milk production of fall-calving range beef cow. J. Anim. Sci. 23:775.
9. Godfrey, R.W., F.M. Rouquette Jr., and R.D. Randel. 1988. Influence of cow weight change on cow reproductive performance and calf performance. J. Prod. Agric. 1:221.
10. Laster, D.B. 1974. Factors affecting pelvic size and dystocia in beef cattle. J. Anim. Sci. 38:496.
11. Roberson, R.L., J.O. Sanders and T.C. Cartwright. 1986. Direct and maternal genetic effects on preweaning characters of Brahman, Hereford, and Brahman-Hereford crossbred cattle. J. Anim. Sci. 63:438.
12. Tudor, G.D. 1972. The effect of pre- and post-natal nutrition on growth of beef cattle. I. The effect of nutrition and parity of the dam on calf birth weight. Aust. J. Agric. Res. 23: 389.

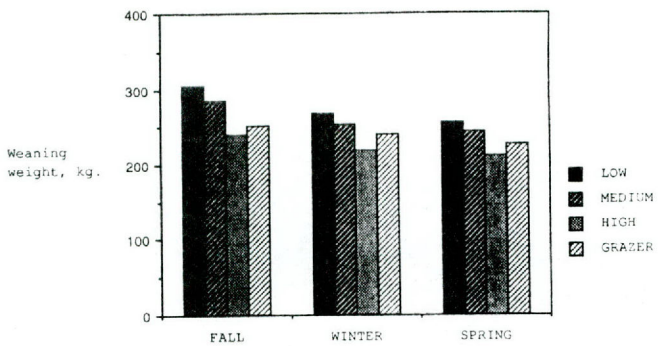




Figure 1. Effect of stocking rate on weaning weight of Simmental-sired calves from Brahman x Hereford ($F_1$) dams

TABLE 1. LEAST-SQUARE MEANS AND STANDARD ERRORS BY STOCKING RATE FOR WEANING WEIGHT OF SIMMENTAL-SIRED CALVES WITH BRAHMAN X HEREFORD (F-1) DAMS

| Stocking rate (SR) | Fall[a] n | Fall[a] Weaning weight, kg. | Winter[b] n | Winter[b] Weaning weight, kg. | Spring[c] n | Spring[c] Weaning weight, kg. | Total n | Total Weaning weight, kg. |
|---|---|---|---|---|---|---|---|---|
| Low | 168 | 313.01 ±3.35 | 119 | 286.55 ±4.88 | 24 | 237.43 ±6.70 | 306 | 276.14 ±2.87 |
| Medium | 192 | 293.29 ±3.29 | 114 | 271.13 ±4.89 | 22 | 224.27 ±7.53 | 325 | 261.54 ±2.85 |
| High | 158 | 248.97 ±3.47 | 138 | 234.03 ±4.78 | 39 | 190.08 ±6.72 | 330 | 223.95 ±2.60 |
| Grazer | 367 | 259.95 ±2.71 | 222 | 251.47 ±4.48 | 59 | 199.90 ±5.88 | 644 | 240.53 ±2.20 |
| Creep Fed | 39 | 355.91 ±5.96 | 16 | 336.08 ±7.61 | | | | |

[a] Fall includes those calves born from September 1 to December 15
[b] Winter includes those calves born from December 16 to March 15
[c] Spring includes those calves born from March 16 to May 31

TABLE 2. ABSOLUTE MEANS AND STANDARD ERRORS BY STOCKING RATE FOR WEANING WEIGHT OF SIMMENTAL-SIRED CALVES WITH BRAHMAN X HEREFORD (F-1) DAMS

| Stocking rate (SR) | Fall[a] n | Fall[a] Weaning weight, kg. | Winter[b] n | Winter[b] Weaning weight, kg. | Spring[c] n | Spring[c] Weaning weight, kg. | Total n | Total Weaning weight, kg. |
|---|---|---|---|---|---|---|---|---|
| Low | 168 | 320.80 ±2.45 | 119 | 293.42 ±3.06 | 24 | 232.43 ±6.54 | 306 | 296.16 ±2.45 |
| Medium | 192 | 303.39 ±2.56 | 114 | 278.19 ±3.31 | 22 | 220.32 ±6.73 | 325 | 282.50 ±2.41 |
| High | 158 | 258.24 ±2.99 | 138 | 240.59 ±2.33 | 39 | 190.09 ±3.50 | 330 | 236.66 ±2.14 |
| Grazer | 367 | 258.79 ±1.91 | 222 | 259.04 ±2.74 | 59 | 191.49 ±3.62 | 644 | 246.66 ±1.62 |
| Creep Fed | 39 | 380.82 ±5.49 | 16 | 367.18 ±7.73 | | | | |

[a] Fall includes those calves born from September 1 to December 15
[b] Winter includes those calves born from December 16 to March 15
[c] Spring includes those calves born from March 16 to May 31

# Evaluation of Productivity of F1 Females Sired by Five Zebu Breeds

A.D. Herring, E.B. Elizondo, J.O. Sanders and D.K. Lunt


## Summary

Calves out of five different types of Zebu-sired cows were evaluated for birth and growth characteristics. Cows were F1 females sired by Gray Brahman, Gir, Indu Brazil, Nellore, and Red Brahman bulls; in addition, cows sired by Angus bulls were used as an experimental control. All F1 females were out of Hereford cows. All five types of Zebu-sired females had calves that weighed less at birth as compared to those out of Angus-sired cows. In addition, calves out of Angus-sired cows had larger heart girths than those out of Zebu F1 females. Calves out of Zebu-sired cows were heavier and taller at weaning than those out of Angus-sired females. Females sired by Zebu bulls exhibited higher reproductive rates than those by Angus bulls.


## Introduction

Zebu cattle were imported from Brazil in 1980, '81, and '82 into the U. S. through the Harry S. Truman Import Center. Both bulls and heifers of the Nellore, Gir, Indu Brazil and Guzerat breeds were imported. This study was initiated in 1980 to compare different measures of productivity of these Zebu breeds with those of the American Gray Brahman and Red Brahman. There were not adequate numbers of the Guzerat imported to allow for an accurate representation of that breed; as a result, the Guzerat breed was not included in this study. There were enough of the Nellore, Gir, and Indu Brazil for accurate representations of these breeds.

Zebu cattle, specifically Brahman, have been used in the Southern U. S. because of their adaptability to hot climates, resistance to parasites, and hardiness in regard to forage availability (1, 5). However, Zebu breeds seem to exhibit lower reproductive rates and lower calf survival than *Bos taurus* breeds. By crossbreeding *Bos indicus* with *Bos taurus*, hybrid vigor for calving rate, weaning rate, maternal effects, and reproductive rate can be utilized. Sanders et al. (4) stated the major advantage of crossbreeding is the use of the crossbred brood cow.

## Experimental Procedure

Hereford cows were bred to Angus, Gray Brahman, Gir, Indu Brazil, Nellore, and Red Brahman bulls. All bulls used were chosen to be representative of their respective breeds. All Hereford cows had previously produced at least one calf before being included in the study. Cows were bred to calve in the fall of the 4 years, 1982-85. For information on the performance of the F1 calves for birth, growth, and carcass characteristics see Sanders et al. (3).

The F1 females evaluated in this study were born in 1982, '83, '84, and '85. The F1 heifers were bred to calve at approximately 30 months of age; all heifers were bred to Charolais bulls in 1984 through 1988. F1 cows 3 years of age or older were bred to Charolais bulls as well in 1985 and '86. In the 1987 and '88 breeding seasons, F1 cows that had calved at least once were randomly distributed within age and breed of sire and bred to Charolais and Salers bulls. All bulls used as sires in this study were chosen to exhibit typical characteristics of their breeds.

During each calving season, birth measurements were taken within 48 hours after birth. These included calving ease, calf vigor, cannon bone length, heart girth, and birth weight. At time of weaning, weight of the calf as well as hip height was measured. A total of 351 birth records and 320 weaning records were analyzed.

## Results and Discussion

Calving difficulty among first calf heifers was discussed previously by Sanders and Elizondo (2). Angus-sired heifers had considerably more dystocia than any of the Zebu-sired heifers. There was essentially no calving difficulty in multiparous cows. Calves produced by Angus-Hereford females had higher birth weights than those out of Zebu-Hereford females (Table 1). Among the *Bos indicus* cross females, Gray Brahman-sired cows had the heaviest calves at birth (83.8 lb) and calves out of the Gir-sired cows were the lightest (75.8 lb). Angus-sired females also had calves with larger heart girths than those out of Zebu cross cows. All *Bos indicus* crosses produced calves with longer cannon bone lengths than the Angus-sired cows. Among the Zebu cross cows, Indu Brazil had calves with the longest cannon bone length (11.7 in).

All Zebu cross females produced calves that weighed more and were taller at weaning than those out of Angus-sired dams. Calves out of Gray Brahman- and Red Brahman-sired cows had the heaviest weaning weights and tallest hip heights; among the Zebu crosses, Gir- and Indu Brazil-sired cows had calves that weighed the least and were the shortest.

In regard to fertility and reproductive rates, all five types of Zebu cross cows appeared to be more productive than the Angus-sired females (Table 2). Percent calf crop weaned was calculated as the total number of calves weaned divided by the total number of cows exposed within each sire breed of dam. All of

the Zebu-sired females had a higher percent calf crop weaned than the Angus-sired females. Among the Zebu-sired cows, Indu Brazil-sired dams had the highest rate (93.4%) followed by Nellore- (92.1%), Gir- (88.5%), Gray Brahman- (82.6%) and Red Brahman-sired (82.5%) cows. Of the cows that were still in production through 1989, all groups of Zebu-sired females had higher percentages of cows with perfect weaning records (weaned a calf every time they were exposed to breeding) as compared to Angus-sired cows. Among the *Bos indicus* crosses, Gir-sired cows had the highest percentage of cows with perfect weaning records (12 of 14), while Red Brahman-sired cows had the lowest (13 of 18).

## Literature Cited


1. Franke, D.E. 1980. Breed and heterosis effects of American Zebu cattle. J. Anim. Sci. 50:1206.
2. Sanders, J.O., and E.B. Elizondo. 1988. Evaluation of five Zebu breeds for cow productivity. McGregor Field Day Report. Technical Report 88-1:4.
3. Sanders, J.O., J.C. Paschal, and R.M. Thallman. 1987. Preweaning performance of Senepol-, Angus- and Zebu-sired calves in Texas. International Senepol Research Symposium. 1:75.
4. Sanders, J.O., J.C. Paschal and J.L. Kerr. 1988. Evaluation of five Zebu breeds for birth, growth, and carcass characteristics. Beef Cattle Research in Texas. PR-4609:77.
5. Turner, J.W. 1980. Genetic and biological aspects of Zebu adaptability. J. Anim. Sci. 50:1201.


TABLE 1. BIRTH MEASUREMENTS BY BREED OF COW'S SIRE

| Sire Breed Of Cow | No. Born | Birth Weight (lb) | Cannon Length (in) | Heart Girth (in) |
|---|---|---|---|---|
| Angus | 46 | 86.4 | 11.4 | 30.2 |
| Gray Brahman | 65 | 83.8 | 11.6 | 29.3 |
| Gir | 50 | 75.8 | 11.5 | 28.8 |
| Indu Brazil | 58 | 82.3 | 11.7 | 29.4 |
| Nelore | 72 | 80.4 | 11.5 | 29.6 |
| Red Brahman | 60 | 80.2 | 11.5 | 29.2 |

TABLE 2. WEANING MEASUREMENTS BY BREED OF COW'S SIRE

| Sire Breed of Cow | No. Weaned | Weaning Weight (lb) | Hip Height (in) |
|---|---|---|---|
| Angus | 38 | 508.3 | 43.6 |
| Gray Brahman | 57 | 579.5 | 46.1 |
| Gir | 46 | 548.5 | 45.8 |
| Indu Brazil | 57 | 540.7 | 45.7 |
| Nelore | 70 | 552.8 | 46.0 |
| Red Brahman | 52 | 576.8 | 46.3 |

TABLE 3. PERCENT CALF CROP WEANED BY BREED OF COW'S SIRE

| Breed of Cow's Sire | No. Weaned | % Weaned |
|---|---|---|
| Angus | 38 | 74.5 |
| Gray Brahman | 57 | 82.6 |
| Gir | 46 | 88.5 |
| Indu Brazil | 57 | 93.4 |
| Nelore | 70 | 92.1 |
| Red Brahman | 52 | 82.5 |
| Total | 320 | 86.0 |

# Comparison of Birth, Growth, and Carcass Characters of Calves Sired by Angus, Charolais, or Salers

B.R. Lott, J.O. Sanders, D.K. Lunt and J.F. Baker


## Summary

Calves sired by Angus, Charolais, or Salers bulls were evaluated for birth, growth, and carcass characteristics. The results of data analyzed to date indicate small differences among calves sired by these three breeds, if any, for birth and weaning characters, but significant differences among them for carcass characters.

The lack of differences for birth and weaning weights was unexpected, while the differences for carcass characters were as expected since sire breed is known to play a major role in the carcass merit of the offspring. The results reported are dependent on a representative sample of bulls from the three sire breeds, and the inclusion of the carcass characters for the 1990-born calves should allow for more accurate results.


## Introduction

The importance of utilizing crossbreeding to improve the efficiency of cattle production has been recognized in commercial cow/calf production; more than 70 percent of all cattle marketed in the United States are crossbred (2). Since breed effects are a benefit obtained from crossbreeding, the breed of sire to be used in a crossbreeding program is obviously very important.

In addition to birth and growth characters, carcass merit has received considerable attention lately by all segments of the beef industry. Comparison of breeds under controlled conditions becomes more important as producers attempt to improve production efficiency. Information on breed performance and their crosses is required to effectively design a crossbreeding program because each producer has specific resources and goals and should match breed-type to their production scheme (3, 5). This progress report represents results from a study designed to compare calves sired by Angus, Charolais, or Salers for birth, growth, and carcass characters.

## Experimental Procedure

This project sampled bulls from the Angus (n=10), Charolais (n=10) and Salers (n=12) breeds, and each was mated by natural service in single sire pastures. The bulls were either purchased by the Texas A&M University Agricultural Research Center at McGregor or were loaned to the Center for the breeding season. The cows were all aged cows and were produced in a crossbreeding project involving five breeds (Angus, Brahman, Hereford, Holstein, and Jersey).

This report is based on data from both steer and heifer calves born during the spring of 1988 (n=150), 1989 (n=164), and 1990 (n=115). Birth, weaning and carcass data were evaluated. Cows were monitored at calving and calving ease/difficulty, calf vigor, and nursing scores were recorded. At birth, calves were weighed and cannon bone length measurements were taken. Birth date, sex, and color were also recorded. All calves were vaccinated at approximately 4 weeks of age, dehorned if necessary, implanted with Ralgro, and all bull calves were castrated.

The calves were weaned at approximately 7 months of age at four different times each year, depending on the month of birth, and were started on feed immediately after weaning. A starter ration was fed for approximately 2 weeks, then an intermediate ration for 8 to 10 days before switching to a finishing ration which was fed until slaughter. Weights and hip height measurements were taken every 28 days.

The 1988-born calves were slaughtered by weaning group in May and June 1989 at a commercial packing plant in Abilene, Texas. The 1989-born calves were slaughtered by weaning group in May and June 1990 at a commercial packing plant in Abilene, Texas, at the Rosenthal Meat Science and Technology Center on the Texas A&M University campus, or at a commercial packing plant in Corpus Christi, Texas. The calves were weighed prior to shipping and this was used as the final live weight. On the day of slaughter, carcasses were tagged for later identification and a warm carcass weight was taken just prior to going into the chilling room. Approximately 20 to 22 hours after slaughter, lean maturity, skeletal maturity, fat thickness at 12th rib, ribeye area, percentage kidney, pelvic and heart fat (KPH), and USDA marbling scores were obtained. The yield grade and quality grade were then determined using these measurements.

The data were analyzed with a statistical model that included: sire breed, sire within sire breed (random effect), sex of calf, birth month, birth year, dam breed, and the interaction between sire breed and sex of calf. The effect of sire breed was tested with sire nested within breed.

## Results and Discussion

Sire breed proved to be a significant effect for cannon bone length, condition score at final weight, marbling score, fat thickness, ribeye area, KPH fat,

quality grade, and yield grade (P<.05), but not for birth weight, weaning weight, weaning hip height, final hip height, final weight or carcass weight, with similar results reported at an earlier phase of the study (1, 4). Sire, within sire breed, was significant for all characters (P<.05) except birth weight, weaning weight, final hip height, and cannon bone length. The sire breed by sex interaction was significant only for weaning hip height, marbling score, and quality grade (P<.05). Marbling score and quality grade were highly correlated.

Although sire breed differences were not significant for final weight or carcass weight, Angus-sired calves had a slightly heavier average final weight than Salers-sired calves, followed by Charolais-sired calves. However, the Salers-sired calves had a heavier average carcass weight, followed by the Angus- and Charolais-sired calves. This change of ranking suggests that the Salers-sired calves tended to have a slightly higher dressing percentage than the Angus-sired calves.

These rankings for final weight and carcass weight are in contrast to the ranking for weaning weight. The Charolais-sired calves weaned heavier than the Salers-sired calves, which were followed by the Angus-sired calves, as shown in Table 1. This change was caused by the postweaning gain of the Angus-sired calves being superior to the others. The Charolais-sired calves had the poorest postweaning gain in this study. This is especially apparent for the Charolais-sired heifers. Although these were the heaviest heifers at weaning, they were the lightest at slaughter and had the lowest marbling scores and quality grades in the study; these heifers had the overall lowest (leanest) yield grades in the study, as shown in Table 1.

Although the Charolais-sired calves had less marbling and the overall lowest quality grades (Table 1), they did have the lowest (most desirable) yield grade with ribeye area measurements intermediate to Angus- and Salers-sired calves, with the Salers-sired calves having the largest ribeye area and Angus-sired calves having the highest (least desirable) yield grade. The Charolais-sired calves also had the least amount of fat thickness and KPH fat. The Salers-sired calves were very comparable to the Angus-sired calves for quality grade.

Dam breed was significant for birth weight, cannon bone length, weaning weight, weaning hip height, final hip height, final weight, marbling score, fat thickness, ribeye area, quality grade, and carcass weight (P<.05). Sex of calf was significant for birth weight, cannon bone length, weaning weight, weaning hip height, final hip height, final weight, marbling score, ribeye area, quality grade, and carcass weight (P<.05). The differences between the sexes are shown in Table 1. Neither dam breed nor sex of calf was significant for condition score at final weight, KPH fat, or yield grade.

## Literature Cited


1. Baker, J. F. 1989. Comparison of birth characters of calves sired by Angus, Charolais or Salers. McGregor Field Day Report.
2. Koch, R. M., G. E. Dickerson, L. V. Cundiff, and K. E. Gregory. 1985. Heterosis retained in advanced generations of crosses among Angus and Hereford cattle. J. Anim. Sci. 60:1117.
3. Koger, M., F. M. Peacock, W. G. Kirk, and J. R. Crockett. 1975. Heterosis effects on weaning performance of Brahman-Shorthorn calves. J. Anim. Sci. 40:826.
4. Lott, B. R., J. F. Baker, and D. K. Lunt. 1989. Sire breed effects for carcass merit. McGregor Field Day Report.
5. McElhenney, W. H., C. R. Long, J. F. Baker, and T. C. Cartwright. 1985. Production characters of first-generation cows of a five-breed diallel: Reproduction of young cows and preweaning performance of inter se calves. J. Anim. Sci. 61:55.


Table 1. Sire Breed Least Squares Means of Birth, Weaning and Carcass Characters

| | Angus | | Charolais | | Salers | |
|---|---|---|---|---|---|---|
| Variable | Steer | Heifer | Steer | Heifer | Steer | Heifer |
| Number (birth) | 79 | 57 | 65 | 60 | 69 | 51 |
| Birth Wt., lb | 77.9 | 72.3 | 79.9 | 72.7 | 77.8 | 73.9 |
| Cannon Bone, cm | 29.3 | 29.0 | 29.8 | 29.5 | 29.6 | 29.3 |
| Weaning Wt., lb | 502.8 | 485.9 | 526.0 | 488.7 | 504.6 | 486.7 |
| Weaning Ht., cm | 111.7 | 110.5 | 112.9 | 110.4 | 112.3 | 111.9 |
| Number (carcass) | 64 | 43 | 59 | 51 | 58 | 46 |
| Final Ht., cm | 130.5 | 126.9 | 130.9 | 126.3 | 131.2 | 127.2 |
| Final Wt., lb | 1162 | 1047 | 1124 | 999 | 1148 | 1042 |
| Condition Score [a] | 6.4 | 6.5 | 6.1 | 6.0 | 6.0 | 6.2 |
| Carcass Wt., lb | 682 | 637 | 694 | 607 | 711 | 641 |
| Fat Thickness, in | .41 | .44 | .33 | .28 | .39 | .43 |
| KPH Fat, % | 2.5 | 2.4 | 2.2 | 2.1 | 2.3 | 2.3 |
| Ribeye Area, $in^2$ | 11.1 | 10.8 | 11.9 | 11.4 | 12.1 | 11.5 |
| USDA Yield Grade | 3.1 | 3.0 | 2.5 | 2.2 | 2.7 | 2.7 |
| Marbling Score | Slight 82 | Slight 79 | Slight 67 | Slight 07 | Slight 75 | Slight 69 |
| USDA Quality Grade | Select 72 | Select 70 | Select 60 | Select 19 | Select 70 | Select 66 |

[a] 1=thin, 9=obese

# Restriction Fragment Length Polymorphisms as an Aid in Selection for Quantitative Traits in Beef Cattle— an Application to Field Data

J.L. Rocha, J.F. Baker, J.E. Womack. J.O. Sanders and J.F. Taylor


## Summary

Statistical associations were detected between a new type of genetic marker, made available by developments in molecular techniques, and production traits in beef cattle. Their potential application in cattle breeding is described. Associations with maternal influences on birth and weaning weights are of particular interest and of considerable magnitude. Evidence of an interaction with presumedly cytoplasmic effects is presented.


## Introduction

Improvements in the efficiency of beef cattle operations can be reached by consideration and appropriate manipulation of both genetic and non-genetic factors. The two main tools to achieve genetic changes in an animal population are selection and mating systems.

The basis for selection has always been the phenotype, i.e., the expression of the desired trait. This external expression is necessarily a reflection of the genetic information contained in the DNA of the chromosomes, though not always an accurate one because many environmental factors interface with the expression of the genetic information. An animal genetically superior but reared in a poor environment may never reach the condition of a genetically inferior animal with adequate feed. However, only a genetically superior animal can consistently produce superior offspring

Quantitative genetics has successfully dealt with the problem of accurately estimating breeding values from phenotypic data, and has led to extraordinary progress in cattle breeding. However, further achievements may still be possible through the adoption of molecular genetics techniques that are gradually becoming available. One of these, whose potential for cattle breeding is now being investigated, is the Restriction Fragment Length Polymorphism (RFLP) methodology.

## RFLPs, What Are They?

While avoiding excessive detail, we can say that RFLPs are a method to directly assess the genetic constitution of an animal at the DNA level, overcoming environmental influences. The genetic variation being monitored is expressed through the length of the DNA restriction fragment that hybridizes with a radioactively labelled probe, hence the name Restriction Fragment Length Polymorphisms. The technique involves the digestion of a DNA sample by a chosen restriction enzyme, which cuts the DNA into fragments of different lengths according to the location of recognition sites unique to each enzyme. These restriction fragments are then separated by means of electrophoretic migration in a gel. Longer and heavier fragments move slower than shorter fragments, which migrate further in the gel. The resulting pattern of fragments is transferred to a solid nylon membrane support (15). This membrane containing the DNA pattern, also called a Southern blot, is then submitted to hybridization with a radioactively labelled probe, which is a cloned copy of a certain gene, and the length of the fragment that hybridizes is revealed by autoradiography. This length is subject to variation within a population, and reflects the DNA constitution in the vicinity of the gene that was probed.

Changes in base pairs may disrupt the recognition site for the restriction enzyme being used, and therefore, the fragments which hybridize may be of different lengths:

```
A
------ R1 ---------- Hy ---------- R2 ------

B
---------- R1 ---- Hy ---------- R2 ------
```

A and B are homologous portions of two different chromosomes, R1 and R2 are recognition sites which determine where the restriction enzyme will cut the DNA, and Hy is the gene homologous to the probe being used and where hybridization to the probe occurs. These two different sized fragments (from R1 to R2), constitute two different alleles of a genetic locus defined by the combination of the restriction enzyme and the probe utilized.

## Associations Between RFLPs and Quantitative Loci

The basic idea of this type of research is that specific RFLPs will be associated with or have a direct effect on economically important traits, so that selection methods can be complemented with information coming from RFLPs. Semen or blood samples collected from prospective breeding animals would be analyzed for RFLPs, and the results obtained could help us to better estimate their breeding values

for a particular trait of importance to our operation.

Three main experimental designs have been proposed to quantify associations between RFLPs and quantitative traits: crosses between inbred lines (14), trait-based analyses (7), and crosses in segregating populations (2, 13). The first two designs require the existence of breeds in fixation, or at least close to fixation for different alleles, while the last demands a large number of relatives (half or full-sibs) per family for best results. Each design leads to a corresponding statistical model, and encouraging results have been published from studies with plants (4, 11).

## Experiental Procedure

Blood or semen samples were collected from about 1,000 individuals more or less equally divided across three generations of a diallel study conducted at the Texas A&M University Agricultural Research Station at McGregor involving five breeds: Angus, Brahman, Hereford, Holstein and Jersey. The sample collection across generations provided a half-sib family structure, and the available quantitative records contain information on many economically important traits. Further details of this diallel study have been presented in the literature (8, 9).

The blood and semen samples were processed following standard procedures (1, 10, 15) to obtain RFLPs. A set of 6 restriction enzyme x probe combinations was first used to evaluate the associated levels of genetic polymorphisms existing in the diallel population. The probe x restriction enzyme combinations utilized were: Growth Hormone-EcoR1 (GH-EcoR1), Growth Hormone-TaqI (GH-TaqI), Prolactin-MspI (PRL-MspI), Osteonectin-EcoR1 (OSTN-EcoR1), Parathyroid Hormone-MspI (PTH-MspI),and Keratin4-MspI (KER-MspI).

When preliminary results were analyzed, taking into consideration the different methods outlined above to determine associations between RFLPs and quantitative effects, we realized that:

1. For only two of the marker-loci (GH-TaqI and PTH-MspI) were the differences in allelic frequencies among breeds wide enough to support an 'inbred lines analysis' (14), considering the Brahman as one inbred line, and the Angus and the Hereford together as another inbred line.
2. Only the same two marker-loci (GH-TaqI and PTH-MspI) displayed a sufficient level of polymorphism to support a 'segregating population analysis' (2, 13).
3. The other four loci could only be used in an analysis aimed at detecting direct effects of the different existing alleles, which is achieved through an analysis of variance with no breed or family structure included.

Based on these conclusions, a strategy was outlined to collect additional RFLP data, and to match such genotypic information with all the quantitative measurements available from the diallel, which included birth, weaning, yearling, and other records on weights; heights, growth rates, etc.; reproductive parameters such as calving interval, ease, survival, etc.; and heat tolerance information. The basic statistical tool utilized for this matching was a SAS generalized linear model (5), including terms associated with breed, year and month of birth, and marker-genotype effects. Additional covariates were considered for some of the variables analyzed. See Rocha (12) for more details.

## Results and Discussion

### *1. Growth Hormone-EcoR1*

Statistically significant quantitative effects found for one of the alleles of this marker are presented in Table 1.

Before any interpretation is attempted, it should be emphasized that all the results reported are strictly statistical associations, whose biological or genetic validity cannot be verified within the scope of this experiment. The relatively small numbers of animals involved, the nature of the quantitative data available reflecting many different sources of non-genetic variation, and the intrinsic difficulties of this type of work make these results simply clues which, if considered sufficiently interesting, require further work to be adequately validated.

With such limitations in mind, Table 1 indicates that through the GH-EcoR1 marker, we could possibly obtain information on, and produce changes in traits like gestation length and yearling growth. To reduce gestation length, we should try to keep the frequency of the B allele as low as possible within our herd. Bulls, in particular, could be screened to determine whether they are carriers of the B allele. If so, they should be avoided. This should also bring along an increase in yearling growth rates. However, some elements of doubt exist with respect to this marker (12), which cause even more caution in the interpretation of these results.

**Table 1. Quantitataive effects of GH-EcoR1 B allele (12.7 kb).**

| | Regres. Coef.[a] | Std. Err. | Signif. Level | %Var. Expln. |
|---|---|---|---|---|
| Gestation Length (d) | +4.2 (.61)[b] | 1.4 | .003 | 8.3% |
| Yrl. wt (kg) | -28.5 (.41) | 6.9 | .0001 | 1.8% |
| Yrl. wt/ht (kg/cm) | -.21(.43) | .05 | .0001 | 2.3% |
| Post-Wean. girth(kg) | -21.9 (.42) | 5.7 | .0002 | .9% |

[a]Results obtained from gene-substitution models: The regression coefficients express the average effects, which occur when a B allele replaces any other allele in a genotype.

[b]Values in parentheses represent the allelic effect expressed as a fraction of the phenotypic standard deviation for the quantitative trait.

Standard errors and significance levels express, respectively, the amounts of expected error associated with the estimation of such effects, and the probability of such results being simple chance events. The last column represents the amount of phenotypic variance explained by the marker-effect.

### *2. Growth Hormone-TaqI*

Quantitative effects found to be statistically associated with alleles of the GH-TaqI marker are presented in Table 2.

Results in Table 2 seem to imply that three alleles, B, C, and D, all found in high frequency in the Brahman breed, are associated with decreases in calf birth weight when present in the dams. When present in the calves, they also seem to determine decreases in shoulder width at birth. If proven true, these are extremely interesting and potentially very useful effects. In fact, a classical and difficult goal in beef cattle breeding relates to simultaneously attaining heavy slaughter weights and mature sizes while keeping low birth weights to prevent associated dystocia problems. Apparently, the GH-TaqI marker does not bear any effect on weaning or yearling weights. Therefore, it seems an ideal marker to help in such an objective. Bulls and replacement heifers could be screened for RFLPs, and along with other selection objectives, an attempt could be made to choose those animals carrying these favourable alleles, B, C, and D. Reductions in birth weight and shoulder width would be expected, hopefully resulting in lower levels of dystocia but not having any effect upon slaughter weights or mature sizes in the next generation. Statistical procedures could also be developed for birth-weight EPDs that would include and reflect such type of marker-information. Results in Tables 3 and 4 further support those in Table 2. In fact, among F2 Angus-Brahman and Brahman-Hereford cows, those homozygous for the 'Brahman' alleles gave birth to calves 4.0 kg lighter than cows homozygous for the A allele. This explains the total Brahman vs Angus and Hereford breed difference, and represents one phenotypic standard deviation (Table 4), constituting a genic effect of considerable magnitude. Also, at birth, F2 calves homozygous for the 'Brahman' alleles were 0.8 cm narrower at the shoulders than those homozygous AA (Tables 3 and 4).

**Table 2. Quantitative effects of GH-TaqI alleles.**

| | Regres. coef. | Std. Err. | Signif. Level | %Var. Expln.[a] |
|---|---|---|---|---|
| Av. calf birth wt/cow (kb) | | | | 7.1% |
| allele B (5.2 kb) | -1.4 (.35) | .51 | .006 | |
| allele C (4.5 kb) | -1.1 (.28) | .59 | .06 | |
| allele D (4.25 kb) | -2.6 (.66) | .71 | .0003 | |
| Birth shoulder width (cm) | | | | 10.6% |
| allele B | -.40(.22) | .13 | .003 | |
| allele C | -.44(.24) | .21 | .04 | |
| allele D | -.59(.33) | .28 | .04 | |

[a]See legend of Table 1 for interpretation.

The large negative maternal influence of Brahman cows on the birth weight of their calves is well known (18). It is also known that two TaqI recognition sites are included within the Bovine Growth Hormone gene (3), which makes it very likely that through the GH-TaqI marker we are monitoring genetic variation occurring in the Growth Hormone gene itself, or in closely linked genomic regions. In humans, the Growth Hormone and the Placental Lactogen genes are closely linked (6), and similar linkage arrangements may also hold in cattle (17). Placental Lactogen is a hormone that contributes to the regulation of fetal growth (16), therefore, all these findings appear to be rather meaningful; RFLPs provide a tool capable of a genetic scrutiny that was not available before.

**Table 3. Least squares means for F2 marker-genotypes.**

| | GH-TaqI | | | PTH-MspI | | |
|---|---|---|---|---|---|---|
| | AA | Het. | Non-A Hom. | AA | Het. | Non-A Hom. |
| Yrl. pelvic wth (cm) | 13.1(.4)[a] | 14.0(.4) | 12.4(.7) | | | |
| Yrl. pelvic ht (cm) | 15.9(.3) | 16.5(.2) | 15.4(.4) | | | |
| Yrl. ht (cm) | | | | 113.6(3) | 122.9(2) | 116.7(3) |
| Post-Wean. Growth (kg) | | | | 117.3(11) | 131.1(7) | 151.1(9) |
| 2 Yr ht (cm) | | | | 131.7(2) | 137.5(1) | 136.2(2) |
| Av. calf birth wt/cow (Kg) | 32.3(.8) | 28.9(.8) | 28.3(1.0) | | | |
| Av. calf wean. wt/cow (kg) | | | | 180.2(6) | 194.5(5) | 197.7(5) |
| Birth shoulder wth (cm) | 17.7(.2) | 16.8(.3) | 16.9(.4) | | | |

[a]Number in parentheses is the standard error.

**Table 4. Differences between F2 alternate homozygotes.**

| | a | a/Breed Diff. | a/Std. Dev. | p-Value | Marker |
|---|---|---|---|---|---|
| Yrl. pelvic wth (cm) | .7 | -5.8 | .30 | .14 | GH-TaqI |
| Yrl. pelvic ht (cm) | .5 | -5.0 | .25 | .05 | GH-TaqI |
| Yrl. ht (cm) | 3.1 | .30 | .37 | .05 | PTH-MspI |
| Post-wean. growth (kg) | 33.8 | -1.7 | .64 | .06 | PTH-MspI |
| 2-yr ht (cm) | 4.5 | .40 | .56 | .08 | PTH-MspI |
| Av. calf birth wt/cow (kg) | 4.0 | 1.2 | 1.0 | .03 | GH-TaqI |
| Av. calf wean. wt/cow (kg) | 17.5 | .99 | .80 | .03 | PTH-MspI |
| Birth shoulder wth (cm) | .8 | .57 | .44 | .03 | GH-TaqI |

a Quantitative difference between F2 alternate homozygotes (compare with Table 3).

The second column represents the a value expressed as a fraction of the Brahman vs Angus and Hereford breed difference.

The third column expresses the a value as a fraction of the phenotypic standard deviation, while the p-value represents the probability of such results being simple chance events.

Furthering the study of this marker-effect on maternal influences on birth weight, the breed-types of the maternal grand-dams of 42 F2 Brahman-Angus and Brahman-Hereford cows were identified and added to the statistical model. Such a maternal grand-dam breed effect could represent a cytoplasmic effect, which may also affect birth characteristics. In fact, maternal influences can be due to causes other than the uterine environment. When the ovum is fertilized, the male contributes only nuclear genetic material. The female, however, contributes not only the other half of the nuclear genetic material, but also all of the cytoplasm, which includes additional genetic material, which may impact certain birth traits and other characteristics.

In crossbred F2 males and females, the maternal grand-dam provides the origin of the cytoplasmic genetic material carried by the animals. Evidence of an interaction between this putative cytoplasmic effect and the marker-effect on birth-weight was found and is presented in Table 5.

**Table 5. Interaction between cytoplasmic and marker effects on birth-wt.**

| GH-TaqI Genotype | Breed of cytoplasm | |
|---|---|---|
| | Angus-Hereford | Brahman |
| AA | 32.8 kg* | 31.8 kg |
| A-Heterozygous | 31.1 kg | 26.7 kg |
| Brahman Homozygous | 24.8 kg | 31.8 kg |

*Numbers are least squares means.

The interaction was statistically significant at the .02 percent level, and the cytoplasmic and the marker effects together account for 10.5 percent of the phenotypic variation in birth weight. The small numbers of observations preclude us from strong conclusions. It is interesting to notice, however, how cytoplasmic effects may in fact play a role in the expression of some traits. One would expect Angus-Hereford cytoplasm to be associated with heavier birth-weights, and that is in fact observed most of the time. The marker-effect also behaves as just described most of the time. However, in cows that inherited both Brahman alleles, if they also inherited a British-type cytoplasm, a reversal of the ranking occurs, causing the statistical interaction. This is a very interesting phenomenon, which could result from some kind of metabolic or genetic balance lost when unusual nuclear-cytoplasmic combinations occur.

### *3. Parathyroid Hormone-MspI*

Several associations were found for PTH-MspI as listed in Tables 3, 4, and 6.

**Table 6. Estimates of quantitative effects linked to the PTH-MspI locus.**

| | a | a/Std. Dev. | P-Value |
|---|---|---|---|
| Yrl wt (kg) | 29.4 | .42 | .003 |
| Yrl ht (cm) | 5.2 | .62 | .09 |
| Yrl wt/ht (kg/cm) | .22 | .45 | .001 |
| Post-wean. growth (kg) | 27.5 | .52 | .007 |
| 3 yr ht (cm) | 5.1 | .70 | .04 |
| Av. calf-wean. wt/cow (kg) | 17.2 | .79 | .04 |

a Average quantitative difference between alternate offspring groups within half-sib families (see text).

The second column expresses the a value as a fraction of the phenotypic standard deviation, while the p-value represents the probability of such results being simple chance events

Tables 3 and 4 show that among F2 Angus-Brahman and Brahman-Hereford calves, those homozygous for the 'Brahman' alleles (C, L, I, and H) were taller, heavier, and had higher growth rates than those homozygous for the A allele. The data in Table 6 further support these findings. Among offspring of heterozygous bulls or cows, statistically significant differences for the same traits exist between those offspring that inherited one parental allele-type and those that inherited the other parental allele-type.

It therefore appears that through this marker we could manipulate genetic changes in body size. Particularly interesting is the effect on weaning weight as a maternal trait. In Tables 3 and 4 we see that those F2 cows homozygous for the 'Brahman' alleles weaned calves heavier than those cows homozygous for the A allele. The Brahman is recognized to have a larger additive maternal effect for weaning weight compared to Angus, and much larger compared to Hereford cows (18), and it seems as if the PTH-MspI marker explains a considerable proportion of this breed difference. Breed of cytoplasm effects were also investigated for this trait, but no influence on the expression of maternal influences on weaning weight was detected.

No statistically significant associations were found for the other three markers (PRL-MspI, OSTN-EcoR1, and KER-MspI). Rocha (12) gave additional details of methods and results.

## Conclusions

The results reported are statistical associations that require validation before they can be accepted as true. They constitute, however, a good example of what RFLPs may be able to achieve for cattle breeding. Especially those associations involving maternal effects on birth and weaning weights, and direct

effects on birth shoulder width, seem interesting and promising enough to deserve further study. If proven true, they could become useful tools for cattle breeders. RFLPs, therefore, appear to hold some potential for livestock breeding.

## Acknowledgements

We would like to express our appreciation to Mr. Ronnie Knutson and to all the staff of the McGregor Research Station, as well as to Yvonne Moll, David Threadgill, Susan Pletscher, Alan Dietz, and all the graduate students of the molecular genetics lab of the Vet. Pathobiology Dept. of Texas A&M University.

## Literature Cited

1. Ausubel, F., R. Brent, R. Kingston, D. Moore, J. Seidman, J. Smith, K. Strohl (Editors). 1989. Current Protocols in Molecular Biology. Greene Publishing Associates & Wiley Inter-Science, New York.
2. Beckmann, J. and M. Soller. 1988. Detection of linkage between marker loci and loci affecting quantitative traits in crosses between segregating populations. Theoretical and Applied Genetics 76:228-236.
3. Cowan, C., M. Dentine, R. Ax and L. Schuler. 1989. Restriction Fragment Length Polymorphisms associated with Growth Hormone and Prolactin genes in Holstein bulls: evidence for a novel Growth Hormone allele. Animal Genetics 20:157-165.
4. Edwards, M., C. Stuber, and J. Wendel. 1987. Molecular-marker-facilitated investigations of Quantitative-trait loci in maize : I) numbers, genomic distribution and types of gene action. Genetics 116:113-125.
5. Freund, R., R. Littell and P. Spector. 1986. SAS System for Linear Models. SAS Institute Inc., Cary, North Carolina.
6. Kidd, V. and G. Saunders. 1982. Linkage arrangement of human Placental Lactogen and Growth Hormone genes. Journal of Biological Chemistry 477:10673-10680.
7. Lebowitz, R., M. Soller, and J. Beckmann. 1986. Trait-based analyses for the detection of linkage between marker loci and quantitative trait loci in crosses between inbred lines. Report on the Research Project 'Restriction Fragment Length Polymorphisms in Varietal Identification and Genetic Improvement' of the Binational (U.S.-Israel) Agricultural Research and Development Fund (BARD): 21-37. Department of Plant Genetics and Breeding, ARO, The Volcani Center, Bet Dagan, Israel.
8. Long, C., T. Stewart, T. Cartwright, and T. Jenkins. 1979. Characterization of cattle of a five breed diallel: I) measures of size, condition and growth in bulls. Journal of Animal Science 49 (2):418-431.
9. Long, C., T. Stewart, T. Cartwright, and J. Baker. 1979. Characterization of cattle of a five breed diallel: II) measures of size, condition and growth in heifers. Journal of Animal Science 49 (2):432-447.
10. Maniatis, T., E. Fritsch, and J. Sambrook. 1982. Molecular Cloning - A Laboratory Manual. Cold Spring Harbor Laboratory. Cold Spring Harbor, New York.
11. Paterson, A., E. Lander, J. Hewitt, S. Peterson, S. Lincoln, and S. Tanksley. 1988. Resolution of quantitative traits into Mendelian factors by using a complete linkage map of Restriction Fragment Length Polymorphisms. Nature 335:721-726.
12. Rocha, J. 1990. Statistical Associations between Restriction Fragment Length Polymorphisms and Quantitative Traits in Beef Cattle. A Master's Thesis. Texas A&M University, College Station.
13. Soller, M., and A. Genizi. 1978. The efficiency of experimental designs for the detection of linkage between a marker locus and a locus affecting a quantitative trait in segregating populations. Biometrics 34:47-55.
14. Soller, M., T. Brody, and A. Genizi. 1976. On the power of experimental designs for the detection of linkage between marker loci and quantitative loci in crosses between inbred lines. Theoretical and Applied Genetics 47: 35-39.
15. Southern, E. 1975. Detection of specific sequences among DNA fragments separated by gel electrophoresis. Journal of Molecular Biology, 98: 503-517.
16. Talamantes, F. and L. Ogren. 1988. The placenta as an endocrine organ: polypeptides. *In*: The Physiology of Reproduction: 2093-2112, by E. Knobil, J. Neill, et al., (Editors). Raven Press, Ltd, New York.
17. Womack, J. and Y. Moll. 1986. Gene map of the cow: conservation of linkage with mouse and man. Journal of Heredity 77:2-7.
18. Wyatt, W., and D. Franke. 1986. Estimation of direct and maternal additive and heterotic effects for preweaning growth traits in cattle breeds represented in the Southern Region. Southern Cooperative Series, bulletin no. 310. Louisiana Agricultural Experiment Station, Baton Rouge.

# Evaluation of Differences in Birth, Weaning, and Carcass Characters of Offspring of Angus Sires Available Prior to 1970 and Those Born Since 1985

T.D. Ruffin, J.O. Sanders, D.K. Lunt and J.F. Baker


## Summary

Angus sires available before 1970 (OLD) and those born since 1985 (NEW) were mated to Simmental cows. The resulting offspring were compared for birth, weaning and carcass characters. The calves sired by OLD sires were lighter at birth and weaning, had smaller cannon bone lengths and heart girths at birth along with smaller weaning hip heights and weaning hip widths than calves sired by NEW sires. NEW sired calves had larger carcass weights while both groups were similar for actual and adjusted fat thickness, ribeye area and kidney, pelvic, and heart fat. No significant differences were found to exist between the two sire groups for marbling.


## Introduction

The Angus breed has been and is widely used in the U.S. The breed's popularity produces more registrations annually than any other beef breed association. The breed is recognized for its outstanding characteristics for carcass quality and palatability. The success of the Certified Angus Beef (C.A.B.) program is largely due to the reputation and confidence placed in Angus-sired calves.

The Angus breed has been evaluated in numerous research projects. Probably the most thorough crossbreeding study was at the Roman L. Hruska U.S. Meat Animal Research Center at Clay Center, Nebraska. The research involved four cycles, and preliminary results of Cycle IV have been published (1). The fourth cycle introduced new Angus and Hereford sires into the crossbreeding study. The results reported indicated that calves sired by modern bulls were heavier at birth and weaning and produced heavier carcasses than calves from conventional sires (1). However, the two groups were similar for fat thickness, ribeye area, and marbling score.

There have been many obvious changes in the breed since the early 1970s. Many breeders have selected for more rapid growth and increased frame score as a result of a desire to increase the efficiency of Angus cattle and greater competition for bull sales from breeders of continental European breeds. It had not been known to what extent these changes have affected birth, growth, and carcass characteristics.

## Experimental Procedure

To document whether major differences exist between modern Angus sires and conventional An gus sires, Simmental cows were mated by artificial insemination to (1) 18 conventional bulls (OLD) or (2) 9 modern bulls (NEW). The cows are high percentage Simmental from one location in Missouri. Half of the cows were randomly allotted to each of the two groups of sires with re-randomization before each breeding season. This progress report is based on 68 records for 1989 and 29 records for 1990 for birth characters and 55 records for 1989 and 26 records for 1990 for weaning characters. There were 54 records for carcass traits from offspring produced in 1989.

The nine modern sires were selected from young Angus sires born since 1985 and available from semen donations or purchases. The eighteen conventional sires were selected from the sires used in a comprehensive crossbreeding study initiated at the Texas A&M University Agricultural Research Center at McGregor during the early 1970s.

The calves produced from these matings were weighed at birth and weaning (approximately seven months of age) and were weighed at 28-day intervals until approximately one year of age when a final weight was taken. All calves were slaughtered and carcass data were collected.

## Results and Discussion

The least squares means and standard errors for birth characters are presented in Table 1. A general linear model was used to analyze the data which included sex of calf, year of birth, age of dam in years, generation of sire (OLD or NEW) and sire within generation (random effect). Generation of sire was significant for birth weight, cannon bone length, and heart girth. Age of dam was significant for birth weight, sire within generation was significant for birth weight and cannon bone length, and year of birth was significant for cannon bone length. Sex was not significant for any birth character studied, but bull calves were larger for all three traits. Calves sired by OLD sires had least squares means for birth weight 11.4 lb less than those by NEW sires. The least squares means for cannon bone length and heart girth were higher for NEW sired calves than OLD sired calves (30.1 vs. 28.2 cm) and (78.2 vs. 74.0 cm). Least squares means of males versus females for birth weight were 85.8 lb and 81.5 lb. Differences between sexes for cannon bone length and heart girth were small, but the least squares means were higher for the bull calves.

The least squares means and standard errors for weaning traits are presented in Table 2. The model used to analyze weaning traits included sex of calf,

age of calf at weaning in days, year of birth, age of dam in years, generation of sire, and sire within generation (random effect). Generation of sire, age of dam, and year of birth were significant for weaning weight, weaning hip height, and weaning hip width. Sex of calf, age of calf, and sire within generation was not significant for any weaning trait studied. The least squares means for weaning weight and weaning hip height of calves sired by OLD bulls were 70.8 lb lower and 7.3 cm shorter than calves sired by NEW bulls (481.1 vs 551.9 lb) and (108.3 vs 115.6 cm). The least squares means for hip width at weaning were 13.3 cm for OLD sired calves and 14.0 cm for NEW sired calves. Least squares means of steers and heifers at weaning were not significantly different (P>.05), but steers were larger for all three traits.

The least squares means and standard errors for carcass characters are presented in Table 3. The model used to analyze the data for carcass weight, actual fat thickness, adjusted fat thickness, ribeye area, percent kidney, pelvic and heart fat (KPH), marbling, and USDA yield grade included sex of animal, age at slaughter in days, generation of sire, and sire within generation (random effect). Sex and age of animal and generation of sire were significant for carcass weight. Sire within generation was significant for actual fat thickness. Age of animal was significant for KPH and sex of animal was significant for marbling while none of the factors were significant for adjusted fat thickness, ribeye area, and USDA yield grade. An additional analysis for ribeye area was also performed which included carcass weight as a covariate. The regression coefficient for ribeye area was .9 in $^2$ per 100 lb of carcass weight. NEW sire calves had a least squares mean carcass weight 72.0 lb heavier than OLD sired calves (753.6 vs 681.6 lb). The least squares means for actual fat thickness, adjusted fat thickness, ribeye area, KPH, and marbling are shown in Table 3. USDA yield grade for NEW sired calves was 3.2 versus 2.9 for OLD sired calves. Confoundings exist for actual and adjusted fat thickness and KPH between steers and heifers because the carcass data were collected by different evaluators in different slaughter facilities. This confounding would not only effect actual and adjusted fat thickness and KPH between the sexes, but more importantly, it would affect USDA yield grade between the sexes.

## Literature Cited


1. Cundiff, L. V., R. M. Koch, K. E. Gregory, J. D. Crouse, and M. E. Dikeman. 1990. Preliminary results from cycle IV of the germplasm evaluation program at the Roman L. Hruska U.S. Meat Animal Research Center. USDA. Progress Report No. 12.


Table 1. Least Squares Means and Standard Errors for Birth Characters

| | Birth weight (lbs) | Cannon bone length (cm) | Heart girth circumference (cm) |
|---|---|---|---|
| OLD Generation | 78.1 ± 1.7 | 28.2 ± .2 | 74.0 ± .6 |
| NEW Generation | 89.5 ± 2.1 | 30.1 ± .2 | 78.2 ± .8 |
| Male | 87.0 ± 2.3 | 29.4 ± .2 | 76.8 ± .9 |
| Female | 80.6 ± 1.9 | 28.9 ± .2 | 75.4 ± .7 |

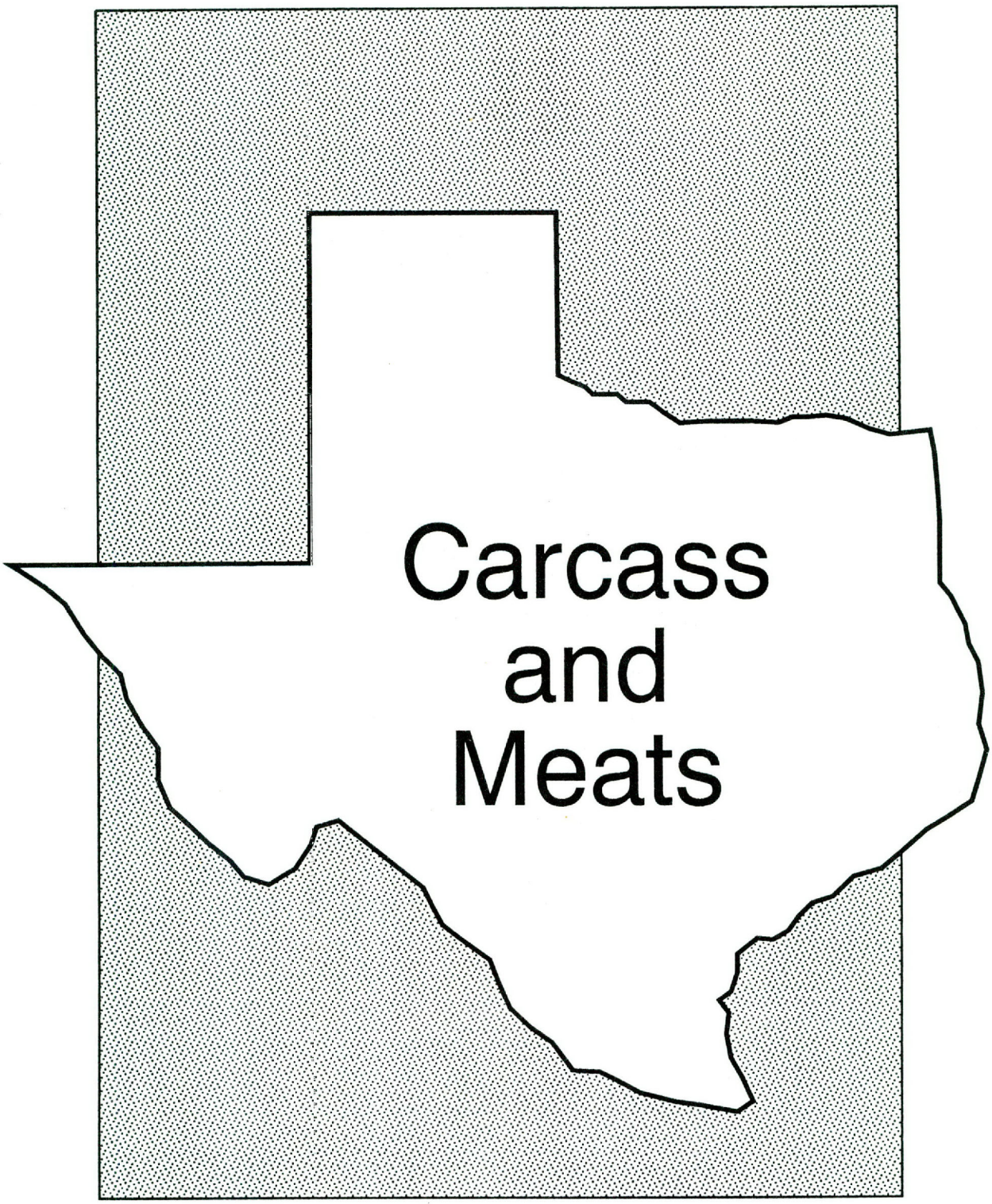
Table 2. Least Squares Means and Standard Errors for Weaning Characters

| | Weaning weight (lbs) | Weaning hip height (cm) | Weaning hip width (cm) |
|---|---|---|---|
| OLD Generation | 481.1 ± 15.9 | 108.3 ± .9 | 13.3 ± .2 |
| NEW Generation | 551.9 ± 19.0 | 115.6 ± 1.1 | 14.0 ± .2 |
| Steers | 531.9 ± 21.5 | 112.1 ± 1.2 | 13.8 ± .2 |
| Heifers | 501.0 ± 16.8 | 111.7 ± .9 | 13.5 ± .2 |

Table 3. Least Squares Means and Standard Errors for Carcass Characters

| | Carcass weight (lbs) | Actual fat thickness (in) | Adjusted fat thickness (in) | Kidney pelvic and heart fat % | Ribeye area ($in^2$) | Marbling score[a] | USDA yield grade |
|---|---|---|---|---|---|---|---|
| OLD Generation | 681.6 ± 19.5 | .51 ± .02 | .54 ± .03 | 2.70 ± .11 | 12.9 ± .3 | 382 ± 16 | 2.9 ± .1 |
| NEW Generation | 753.6 ± 21.9 | .54 ± .03 | .56 ± .03 | 2.77 ± .13 | 12.8 ± .3 | 381 ± 18 | 3.2 ± .1 |
| Steers | 782.3 ± 27.1 | .53 ± .03 | .53 ± .04 | 2.92 ± .16 | 13.2 ± .4 | 346 ± 22 | 3.2 ± .2 |
| Heifers | 652.9 ± 19.9 | .52 ± .02 | .57 ± .03 | 2.56 ± .12 | 12.5 ± .3 | 417 ± 17 | 2.9 ± .1 |

[a] 300 = Slight$^{00}$; 400 = Small$^{00}$.


Carcass
and
Meats

# Whole Muscle and Steak, Storage and Display Characteristics of Electrically Stimulated, Hot-Boned and Nonstimulated, Cold-Boned Beef

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C.F. Brasington, G.C. Smith and J.W. Savell

## Summary

Alternate sides, randomly selected from each of 33 carcasses from forage-fed steers, were electrically stimulated within 30 minutes of bleeding and hot-boned (ESHB). Opposite sides were not electrically stimulated and were cold-boned (NESCB) following a 24 hour chill (32°F). From 17 ESHB sides, portions of the ribeye (RE) and top round (TR) were removed and immediately vacuum packaged. RE and TR were removed from the remaining 16 ESHB sides, wrapped in polyvinyl chloride film, chilled (32°F) for 22 hours and then vacuum packaged. RE and TR from NESCB sides (n=33) were removed and vacuum packaged at 24 hours postmortem. Whole-muscle characteristics were evaluated initially and after storage periods of 7, 14, or 21 days and steaks were displayed for 5 days thereafter. Neither hot- versus cold-boning nor storage for 21 days affected retail display characteristics of RE and TR steaks. As retail display time increased, retail lean color, fat color, and overall appearance scores decreased.

## Introduction

Vacuum packaging has become the most common packaging method for storage and shipment of primal and subprimal beef. Boning of carcasses to generate primals/subprimals or whole muscles before chilling (hot-boning) has been proposed as an alternative to conventional processing due to possible savings in space, energy and boning-time requirements (4, 5). If hot-boning is to be incorporated into beef processing and fabrication protocols in the U.S., it most likely will occur in a centralized slaughter/fabrication operation where labor and handling efficiencies dictate that packaging occur soon after boning. Previous work has shown — after 20 days storage — that hot-boned, vacuum-packaged cuts, in comparison to conventionally processed cuts, were similar in lean color but whiter in fat color and that they sustained less purge and maintained vacuum in the package longer (3). Research is needed to compare whole-muscle characteristics of hot-boned muscles to those of conventionally processed (cold-boned) muscles. Also, retail display characteristics of steaks from hot- versus cold-boned muscles should be compared. The present study investigated effects of time of packaging and length of storage on whole-muscle and steak, storage and display characteristics of electrically stimulated, hot-boned and nonstimulated, cold-boned beef.

## Experimental Procedure

Thirty-three forage-fed steers were slaughtered and the carcasses were split. Within 30 minutes after bleeding, alternate sides of each carcass were electrically stimulated [17 pulses — 1.8-second duration, 1.8-second pause between pulses of 550 volts (AC), 2 to 6 amps and 60 Hertz]. Ribeye (RE) and top round (TR) were removed from those sides at 2 hours postmortem; cuts from 17 of those sides were immediately vacuum packaged (ESHB-2) while cuts from the other 16 sides were wrapped in polyvinyl chloride film, chilled (35°F) on stainless steel racks for 22 hours and then vacuum packaged (ESHB-24). Opposite sides of each carcass were not electrically stimulated and were cold-boned after chilling at 32°F for 24 hours (NESCB).

At 24 hour postmortem and later, after storage (32°F, in corrugated cardboard boxes placed singly on stainless steel racks) for 7, 14, or 21 days, a four-member trained panel scored all vacuum packaged whole muscles using 15-point rating scales for lean color, fat color, purge, and overall appearance (15 = extremely bright red, white, little, or desirable and 1 = extremely dark brown, dark yellow, abundant, or undesirable).

Whole-muscles were then removed from the vacuum bags, faced and cut to provide two 1-inch steaks. Steaks were placed singly in plastic foam trays, overwrapped with PVC film, and displayed for 5 days in retail cases at 35°F under fluorescent light (14 hours on; 10 hours off). A six-member trained panel evaluated the steaks on 15-point rating scales for lean color, fat color, surface discoloration, and overall appearance (15=extremely bright red, white, nondiscolored, or desirable and 1=extremely dark brown, dark, discolored, or undesirable) on each day.

## Results and Discussion

Muscles used in this study were from carcasses that averaged 585 lb, were "A" maturity (10) and had an average adjusted fat thickness at the 12th rib of 0.3 inches. The average USDA Yield Grade was 2.9 and the average USDA Quality Grade was high Standard.

Color of meat is a primary selection criteria of consumers and meat purveyors. Thus, in this study, color of vacuum packaged whole-muscles was evaluated initially and after a designated storage period. Lean color scores were in the upper one-third of the 15-point scale (Table 1). There were no differences in

initial lean color of TR muscles due to treatment. However, RE muscles that were vacuum-packaged at 2 hours postmortem (ESHB-2) had lower lean color scores than RE muscles which were excised, wrapped in PVC film, chilled for 24 hours and then vacuum packaged (ESHB-24). It has been reported that muscles removed at 2-6 hours postmortem were darker colored than those removed at 48 hours (6, 7). The one-half unit mean difference in color scores observed in the present study may not be of practical significance.

To evaluate changes in whole-muscle characteristics over time, differences in mean scores were calculated and analyzed (data not presented in tabular form). Lean color scores after storage were not different due to treatments for either the RE or TR muscles and all means declined by less than one-half unit, indicating little change in lean color. These results do not agree with previous work that showed that muscles removed at 1 hour postmortem were significantly darker than those removed at 48 hour, postmortem after storage for 20 days (2).

**Table 1. Means by treatment for initial vacuum packaging characteristics of electrically stimulated, hot-boned and nonstimulated, cold-boned beef.**

| Score[a] | Treatment[b] | | |
|---|---|---|---|
| | ESHB-2 | ESHB-24 | NESCB |
| Ribeye | | | |
| Lean color | 11.5 | 12.0 | 12.0 |
| Fat color | 9.2 | 9.1 | 8.9 |
| Purge | 14.1 | 14.3 | 13.7 |
| Overall appearance | 11.3 | 11.9 | 11.0 |
| Top round | | | |
| Lean color | 11.6 | 11.4 | 11.6 |
| Fat color | 9.3 | 8.8 | 9.0 |
| Purge | 12.8 | 13.9 | 12.2 |
| Overall appearance | 10.6 | 10.6 | 10.1 |

[a]Lean color, fat color, purge, and overall appearance scored on a 1- to 15-point rating scale (15 = extremely bright red, white, little, or desirable and 1 = extremely dark brown, dark yellow, abundant, or undesirable).

[b]ESHB-2 = muscles were removed from electrically stimulated, hot-boned sides and vacuum packaged at 2 hours postmortem; ESHB-24 = muscles were removed from electrically stimulated, hot-boned sides, chilled and vacuum packaged at 24 hours postmortem; NESCB = muscles were removed from nonstimulated sides at 24 hours postmortem and vacuum packaged.

Fat color is another packaging characteristic used to evaluate subprimal quality. It has been reported that fat from cold-boned cuts was not as white as that from hot-boned cuts and this difference was attributed to greater purge accumulation in cold-boned cuts (2). In the present study, no differences (Table 1) due to treatment in initial fat color or in changes after storage were noted. Forage-fed cattle, with more yellow fat, were used in the present study. Thus, fat color may have changed less during storage than in previous studies (2).

Excessive purge (liquid accumulation) in vacuum-packaged cuts can be visually as well as economically detrimental. Several researchers have shown that hot-boning combined with electrical stimulation results in less purge in vacuum packaged cuts (stored for 7, 14, or 20 days) than does cold-boning (2, 3, 8). It has been reported that hot deboning reduced total carcass drip loss, but to a lesser extent when electrical stimulation was used (9). Results of the present study (Table 1) concur for both RE and TR muscles when visible purge scores for ESHB muscles were compared to those for NESCB muscles. It appears that time postmortem of vacuum packaging as well as time postmortem of muscle removal influences purge. TR that were hot-boned, chilled and packaged at 24 hours postmortem had less purge than those vacuum packaged at 2 hours postmortem.

Overall appearance scores (Table 1) were higher initially for ESHB muscles than for NESCB muscles and remained higher after 7, 14, or 21 days of storage. Scores declined with time, but the rate of decline was similar for all treatments.

Because most U.S. retailers use vacuum packaged beef primals or subprimals to prepare retail-ready steaks and roasts, the effects of treatments on the retail characteristics of steaks from RE and TR muscles were investigated. There were no differences in the retail display characteristics of RE and TR steaks from ESHB-2, ESHB-24, and NESCB treatments. This implied that muscles can be removed hot and vacuum packaged without detrimental effects on subsequent retail display characteris tics. Because color is the primary selection criterion of consumers, only the data indicating the storage by retail display time interactions for lean color are presented (Figures 1 and 2). Lean color scores for RE and TR steaks from muscles stored for 21 days were higher on the first day of retail display than scores for those steaks from muscles stored for 7 and 14 days. These results agree with previous findings that muscle color of top sirloin steaks became lighter between 14 and 28 days of storage (1). RE steaks in the present study became darker with increased retail display time (Figure 1). After 5 days of retail display, lean color of RE steaks from muscles stored for 21 days was higher than that of steaks from muscles stored for 7 and 14 days. No differences in lean color were evident for TR steaks from muscles stored for 7, 14, or 21 days (Figure 2).

These data indicated no differences in vacuum packaging characteristics due to packaging of hot-boned muscles from electrically stimulated carcasses at 2 versus 24 hours postmortem. Electrically stimulated, hot-boned RE and TR muscles had less visible purge in the vacuum package and higher overall appearance scores than non-stimulated, cold-boned muscles. Storage of RE and TR muscles for 7, 14, or 21 days did not affect whole-muscle appearance characteristics. Thus, it appears that hot-boned muscles from electrically stimulated sides can be vacuum-packaged and stored as are conventionally

processed (cold-boned) muscles with no detrimental effect on appearance.

Retail display characteristics of steaks from hot-boned RE and TR muscles from electrically stimulated sides and from cold-boned, not electrically stimulated sides were similar. Lean color of steaks from muscles stored for 21 days was brighter than the lean color of steaks from muscles stored for 7 or 14 days. Other retail display characteristics were similar regardless of storage time of the muscles. Lean color, fat color, and overall appearance scores decreased with increasing retail display time. Thus, if electrical stimulation is used in conjunction with hot-boning, muscles can be stored for 7 to 21 days in vacuum packages with no detrimental effects on subsequent retail display characteristics of the steaks.

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## Literature Cited

1. Carpenter, Z.L., S.D. Beebe, G.C. Smith, K.E. Hoke, and C. Vanderzant. 1976. Quality characteristics of vacuum-packaged beef as affected by postmortem chill, storage temperature and storage interval. J. Milk Food Technol. 39:952.
2. Cross, H.R., I. Tennent, and D.A. Muse. 1979. Storage properties of primal cuts of hot- and cold-boned beef. J. Food Quality 4:89.
3. Cross, H.R., and I. Tennent. 1980. Accelerated processing systems for USDA Choice and Good beef carcasses. J. Food. Sci. 45:765.
4. Henrickson, R.L. 1975. Hot boning. Proc. Meat Ind. Res. Conf. p. 45.
5. Kastner, C.L. 1977. Hot processing: Update on potential energy and related economies Proc. Meat Ind. Res. Conf. p. 43.
6. Kastner, C.L., R.L. Henrickson, and R.D. Morrison. 1973. Characteristics of hot boned bovine muscle. J. Anim. Sci. 36:484.
7. Kastner, C.L., and T.S. Russell. 1975. Characteristics of conventionally and hot-boned bovine muscle excised at various conditioning periods. J. Food Sci. 40:747.
8. Seideman, S.C., G.C. Smith, T.R. Dutson, and Z.L. Carpenter. 1979. Physical, chemical and palatability traits of electrically stimulated, hot boned, vacuum-packaged beef. J. Food Prot. 42:651.
9. Taylor, A.A., B.G. Shaw, and D.B. Macdougall. 1981. Meat Sci. 5:109.
10. USDA. 1989. Official United States standards for grades of carcass beef. Agri. Marketing Service, United States Department of Agriculture, Washington, DC.

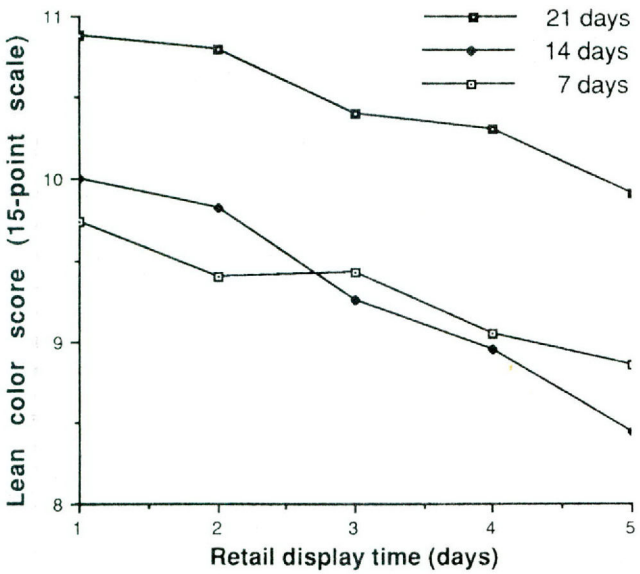


Figure 1. Interaction of vacuum package storage time and retail display time on retail lean color scores of ribeye steaks.

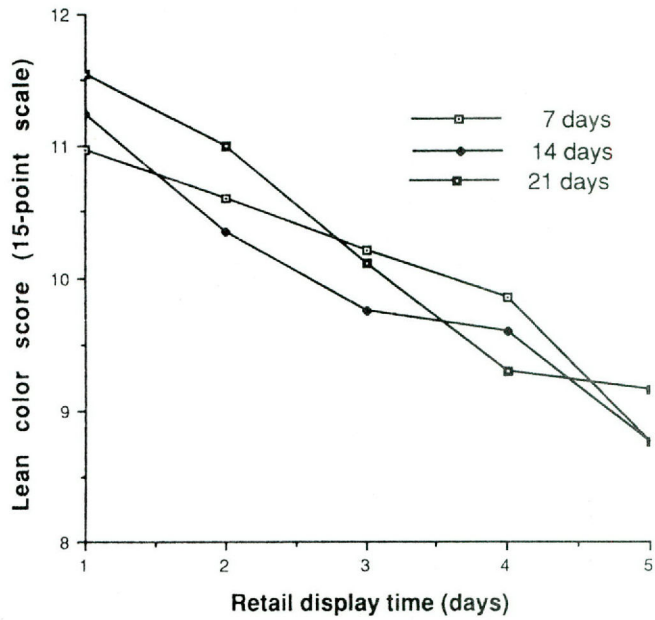


Figure 2. Interaction of vacuum package storage time and retail display time on retail lean color scores of top round steaks.

# Evaluating the Tenderness/Toughness of Beef Top Sirloin Steaks Destined for Foodservice

J.J. Harris, R.K. Miller, J.W. Savell, H.R. Cross and L.J. Ringer


## Summary

Beef top sirloin butt and strip loin subprimals were obtained from both sides of 20 U.S. Choice beef carcasses. After obtaining a sample from each subprimal (approximately 48 h postmortem) for measurement of sarcomere length, all subprimals were cut into six steaks (1.0 in thick). The six steaks were assigned randomly to one of six aging treatments (0, 7, 14, 21, 28, or 35 days). At the end of each aging period, steaks from the left carcass sides were evaluated for sensory attributes and mechanical shear force measurements. Steaks from the right carcass sides were subjected to lab analyses to determine myofibrillar fragmentation index (MFI), total collagen content, and percent solubility of the collagen.

There was no difference in sarcomere length between top loin and top sirloin steaks. Top sirloin steaks received lower sensory panel tenderness and connective tissue scores, and they were more variable in sensory panel attributes than top loin steaks. Top sirloin steaks also had higher shear force values than top loin steaks. Top sirloin steaks required longer periods of postmortem aging than top loin steaks to achieve similar improvements in tenderness. Top loin steaks had lower MFIs than top sirloin steaks at 14 and 35 days postmortem. Top sirloin steaks had higher amounts and were more variable in total collagen content than top loin steaks. Percent solubility of the collagen did not differ between the two steak types. Evaluation of the frequency distributions for MFI, sarcomere length, and collagen solubility indicated that, although these characteristics were not statistically different between top sirloin and top loin steaks, top sirloin steaks were more likely than top loin steaks to have high MFIs (>700), short (<1.8μm) sarcomeres, and low (<15%) collagen solubility. The results of this study indicate that the tenderness problem associated with top sirloin steaks was due, in large part, to higher amounts of collagen in combination with myofibrillar factors that, together, make it more likely for a consumer to be presented a top sirloin steak with less than desirable tenderness characteristics.


## Introduction

Beef top sirloin steaks are among the most commonly served steaks in restaurants across the United States. Most restaurants will offer the top sirloin steak as a lower priced entree compared to steaks such as the ribeye, filet mignon, New York strip (top loin), T-bone, or roasts such as the prime rib and chateaubriand. The top sirloin steak, however, has problems with respect to the consistency of tenderness when evaluated in the laboratory (36,25). Methods to improve cooked beef tenderness and to reduce the variability in tenderness of top sirloin steaks is imperative if maximum consumer satisfaction is to be maintained. Additionally, if beef's competitiveness as a moderately priced menu alternative is to be optimized, these issues must be addressed and solutions identified. The solution to this problem will require the identification and characterization of the causes of the increase in variability and/or decrease in tenderness associated with the top sirloin steak. Several factors have been shown to be related to the tenderness of cooked beef steaks. Numerous researchers have demonstrated that sarcomere length is correlated positively with beef tenderness (22, 23, 15, 19, 4) in that short sarcomeres indicate tougher beef and long sarcomeres indicate relatively more tender beef. Myofibrillar fragmentation index has also been shown to be a good predictor of beef steak tenderness (9, 2, 28, 26, 8, 27).

One of the most widely recognized and studied tenderness related components is connective tissue, specifically collagen. Numerous researchers have demonstrated that the age-related decrease in tenderness associated with beef cuts from animals of advanced maturity can be largely accounted for by the amount and characteristics of collagen in the muscle tissue (17, 37, 13, 24, 16, 5). Moreover, these same researchers have demonstrated that as tenderness decreases with increasing age of the animal, the amount of collagen that is heat labile (percent solubility) also decreases. Other researchers have shown that the total amount of collagen present often varies between muscles within a carcass, and the muscles with more collagen tend to be less tender (3, 12, 16).

This experiment was designed to identify and characterize some factors contributing to the decrease in tenderness and the increase in the variability of tenderness associated with beef top sirloin steaks from carcasses of the same maturity and USDA grade.

## Experimental Procedure

Beef IMPS #184 top sirloin butts (34) along with the matched beef IMPS #180 strip loins (34) were obtained approximately 36 h postmortem from both sides of 20 U.S. Choice (35) beef carcasses at a large beef packing plant in the Texas panhandle. Cuts were vacuum packaged, boxed, and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. The strip loins were selected

to serve as the controls for baseline tenderness evaluations. Immediately upon arrival, each subprimal was cut into steaks (1.0 in thick), which were trimmed to have no more than 0.25 in external fat remaining. All top sirloin steaks were trimmed to contain only the *guteus medius* muscle and top loin steaks were trimmed so that only the *longissimus dorsi* muscle remained. The steaks then were vacuum packaged in a high oxygen barrier film, identical to that in which the subprimals were packaged, and stored under refrigeration (34°F). Previous experiments (30, 31, 33) have indicated that individually packaged steaks provide a good model to simulate the aging of wholesale subprimals. In addition to the steaks, a 10 g muscle sample was removed from each subprimal for measurement of sarcomere length.

At the end of six aging intervals (0, 7, 14, 21, 28, or 35 days), one steak from each subprimal was selected randomly for laboratory and/or sensory analyses. This provided two top sirloin steaks (one from the left carcass side and one from the right carcass side) and two top loin steaks for each aging interval. The steaks from the left carcass sides were broiled on a Farberware Open Hearth Broiler (Farberware Company, Bronx, NY) to an internal temperature of 158°F, monitored by copper constantan thermocouples attached to a Honeywell potentiometer, and evaluated by a trained sensory panel. After serving samples to the sensory panel, the remaining portion of the steak was designated for Warner-Bratzler shear force determination. The sensory panel ratings and the Warner-Bratzler shear force values were used to determine tenderness levels. Those steaks from the right carcass sides were analyzed raw for myofibrillar fragmentation index, total collagen (mg/g) and collagen solubility (%). These steaks were cut into two portions. One portion was homogenized in a Cuisinart food processor and stored frozen until subsequent collagen analysis. The remaining portion was vacuum packaged and stored frozen until analyzed for myofibrillar fragmentation index.

### *Sensory Evaluation*

Warm (approximately 140°F) 0.4 in X 0.4 in X 0.4 in cubes of cooked steak were served in duplicate to an eight-member sensory panel trained according to the methods of Cross et al. (6). The panel evaluated each sample for muscle fiber tenderness, connective tissue amount and overall tenderness based on an 8-point scale where 8=extremely tender or no perceivable connective tissue and 1=extremely tough or an abundant amount of connective tissue. The remaining portion of the steak was cooled for 2 hours at room temperature (74°F). Five to ten 0.5 in diameter cores were taken from each steak parallel to the length of the muscle fibers. Each core was sheared once with a Warner-Bratzler shear machine. The shear force (lb) for each steak was the computed average value for the cores.

### *Sarcomere Length*

Myofibrils were prepared for measurement of sarcomere length by homogenizing 10 g of muscle tissue in 50 ml 0.25M sucrose solution for 20s with a Virtishear homogenizer (Virtis Company, Gardiner, NY). A single drop of the resulting myofibril suspension was placed on a glass slide and covered with a cover slip. The sarcomere length then was measured using a Timbrell/Coulter Shearicon particle size analyzer as described by Cross et al. (7). Twenty-five sarcomeres were measured for each sample and the sarcomere length was determined by averaging the 25 measurements.

### *Myofibrillar Fragmentation Index*

Myofibrillar fragmentation index (MFI), as an indicator of muscle fiber tenderness or fragmentability, was determined according to the methods of Culler et al. (8) as modified by Davis et al. (10).

### *Collagen Analysis*

The collagen content of the top loin and top sirloin steaks was determined by isolating the hydroxyproline from the steaks according to the methods of Hill (18) and using a color reaction as described by Bergman and Loxley (1) to measure the hydroxyproline concentration and then convert hydroxyproline to collagen content as defined by Cross et al. (5).

An additional subset of 10 cooked steaks (5 top sirloin and 5 top loin) was analyzed to investigate the effects of cooking on the collagen content and percent solubility.

### *Statistics*

Data were analyzed using a main frame statistics software package (29). All data were subjected to analysis of variance blocking by carcass number and treating the experiment as a 2 subprimal X 6 aging treatment factorial design. Sensory panel data also were blocked by panelist to eliminate from the statistical model variation between panelists. Tests for interactions between postmortem age and steak type were included in the design. When significant differences were found, means were separated using the Student-Newman-Keuls procedure.

## Results and Discussion

### *Sensory Panel*

The mean sensory panel ratings for the overall tenderness of top sirloin and top loin steaks are reported in Table 1. Top loin steaks received higher ($P<.05$) overall tenderness ratings than top sirloin steaks at each aging period; however, the two steaks did not respond the same to postmortem aging. The top sirloin steaks showed no significant increase in overall tenderness until 28 days of storage; whereas,

the top loin steaks increased in overall tenderness after only 7 days of postmortem aging. Also, there was an increase in overall tenderness between day 28 and 35 for top loin steaks. Therefore, an interaction ($P<.05$) between steak type and postmortem aging time occurred. In addition, top sirloin steaks tended to be more variable with respect to sensory panel overall tenderness ratings.

The top loin steaks also received higher ($P<.05$) sensory panel ratings than did top sirloin steaks for all aging treatments (Table 1). Just as with overall tenderness, top sirloin steaks did not respond to aging until 28 days, while top loin steaks demonstrated an improvement in muscle fiber tenderness after only 7 days of postmortem aging and another increase after 28 days. Again, an interaction ($P<.05$) was found between steak type and postmortem age.

The mean sensory panel ratings for connective tissue amount also are given in Table 1. The top loin steaks again received higher ($P<.05$) and less variable sensory panel ratings than did top sirloin steaks at each aging period. There was limited improvement in connective tissue ratings in response to postmortem aging for top sirloin and top loin steaks. Connective tissue tends to remain relatively stable and intact during aging. Although there are endogenous enzyme systems capable of softening or degrading collagen (20, 11, 38), these enzymes have not been shown to be released in sufficient quantities postmortem to initiate such changes.

### *Warner-Bratzler Shear Force*

The Warner-Bratzler shear force values are reported in Table 1. Top sirloin steaks had higher ($P<.05$) shear force values than top loin steaks at each aging period. The top sirloin steaks demonstrated no decrease in shear force values in response to postmortem aging; the top loin steaks, however, showed a relatively steady decrease in shear force value as postmortem aging increased. Many researchers, including Smith et al. (33), have demonstrated a characteristic improvement in beef tenderness during postmortem aging in response to myofibrillar protein degradation by endogenous proteases. If the top sirloin steaks in this study were less tender due to higher concentrations of connective tissue (not degraded during postmortem conditioning), this lack of shear force decline would not be surprising.

### *Myofibrillar Fragmentation Index*

The myofibrillar fragmentation indices (MFIs) for top sirloin and top loin steaks are presented in Table 1. Lower MFIs are associated with more tender beef, and tougher beef generally has higher MFIs (9, 2, 28, 26, 8, 27). The top loin steaks in this study had lower ($P<.05$) MFIs than top sirloin steaks in the 14 and 35 day aging treatments; there were no differences ($P>.05$) between the top sirloin and top loin steaks in the 0, 7, 21, or 28 day treatments. Although the differences found at days 14 and 35 were statistically significant, they were not of a large magnitude and were due very likely to chance. The fact that, generally, there was no difference in MFI between top loin and top sirloin steaks (all epimysium and visible connective tissue were removed before MFI determination) would again indicate that connective tissue could be playing a role in the decreased tenderness of top sirloin steaks when compared to top loin steaks.

### *Sarcomere Length*

There was no difference ($P>.05$) in sarcomere length between lean samples from the strip loins and top sirloin butts used in this study (Table 2). Although shortened sarcomere lengths have been associated with instances of tough beef (21, 32), large differences in sarcomere length between subprimals of the same carcass would not be expected. Therefore, the differences in tenderness between top loin and top sirloin steaks found in the present experiment were not due to excessive cold shortening of the top sirloins; however, there was a tendency for top sirloins to have slightly shorter sarcomeres.

### *Collagen*

The total collagen content (mg/g) and the percent solubility of the collagen are reported in Table 2. Collagen analysis was performed on those steaks that were aged 0 and 35 days. No differences ($P>.05$) were found between the 0 and 35 day aging treatments; therefore, the collagen data from both of these aging treatments were grouped and overall mean total collagen and collagen solubility were reported (Table 2). Top loin steaks had less ($P<.05$) total collagen than top sirloin steaks. The percent solubility of the collagen was not different ($P>.05$) between top loin and top sirloin steaks. Previous researchers have demonstrated that collagen solubility is more important than total collagen as a hindrance to tenderness when considering the toughening associated with increased maturity (13, 14, 18, 16, 5); however, data from the present study indicated that total collagen content was a more important characteristic than collagen solubility in explaining the variability in tenderness between top loin and top sirloin steaks from the same carcass.

The subset of cooked samples analyzed for collagen content and solubility were not different ($P>.05$) from the raw samples. The soluble collagen that was lost due to drip loss was offset by the concurrent moisture loss during cooking.

### *Frequency Distributions*

To better understand some of the factors that may be playing a role in the decreased tenderness of top sirloin steaks, frequency (percentage) distributions were generated for some of the variables included in this study (Figures 1-4). Distributions for variables such as sensory panel ratings and Warner-Bratzler shear force were not included because they

could have almost been predicted based upon the significant differences between top sirloin and top loin steaks with respect to these characteristics as presented in Tables 1-2; however, for other characteristics (MFI, sarcomere length, and collagen), these frequency distributions better illustrated differences between top sirloin and top loin steaks.

The percentage distribution of MFIs (Figure 1) for top sirloin and top loin steaks indicates that, although there were few statistically significant differences between the two steak types, the top sirloin steaks were more likely than top loin steaks to have MFIs of over 700.

Statistically, there were no differences in sarcomere length between top sirloins and strip loins; however, Figure 2 illustrates that 25 percent of the top sirloins had sarcomere lengths of less than 1.8μm, as compared with only 10 percent of the strip loins. Conversely, 20 percent of all strip loins had sarcomere lengths of greater than 2.2μm and only 5 percent of top sirloins were in this category.

The percentage distribution of total collagen content (Figure 3) shows that top sirloin steaks were 7 times more likely than top loin steaks to have over 12 mg/g of collagen. Over 12 percent more top sirloin than top loin steaks had collagen solubilities of less than 15 percent (Figure 4). So, although the means were not statistically different, it can be seen that the top sirloin steaks were more likely than top loin steaks to have a low collagen solubility.

Beef top sirloin steaks were less tender and more variable in tenderness than top loin steaks when measured by a trained sensory panel and Warner-Bratzler shear force. The results of this study indicated that this difference was due, in large part, to higher amounts of collagen in combination with myofibrillar factors that, together, make it more likely for a consumer to experience a top sirloin steak having less than desirable tenderness characteristics. If the consistency in palatability of beef top sirloin steaks destined for foodservice is to be optimized, it appears that these characteristics must be manipulated, chemically or mechanically, to overcome these inherent tenderness problems found in top sirloin steaks.

## Literature Cited


1. Bergman, I. and R. Loxley. 1963. Two improved and simplified methods for the spectrophotometric determination of hydroxyproline. Analytical Chem. 35:1961.
2. Berry, B.W. 1972. Characteristics of bovine muscle, cartilage and bone as influenced by physiological maturity. Ph.D. Dissertation. Texas A&M University, College Station.
3. Cover, S., S.J. Ritchey, and R.L. Hostetler. 1962. Tenderness of beef. I. The connective tissue component of tenderness. J. Food Sci. 27:469.
4. Cross, H.R., G.C. Smith, and Z.L Carpenter. 1972. Palatability of individual muscles from ovine leg steaks as related to chemical and histological traits. J. Food Sci. 37:282.
5. Cross, H.R., Z.L. Carpenter, and G.C. Smith. 1973. Effects of intramuscular collagen and elastin on bovine muscle tenderness. J. Food Sci. 38:998.
6. Cross, H.R., R. Moen, and M.S. Stanfield. 1978. Training and testing of judges for sensory analysis of meat quality. Food Tech. 32:48.
7. Cross, H.R., R.L. West, and T.R. Dutson. 1981. Comparison of methods for measuring sarcomere length in beef semitendinosus muscle. Meat Sci. 5:261.
8. Culler, R.D., F.C. Parrish, Jr., G.C. Smith, and H.R. Cross. 1978. Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristics of bovine longissimus muscle. J. Food Sci. 43:1177.
9. Davey, C.L., and K.V. Gilbert. 1969. Studies in meat tenderness. 7. Changes in the fine structure of meat during aging. J. Food Sci. 34:69.
10. Davis, G.W., T.R. Dutson, G.C. Smith, and Z.L. Carpenter. 1980. Fragmentation procedure for bovine longissimus muscle as an index of cooked steak tenderness. J. Food Sci. 45:880.
11. Dutson, T.R., G.C. Smith, and Z.L. Carpenter. 1980. Lysosomal enzyme distribution in electrically stimulated ovine muscle. J. Food Sci. 45:1097.
12. Field, R.A., A.M. Pearson, and B.S. Schweigert. 1970. Labile collagen from epimysial and intramuscular connective tissue as related to Warner-Bratzler shear values. Ag. Food Chem. 18:280.
13. Goll, D.E., R.W. Bray, and W.G. Hoekstra. 1963. Age-associated changes in muscle composition. The isolation and properties of a collagenous residue from bovine muscle. J. Food Sci. 28:503.
14. Goll, D.E., R.W. Bray, and W.G. Hoekstra. 1964. Age-associated changes in bovine muscle connective tissue. III. Rate of solubilization at 100°C. J. Food Sci. 29:622.
15. Herring, H.K., R.G. Cassens, and E.J. Briskey. 1965. Further studies on bovine muscle tenderness as influenced by carcass position, sarcomere length and fiber diameter. J. Food Sci. 30:1049.
16. Herring, H.K., R.G. Cassens, and E.J. Briskey. 1967. Factors affecting collagen solubility in bovine muscles. J. Food Sci. 32:534.
17. Hershberger, T., R. Deans, L.E. Kunkle, P. Gerlough, and F.E. Deatherage. 1951. Studies on meat. III. The biochemistry and quality of meat in relation to certain feeding and management practices. Food Tech. 5:523.
18. Hill, F. 1966. The solubility of intramuscular collagen in meat animals of various ages. J. Food Sci. 31:161.
19. Hostetler, R.L., W.A. Landmann, B.A. Link, and H.A. Fitzhugh, Jr. 1970. Influence of carcass position during rigor mortis on tenderness of beef muscles: Comparison of two treatments. J. Anim. Sci. 31:47.
20. Kopp, J. and C. Valin. 1980-81. Can muscle lysosomal enzymes affect muscle collagen postmortem? Meat Sci. 5:319.
21. Locker, R.H. 1960. Degree of muscular contraction as a factor in tenderness of beef. Food Res. 25: 304.
22. Locker, R.H. and C.J. Hagyard. 1963. A cold shortening effect in beef muscles. J. Food Agric. 14:787.
23. Marsh, B.B. and N.G. Leet. 1966. Studies in meat tenderness. 3. The effects of cold shortening on tenderness. J. Food Sci. 31:450.
24. McClain, P.E., A.M. Mullins, S.L. Hansard, J.D. Fox, and R.F. Boulware. 1965. Relationship of alkali insoluble collagen to tenderness of three bovine muscles. J. Anim. Sci. 24:1104.
25. McKeith, F.K., J.W. Savell, and G.C. Smith. 1981. Tenderness improvement of the major muscles of the beef carcass by electrical stimulation. J. Food Sci. 46:1774.

26. Olson, D.G., F.C. Parrish, Jr., and M.H. Stromer. 1976. Myofibril fragmentation and shear resistance of three bovine muscles during postmortem storage. J. Food Sci. 41:1036.
27. Parrish, F.C., Jr., C.J. Vandell, and R.D. Culler. 1979. Effect of maturity and marbling on the myofibril fragmentation index of bovine longissimus muscle. J. Food Sci. 44:1668.
28. Reagan, J.O., T.R. Dutson, Z.L. Carpenter, and G.C. Smith. 1975. Muscle fragmentation indices for predicting cooked beef tenderness. J. Food Sci. 40:1093.
29. SAS. 1988. SAS User's Guide: Statistics. SAS Institute, Inc., Cary, NC.
30. Savell, J.W., F.K. McKeith, and G.C. Smith. 1981. Reducing postmortem aging time of beef with electrical stimulation. J.Food Sci. 46:1777.
31. Savell, J.W., F.K. McKeith, C.E. Murphey, G.C. Smith, and Z.L. Carpenter. 1982. Singular and combined effects of electrical stimulation, post-mortem ageing and blade tenderization on the palatability attributes of beef from young bulls. Meat Sci. 6:97.
32. Smith, G.C., T.R. Dutson, R.L. Hostetler, and Z.L. Carpenter. 1976. Fatness, rate of chilling and tenderness of lamb. J. Food Sci. 41:748.
33. Smith, G.C., G.R. Culp, and Z.L. Carpenter. 1978. Postmortem aging of beef carcasses. J. Food Sci. 43:823.
34. USDA. 1975. Institutional Meat Purchase Specifications for Fresh Beef. Agricultural Marketing Service, United States Department of Agriculture, Washington, DC.
35. USDA. 1989. Official United States Standards for Grades of Carcass Beef. Agricultural Marketing Service, United States Department of Agriculture, Washington, DC.
36. Wheeler, T.L., R.K. Miller, J.W. Savell, and H.R. Cross. 1990. Palatability of chilled and frozen beef steaks. J. Food Sci. 55:301.
37. Wierbicki, E., L.E. Kunkle, V.R. Cahill, and F.E. Deatherage. 1954. The relation of tenderness to protein alterations during postmortem aging. Food Tech. 8:506.
38. Wu, J.J., T.R. Dutson, and Z.L. Carpenter 1981. Effect of postmortem time and temperature on the release of lysosomal enzymes and their possible effect on bovine connective tissue components of muscle. J. Food Sci. 46:1132.

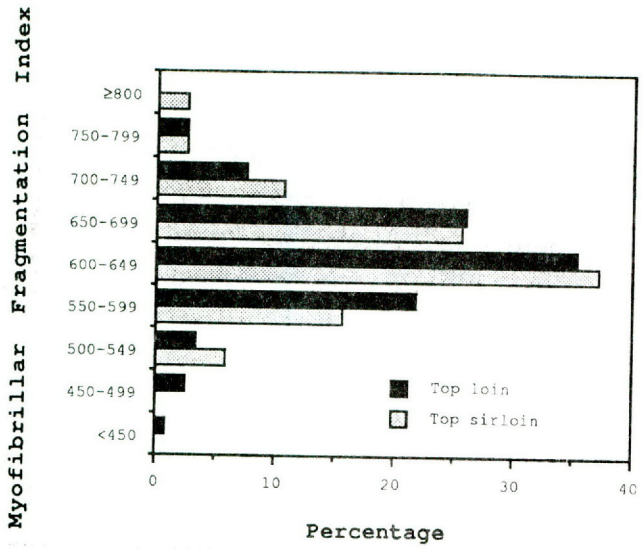


Figure 1. Percentage distribution of myofibrillar fragmentation index for top sirloin and top loin steaks.

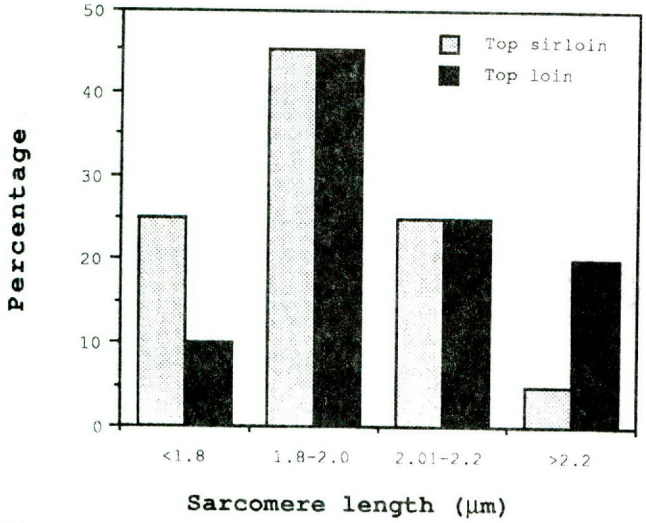


Figure 2. Percentage distribution of sarcomere length for top sirloin and top loin steaks.

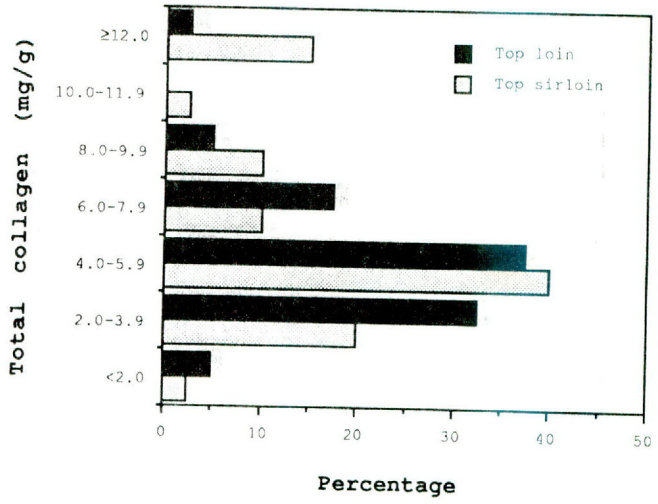


Figure 3. Percentage distribution of total collagen for top sirloin and top loin steaks.

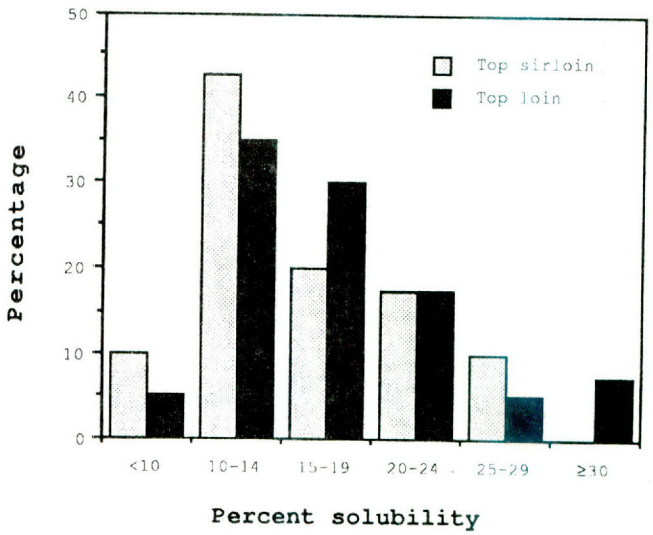


Figure 4. Percentage distribution of collagen percent solubility for top sirloin and top loin steaks.

TABLE 1. SENSORY PANEL RATING, WARNER-BRATZLER SHEAR FORCE AND MYOFIBRILLAR FRAGMENTATION INDEX MEANS, STRATIFIED BY AGE, FOR TOP SIRLOIN AND TOP LOIN STEAKS

| | Aging time (days) | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | 35 |
| Overall Tend.[a] | | | | | | |
| Top sirloin | 5.18$^{f}$ | 5.37$^{f}$ | 5.18$^{f}$ | 5.17$^{f}$ | 5.71$^{g}$ | 5.78$^{g}$ |
| Top loin | 5.91$^{f}$ | 6.36$^{gh}$ | 6.27$^{h}$ | 6.40$^{gh}$ | 6.46$^{h}$ | 6.72$^{i}$ |
| Fiber Tenderness[b] | | | | | | |
| Top sirloin | 5.30$^{f}$ | 5.48$^{f}$ | 5.35$^{f}$ | 5.41$^{f}$ | 5.78$^{g}$ | 5.86$^{g}$ |
| Top loin | 5.92$^{f}$ | 6.36$^{gh}$ | 6.30$^{h}$ | 6.44$^{gh}$ | 6.48$^{g}$ | 6.76$^{i}$ |
| Connective Tissue[c] | | | | | | |
| Top sirloin | 6.29$^{fg}$ | 6.41$^{gh}$ | 6.26$^{fg}$ | 6.15$^{f}$ | 6.58$^{hi}$ | 6.73$^{i}$ |
| Top loin | 6.88$^{f}$ | 7.18$^{gh}$ | 7.07$^{h}$ | 7.26$^{gi}$ | 7.34$^{gi}$ | 7.38$^{i}$ |
| Shear Force[d] | | | | | | |
| Top sirloin | 10.69$^{f}$ | 10.01$^{f}$ | 9.26$^{f}$ | 10.67$^{f}$ | 9.17$^{f}$ | 9.26$^{f}$ |
| Top loin | 9.50$^{f}$ | 8.43$^{g}$ | 7.59$^{h}$ | 8.27$^{gh}$ | 7.22$^{hi}$ | 6.75$^{i}$ |
| MFI[e] | | | | | | |
| Top sirloin | 640$^{f}$ | 594$^{g}$ | 633$^{f}$ | 633$^{f}$ | 642$^{f}$ | 723$^{h}$ |
| Top loin | 634$^{f}$ | 619$^{f}$ | 605$^{f}$ | 626$^{f}$ | 640$^{f}$ | 646$^{f}$ |

[a]Sensory panel overall tenderness ratings. Top loin steaks received higher (P<0.05) overall tenderness ratings than top sirloin steaks in all aging treatments.
[b]Sensory panel muscle fiber tenderness ratings. Top loin steaks received higher (P<0.05) muscle fiber tenderness ratings than top sirloin steaks in all aging treatments.
[c]Sensory panel connective tissue ratings. Top loin steaks received higher (P<0.05) connective tissue ratings than top sirloin steaks in all aging treatments.
[d]Warner-Bratzler shear force values (lbs.). Top loin steaks had lower (P<0.05) shear force values than top sirloin steaks in all aging treatments.
[e]Myofibrillar Fragmentation Index. Top loin steaks had lower (P<0.05) MFI's than top sirloin steaks for the 14 and 35 day aging treatments.
[f-i]Means within a row having common superscripts were not different (P<0.05).

TABLE 2. SARCOMERE LENGTH (μm), TOTAL COLLAGEN CONTENT (mg/g) AND COLLAGEN SOLUBILITY (%) FOR TOP SIRLOIN AND TOP LOIN STEAKS

| | Top sirloin steaks | | Top loin steaks | |
|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. |
| Sarcomere length (μm) | 1.91 | 0.20 | 2.02 | 0.21 |
| Total collagen (mg/g) | 6.91$^{a}$ | 4.19 | 4.86$^{b}$ | 2.43 |
| Collagen solubility (%) | 16.55 | 5.82 | 18.41 | 9.38 |

[a,b]Means within a row with different superscripts were different (P<0.05).

# Fatty Acid Modification of Beef Products and Their Effect on Serum Cholesterol

K.W. Lin, J.T. Keeton and S.B. Smith


## Summary

Six steers were slaughtered and the lean and fat tissues utilized for manufacturing typical beef bologna (as control) with relatively high palmitate (C16:0) content and modified beef bologna with relatively low palmitate (or high stearate). Palmitate and stearate ratios from the animal tissues were adjusted to predetermined levels with commercially produced tallow. Beef tallow high in stearate (C18:0) was incorporated into formulations to produce modified beef bologna, while regular beef tallow (relatively high in palmitate) was used to supplement typical beef products.

Both bologna treatments were formulated to contain 32 percent total fat with 40 percent of the total fat substituted with tallow. Each bologna log was portioned into 1.76 oz slices, the slices crust-frozen, vacuum-packaged, and held at -4°F for shipping to the University of Texas Southwestern Medical Center at Dallas for inclusion in a dietary study.

Small amounts of regular and modified tallow will be added to bakery items such as muffins to maintain an isocaloric intake and to balance stearate and palmitate contents (and their ratios) in patient diets. Each patient will receive a 36.9-37.3 percent fat in the diet each day from 5.24 oz of meat (seasoned and unseasoned bologna). At this level, 41.5 percent of the total daily caloric intake comes from fat. Lipid components in the blood and serum of the test patients will be monitored over a 21 day period to evaluate the effect of stearate and palmitate in the diet and determine human responses to saturated fats from beef.


## Introduction

Saturated fatty acids (such as lauric acid, myristic acid or palmitic acid) are recognized as the major dietary factors contributing to high levels of serum cholesterol, and meat products, especially beef, are relatively rich in saturated fatty acids. Because of the positive relationship between the coronary heart disease (CHD) and serum cholesterol, some consumers have tended to avoid beef to reduce their intake of saturated fatty acids. Bonanome and Grundy (1) demonstrated that stearic acid (C18:0), a saturated fatty acid abundant in beef, does not raise serum cholesterol as previously thought. They also indicated that only dietary lauric acid (C12:0), myristic acid (C14:0), and palmitic acid (C16:0) contributed to the serum cholesterol rise associated with ingestion of saturated fatty acids in diets.

This study conducted in collaboration with Dr. Scott Grundy will demonstrate whether modified beef products (relatively low in palmitate and high in stearate) will effect a change in serum cholesterol in comparison to typical beef products (relatively high in palmitate) when both are used in solid food diets. Beef products included in the study will be formulated by the Meat Science Section at Texas A&M University, College Station, and the dietary intervention study will be performed by the Center for Human Nutrition at the University of Texas Southwestern Medical Center, Dallas, TX.

## Materials and Methods

### *Sample Preparation*

Six steers were slaughtered at the Rosenthal Meat Science and Technology Center of Texas A&M University, College Station, fabricated into primal cuts, vacuum-packaged, and stored at -4°F. Meat blocks from individual animals were thawed in a refrigerated cutting room (approximately 45°F) for 24 h, the lean and fat tissues separated (with shank or heavy connective tissues removed) and both ground separately through a 1/8 inch plate fitted on a Butcher Boy® grinder. Uniform, ground lean and fat tissues were collected for chemical analyses and the remainder was vacuum-packaged and stored in the freezer for subsequent product manufacture.

### *Chemical Analyses*

The lean and fat tissue samples were homogenized using a Robot Coupe® homogenizer and proximate composition for fat and moisture determined (2) using a CEM, model AVC-80, Automatic Volatility Computer. Total lipids were extracted following a modified Folch procedure (3), and lipid extracts were methylated using 14 percent (w/v) boron trifluoride in methanol to produce fatty acid methyl esters which were identified using a Varian 2860 flame ionization detector gas chromatograph as described by Sweeten et al. (4). Table 1 shows the proximate composition and percentages of the major fatty acids in the raw tissues. Because tissues from both treatments did not contain high enough palmitate or stearate to produce sufficiently modified beef products, commercially produced tallow was purchased for adjusting the fatty acid compositions. The modified beef tallow high in stearic acid was provided by Kraft Food and prepared by randomization of fully hydrogenated soybean oil and high oleic safflower oil (1:1, w/w) (1). The regular beef tallow (relatively high in palmitate) that was used to supplement typical beef products was purchased from an edible oil manufacturer (Bunge Foods). Analytical compositions of each tallow are included in Table 1.

### *Formulations*

Preliminary tests determined that an emulsion-type product such as a frankfurter or bologna was most suitable for this study. Dietary requirements necessitated that the products contain approximately 35.6-37.3 percent total fat to provide 480-504 kilocalories (kcal) from fat in the meat which would contribute 40-42 percent of the calories in a 2,400 kcal daily diet. Because of the physical characteristics of the tallow and the need to entrap fat and/or tallow in the product, bologna formulations containing 32 percent total fat with 40 percent of the total fat substituted with tallow were produced having fatty acid profiles for typical and high stearate, low palmitate beef products. Percentage estimates of the major fatty acids and formulations for both products are shown in Tables 2 and 3, respectively.

### *Processing Procedures*

Frozen lean tissues were tempered in a cooler (45°F) for 12 h, re-ground through a 1/4 inch plate and mixed in a Seydelmann® chopper (85-90% vacuum) at low speed for 2 min and then high speed for 1 min after the addition of 1/2 the water as ice, NaCl, and all non-meat ingredients. Crushed tallow then was added and chopping continued for 1 min at low speed, and 30 s at high speed to keep the temperature of the mixture below 52°F. The "preblends" then were transferred to shallow containers to rapidly dissipate heat and avoid microbial growth. Containers were covered with plastic-coated wrapping paper, held in a cooler (35°F) overnight (less than 24 hr), and emulsified with fine-ground (1/8 inch) fat tissue in the Seydelmann® with 1/2 of the remaining water added as ice. Unseasoned batches of bologna for both treatments were processed in two replications (77.2 lb each) because of the limited capacity of the equipment. The batters were chopped at low speed for 2 min and then high speed for 30 s or until the temperature reached 65°F. Emulsions were loaded into a Vemag® vacuum stuffer, encased in 5.5 inch diameter moisture-permeable, fibrous casings and cooked immediately (without smoke) in an air-conditioned smokehouse (Alkar Food Processing Oven) preheated at 130°F. Hourly increments of 10°F at a relative humidity of 38 percent (35-40%) were made until an internal temperature of 150°F was achieved. Nickel-chromium thermocouple probes (Omega) were inserted into the geometric center of bologna logs and situated in different positions of the smokehouse to monitor the internal temperature. Following overnight chilling (45°F), each log was split in half lengthwise, portioned with a Berkel slicer into 1.76 oz halfmoon-shaped slices and the slices crust-frozen in a -4°F freezer. According to each serving plan, one, two, or three slices, respectively, were vacuum-packaged in 7" x 10" B540 Cryovac bags and held at -4°F for shipping to the University of Texas Southwestern Medical Center at Dallas for the clinical phase of the study.

### *Clinical Study (Hypercholesterolemic Patients)*

Twenty healthy, male patients (ages 30-65 years) with borderline-high to high serum cholesterol (200-300 mg/dl) will be recruited for an inpatient metabolic diet study. The study will compare typical beef products (relatively high in palmitate content and high in stearate) with modified beef products (relatively low in palmitate content) as the major source of dietary fat, and the subjects will consume each diet for a total of 3 weeks. The remainder of the diet will consist of natural solid foods and will be matched for dietary cholesterol content (300 mg per day). Blood will be drawn daily during the last 6 days of each diet period, and the serum separated for lipid, lipoprotein, and apolipoprotein analyses. Total serum cholesterol and triglycerides also will be determined.

## Results and Discussion

The average percentage of moisture, fat, and cooking loss of each bologna treatment in Table 4. Because of inherent variation within the raw materials and between replicates, the final fat content was slightly lower than the targeted level of 32 percent. Seasoned, typical beef bologna had less cooking loss but a higher fat content possibly due to a larger percentage loss of moisture than of fat and/or tallow.

Table 5 shows the percentage of the major fatty acids in each cooked bologna treatment. Some tallow was released during thermal processing; therefore, palmitate and stearate contents were lower than the original targeted levels for both treatments while palmitate contents of modified beef products were higher. The slightly lower stearate and palmitate contents and their ratios indicated that a small amount of tallow was needed to supplement both products and approach the projected targets. Small amounts of regular and modified tallow were therefore added to bakery items such as muffins to maintain an isocaloric intake and to balance stearate and palmitate contents (and their ratios) in each patient's diet (Table 6). Each patient will receive 5.28 oz of meat per day which consists of 1.76 oz seasoned bologna and 3.52 oz unseasoned bologna while on alternate days only 5.28 oz unseasoned bologna will be served. Total fat content for a daily serving was adjusted to an average of 36.87-37.27 percent, amounting to approximately 41.5 percent of the total daily caloric intake. Because of lower stearate contents in unseasoned, typical beef products, proportionate amounts of modified tallow were mixed with regular tallow to increase the stearate content in the diet. Exact amounts of regular and modified tallow were melted and mixed to assure a uniform mixture. Although stearate and palmitate contents were lower than targeted levels (Table 5) by approximately 2 percent in typical beef bologna, and 2.8 percent in modified beef bologna, there were enough differences in fatty acid composition between the products to satisfy the requirements for dietary modification.

The total amount (oz) of tallow or tallow mixture to be added to the muffins was calculated on per patient, per day basis (Table 6). Tallow and the tallow mixture were placed in separate Rubbermaid® containers and shipped on dry ice to the University of Texas Southwestern Medical Center at Dallas by Airborne Express for the inpatient study.


## Acknowledgment

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## Literature Cited


1. Bonanome, A. and S.M. Grundy. 1988. Effect of dietary stearic acid on plasma cholesterol and lipoprotein levels. N. Engl. J. Med. 318:1244.
2. Bostian, M.L., D.L. Fish, N.B. Webb, and J.J. Arey. 1985. Automated methods for determination of fat and moisture in meat and poultry products: collaborative study. J. Assoc. Off. Anal. Chem. 68: 876.
3. Folch, J., M. Lees, and G.H.S. Stanley. 1957. Simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226: 497.
4. Sweeten, M.K., H.R. Cross, G.C. Smith, and S.B. Smith. 1990. Subcellular distribution and composition of lipids in muscle and adipose tissues. J. Food Sci. 55:43.


TABLE 1. CORRECTED AREA PERCENTAGE OF FATTY ACIDS AND PROXIMATE COMPOSITIONS OF RAW BEEF TISSUE AND TALLOW

| | Typical Beef | | | | | | Modified Beef | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 376C | | 397C | | 320C | | 274T | | 395T | | 399T | | Regular | Modified |
| Fatty acid(%) | Lean | Fat | Lean | Fat | Lean | Fat | Lean | Fat | Lean | Fat | Lean | Fat | Tallow | Tallow |
| Myristic | 2.95 | 3.14 | 2.73 | 2.86 | 3.07 | 3.17 | 3.50 | 4.00 | 3.74 | 4.09 | 3.89 | 4.34 | 3.00 | 0.10 |
| Palmitic | 24.82 | 24.14 | 22.81 | 22.90 | 24.45 | 24.20 | 21.34 | 21.94 | 22.74 | 22.76 | 22.30 | 22.43 | 26.20 | 8.10 |
| Palmitoleic | 4.91 | 3.69 | 4.44 | 4.47 | 5.53 | 5.99 | 4.10 | 4.71 | 3.90 | 4.58 | 4.01 | 3.31 | 2.60 | 0.12 |
| Stearic | 15.20 | 20.22 | 13.30 | 15.03 | 13.71 | 20.48 | 15.98 | 17.56 | 17.98 | 17.18 | 17.07 | 21.00 | 22.40 | 42.77 |
| Oleic | 44.12 | 41.25 | 48.53 | 47.31 | 47.51 | 41.41 | 48.30 | 45.51 | 46.42 | 45.83 | 47.41 | 44.48 | 43.10 | 39.61 |
| Linoleic | 3.80 | 3.54 | 3.49 | 2.89 | 2.51 | 1.97 | 2.69 | 1.81 | 1.97 | 1.33 | 1.66 | 1.16 | 1.40 | 7.89 |
| Arachidic | 0.05 | 0.11 | 0.07 | 0.06 | 0.03 | 0.09 | 0.08 | 0.09 | 0.08 | 0.09 | 0.07 | 0.08 | -- | 0.78 |
| **Total (%)** | 95.85 | 96.09 | 95.37 | 95.52 | 96.81 | 97.31 | 95.99 | 95.62 | 96.83 | 95.86 | 96.41 | 96.80 | 98.70 | 99.37 |
| Moisture (%) | 68.86 | 22.16 | 65.69 | 31.12 | 65.52 | 24.71 | 68.50 | 30.41 | 66.39 | 23.35 | 62.13 | 22.92 | 0.05 | 0.37 |
| Fat (%) | 9.01 | 70.50 | 13.73 | 58.64 | 14.65 | 68.07 | 10.33 | 59.29 | 13.32 | 69.08 | 17.84 | 69.65 | 99.00 | 99.38 |
| **Total (%)** | 77.87 | 92.66 | 79.42 | 89.76 | 80.17 | 92.78 | 78.83 | 89.70 | 79.71 | 92.43 | 79.97 | 92.57 | 99.05 | 99.75 |

TABLE 2. ESTIMATED PERCENTAGES OF THE MAJOR FATTY ACIDS IN BOLOGNA FORMULATIONS[a]

| | | est.%Palmitate | est.%Stearate | Ratio(Sta:Palm) |
|---|---|---|---|---|
| Typical Beef | 376C | 25.10 | 20.34 | 0.810 |
| | 397C | 24.20 | 17.58 | 0.726 |
| | Targeted | 25.50 | 21.60 | 0.847 |
| Modified Beef | 274T | 16.31 | 27.39 | 1.679 |
| | 399T | 16.65 | 28.34 | 1.702 |
| | 395T | 16.89 | 27.60 | 1.634 |
| | Targeted | 14.00 | 33.10 | 2.364 |

[a] Finished products were formulated to contain 32% total fat in which 40% was substituted with tallow.

TABLE 3. FORMULATIONS[a] FOR TYPICAL AND MODIFIED BEEF BOLOGNA

| Materials | Typical Beef | | Modified Beef | |
|---|---|---|---|---|
| | Seasoned | Unseasoned | Seasoned | Unseasoned |
| Lean (lb) | 36.85 | 104.39 | 25.98 | 98.14 |
| Fat (lb) | 14.19 | 40.17 | 12.32 | 45.56 |
| Tallow (lb)[b] | 8.98 | 25.41 | 6.71 | 25.30 |
| Water (lb)[c] | 7.19 | 20.39 | 5.39 | 20.39 |
| NaCl (lb) | 1.34 | 8.49 | 1.01 | 8.49 |
| Prague® (oz) | 2.40 | 6.79 | 1.80 | 6.79 |
| Erythobate (oz) | 0.53 | 1.50 | 0.40 | 1.50 |
| Seasoning (oz) | 18.60 | -- | 13.95 | -- |
| Dextrose (oz) | -- | 13.60 | -- | 13.60 |

[a] Emulsions were formulated to contain 32% fat in finished products.

[b] Regular or modified beef tallow was added to typical or modified beef bologna, respectively.

[c] Water was added to compensate for an estimated 12% cooking loss.

TABLE 4. AVERAGE MOISTURE AND FAT CONTENTS AND COOKING LOSSES OF BEEF BOLOGNAS

| | | Typical Beef | | Modified Beef | |
|---|---|---|---|---|---|
| | | Seasoned | Unseasoned[a] | Seasoned | Unseasoned[a] |
| Raw | Moisture (%) | 54.38 | 52.56 | 53.08 | 53.75 |
| | Fat (%) | 29.86 | 32.00 | 31.78 | 31.31 |
| Cooked | Moisture (%) | 50.62 | 52.41 | 51.65 | 51.55 |
| | Fat (%) | 31.78 | 29.36 | 29.55 | 30.08 |
| Cooking Loss (%) | | 8.95 | 12.40 | 11.40 | 13.60 |

[a] Average of two replications.

TABLE 5. CORRECTED PERCENTAGE OF TOTAL FATTY ACIDS OF COOKED BEEF BOLOGNA AND TARGETED LEVELS

| Fatty acids (%) | Typical Beef | | | Modified Beef | | |
|---|---|---|---|---|---|---|
| | Seasoned | Unseasoned | Targeted | Seasoned | Unseasoned | Targeted |
| Myristic | 3.23 | 3.14 | 3.30 | 2.39 | 2.38 | 1.00 |
| Palmitic | 24.14 | 24.24 | 25.50 | 16.73 | 16.52 | 14.00 |
| Palmitoleic | 3.82 | 4.00 | 3.40 | 2.62 | 2.84 | 2.00 |
| Stearic | 18.60 | 16.73 | 21.60 | 24.80 | 25.54 | 33.10 |
| Oleic | 41.68 | 44.27 | 38.70 | 45.92 | 45.85 | 39.40 |
| Linoleic | 3.01 | 2.89 | 2.20 | 4.50 | 4.11 | 4.50 |
| Arachidic | 0.06 | 0.06 | 0.10 | 0.11 | 0.12 | 0.20 |
| **Total (%)** | 95.97 | 95.56 | 94.80 | 98.09 | 98.38 | 94.20 |
| S/P ratio[a] | 0.771 | 0.690 | 0.847 | 1.482 | 1.546 | 2.364 |

[a] Stearate/Palmitate ratio.

TABLE 6. AMOUNT OF TALLOW ADDED TO EACH TREATMENT AND ESTIMATES OF THE MAJOR FATTY ACIDS IN THE BOLOGNA PRODUCTS WITH TALLOW ADJUSTMENT

| | Typical Beef | | | Modified Beef | | |
|---|---|---|---|---|---|---|
| Tallow Added (oz) | Seasoned 1.76 oz serving | Unseasoned[a] 3.52 oz serving | Unseasoned[a] 5.28 oz serving | Seasoned 1.76 oz serving | Unseasoned 3.52 oz serving | Unseasoned 5.28 oz serving |
| Regular | 0.14 | 0.32 | 0.48 | --- | --- | --- |
| Modified | --- | 0.11 | 0.16 | 0.22 | 0.40 | 0.60 |
| Total oz added[b] | 0.14 | 0.43 | 0.64 | 0.22 | 0.40 | 0.60 |
| Total fat (%) | 36.81 | 36.93 | 36.96 | 37.34 | 37.19 | 37.19 |
| %Palmitate | 24.55 | 23.48 | 23.46 | 14.14 | 14.21 | 14.21 |
| %Stearate | 19.36 | 19.89 | 19.92 | 30.14 | 30.26 | 30.26 |
| S/P ratio[c] | 0.789 | 0.847 | 0.849 | 2.132 | 2.129 | 2.129 |

[a] Regular and modified tallow were melted and mixed.

[b] Total amount (oz/patient/day) of tallow added to muffins.

[c] Stearate/Palmitate ratio.

# Carcass Composition and Value as Influenced by Frame Size, Muscle Score, and Fat Thickness

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## Summary

Commercial slaughter steers (n=332) and heifers (n=332) differing in breed type were evaluated for frame size and muscle score (5) by three trained evaluators. The USDA carcass grade data were collected 24 hours postmortem by USDA personnel. The carcasses were assigned to one of three fatness groups based upon the 12/13th rib fat thickness measure (>.60 in, .30-.59 in, <.30 in). One side of each carcass was fabricated into boneless primal and subprimal cuts and trimmed to a quarter of an inch of external fat. There was considerable muscling and fatness variation in the cattle utilized in the study. The percentage yield of boneless .25 in trimmed subprimals ranged from 36.67 percent to 55.23 percent. Fat thickness appears to have the most influence on carcass composition and ultimately on value as compared to frame size and muscle score. The composition data presented in this study suggest that muscle score has a greater impact on composition than does frame size. However, these differences are not as dramatic or consistent as those demonstrated by fat thickness.

## Introduction

The employment of a value based marketing system for beef cattle is closer to reality. The National Cattlemen's Association's Value Based Marketing Task Force final report has called for a reduction of excess trimmable carcass fat by 20 percent by 1995 (8). In addition, the USDA method of price reporting has shifted to a composite value system, which is a more retailer (consumer) driven system than the method used in the past. Within a value based system, it will be vital for feeders and packers to be able to identify and sort live slaughter cattle based upon predicted carcass merit. Therefore, the relationship between phenotypic characteristics of slaughter cattle and carcass composition and ultimately carcass value needs to be examined. This study was conducted to compare the percentage yield of .25 inch trimmed, boneless subprimals for cattle differing in frame size, muscle score, and external fatness.

## Materials and Methods

Commercial slaughter steers (n=332) and heifers (n=332) differing in breed type were evaluated for frame size and muscle score (6) by three trained evaluators. The cattle were selected to represent a cross section of the fed cattle population. The cattle were shipped to a commercial packing facility for slaughter. The USDA carcass grade data were collected 24 hours postmortem by USDA personnel (7). The carcasses were assigned to one of three fatness groups based upon the 12/13th rib fat thickness measure (>.60 in, .30-.59 in, <.30 in). One side of each carcass was fabricated into boneless primal and subprimal cuts and trimmed to a quarter of an inch of external fat, except for the tenderloin and knuckle, which had all external fat removed. Weights were obtained at all stages of fabrication for each cut, as well as for lean trim, fat, bone, and connective tissue. Means, standard deviations, and correlation coefficients were calculated using SAS (3).

## Results and Discussion

Means and the variation of live and carcass traits are characterized in Table 1. There was considerable muscling and fatness variation in the cattle utilized in the study. Fat thickness at the 12/13th rib ranged from .08 to 1.32 inch while ribeye area ranged from 8.2 to 19.0 inch$^2$. The carcasses, also, exhibited a wide range of USDA yield and quality grades with the yield grades ranging from 1.0 to 5.9 and the marbling scores ranging from "practically devoid" (Average Standard) to "moderately abundant" (Average Prime). As would be expected with the large variation in carcass traits, the percentage yield of boneless .25 in trimmed subprimals showed a spread of 18.56 percent.

The simple correlation coefficients indicated that USDA yield grade was the most highly related trait to boneless subprimal yield (Table 2). The fat thickness measure was inversely moderately related to boneless subprimal yield, while muscle score and frame size were lowly associated.

The carcass composition as influenced by frame size, muscle score, and fat thickness for steers and heifers is shown in Tables 3 and 4, while carcass values (on a per hundredweight basis) are presented in Tables 5 and 6. Fat thickness appears to have the most influence on carcass composition and ultimately on value as compared to frame size and muscle score. The change in carcass composition from those carcasses in the >.6 in group compared to those in the <.3 in with frame size and muscle score held constant range from 1 to 8 percent with the fatter carcasses having a lower percentage yield of boneless, closely trimmed subprimals. This is ultimately reflected in

carcass value with the fatter carcasses being worth as much as $16/cwt less than the trimmer carcasses at comparable frame sizes and muscle scores. The ability of fat thickness to influence carcass composition has been demonstrated by numerous researchers (1, 2). These researchers found that fat thickness was the most important variable in predicting USDA yield grade and carcass composition.

Tatum et al. (5) found that feeder cattle with a No. 1 (thick) muscle score produced carcasses with higher muscle to bone ratios than those with No. 3 (thin) muscle scores. Similar results have been shown in other studies (4). The composition data presented in this study suggest that muscle score has a greater impact on composition than does frame size. However, these differences are not as dramatic or consistent as those demonstrated by fat thickness. When comparing carcass values, the effect of muscle score appeared to be more dramatic. However, the use of frame size and muscle score are important in classifying cattle into similar groups for obtaining proper compositional endpoints, even though fat thickness has the most impact on the percentage yield of boneless closely trimmed subprimals.

TABLE 1. MEAN VALUES FOR SELECTED LIVE AND CARCASS TRAITS

| Item | Mean | Standard deviation | Minimum value | Maximum value |
|---|---|---|---|---|
| Adjusted fat thickness 12/13th rib, in. | .52 | .22 | .08 | 1.32 |
| Ribeye area, $in^2$ | 12.6 | 1.83 | 8.2 | 19.0 |
| Kidney, heart and pelvic fat, % | 2.57 | .66 | 1.00 | 5.00 |
| Hot carcass weight, lb. | 669 | 106 | 395 | 1091 |
| USDA yield grade | 2.8 | .89 | 1.0 | 5.9 |
| Marbling score[a] | 413 | 86 | 180 | 880 |
| Live weight, lb. | 1073 | 158 | 685 | 1587 |
| Yield of .25 in. trimmed subprimal, % | 46.36 | 2.94 | 36.67 | 55.23 |
| Trimmable fat to .25 in, % | 19.05 | 4.28 | 8.80 | 33.22 |

[a] Marbling Score: 800 = Moderately Abundant; 400 = Small; 100 = Practically Devoid.

TABLE 2. SIMPLE CORRELATION COEFFICIENTS FOR PERCENTAGE YIELD OF .25 in. BONELESS SUBPRIMALS AND TRIMMABLE FAT TO SELECTED LIVE AND CARCASS TRAITS

| Item | Yield of .25 in. Trimmed Subprimal, % | Trimmable Fat to .25 in., % |
|---|---|---|
| Frame size[a] | -.26** | .31** |
| Muscle score[b] | -.35** | .16** |
| Live weight, lb. | .02 | .06 |
| Adjusted fat thickness 12/13th rib, in. | -.69** | .84** |
| Ribeye area, $in^2$ | .48** | -.31** |
| Kidney, heart and pelvic fat, % | -.48** | .53** |
| Hot carcass weight, lb. | -.04 | .12** |
| USDA yield grade | -.82** | .85** |
| Marbling score[c] | -.55** | .50** |
| Trimmable fat to .25 in., % | -.89** | |

[a] Frame size: 1 = Large; 2 = Medium; 3 = Small.
[b] Muscle score: 1 = Thick; Average; 3 = Thin.
[c] Marbling Score: 800 = Moderately Abundant; 400 = Small; 100 = Practically Devoid.
**P < .05.

## Literature Cited


1. Crouse, J.D., M.E. Dikeman, R.M. Koch, and C.E. Murphey. 1975. Evaluation of traits in the USDA yield grade equation for predicting beef carcass cutability in breed groups differing in growth and fattening characteristics. J. Anim. Sci. 41:548.
2. Powell, W.E., and D.L. Huffman. 1973. Predicting chemical composition of beef carcasses from easily obtainable carcass variables. J. Anim. Sci. 36:1069.
3. SAS. 1985. SAS Users Guide: Statistics. SAS Inst., Inc., Cary, NC.
4. Tatum, J.D., H.G. Dolezal, F. L. Williams, Jr., R.A. Bowling, and R.E. Taylor. 1986. Effects of feeder-cattle frame size and muscle thickness on subsequent growth and carcass development. II. absolute growth and associated changes in carcass composition. J. Anim. Sci. 62:121.
5. Tatum, J.D., G.C. Smith, C.E. Murphey, Z.L. Carpenter, and L. M. Schake. 1982. Feeder cattle frame size, muscle thickness and subsequent beef carcass characteristics. 6:275.
6. USDA. 1976. Draft for study to consider revision of the USDA grades for feeder cattle. USDA, Washington, DC.
7. USDA. 1989. Official United States standards for grades of carcass beef. Agr. Marketing Serv., USDA, Washington, DC.
8. Value based marketing task force. August, 1990. A war on fat!. National Cattlemen's Association. Denver, CO.


TABLE 3. PERCENTAGE YIELD OF .25 in. TRIMMED BONELESS SUBPRIMALS FOR STEER CARCASSES STRATIFIED BY FRAME SIZE, MUSCLE SCORE, AND FATNESS

| Muscle Score | Fatness Group, in. | Frame Size: Large | Medium | Small |
|---|---|---|---|---|
| Thick | > .60 | 46.9 | 46.1 | 45.0 |
| | .30-.59 | 48.6 | 48.9 | 48.3 |
| | < .30 | 50.5 | 51.8 | 52.0 |
| Average | > .60 | 44.2 | 43.1 | 42.4 |
| | .30-.59 | 46.6 | 47.1 | 46.3 |
| | < .30 | 48.1 | 50.2 | 50.1 |
| Thin | > .60 | 45.4 | ** | ** |
| | .30-.59 | 45.8 | 46.8 | 46.1 |
| | < .30 | 46.2 | 47.4 | 48.7 |

** No values available.

TABLE 4. PERCENTAGE YIELD OF .25 in. TRIMMED BONELESS SUBPRIMALS FOR HEIFER CARCASSES STRATIFIED BY FRAME SIZE, MUSCLE SCORE, AND FATNESS[a]

| Muscle Score | Fatness Group, in. | Frame Size: Large | Medium | Small |
|---|---|---|---|---|
| Thick | > .60 | 46.3 | 45.9 | 45.4 |
| | .30-.59 | 48.8 | 47.4 | 49.4 |
| | < .30 | 50.0 | 51.3 | ** |
| Average | > .60 | 44.7 | 43.6 | 43.3 |
| | .30-.59 | 47.1 | 46.8 | 46.9 |
| | < .30 | 50.0 | 49.0 | ** |
| Thin | > .60 | 43.4 | 42.7 | 42.1 |
| | .30-.59 | 46.8 | 45.7 | 44.6 |
| | < .30 | ** | 48.6 | ** |

** No values available

TABLE 5. CARCASS VALUE (/CWT) OF .25 in. TRIMMED BONELESS SUBPRIMALS FOR STEER CARCASSES STRATIFIED BY FRAME SIZE, MUSCLE SCORE, AND FATNESS

| Muscle Score | Fatness Group, in. | Frame Size | | |
|---|---|---|---|---|
| | | Large | Medium | Small |
| Thick | > .60 | 117.79 | 116.07 | 114.96 |
| | .30-.59 | 121.70 | 121.78 | ** |
| | < .30 | 126.16 | 128.64 | ** |
| Average | > .60 | 113.22 | 110.12 | 109.33 |
| | .30-.59 | 118.48 | 118.07 | 118.14 |
| | < .30 | ** | 124.58 | ** |
| Thin | > .60 | ** | ** | ** |
| | .30-.59 | 117.61 | 119.39 | 118.07 |
| | < .30 | 119.50 | 120.63 | 123.59 |

** No values available.

TABLE 6. CARCASS VALUE (/CWT) OF .25 in. TRIMMED BONELESS SUBPRIMALS FOR HEIFER CARCASSES STRATIFIED BY FRAME SIZE, MUSCLE SCORE, AND FATNESS

| Muscle Score | Fatness Group, in. | Frame Size | | |
|---|---|---|---|---|
| | | Large | Medium | Small |
| Thick | > .60 | 118.63 | 118.72 | 118.53 |
| | .30-.59 | 125.23 | 121.90 | 126.33 |
| | < .30 | 134.96 | 130.45 | ** |
| Average | > .60 | 115.69 | 112.83 | 112.82 |
| | .30-.59 | 121.15 | 120.26 | 121.29 |
| | < .30 | 127.62 | 126.34 | ** |
| Thin | > .60 | ** | 111.47 | 110.48 |
| | .30-.59 | 121.35 | 118.82 | 115.92 |
| | < .30 | ** | ** | ** |

** No values available.

# Acceleration of Postmortem Tenderization in Cow Beef through Injection of Calcium Chloride

J.B. Morgan, R.K. Miller, F.M. Mendez, D.S. Hale and J.W. Savell


## Summary

A study involving 10 mature (12 to 17 years old) cows was conducted to determine the effects of calcium chloride ($CaCl_2$) injection on Warner-Bratzler shear force and sensory panel ratings. Infusion of cow subprimals (strip loin, top sirloin, and inside round) with $CaCl_2$ (a 0.3 molar solution injected to 10 percent of subprimal weight) accelerated postmortem tenderization and decreased shear force values (day 14) by 41.1, 40.1, and 15.3 percent in steaks from the strip loin, top sirloin, and inside round, respectively. Additionally, $CaCl_2$-injected subprimals exhibited higher sensory panel tenderness ratings, regardless of aging period. These results indicate that $CaCl_2$ injection dramatically improves ultimate tenderness and sensory ratings of meat from mature carcasses. Observation that $CaCl_2$ injection improves mature cow beef comparable in tenderness to that from youthful beef could be of immense importance to the beef industry.


## Introduction

Dunsing (4), in a investigation of palatability preferences of a consumer panel for beef from young and old animals, determined that eating preferences were consistently in favor of beef from younger animals because more youthful beef was more tender. Decreased tenderness associated with advanced maturity in beef has been attributed to decreased sarcomere length (2), increased fiber diameter (1), increased incidence of wavy fibers (3), and decreased amounts of heat-labile connective tissue (5).

As a consequence of age-associated problems with tenderness, the majority of beef from animals of advanced maturity is currently marketed as boneless manufacturing beef. However, bullocks, heiferettes, forage-fed beef, short-fed dairy steers, and cows are presently slaughtered with the intent to sell the rib and loin to the hotel, restaurant, and institution (HRI) trade for steak items (6). This increased demand for convenience meat items such as steaks (rib and loin) and boneless round cuts has prompted the meat industry to develop alternative methods of meat tenderization.

Several postmortem procedures have been shown to improve ultimate tenderness of cooked meat. Electrical stimulation, blade tenderization, and postmortem aging will increase meat tenderness. More current research (7) has demonstrated that infusing calcium chloride ($CaCl_2$) into lamb carcasses immediately after death accelerates the postmortem aging process and ensured acceptable tenderness values. The objective of this study was to determine whether $CaCl_2$ injection could improve tenderness and sensory panel ratings in meat from mature cow carcasses.

## Experimental Procedure

Ten cows representing five breed-types (Hereford, Angus, Brahman x Jersey, Hereford x Holstein, Holstein x Jersey; 12 to 17 years old, 900 to 1100 lb live weight) were slaughtered according to normal procedures. Following slaughter (approximately 30 minutes), the inside round, top sirloin, and strip loin subprimals were removed (hot-boned) from alternating sides of each carcass and injected (10% of the subprimal weight) with 0.3 M (molar) $CaCl_2$. The above solution was infused with a ham/bacon cure injecting device. Following injection, these subprimals were transferred to a holding cooler (32-34°F) containing the alternate cold-boned sides. After a 24-hour chilling period, the cold-boned controls and hot-boned, infused subprimals were fabricated into retail cuts, vacuum-packaged and aged either 1, 7, or 14 days at 36-38°F. Retail cuts were assigned to aging treatments such that each treatment combination was equally represented for all aging times. After the appropriate aging period, each retail cut was broiled to an internal temperature of 158°F. Cooked retail cut tenderness was analyzed by Warner-Bratzler shear force and a trained sensory panel.

## Results and Discussion

Results reported in Table 1 are consistent with previous $CaCl_2$ infusion research data (7,8), in that $CaCl_2$ injection resulted in accelerated subprimal postmortem aging as evidenced by decreased day-1 shear force values and higher sensory panel tenderness ratings compared to control cuts (Tables 1 and 2). For example, $CaCl_2$-injected top sirloins had shear force values approximately 63 percent lower than control top sirloins after 1 day of aging. Similar results were noticed for strip loin retail cuts. Infused subprimals had lower shear force values and higher sensory panel tenderness ratings compared to control subprimals after all aging periods. $CaCl_2$ injection lowered day-14 shear force values by 41.1, 40.1, and 15.3 percent in steaks from the strip loin, top sirloin and inside round, respectively (Table 1). Less detectable connective tissue and higher flavor inten-

sity scores were observed in CaCl injected retail cuts. Juiciness ratings were not different between treatment groups. These results indicate that $CaCl_2$ infusion dramatically improves ultimate tenderness and sensory ratings of meat from mature carcasses. Observation that $CaCl_2$ injection improves mature cow beef to such an extent that it is comparable in tenderness to youthful beef could be of immense importance to the beef industry.

## Literature Cited


1. Berry, B.W., G.C. Smith, and Z.L. Carpenter. 1974. Relationships of certain muscle, cartilage and bone traits to tenderness of the beef longissimus. J. Food Sci. 39:819
2. Cooper, C.C., B.B. Breidenstein, R.G. Cassens, G. Evans, and R.W. Bray. 1968. Influence of marbling and maturity on the palatability of beef muscle. 2. Histological considerations. J. Anim. Sci. 27:1542.
3. Covington, R.C., H.J. Tuma, D.L. Grant, and A.D. Dayton. 1970. Various chemical and histological characteristics of beef muscle as related to tenderness. J. Anim. Sci. 30:191.
4. Dunsing, M. 1959. Visual and eating preferences of consumer household panel for beef from animals of different age. Food Technol. 13:332.
5. Dutson, T.R. 1974. Connective tissue. Proc. Meat Ind. Res. Conf. p. 99.
6. McKeith, F.K., G.C. Smith, J.W. Savell, T.R. Dutson, Z.L. Carpenter, and D.R. Hammons. 1980. Electrical stimulation of mature cow carcasses. J. Anim. Sci. 50:694.
7. Koohmaraie, M., J.D. Crouse, and H.J. Mersmann. 1989. Acceleration of postmortem tenderization in ovine carcasses through infusion of calcium chloride: Effect of concentration and ionic strength. J. Anim. Sci. 67:934.
8. Koohmaraie, M. , A.S. Babiker, A.L. Shroeder, R.A. Merkel, and T.R. Dutson. 1988. Acceleration of postmortem tenderization of ovine carcasses through activation of $Ca^{2+}$-dependent proteases. J. Food Sci. 53:1638.


TABLE 1. EFFECT OF $CaCl_2$ INJECTION ON WARNER-BRATZLER SHEAR FORCE (LBS.) IN MATURE COW SUBPRIMALS

| | Control | | | Calcium-injected | | |
|---|---|---|---|---|---|---|
| Subprimal | Day 1 | Day 7 | Day 14 | Day 1 | Day 7 | Day 14 |
| Strip loin | 19.62 | 16.59 | 14.43 | 8.49 | 8.05 | 8.49 |
| Top sirloin | 21.67 | 15.84 | 15.20 | 8.09 | 8.99 | 9.06 |
| Inside round | 21.05 | 17.34 | 15.58 | 13.33 | 13.73 | 13.20 |

Table 2. MEANS FOR SENSORY PANEL RATINGS OF $CaCl_2$ INJECTED AND CONTROL COW SUBPRIMALS

| | Control | | | Calcium-injected | | |
|---|---|---|---|---|---|---|
| Subprimal/ Sensory trait | Day 1 | Day 7 | Day 14 | Day 1 | Day 7 | Day 14 |
| **Strip loin** | | | | | | |
| Juiciness[a] | 5.9 | 5.6 | 5.3 | 5.9 | 5.9 | 5.3 |
| Myofibrillar tenderness[b] | 2.7 | 2.7 | 3.9 | 5.3 | 5.8 | 5.6 |
| Connective tissue amount[c] | 3.3 | 3.6 | 3.8 | 4.9 | 5.2 | 5.4 |
| Overall tenderness[b] | 2.5 | 2.7 | 3.6 | 4.8 | 5.3 | 5.3 |
| Flavor intensity[d] | 5.8 | 5.7 | 5.7 | 6.3 | 6.4 | 6.9 |
| **Top sirloin** | | | | | | |
| Juiciness | 5.7 | 5.8 | 4.7 | 6.1 | 5.8 | 5.6 |
| Myofibrillar tenderness | 2.5 | 4.0 | 3.9 | 6.2 | 6.4 | 5.8 |
| Connective tissue amount | 3.6 | 4.2 | 4.2 | 5.5 | 5.9 | 5.2 |
| Overall tenderness | 2.4 | 3.8 | 3.7 | 5.8 | 6.0 | 5.3 |
| Flavor intensity | 5.9 | 5.7 | 5.6 | 6.6 | 6.8 | 7.2 |
| **Inside round** | | | | | | |
| Juiciness | 5.8 | 5.7 | 5.2 | 6.5 | 6.0 | 5.7 |
| Myofibrillar tenderness | 2.6 | 3.1 | 3.6 | 5.3 | 5.2 | 4.9 |
| Connective tissue amount | 2.9 | 3.2 | 3.8 | 4.2 | 4.2 | 4.2 |
| Overall tenderness | 2.4 | 2.9 | 3.3 | 4.7 | 4.7 | 4.3 |
| Flavor intensity | 5.8 | 5.8 | 5.7 | 6.6 | 6.8 | 7.0 |

[a] 8 = extremely juicy, 1 = extremely dry.
[b] 8 = extremely tender, 1 = extremely tough.
[c] 8 = none, 1 = abundant.
[d] 8 = extremely intense, 1 = extremely bland.

# National Beef Tenderness Survey

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## Summary

In order to determine the average tenderness and sensory ratings of beef sold in retail cases across the United States, retail cuts were purchased through typical retail outlets in 14 metropolitan cities and were transported to Texas A&M University for sensory and Warner-Bratzler shear analysis. The overall mean shear force for all cuts was 8.09 lb, while the mean shear force values for chuck, rib, loin, and round were 8.18, 7.39, 6.97, and 9.48 lb, respectively. No difference in tenderness was detected among the cuts from the rib. Mean palatability ratings and shear force values of top loin steaks were similar to rib cuts. Top sirloin steaks were tougher and received the lowest sensory ratings when compared to other loin cuts. Approximately 2 to 3 times as many round and chuck steaks had shear force values in excess of 10.0 lb compared to their roast counterparts. In all cases, roasts were more tender than steaks from the same subprimal source. USDA Choice chuck retail cuts, when compared to Select and No-roll chuck cuts, had approximately 10 percent fewer cuts with shear force values in excess of 8.8 lb compared to USDA Select and No-roll chuck cuts. From this survey, sources causing variation in tenderness were apparent and must be addressed if product consistency is to be improved. An eventual goal for all segments of the beef industry must be that 100 percent of all retail cuts have "acceptable" overall tenderness ratings.

## Introduction

In recent years, economic pressures have challenged the livestock and meat industries to seek ways of producing meat products that will enable the consumer to receive maximum palatability benefits at the lowest costs. Factors such as meat color, flavor, aroma, tenderness, and method of cookery have a collective role in meat "taste" and more importantly consumer acceptance. The National Consumer Retail Beef Study (6,7) clearly revealed the importance of taste to the consumer in the purchasing decision process. This and other studies also have revealed that "tenderness" or meat "texture" is the single most important factor affecting taste or consumer perception of taste.

Many meat retailers, however, indicate that they seldom receive complaints about taste from consumers. Most noted questions are related to such factors as preparation methods, storage life characteristics, and nutritional and cholesterol information. Does this mean that tenderness is not a problem at the retail level or possibly that consumers don't return "tough" meat and/or perhaps will not return for future business? Using sensory panel tenderness scores and Warner-Bratzler shear force values, the present study was designed to determine the variability in tenderness across different individual primal cuts and different regions of the United States.

## Experimental Procedure

### *City and Supermarket Selection*

The study was conducted in 14 cities representing six geographical regions of the United States (Northeast-East, Southeast, North Central, South Central, Mountain, and West).

Two-to-three retail chains per city representing at least one-third of the total volume of supermarket sales were chosen. Within each chain, four stores were selected so that a total of 8 to 12 supermarket stores per metropolitan city were surveyed. This tended to provide a complete, random sample within each city.

### *Meat Sample Selection, Purchasing, and Transportation*

Retail steaks and roasts, (chuck blade and arm sections, chuck mock tender, ribeye, strip loin, tenderloin, round tip, top sirloin, top round, eye of round, and bottom round) were selected from each fresh beef retail meat case. Raw material production dates and sources were obtained from available boxes and packaging materials. Selected retail cuts were purchased and then transported to the Meat Science Section, Sensory Evaluation Testing Facility at Texas A&M University.

### *Retail Cut Cookery*

Cookery methods which are commonly used in the home were employed in this study. Internal temperature for each retail cut was monitored using copper constatan thermocouples inserted into the geometric center of the cut and recorded by Honeywell recorders.

### *Sensory and Shear Force Analysis*

Cooked samples were served to a trained, eight-member Descriptive Attribute Panel (1). The panel

evaluated each sample for juiciness, tenderness, connective tissue amount, flavor intensity, and overall palatability based on eight-point scales. Approximately 25 percent of the retail cuts purchased were served to the descriptive panel members. The remaining cuts were cooked and allowed to cool to room temperature, and up to 10, 1/2-inch diameter cores were removed from each steak or roast and then sheared using a Warner-Bratzler shear apparatus. The shear force value reported for each cut was determined by calculating the mean of the cores sheared for that steak or roast.

## Results and Discussion

### *Post-fabrication Aging Times*

Table 1 summarizes the time (days) for primal and subprimal cuts to arrive from the fabrication plants to the various retail outlets where these cuts became available to the consumer. Aging, as a method for tenderization of meat by storage at above-freezing temperatures in vacuum bags, is very important in assuring a tender and acceptable product (2). This "aging" time will be referred to as "post-fabrication time", (PFT). Data from the present study suggest that the average PFT for all cuts is approximately 17 days. The minimum PFT was 3 days and the maximum PFT was 90 days with the majority falling between 10 and 30 days (data not in tabular form). Chuck cuts had the shortest average PFT (15 days) compared to other primals.

### *Tenderness and Palatability Characteristics of Chuck Cuts*

Sensory panel ratings and Warner-Bratzler shear force means for chuck retail cuts are presented in Table 2. Chuck retail cuts exhibited an overall shear force mean of 8.18 lb. Roasts from the chuck tended to have higher, more desirable sensory ratings along with lower shear force values compared to their chuck steak counterparts. A possible explanation for this difference in tenderness is the longer cooking time required for thicker roast cuts. This would increase the opportunity for solubilization of collagen during thermal processing (3) as well as increasing the moisture content, which could influence the perceived tenderness rating by sensory panelists. Increased marketing of thin-cut steaks and shorter cooking times with more intensive heat could possibly increase meat toughness while decreasing consumer satisfaction.

### *Tenderness and Palatability Characteristics of Rib and Loin Cuts*

Shear force means of 7.39 and 6.97 lb were the averages for rib and loin cuts, respectively. Warner-Bratzler shear force and palatability means are listed in Table 3. With the exception of rib roast juiciness scores, shear force and sensory attribute ratings were not affected by retail cut type within the primal rib. Mean palatability ratings and shear force values of top loin steaks indicated similar eating characteristics compared to rib cuts (Table 3). Top sirloin steaks were the toughest loin cut (7.83 lb) compared to 7.15 and 5.74 lb for top loin and tenderloin steaks, respectively. Mean myofibrillar tenderness, detectable connective tissue amount, and overall tenderness ratings of top sirloin steaks indicated lower palatability compared to other middle meat (rib and loin) cuts. These data, which are similar to those from previous research, indicate that top sirloin steaks were less tender than top loin steaks (4,5,9). Panel tenderness ratings (myofibrillar tenderness and overall tenderness) for top sirloin steaks were lower and shear force values were higher when compared to other rib and loin retail cuts.

### *Tenderness and Palatability Characteristics of Round Cuts*

The overall shear force mean for round retail cuts was 8.71 lb, approximately 12 percent tougher than the next toughest primal cut (Table 4). Similar to chuck, round roasts tended to be more tender, juicier, and have less detectable connective tissue than steaks from the round. As observed between steak and roast cuts from the chuck, round steak cuts were tougher and received lower sensory scores than round roasts. These differences could be attributed to differences in cooking methods (braising versus roasting) and shorter cooking times, along with increased connective tissue amounts detected in the thin-cut steaks. Round tip roasts were more tender when compared to other round cuts. It has been concluded (8) that the round tip (rectus femoris muscle) was the most tender round muscle after 14 d postmortem aging. Top round steaks were the toughest round cut as evidenced by the highest shear force value (11.51 lb) and lower palatability ratings (Table 4).

### *Influence of Quality Grade on Cooked Beef Tenderness*

Conflicts exist concerning the relationship between marbling and meat tenderness. In the present study, frequency distributions of shear force values from steaks and (or) roasts within each quality grade were constructed. One must remember that these comparisons are not necessarily "cause and effect relationships", due to large sources of variation by cattle types and source, different handling systems in the various fabrication facilities, and various post-fabrication times for subprimals. However, this is a representative sample of meat in retail cases throughout the United States. Mean shear force differences appear to be small between chuck cuts from different quality grades; however, the frequency distribution of shear force values indicates approximately 10 percent more cuts from Select and no-roll grades which required 8.8 lb of force or greater when compared to Choice chuck cuts. Similar results were noted for Choice rib and loin cuts which had a lower mean shear, 7.15 lb, compared to shear force values

of 7.41 and 7.26 lb for Select and no-roll cuts, respectively. The inability to distinguish the intermingling of Choice within no-roll or the exact quality definition of no-roll retail cuts could contribute to the variation in tenderness observed in no-roll.

In the present study, USDA quality grade failed to control the variation in panel ratings or shear force values to the degree necessary to ensure consistent beef products to the consumer. Steps must be taken throughout the beef industry to address the palatability variation issue. The beef industry has failed to set in place production and marketing systems necessary to provide the product consistency that could be found through branded beef. Lack of responsibiliy for monitoring the critical control points needed to produce a highly uniform product has resulted in excessive variation in beef produced and marketed.

## Literature Cited


1. Cross, H.R., R. Moen, and M.S. Stanfield. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. 32:48.
2. Davey, C.L., H. Kuttel, and K.V. Gilbert. 1967. Shortening as a factor in meat aging. Food Technol. 2:53.
3. Locker, R.H. 1977. Meat tenderness and gap filaments. Meat Sci. 1:87.
4. Savell, J.W., G.C. Smith, and Z.L. Carpenter. 1977. Blade tenderization of four muscles from three weight-grade groups of beef. J. Food Sci. 42:866.
5. Savell, J.W., G.C. Smith, and D.L. Huffman. 1980. Cutting yields and palatability traits of hand-cut or pressed-cleaved, and fresh-chilled, crust-frozen or frozen-tempered beef subprimals. J. Food Sci. 43:1666.
6. Savell, J.W, R.E. Branson, H.R. Cross, D.M. Stiffler, J.W. Wise, D.B. Griffin, and G.C. Smith. 1987. National Consumer Retail Beef Study: palatability evaluations of beef loin steaks that differed in marbling. 1987. J. Food Sci. 52:517.
7. Savell, J.W., H.R. Cross, J.J. Francis, J.W. Wise, D.S. Hale, D.L. Wilkes, and G.C. Smith. 1989. National Consumer Retail Beef Study: Interaction of trim level, price and grade on consumer acceptance of beef steaks and roasts. J. Food Qual. 12:251.
8. Smith, G.C., G.R. Culp, and Z.L. Carpenter. 1978. Postmortem aging of beef carcasses. J. Food Sci. 43:823.
9. Wheeler, T.L., R.K. Miller, J.W. Savell, and H.R. Cross. 1990. Palatability of chilled and frozen beef steaks. J. Food Sci. 55:301.


TABLE 1. OVERALL POST-FABRICATION TIME MEANS (DAYS) FOR PRIMAL CUTS STRATIFIED ACROSS CITIES

| City | Chuck | Rib | Loin | Round | City Mean |
|---|---|---|---|---|---|
| Houston | 13 | 20 | 24 | 19 | 19 |
| Kansas City | 13 | 24 | 20 | 18 | 19 |
| New York | 12 | 13 | 12 | 14 | 13 |
| Dallas | 14 | 23 | 19 | 13 | 17 |
| Los Angeles | 21 | 27 | 33 | 17 | 25 |
| Atlanta | 11 | 19 | 20 | 16 | 17 |
| Denver | 14 | 22 | 24 | 21 | 20 |
| Chicago | 12 | 10 | 15 | 8 | 11 |
| Philadelphia | 14 | 11 | 15 | 17 | 14 |
| San Francisco | 19 | 10 | 21 | 19 | 17 |
| Tampa | 21 | 21 | 25 | 16 | 21 |
| Detroit | 20 | 21 | 14 | 12 | 17 |
| Seattle | 18 | 24 | 26 | 18 | 22 |
| Baltimore | 11 | 16 | 16 | 18 | 15 |
| **National average** | **15** | **18** | **20** | **16** | **17** |

TABLE 2. MEANS OF SHEAR FORCE AND SENSORY ATTRIBUTES OF CHUCK RETAIL CUTS

| Retail cut | Shear force mean, lb.[a] | Sensory panel ratings[b] | | | | |
|---|---|---|---|---|---|---|
| | | Juiciness | Myofibrillar tenderness | Connective tissue | Overall tenderness | Flavor intensity |
| Arm roast | 8.12 | 3.52 | 5.68 | 6.68 | 5.52 | 5.29 |
| Arm steak | 8.67 | 3.11 | 4.99 | 5.96 | 4.91 | 5.57 |
| Clod roast | 7.90 | 4.55 | 6.01 | 6.60 | 5.97 | 5.54 |
| Clod steak | 8.82 | 3.91 | 5.75 | 6.73 | 5.68 | 5.45 |
| Blade roast | 8.05 | 4.83 | 5.90 | 6.10 | 5.73 | 5.46 |
| Blade steak | 8.40 | 4.12 | 5.30 | 6.07 | 5.11 | 5.36 |
| Chuck roll roast | 7.63 | 4.86 | 6.25 | 6.49 | 6.11 | 5.76 |
| Chuck roll steak | 9.13 | 4.36 | 5.32 | 5.76 | 5.18 | 5.46 |
| Chuck eye steak | 8.16 | 5.22 | 5.94 | 6.81 | 5.92 | 5.66 |
| Chuck tender steak | 8.89 | 3.84 | 5.40 | 6.36 | 5.31 | 5.66 |
| Top blade steak | 6.71 | 4.82 | 6.19 | 6.46 | 6.11 | 5.69 |

[a] Warner-Bratzler shear force determinations made with 1/2-in. diameter cores.

[b] 8= extremely juicy, extremely tender, no connective tissue, extremely tender and extremely flavorable, respectively; 1= extremely dry, extremely tough, abundant amount of connective tissue, extremely tough and extremely unflavorable, respectively.

TABLE 3. MEANS OF SHEAR FORCE AND SENSORY ATTRIBUTES OF RIB AND LOIN RETAIL CUTS

| Retail cut | Shear force mean, lb.[a] | Sensory panel ratings[b] | | | | |
|---|---|---|---|---|---|---|
| | | Juiciness | Myofibrillar tenderness | Connective tissue | Overall tenderness | Flavor intensity |
| Ribeye steak | 7.46 | 5.05 | 6.26 | 7.07 | 6.25 | 5.64 |
| Rib steak | 7.44 | 4.96 | 6.29 | 7.07 | 6.28 | 5.71 |
| Rib roast | 7.30 | 5.67 | 6.57 | 7.23 | 6.53 | 5.59 |
| Top loin steak | 7.15 | 5.39 | 6.46 | 7.12 | 6.41 | 5.84 |
| Top sirloin steak | 7.83 | 4.96 | 5.88 | 6.53 | 5.75 | 5.79 |
| Tenderloin steak | 5.74 | 5.23 | 7.19 | 7.55 | 7.19 | 6.06 |

[a] Warner-Bratzler shear force determinations made with 1/2-in. diameter cores.

[b] 8= extremely juicy, extremely tender, no connective tissue, extremely tender and extremely flavorable, respectively; 1= extremely dry, extremely tough, abundant amount of connective tissue, extremely tough and extremely unflavorable, respectively.

TABLE 4. MEANS OF SHEAR FORCE AND SENSORY ATTRIBUTES OF ROUND RETAIL CUTS

| Retail cut | Shear force mean, lb.[a] | Sensory panel ratings[b] | | | | |
|---|---|---|---|---|---|---|
| | | Juiciness | Myofibrillar tenderness | Connective tissue | Overall tenderness | Flavor intensity |
| Bottom round roast | 8.87 | 5.42 | 6.05 | 5.94 | 5.73 | 5.72 |
| Bottom round steak | 9.64 | 3.24 | 5.05 | 5.36 | 4.77 | 5.77 |
| Top round roast | 8.93 | 4.64 | 5.72 | 6.51 | 5.62 | 5.56 |
| Top round steak | 11.51 | 3.01 | 4.43 | 5.96 | 4.33 | 5.44 |
| Eye of round roast | 9.15 | 5.40 | 6.09 | 6.65 | 6.02 | 5.49 |
| Eye of round steak | 10.27 | 2.82 | 5.09 | 6.25 | 5.04 | 5.31 |
| Round tip roast | 7.77 | 5.19 | 6.31 | 6.81 | 6.21 | 5.52 |
| Round tip steak | 8.82 | 4.21 | 5.61 | 6.48 | 5.55 | 6.05 |
| Rump roast | 9.28 | 5.72 | 6.16 | 5.81 | 5.72 | 5.73 |

[a] Warner-Bratzler shear force determinations made with 1/2-in. diameter cores.

[b] 8= extremely juicy, extremely tender, no connective tissue, extremely tender and extremely flavorable, respectively; 1= extremely dry, extremely tough, abundant amount of connective tissue, extremely tough and extremely unflavorable, respectively.

# Nutrient Retention in Ground Beef Cooked by Preparation Techniques Used to Reduce Fat

K.S. Rhee, H.A. Griffith and Y.A. Ziprin


## Summary

Instructions for convenience food products using ground meat recommend initial browning of meat and draining of the cooked-out liquid before adding other ingredients. When ground beef samples of different particle size (fine or coarse grind) and fat content (10 or 20%) were submitted to this brown-and-drain process, cooking loss was significantly higher for ground beef with 20 percent initial fat than for that with 10 percent initial fat, but particle size had little effect on cooking loss. Both cholesterol and total fat contents were higher in the cooked meat with 20 percent initial fat. However, the fat retention percentage was higher for ground beef with 10 percent initial fat; the cholesterol retention percentage was not affected by initial fat level.

The particle size of the raw meat had no significant effect on total fat and cholesterol retention. Retention percentages for the minerals analyzed (iron, calcium, magnesium, phosphorus potassium, sodium, and zinc) ranged from 84 percent for potassium to 96 percent for iron while those of the water-soluble vitamins analyzed (thiamin, niacin and vitamin $B_{12}$) ranged from 70 percent for thiamin to 82 percent for vitamin $B_{12}$. It is concluded that, from a nutritional point of view, preparation of ground beef dishes/products using extra-lean ground beef without the draining step would be more advisable than using high-fat ground beef with the brown-and-drain process.


## Introduction

The amounts of total fat, saturated fatty acids, and cholesterol are the most important diet/health concerns for many consumers relative to meat consumption. Ground beef is one of the most popular meat purchases, primarily because of its versatility, price, and convenience in usage. As much as 40 percent of the beef consumed currently in the U.S. may be in the form of ground beef. Since the fat content of retail ground beef can be as high as 30 percent, instructions for prepared food products or meat dishes using ground beef recommend browning (initial cooking) of the meat and draining of the cook-out liquid, which consists of fat and aqueous phases, before adding other ingredients and proceeding to the next step in the cooking procedure. The browning and draining processes are to reduce fat and probably cholesterol, both of which are "unhealthful." However, this practice also may reduce beneficial water-soluble nutrients. Moreover, it is not known how effective this practice is for removing membranal cholesterol and whether nutrient profiles of the drained meat is influenced by the initial (raw meat) fat level or particle size. The current study was conducted to address these issues and questions.

## Materials and Methods

Fresh (never frozen) boneless beef chucks (U.S. Choice quality grade) were obtained locally. The meat was separated into fat and lean portions and both were then ground separately through a grinding plate with 3/8 inch-diameter holes. The ground lean and fat batches were mixed in appropriate proportions to prepare meat mixes with two different fat levels (10 and 20%). One half of the mix for each fat level was then reground through a grinding plate with 3/8 inch-diameter holes to form a "coarse" grind and the other one-half through a grinding plate with 1/8 inch-diameter holes to form a "fine" grind. Each of the four treatment groups (10% fat/fine ground, 10% fat/coarse ground, 20% fat/fine ground, 20% fat/coarse ground) was divided into 500-gram subsamples. One 500-gram aliquot of each treatment group was then homogenized and frozen raw for nutrient analyses. The remaining sample aliquots (never frozen) for each treatment group were browned, with constant stirring, in an electric skillet at 300°F for 6.5 minutes. At the end of this cooking period, all of the meat was uniformly browned.

The total lipids were extracted according to the procedure of Folch et al. (3). An aliquot of the total lipid extract was freed of solvent and its lipid content was determined gravimetrically (g/100g). Cholesterol content was determined by the procedure of Bohac et al. (2) and moisture content by the AOAC (1) procedure. Samples were also wet-ashed and then analyzed for various mineral nutrients using an inductively coupled plasma atomic emission spectrometer. Thiamin was determined by a fluorometric method (1), and niacin and vitamin $B_{12}$ were determined by microbiological turbidimetric methods (1).

True retention of a nutrient in the cooked meat was calculated using the following formula:

$$\% \text{ true retention} = \frac{a \times b}{c \times d} \times 100$$

where, a = % nutrient in the cooked meat
b = weight of meat after cooking
c = % nutrient in raw meat
d = weight of meat before cooking.

All data were analyzed by analysis of variance and the Student-Newman-Keuls' mean separation when treatment effects were significant. The model for analysis of variance included initial fat level, particle size and interaction between the two as the variation sources.

## Results and Discussion

Data on total cooking loss and proportions of aqueous and lipid phases in the drip are shown in Table 1. Percentage cooking loss was significantly higher for ground beef with 20 percent initial fat than for ground beef with 10 percent fat. Particle size of the raw meat had little influence on cooking loss. Weight loss due to the fat drip increased with increasing amounts of initial fat while the opposite was found for the aqueous drip.

Moisture, total fat, and cholesterol contents of raw and cooked-and-drained samples are shown in Table 2. Total fat and cholesterol contents were higher in both the raw and cooked ground beef with 20 percent initial fat, while moisture was higher in the raw and cooked meat with 10 percent initial fat. Particle size had little or no marked effect on moisture, total fat, and cholesterol contents of the cooked meat. Retention percentages for moisture, total fat, and cholesterol are shown in Table 3. Retention of total fat was higher in the cooked meat with 10 percent initial fat whereas cholesterol retention was not affected by initial fat level. Particle size had no significant effect on either total fat or cholesterol retention.

Mineral retention data are presented in Table 4. Overall retention percentages ranged from 84 percent for potassium to 96 percent for iron and 100 percent for zinc. Zinc and heme iron are protein-bound in tissues and therefore were not as readily lost into the cook-out drip as were potassium, phosphorus, and sodium. Although hemoproteins (mostly meat pigments), the major source of iron in the red meat, can be partially destroyed when the meat is cooked, with accompanied release of the iron as nonheme iron, the extent of heat treatment during the browning process is unlikely to cause a large loss of heme iron into the drip as nonheme iron. Zinc retention was extremely high regardless of initial fat content or particle size. Zinc was also reported to be the best retained nutrient in ground beef cooked in the patty form (4). Mineral retention values were not significantly different between fat levels except for phosphorus; the cooked meat with 10 percent initial fat had a higher retention of phosphorus. Particle size had little effect on retention of minerals.

Percentage retention values for thiamin, niacin, and vitamin $B_{12}$ in the cooked meat are shown in Table 5. Overall retention percentages ranged from 69.8 percent for thiamin to 82.3 percent for vitamin $B_{12}$. The low retention of thiamin is due partly to the fact that thiamin is much more heat-labile than niacin and vitamin $B_{12}$. Initial fat level had no significant effect on thiamin and niacin retention, while vitamin $B_{12}$ retention was higher at an initial fat level of 10 percent.

Results of this study indicate that substantial amounts of important mineral nutrients can be lost through the brown-and-drain process in ground beef preparation, although the practice also reduces nutritionally undesirable constituents, such as fat and cholesterol, in the cooked meat. From a nutritional point of view, preparation of ground beef dishes/products using extra-lean ground beef without the draining step would be more recommendable than using high-fat ground meat with the brown-and-drain process.

## Acknowledgment

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## Literature Cited

1. AOAC. 1984. "Official Methods of Analysis." 14th ed. Association of Official Analytical Chemists, Washington, DC.
2. Bohac, C. E., K. S. Rhee, H. R. Cross, and K. Ono. 1988. Assessment of methodologies for colorimetric cholesterol assay of meats. J. Food Sci. 53: 1642.
3. Folch, J., M. Lees, and G. H. S. Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 226: 497.
4. Ono, K., B. W. Berry, and E. Paroczay. 1985. Contents and retention of nutrients in extra lean, lean and regular ground beef. J. Food Sci. 50: 701.

TABLE 1. PERCENT TOTAL COOKING LOSS AND DRIP COMPOSITION AS AQUEOUS AND LIPID PHASES

| Variable | Total cooking loss (%) | Drip composition (%) | |
|---|---|---|---|
| | | Aqueous phase | Lipid phase |
| Initial fat (%) | | | |
| 10 | 23.6[b] | 92.2[a] | 7.8[b] |
| 20 | 28.4[a] | 49.5[b] | 50.7[a] |
| Particle size | | | |
| Fine | 25.0[a] | 72.1[a] | 27.9[a] |
| Coarse | 26.9[a] | 71.3[a] | 28.7[a] |

[a,b]Means within a column within the same variable category (initial fat or particle size) which are followed by the same superscript letter are not significantly different ($p>0.05$).

TABLE 2. MOISTURE, TOTAL FAT AND CHOLESTEROL CONTENTS

| Variable | Moisture (%) | | Total fat (%) | | Cholesterol (mg/100g) | |
|---|---|---|---|---|---|---|
| | Raw | Cooked | Raw | Cooked | Raw | Cooked |
| Initial fat (%) | | | | | | |
| 10 | 70.0[a] | 60.6[a] | 10.4[b] | 13.1[b] | 65.6[b] | 81.9[b] |
| 20 | 62.5[b] | 58.2[b] | 20.4[a] | 16.5[a] | 68.6[a] | 90.3[a] |
| Particle size | | | | | | |
| Fine | 66.2[a] | 59.0[a] | 15.4[a] | 15.3[a] | 66.1[a] | 85.7[a] |
| Coarse | 66.2[a] | 59.7[a] | 15.4[a] | 14.2[b] | 66.1[a] | 86.5[a] |

[a,b]Means within a column within the same variable category (initial fat or particle size) which are followed by the same superscript letter are not significantly different ($p>0.05$).

TABLE 3. RETENTION OF MOISTURE, TOTAL FAT AND CHOLESTEROL IN THE COOKED MEAT

| Variable | Retention (%) | | |
|---|---|---|---|
| | Moisture | Total fat | Cholesterol |
| Initial fat (%) | | | |
| 10 | 66.1[a] | 96.7[a] | 98.8[a] |
| 20 | 66.9[a] | 57.8[b] | 94.2[a] |
| Particle size | | | |
| Fine | 66.9[a] | 81.3[a] | 97.3[a] |
| Coarse | 66.0[a] | 73.2[b] | 95.8[a] |
| Overall | 66.5 | 77.3 | 96.5 |

[a,b]Means within a column within the same variable category (initial fat or particle size) which are followed by the same superscript letter are not significantly different ($p>0.05$).

TABLE 4. RETENTION OF MINERALS IN THE COOKED MEAT

| Variable | Retention (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | P | K | Ca | Mg | Na | Fe | Zn |
| Initial fat (%) | | | | | | | |
| 10 | 91.8[a] | 87.0[a] | 87.7[a] | 88.3[a] | 89.3[a] | 96.1[a] | 100.6[a] |
| 20 | 82.4[b] | 81.2[a] | 93.5[a] | 83.8[a] | 84.7[a] | 96.7[a] | 99.1[a] |
| Particle size | | | | | | | |
| Fine | 87.6[a] | 86.9[a] | 92.3[a] | 87.7[a] | 89.5[a] | 96.5[a] | 99.1[a] |
| Coarse | 86.7[a] | 81.2[a] | 88.9[a] | 84.4[a] | 84.5[a] | 96.3[a] | 100.7[a] |
| Overall | 87.1 | 84.1 | 90.6 | 86.1 | 87.0 | 96.4 | 99.9 |

[a,b]Means within a column within the same variable category (initial fat or particle size) which are followed by the same superscript letter are not significantly different ($p>0.05$).

TABLE 5. RETENTION OF WATER-SOLUBLE VITAMINS

| Variable | Retention (%) | | |
|---|---|---|---|
| | Thiamin | Niacin | Vitamin $B_{12}$ |
| Initial fat (%) | | | |
| 10 | 62.3[a] | 77.2[a] | 97.3[a] |
| 20 | 77.3[a] | 75.7[a] | 67.2[b] |
| Particle size | | | |
| Fine | 71.9[a] | 76.5[a] | 83.3[a] |
| Coarse | 67.7[a] | 76.4[a] | 81.2[a] |
| Overall | 69.8 | 76.4 | 82.3 |

[a,b]Means within a column within the same variable category (initial fat or particle size) which are followed by the same superscript letter are not significantly different ($p>0.05$).

# Identification of Threshold Levels for Warner-Bratzler Shear Force in Beef Top Loin Steaks

S.D. Shackelford, J.B. Morgan, H.R. Cross and J.W. Savell


## Summary

Warner-Bratzler shear (WBS) force values and trained sensory panel overall tenderness ratings of beef top loin steaks from A- and B-maturity carcasses (n=678) were used to determine threshold WBS values. Quality assurance guidelines for retail and foodservice beef were based on 50 and 68 percent confidence levels, respectively, for overall tenderness ratings of "slightly tender". Due to the extreme variation in tenderness that exists in the current U.S. beef population, more stringent confidence levels were not practical. The maximum WBS values for retail and foodservice beef were found to be 10.1 and 8.5 lb, respectively. When these values were tested against the population of beef in the National Consumer Retail Beef Study, the 10.1 lb value was 88.6 percent accurate at determining whether or not a steak would be rated less than "slightly tender" by consumers.


## Introduction

A limitation to the development of quality assurance guidelines for beef tenderness has been the lack of an objective goal. Though Warner-Bratzler shear (WBS) force has allowed for objective assessment of meat tenderness, the relationship of WBS force with consumer acceptability has not been established. Most tenderness research has addressed simple differences in WBS values (or other objective measures of tenderness) between different levels of effects or treatments, while other research has addressed variation about the means. However, little research has utilized frequency distributions to segment (based on WBS values) cases in which unacceptable consumer responses are likely from those cases in which acceptable consumer responses are likely. The value of research to improve meat tenderness hinges upon establishing the relationship of tenderness with consumer purchasing decisions. Therefore, the objectives of this study were to 1) investigate the relationship of WBS force with sensory and consumer panel tenderness ratings of beef top loin steaks, and 2) develop quality assurance guidelines for tenderness of retail and foodservice beef.

## Experimental Procedure

Beef carcasses (n=678) of A and B maturity (5) were selected from eight packing plants in six states. These carcasses represented A and B maturities and marbling scores of Practically Devoid to Moderately Abundant. A detailed description of the experimental protocol was reported previously (4). Briefly, eight top loin steaks (one inch thick) were removed from the strip loin of each carcass. At the time of cutting, four of the eight steaks from each strip loin were assigned to Texas A&M Univ.; the remaining four steaks were assigned to either Iowa State Univ., Colorado State Univ., or the Meat Science Research Laboratory of USDA. Frozen steaks were air-shipped to each cooperator in plastic-foam and corrugated fiberboard containers; shipment time did not exceed 12 hours. Top loin steaks were thawed for 24 hours and cooked to an internal temperature of 158°F on electric broilers. At each institution, 1 of each pair of steaks was served to a 10-member trained sensory panel while the other steak was allowed to cool to room temperature before four (one-half-inch thick) cores were removed for determination of WBS values.

Regression analysis was performed using the General Linear Model (2). Three confidence levels (CL), 50 percent (mean), 68 percent (mean minus standard deviation), and 95 percent (mean minus [2 X standard deviation]) were determined for the WBS values associated with overall tenderness ratings of "slightly tough," "slightly tender," "moderately tender" and "very tender" (4, 5, 6, and 7 on an 8-point scale). Quality assurance guidelines for retail and foodservice beef were based on 50 and 68 percent CL, respectively, for overall tenderness ratings of "slightly tender".

## Results and Discussion

The maximum WBS values for retail and foodservice beef were found to be 10.1 and 8.5 lb, respectively (Table 1). These values were subsequently tested against a population of beef (4) to determine how accurate they were in culling beef that would be rated less than "slightly tender" (Table 2). The 10.1 and 8.5 lb values were 86.7 and 81.5 percent accurate, respectively, at determining whether or not a steak would be rated less than "slightly tender". Nineteen percent of top loin steaks were rated less than "slightly tender". Of those steaks that were rated less than "slightly tender," 65 percent had WBS values in excess of 10.1 lb while 91 percent had WBS values in excess of 8.5 lb.

When tested against trained sensory panel data from the National Consumer Retail Beef Study (NCRBS) (3), the 10.1 and 8.5 lb values were 81.2 and 76.5 percent accurate, respectively, at determining

whether a steak would be rated less than "slightly tender" (5 on an 8-point scale) (Table 3). The accuracy of prediction was slightly decreased (approximately 5%) for the NCRBS population because there were few (7.4%) steaks in the NCRBS that had shear forces in excess of 10.1 lb.

The 10.1 and 8.5 lb values were 88.6 and 74.3 percent accurate, respectively, at determining whether a steak would be rated less than "slightly tender" (6 on a 9-point scale) by the household consumer panel of the NCRBS (Table 4). As stated previously, the 50 percent CL (10.1 lb) was developed as a quality assurance guideline for retail beef. These data indicate that the 10.1 lb threshold value was accurate at determining consumer response despite variation in method of sample handling and cookery from household-to-household. The percentage of consumers in the NCRBS that used outside grilling, inside grilling, oven broiling, and pan frying were 19, 8, 46 and 26, respectively (1). The percentage of consumers that cooked their steaks to "rare," "medium rare," "medium," "well done," and "very well done" were 9, 27, 32, 22, and 10, respectively.

## Implications

This research provides the beef retail and foodservice industries with guidelines for the development of quality assurance programs for beef tenderness. The values suggested in this study will be benchmarks for developing frequency distributions in future beef tenderness research.

TABLE 1. WARNER-BRATZLER SHEAR FORCE (LB) CONFIDENCE LEVELS FOR TRAINED SENSORY PANEL OVERALL TENDERNESS RATINGS OF BEEF TOP LOIN STEAKS

| | Confidence level | | |
|---|---|---|---|
| Tenderness rating[a] | 50%[b] | 68% | 95% |
| 4 | 12.3 | 10.8 | 9.2 |
| 5 | 10.1 | 8.5 | 5.9 |
| 6 | 7.9 | 6.4 | 4.8 |
| 7 | 5.7 | 4.2 | 2.6 |

[a]Scored on an 8-point scale (4 = "slightly tough," 5 = "slightly tender," 6 = "moderately tender" and 7 = "very tender").

[b]Steaks having Warner-Bratzler shear force values less than 12.3 lb have a 50% chance of being rated "slightly tough" (4 on an 8-point scale) or higher for overall tenderness by a trained sensory panel.

TABLE 2. VERIFICATION OF WARNER-BRATZLER SHEAR FORCE CONFIDENCE LEVELS AS A MEANS OF PREDICTING WHETHER TRAINED SENSORY PANEL OVERALL TENDERNESS RATINGS OF TOP LOIN STEAKS WILL BE LESS THAN "SLIGHTLY TENDER"

| | Confidence level (associated shear force) | | |
|---|---|---|---|
| | 50% | 68% | 95% |
| Tenderness scenario[a] | (10.1 lb) | (8.5 lb) | (5.9 lb) |
| Correct | 86.7 | 81.5 | 56.7 |
| Scenario 1 | 12.2 | 17.3 | 18.6 |
| Scenario 2 | 74.5 | 64.2 | 38.1 |
| Incorrect | 13.3 | 18.5 | 43.3 |
| Scenario 3 | 6.6 | 16.9 | 43.0 |
| Scenario 4 | 6.3 | 1.6 | .3 |

[a]Correct = scenario 1 + scenario 2. Tenderness scenario 1 is the percentage of steaks that had Warner-Bratzler shear (WBS) values greater than the confidence level (CL) and were rated less than "slightly tender" for overall tenderness. Tenderness scenario 2 is the percentage of steaks that had WBS values less than the CL and were rated "slightly tender" or higher for overall tenderness. Incorrect = scenario 3 + scenario 4. Tenderness scenario 3 is the percentage of steaks that had WBS values greater than the CL and were rated "slightly tender" or higher for overall tenderness. Tenderness scenario 4 is the percentage of steaks that had WBS values less than the CL and were rated less than "slightly tender" for overall tenderness.

## Acknowledgments

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## Literature Cited

1. Branson, R.E., H.R. Cross, J.W. Savell, G.C. Smith, and R.A. Edwards. 1986. Marketing implications from the National Consumer Beef Study. Western J. of Ag. Econ. 11:82.
2. SAS. 1985. SAS User's Guide: Statistics. SAS Institute, Inc., Cary, NC.
3. Savell, J.W, R.E. Branson, H.R. Cross, D.M. Stiffler, J.W. Wise, D.B. Griffin, and G.C. Smith. 1987. National Consumer Retail Beef Study: Palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. 52:517.
4. Smith, G.C., H.R. Cross, Z.L. Carpenter, C.E. Murphey, J.W. Savell, H.C. Abraham, and G.W. Davis. 1982. Relationship of USDA maturity groups to palatability of cooked beef. J. Food Sci. 47:1100
5. USDA. 1973. Official United States standards for grades of carcass beef. Agri. Marketing Service, United States Dept. of Agriculture, Washington, DC.

TABLE 3. VERIFICATION OF WARNER-BRATZLER SHEAR FORCE CONFIDENCE LEVELS AS A MEANS OF PREDICTING WHETHER TRAINED SENSORY PANEL OVERALL TENDERNESS RATINGS OF TOP LOIN STEAKS WILL BE LESS THAN "SLIGHTLY TENDER" FOR THE POPULATION OF BEEF USED IN THE NATIONAL CONSUMER RETAIL BEEF STUDY

| | Confidence level (associated shear force) | | |
|---|---|---|---|
| | 50% | 68% | 95% |
| Tenderness scenario[a] | (10.1 lb) | (8.5 lb) | (5.9 lb) |
| Correct | 81.2 | 76.8 | 54.8 |
| Scenario 1 | 4.9 | 11.9 | 18.6 |
| Scenario 2 | 76.3 | 64.9 | 36.2 |
| Incorrect | 18.7 | 23.2 | 45.2 |
| Scenario 3 | 2.5 | 14.0 | 42.7 |
| Scenario 4 | 16.2 | 9.2 | 2.5 |

[a]Correct = scenario 1 + scenario 2. Tenderness scenario 1 is the percentage of steaks that had Warner-Bratzler shear (WBS) values greater than the confidence level (CL) and were rated less than "slightly tender" for overall tenderness. Tenderness scenario 2 is the percentage of steaks that had WBS values less than the CL and were rated "slightly tender" or higher for overall tenderness. Incorrect = scenario 3 + scenario 4. Tenderness scenario 3 is the percentage of steaks that had WBS values greater than the CL and were rated "slightly tender" or higher for overall tenderness. Tenderness scenario 4 is the percentage of steaks that had WBS values less than the CL and were rated less than "slightly tender" for overall tenderness.

TABLE 4. VERIFICATION OF WARNER-BRATZLER SHEAR FORCE CONFIDENCE LEVELS AS A MEANS OF PREDICTING WHETHER OR NOT CONSUMER TENDERNESS RATINGS OF TOP LOIN STEAKS WILL BE LESS THAN "SLIGHTLY TENDER" FOR THE POPULATION OF BEEF USED IN THE NATIONAL CONSUMER RETAIL BEEF STUDY

| | Confidence level (associated shear force) | | |
|---|---|---|---|
| | 50% | 68% | 95% |
| Tenderness scenario[a] | (10.1 lb) | (8.5 lb) | (5.9 lb) |
| Correct | 88.6 | 74.3 | 44.6 |
| Scenario 1 | 2.0 | 4.2 | 6.8 |
| Scenario 2 | 86.6 | 70.1 | 37.8 |
| Incorrect | 11.5 | 25.7 | 55.4 |
| Scenario 3 | 5.2 | 21.6 | 53.9 |
| Scenario 4 | 6.3 | 4.1 | 1.5 |

[a]Correct = scenario 1 + scenario 2. Tenderness scenario 1 is the percentage of steaks that had Warner-Bratzler shear (WBS) values greater than the confidence level (CL) and were rated less than "slightly tender." Tenderness scenario 2 is the percentage of steaks that had WBS values less than the CL and were rated "slightly tender" or higher. Incorrect = scenario 3 + scenario 4. Tenderness scenario 3 is the percentage of steaks that had WBS values greater than the CL and were rated "slightly tender" or higher. Tenderness scenario 4 is the percentage of steaks that had WBS values less than the CL and were rated less than "slightly tender."

# Performance and Carcass Characteristics of Bulls as Influenced by Exogenous Hormones

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B.D. Schanbacher and D.D. Johnson

## Summary

One-hundred forty-four weanling bulls of Angus (n=48), Simmental x Hereford (n=48), and Simmental (n=48) breeding were either castrated, left intact, left intact and implanted with Ralgro, or left intact and implanted with Synovex S. Cattle were slaughtered after either 190, 246, or 315 days of high-energy feeding and the right side of each carcass was electrically stimulated. Steers were inferior to intact treatments for most performance and carcass cutability traits, but steers were superior in marbling and lean quality. There were no difference in dressing percentage and ribeye area per 100 lb of carcass weight among treatments. Relative to non-implanted bulls, Ralgro and Synovex S increased carcass masculinity characteristics. Ralgro increased lean, skeletal, and overall maturity scores and decreased marbling scores. Implanted treatments did not differ from intacts for feed conversion, average daily gain, yield grade characteristics, percent ribeye muscle chemical fat, and 9-10-11$^{th}$ rib composition. Time on feed did not affect the differences in carcass composition between intact bulls and steers. Simmental and Angus ranked highest and lowest, respectively, for carcass cutability traits, while the opposite was true for carcass quality traits. Electrical stimulation improved all carcass quality traits. Synthetic estrogen implants did not improve bull performance or carcass merit.

## Introduction

Implantation of bulls with synthetic estrogen has been shown to increase carcass fatness (10). This effect is in contrast to that obtained in steers and suggested that synthetic estrogen may improve the quality of young bull carcasses (1,7). Losses associated with sexual aggression have been a major concern with feeding intact males. Previous work has shown no effect on testicular growth, behavioral characteristics, and degree of development of secondary sex characteristics when the anabolic agent zeranol was implanted in intact males at one year of age (6). When implanted in intact males at a young age (preweaning) and continued at approximately 106 day intervals until slaughter, Ralgro has been reported to decrease testicle size, aggressive male behavior, and development of secondary sex characteristics (5), and has been shown to increase docility of bulls (9).

With consumers' increased demand for lean beef and the advent of 1/4-inch subprimal trimming by the packing industry, the need exists for the production of lean, palatable beef. Therefore, this study investigated the effects of implanting young intact bulls with synthetic estrogen implants on performance and carcass characteristics.

## Experimental Procedure

One-hundred forty-four fall-born weanling bulls of Angus (A, n=48), Simmental x Hereford (SH, n=48) and Simmental (S, n=48) breeding were either castrated, left intact, left intact and implanted with Ralgro, or left intact and implanted with Synovex S. At weaning (approximately 450 lb live weight), cattle within each breed were assigned randomly to treatment (castrate, intact, intact+Ralgro, intact+Synovex S) within one of three slaughter groups (12, 14, or 16 months of age). Cattle were fed in 48 pens where each pen contained one animal of each breed and served as one replicate of one treatment within one slaughter group.

The length of the feeding period was 190, 246, and 315 days for slaughter groups 1, 2, and 3, respectively. Cattle were fed a growing diet for 84 days and then the energy content of the diet was gradually increased over a 2-week period (Table 1). Slaughter groups 1, 2, and 3 were fed the finishing diet for 90, 146, and 215 days, respectively.

At slaughter, ending weight, hot carcass weight, and dressing percentage were recorded. Testicle weights were recorded on all intact treatments. The right side of each carcass was electrically stimulated and the degree of contraction of each stimulated side was scored on a 1- to 5-point scale (1=no contraction and 5=extreme contraction). The electrical stimulation consisted of 17 pulses at 550 volts (AC), 2 to 2.5 amps, and 60 Hertz; for a 1.8-second duration with a 1.8-second pause between impulses. Carcasses were chilled for 24 hours at 29.3°F.

Both sides of each carcass were ribbed between the 12$^{th}$ and 13$^{th}$ ribs at 24 hours postmortem for determination of USDA quality and yield grade data (11). For each carcass side, skeletal maturity, lean maturity, overall maturity, marbling, lean color, and lean texture were scored. Actual fat thickness, adjusted fat thickness, ribeye area, percentage kidney, pelvic and heart fat, USDA yield grade, and carcass

masculinity were recorded for the right side of each carcass. The scoring system used for lean color, lean texture, and carcass masculinity was a 1- to 8-point scale (8=bleached, fine, or masculine and 1=dark, coarse, or nonmasculine).

At 24 hours postmortem, 9-10-11th, rib sections were removed from the right side of each carcass (8). Rib sections were dissected and separated into 1) subcutaneous fat, 2) seam fat, 3) bone, cartilage and connective tissue, and 4) lean. Soft tissues were ground, homogenized, and analyzed for moisture and fat content. One steak was removed opposite the 12th thoracic vertebra of the right side of each carcass for determination of ribeye muscle (RE) chemical composition.

## Results and Discussion

Steers were inferior to all intact treatments for average daily gain, feed conversion, ending weight, hot carcass weight, actual and adjusted fat thickness, ribeye area, percent kidney, pelvic and heart fat, and yield grade (Table 2). Also, percent total separable fat, percent separable seam fat, percent soft tissue chemical fat, and percent RE chemical fat were higher for steers. Steer carcasses had higher marbling scores and were more youthful with brighter, finer textured lean. These data are in agreement with findings of previous reviews (4, 10).

Treatment did not affect dressing percentage, ribeye area per 100 lb of carcass weight, percent separable subcutaneous fat, or percent separable bone, cartilage, and connective tissue. Carcasses from bulls implanted with Ralgro or Synovex S were more masculine than those from nonimplanted bulls. Synovex S implantation resulted in higher lean color scores than Ralgro. Ralgro increased lean, skeletal, and overall maturity scores and decreased marbling scores. Concomitantly, percent chemical fat in the ribeye was lower and percent moisture was higher for carcasses from bulls implanted with Ralgro than those from bulls implanted with Synovex S. Implantation of bulls with Ralgro or Synovex S did not affect testicle weights or performance and carcass cutability traits.

Average daily gain was highest for the second slaughter group and lowest for the third slaughter group, while the second slaughter group had the lowest feed to gain ratio (Table 3). Ending weight, hot carcass weight, testicle weight, actual fat thickness, adjusted fat thickness, ribeye area, percent kidney, pelvic and heart fat, yield grade, percent total separable fat, percent separable subcutaneous fat, percent separable seam fat, percent soft tissue fat, and percent RE fat all increased as time on feed increased. Concomitantly, ribeye area per 100 lb of carcass weight and percent separable lean decreased with increased time on feed. Masculinity and dressing percentage were not affected by slaughter endpoint. Previously, 9-10-11th rib section percent ether extractable fat has been shown to be higher for bulls fed to 1100 lb live weight as compared to bulls fed to 1000 lb (5).

Angus had the lowest average daily gain and ending weight while S had the highest ending weight and hot carcass weight (Table 4). Actual and adjusted fat thickness, percent kidney, pelvic and heart fat, and yield grade were highest for A, intermediate for SH and lowest for S, while S had the highest ribeye area. This was evidenced further by the rib dissection data, which showed that A had the highest percent total separable fat, percent separable subcutaneous fat, percent separable seam fat, and percent soft tissue chemical fat, while S possessed the least. Ribeye area per 100 lb of carcass weight was not affected by breed but tended to favor S versus A. Also, percent separable lean was highest for S, intermediate for SH, and lowest for A. Lean color, lean texture, marbling, and chemical fat content of the RE were highest for A, intermediate for SH, and lowest for S. Lean, skeletal, and overall maturity scores were most youthful for A and most mature for S.

Marbling, lean color, and lean texture scores were increased by electrical stimulation (Table 5). Moreover, electrical stimulation improved lean and overall maturity scores while not affecting skeletal maturity. These data agree with those previously reported for young bulls and steers (3, 2).

## Implications

Both implanted and nonimplanted bulls were superior to steers for performance and carcass cutability but inferior to steers in marbling and lean quality. Performance and carcass traits of bulls were not improved by implantation of exogenous hormones.

## Acknowledgments

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## Literature Cited

1. Bailey, C.M., C.L. Probert, P. Richardson, V.R. Bohman, and J. Chancerelle. 1966. Quality factors of the longissimus dorsi of young bulls and steers. J. Anim. Sci. 25:504.
2. Cross, H.R., J.D. Crouse, and M.D. MacNeil. 1984. Influence of breed, sex, age, and electrical stimulation on carcass and palatability traits of three bovine muscles. J. Anim. Sci. 58:1358.
3. Crouse, J.D., S.C. Seideman, and H.R. Cross. 1983. The effects of carcass electrical stimulation and cooler temperature on the quality and palatability of bull and steer beef. J. Anim. Sci. 56:81.
4. Field, R.A. 1971. Effect of castration on meat quality and quantity. J. Anim. Sci. 32:849.

5. Greathouse, J.R., M.C. Hunt, M.E. Dikeman, L.R. Corah, C.L. Kastner, and D.H. Kropf. 1983. Ralgro-implanted bulls: performance, carcass characteristics, longissimus palatability and carcass electrical stimulation. J. Anim. Sci. 57:355.
6. Gregory, K.E., and J.J. Ford. 1983. Effects of late castration, zeranol and breed group on growth, feed efficiency and carcass characteristics of late maturing bovine males. J. Anim. Sci. 56:771.
7. Harte, F.J. 1969. Six years of bull beef production research in Ireland. In: Meat Production from Entire Male Animals. D. N. Rhodes (Ed.). pp. 153-172. J. and A Churchill Ltd., London.
8. Hankins, O.G., and P.E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. USDA Tech. Bull. 926. Washington, DC.
9. Price, M.A., and M. Makarechian. 1982. The effects of Ralgro on the feedlot performance and carcass traits of young feedlot bulls. 61st Annu. Feeders' Day Rep., Agriculture and Forestry Bull., Special Issue Dept. of Anim Sci., Univ. of Alberta. p 19.
10. Seideman, S.C., H.R. Cross, R. R. Oltjen and B. D. Schanbacher. 1982. Utilization of the intact male for red meat production: A review. J. Anim. Sci. 55:826.
11. USDA. 1989. Official United States standards for grades of carcass beef. Agr. Marketing Service, United States Department of Agriculture, Washington, DC.

TABLE 1. COMPOSITION OF DIETS ON AN AS FED BASIS[a]

| Ingredient | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Corn silage | 89.4 | 81.9 | 71.3 | 58.8 | 43.1 |
| High moisture corn | 5.1 | 12.1 | 24.3 | 37.9 | 53.5 |
| Soybean meal | 2.8 | 2.8 | 1.7 | | |
| Mineral premix | 2.7 | 3.2 | 2.7 | 3.3 | 3.4 |

[a]Diets 1, 2, 3 and 4 were fed for 84, 4, 6 and 6 days, respectively. Slaughter groups 1, 2 and 3 were fed diet 5 for 90, 146 and 215 days, respectively.

TABLE 2. EFFECT OF TREATMENT ON PERFORMANCE AND CARCASS TRAITS

| Trait | Steer | Intact | Intact Ralgro | Intact Synovex S |
|---|---|---|---|---|
| Average daily gain (lb) | 2.4 | 2.9 | 2.9 | 2.9 |
| Feed conversion (F/G) | 12.9 | 11.4 | 12.1 | 11.7 |
| Ending weight (lb) | 1034 | 1160 | 1157 | 1173 |
| Hot carcass weight (lb) | 633 | 710 | 723 | 728 |
| Dressing percentage | 61.1 | 61.2 | 62.3 | 61.8 |
| Testicle weight (lb) | | 1.72 | 1.65 | 1.54 |
| Degree of contraction[a] | 4.5 | 4.3 | 4.7 | 4.6 |
| Actual fat thickness (in) | .35 | .30 | .28 | .29 |
| Adjusted fat thickness (in) | .32 | .26 | .24 | .30 |
| Ribeye area ($in^2$) | 11.6 | 12.9 | 13.1 | 13.1 |
| Ribeye area per 100 lb of carcass ($in^2$) | 1.85 | 1.82 | 1.81 | 1.80 |
| Kidney, pelvic and heart fat (%) | 2.8 | 2.3 | 2.1 | 2.2 |
| Yield grade | 2.6 | 2.2 | 2.1 | 2.3 |
| Masculinity[b] | 1.7 | 5.0 | 6.0 | 5.9 |
| Lean color[b] | 5.5 | 4.8 | 4.6 | 4.9 |
| Lean texture[b] | 5.0 | 4.1 | 4.1 | 4.3 |
| Lean maturity[c] | 138 | 142 | 146 | 141 |
| Skeletal maturity[c] | 135 | 142 | 143 | 142 |
| Overall maturity[c] | 136 | 142 | 144 | 141 |
| Marbling score[d] | 390 | 313 | 298 | 323 |
| Ribeye moisture (%) | 72.3 | 73.6 | 74.2 | 73.5 |
| Ribeye fat (%) | 5.6 | 4.0 | 3.6 | 4.5 |
| 9-10-11th rib section composition | | | | |
| Total separable fat (%) | 29.1 | 25.2 | 24.9 | 26.5 |
| Separable subcutaneous fat (%) | 12.2 | 11.0 | 11.0 | 11.7 |
| Separable seam fat (%) | 16.9 | 14.2 | 14.0 | 14.8 |
| Separable bone, cartilage and connective tissue (%) | 19.2 | 20.0 | 19.2 | 18.8 |
| Separable lean (%) | 50.9 | 54.2 | 55.1 | 54.0 |
| Soft tissue moisture (%) | 51.5 | 55.0 | 55.2 | 53.9 |
| Soft tissue fat (%) | 33.8 | 29.3 | 28.9 | 30.6 |

[a]Degree of contraction is the degree of side contraction during electrical stimulation scored on a one- to five-point scale (1 = no contraction and 5 = extreme contraction).
[b]Scored on a one- to eight-point scale (8 = masculine, bleached or fine and 1 = nonmasculine, dark or coarse).
[c]100 = $A^0$ and 200 = $B^0$.
[d]200 = $Traces^0$, 300 = $Slight^0$ and 400 = $Small^0$.

TABLE 3. EFFECT OF SLAUGHTER ENDPOINT ON PERFORMANCE AND CARCASS TRAITS

| | Days on feed | | |
|---|---|---|---|
| Trait | 190 | 246 | 315 |
| Average daily gain (lb) | 2.80 | 2.93 | 2.62 |
| Feed conversion (F/G) | 12.5 | 11.4 | 12.2 |
| Ending weight (lb) | 963 | 1153 | 1276 |
| Hot carcass weight (lb) | 589 | 719 | 785 |
| Dressing percentage | 61.0 | 62.2 | 61.6 |
| Testicle weight (lb) | 1.39 | 1.76 | 1.79 |
| Degree of contraction[a] | 4.9 | 4.6 | 4.2 |
| Actual fat thickness (in) | .23 | .32 | .36 |
| Adjusted fat thickness (in) | .20 | .30 | .33 |
| Ribeye area ($in^2$) | 11.7 | 13.0 | 13.3 |
| Ribeye area per 100 lb of carcass ($in^2$) | 1.99 | 1.81 | 1.69 |
| Kidney, pelvic and heart fat (%) | 2.1 | 2.5 | 2.6 |
| Yield grade | 1.9 | 2.3 | 2.6 |
| Masculinity[b] | 4.6 | 4.9 | 4.5 |
| Lean color[b] | 4.7 | 5.1 | 5.1 |
| Lean texture[b] | 4.1 | 4.7 | 4.4 |
| Lean maturity[c] | 139 | 139 | 147 |
| Skeletal maturity[c] | 134 | 138 | 150 |
| Overall maturity[c] | 136 | 139 | 148 |
| Marbling[d] | 259 | 356 | 377 |
| Ribeye moisture (%) | 74.8 | 73.2 | 72.2 |
| Ribeye fat (%) | 3.4 | 4.4 | 5.7 |
| 9-10-11th rib section composition | | | |
| Total separable fat (%) | 23.8 | 27.4 | 28.1 |
| Separable subcutaneous fat (%) | 10.3 | 11.2 | 12.9 |
| Separable seam fat (%) | 13.5 | 16.2 | 15.2 |
| Separable bone, cartilage and connective tissue (%) | 19.9 | 18.6 | 19.5 |
| Separable lean (%) | 55.7 | 53.3 | 51.7 |
| Soft tissue moisture (%) | 57.4 | 52.7 | 51.6 |
| Soft tissue fat (%) | 26.7 | 31.6 | 33.7 |

[a]Degree of contraction is the degree of side contraction during electrical stimulation scored on a one- to five-point scale (1 = no contraction and 5 = extreme contraction).
[b]Scored on a one- to eight-point scale (8 = masculine, bleached or fine and 1 = nonmasculine, dark or coarse).
[c]100 = $A^0$ and 200 = $B^0$.
[d]200 = $Traces^0$, 300 = $Slight^0$ and 400 = $Small^0$.

TABLE 4. EFFECT OF BREED ON PERFORMANCE AND CARCASS TRAITS

| Trait | Angus | Simmental-Hereford | Simmental |
|---|---|---|---|
| Average daily gain (lb) | 2.6 | 2.9 | 2.9 |
| Ending weight (lb) | 1071 | 1131 | 1193 |
| Hot carcass weight (lb) | 664 | 692 | 734 |
| Dressing percentage | 62.1 | 61.2 | 61.6 |
| Testicle weight (lb) | 1.54 | 1.61 | 1.76 |
| Degree of contraction[a] | 4.6[ef] | 4.7 | 4.3 |
| Actual fat thickness (in) | .43 | .28 | .21 |
| Adjusted fat thickness (in) | .41 | .26 | .17 |
| Ribeye area ($in^2$) | 11.9 | 12.6 | 13.5 |
| Ribeye area per 100 lb of carcass ($in^2$) | 1.79 | 1.82 | 1.84 |
| Kidney, pelvic and heart fat (%) | 2.7 | 2.3 | 2.1 |
| Yield grade | 2.8 | 2.2 | 2.1 |
| Masculinity[b] | 4.0 | 4.5 | 5.5 |
| Lean color[b] | 5.5 | 4.8 | 4.5 |
| Lean texture[b] | 4.8 | 4.4 | 4.0 |
| Lean maturity[c] | 137 | 142 | 146 |
| Skeletal maturity[c] | 138 | 141 | 143 |
| Overall maturity[c] | 138 | 141 | 144 |
| Marbling[d] | 380 | 317 | 296 |
| Ribeye moisture (%) | 72.7 | 73.2 | 74.2 |
| Ribeye fat (%) | 5.5 | 4.4 | 3.6 |
| 9-10-11th rib section composition | | | |
| Total separable fat (%) | 31.2 | 26.2 | 21.9 |
| Separable subcutaneous fat (%) | 13.4 | 11.8 | 9.2 |
| Separable seam fat (%) | 17.7 | 14.4 | 12.8 |
| Separable bone, cartilage and connective tissue (%) | 18.5 | 19.5 | 19.9 |
| Separable lean (%) | 49.6 | 53.6 | 57.4 |
| Soft tissue moisture (%) | 49.6 | 53.9 | 58.2 |
| Soft tissue fat (%) | 36.6 | 30.5 | 24.9 |

[a]Scored on a one- to five-point scale (five = extreme contraction and one = no contraction).
[b]Scored on a one- to eight-point scale (eight = masculine or coarse and one = nonmasculine or fine).
[c]100 = $A^0$ and 200 = $B^0$.
[d]200 = Traces$^0$, 300 = Slight$^0$ and 400 = Small$^0$.

TABLE 5. EFFECT OF ELECTRICAL STIMULATION ON CARCASS QUALITY TRAITS

| Trait | Stimulated | Nonstimulated |
|---|---|---|
| Lean color[a] | 5.5 | 4.4 |
| Lean texture[a] | 4.7 | 4.0 |
| Lean maturity[b] | 138 | 146 |
| Skeletal maturity[b] | 140 | 141 |
| Overall maturity[b] | 139 | 143 |
| Marbling[c] | 340 | 321 |

[a]Scored on a one- to eight-point scale (eight = bleached or fine and one = dark red or coarse).
[b]100 = $A^0$ and 200 = $B^0$.
[c]200 = Traces$^0$, 300 = Slight$^0$ and 400 = Small$^0$.

# Palatability of Beef from Bulls Administered Exogenous Hormones

S.D. Shackelford, J.W. Savell, J.D. Crouse, H.R. Cross,
B.D. Schanbacher, D.D. Johnson and M.L. Anderson

## Summary

One-hundred forty four weanling bulls of Angus (A, n =48), Simmental x Hereford (SH, n=48), and Simmental (S, n=48) breeding were either castrated, left intact, left intact and implanted with Ralgro, or left intact and implanted with Synovex S. Cattle were slaughtered after either 190, 246, or 315 days of high-energy feeding and the right side of each carcass was electrically stimulated. Sensory analysis was conducted on Longissimus muscle steaks after 5 days aging and Warner-Bratzler shear force (WBS) was measured after 5, 10, and 15 days aging. Steers had lower WBS and more desirable sensory panel scores for juiciness, ease of fragmentation, amount of connective tissue, and overall tenderness than all intact treatments. Off-flavors were more detectable in implanted bulls than nonimplanted bulls and steers. Across breed types, WBS was greatest for S and lowest for A. Electrical stimulation eliminated the variation in amount of connective tissue, ease of fragmentation, and overall tenderness scores among breeds. For the nonstimulated sides, A, SH, and S scored highest, intermediate, and lowest, respectively, for amount of connective tissue, ease of fragmentation, and overall tenderness; however, for the stimulated sides, there were no differences between breeds for each trait. The implanting of weanling bulls with synthetic estrogen did not result in a practical improvement in beef tenderness.

## Introduction

Many researchers have suggested the use of intact males in red meat production to meet consumer demand for a leaner product. Meat toughness or variability in tenderness has been a major limitation to the use of intact bulls for lean beef production (6). Implantation of young bulls with Ralgro, Synovex, or Compudose during a 118 day finishing period has been shown to have no effect on palatability traits (5). However, it should be noted that the bulls used in that study were approximately one year of age at the time treatment began and, thus, the onset of puberty had already occurred. Researchers have reported that testicle size, aggressive male behavior, and development of secondary sex characteristics were decreased when bulls were implanted with Ralgro at a young age (preweaning) and continued at approximately 106 day intervals until slaughter (3). In the same study, Ralgro improved taste panel tenderness ratings and decreased Warner-Bratzler shear force (WBS) values. Therefore, the objective of this study was to examine the changes in palatability of meat from intact males caused by implanting weanling intact bulls with synthetic estrogen.

## Experimental Procedure

Experimental design, dietary regimens, and carcass traits of the cattle used in this study were reported in the previous article. At 24 hours postmortem, one-inch steaks were removed from the strip loin of each side of the carcasses for determination of sensory panel attributes at 5 days postmortem and WBS values at 5, 10, and 15 days postmortem. Steaks were vacuum packaged and aged at 35°F until the appropriate day postmortem. Steaks were broiled to an internal temperature of 104°F, turned, and broiled to a final internal temperature of 158°F on electric broilers. Trained sensory panelists (1) scored the steaks on a 1- to 8-point rating scale for juiciness, ease of fragmentation, amount of connective tissue, overall tenderness, flavor intensity, and off-flavor (8=extremely juicy, easy, little, tender, intense, or nondetectable and 1=extremely dry, hard, abundant, tough, bland, or strong). Steaks for WBS determination were broiled as before and six one-half-inch diameter cores were removed from each steak. Cores were sheared with a WBS device attached to an Universal Testing Machine.

At 24 hours postmortem, an one inch thick steak was removed from the strip loin opposite the last thoracic vertebra of the left side of a subsample (n=48) of the carcasses for determination of collagen characteristics (total and percent soluble collagen).

## Results and Discussion

Steers had lower WBS values and scored higher for juiciness, ease of fragmentation, amount of connective tissue, and overall tenderness than all intact treatments (Table 1). These findings are similar to those reported in previous reviews (2,6). Ralgro-implanted bulls had higher WBS values than the nonimplanted bulls, while bulls implanted with Synovex S scored lower for overall tenderness. Flavor intensity scores were not affected by treatment, while off-flavor scores were lower for the implanted treatments. The present study failed to show any improvement in bull beef palatability due to synthetic estrogen implantation. Meat from nonimplanted

intact bulls and bulls implanted with Ralgro, Synovex, or Compudose has been shown to be similar in juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness, off-flavor, overall palatability, and shear force (5). In that study, bulls were first implanted at approximately one year of age while in the present study, cattle were implanted at weaning. Also, implantation of bulls with Ralgro has been reported to improve flavor and connective tissue amount scores (3). In the same study, no differences were seen in myofibrillar tenderness, overall tenderness, and WBS between nonimplanted and implanted bulls fed to a heavy weight (1100 lb) endpoint, but implanted bulls resulted in more tender meat when fed to a light weight (1000 lb) end point.

Electrical stimulation and slaughter endpoint interacted to affect WBS values (Figure 1). The amount of improvement in WBS values due to electrical stimulation decreased as the WBS values of the nonstimulated sides decreased with additional feeding. Also, postmortem aging period and slaughter endpoint interacted to affect WBS values (Figure 2). The response to aging was greatest for the first slaughter group and least for the last slaughter group (Figure 2). Ease of fragmentation, amount of connective tissue, overall tenderness and off-flavor scores did not differ between 190 and 246 days on feed but were higher after 315 days on feed (Table 2). Juiciness and flavor intensity were not affected by slaughter endpoint.

Across breed types, WBS was greatest for S, intermediate for SH, and lowest for A (Table 3). Juiciness, flavor intensity, and off-flavor were not affected by breed type. In a similar study, there were no differences between breed types (Hereford, Hereford-Angus, and Charolais cross) for juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness, off-flavor, and WBS (5). Electrical stimulation eliminated the variation in amount of connective tissue (Figure 3), ease of fragmentation (Figure 4), and overall tenderness (Figure 5) scores among breeds. For the nonstimulated sides, A, SH, and S scored highest, intermediate, and lowest, respectively, for amount of connective tissue, ease of fragmentation, and overall tenderness; however, for the nonstimulated sides, there were no differences between breeds for each trait.

Electrical stimulation and postmortem aging period interacted to affect WBS values (Figure 6). The amount of improvement in WBS values due to aging was much lower for the electrically stimulated sides.

Steers, bulls, bulls implanted with Ralgro, and bulls implanted with Synovex S did not differ in collagen solubility or total collagen content (Table 1). Moreover, collagen traits did not change with added time on high energy feed (Table 2). Total collagen was higher in A than S and SH (Table 3). Based on the WBS data, one would have expected collagen content to be greatest in S and least in A. Simple correlations of percent soluble collagen and total collagen with WBS at 5, 10, and 15 d postmortem were not significant.

## Implications

Bull beef palatability was not improved by the implanting of weanling bulls with Ralgro or Synovex S. This suggested that synthetic estrogen may need to be administered to bulls at a very young age (prepuberal) in order to prevent the development of tough, unpalatable beef. Further research must be conducted to determine methods by which the biochemical changes that occur in the muscle of bulls during puberty can be manipulated.

## Literature Cited


1. Cross, H.R., R. Moen, and M.S. Stanfield. 1978. Training and testing of judges for sensory analysis of meat quality. Food Technol. 36:48.
2. Field, R.A. 1971. Effect of castration on meat quality and quantity. J. Anim. Sci. 32:849.
3. Greathouse, J.R., M.C. Hunt, M.E. Dikeman, L.R. Corah, C.L. Kastner, and D.H. Kropf. 1983. Ralgro-implanted bulls: performance, carcass characteristics, longissimus palatability and carcass electrical stimulation. J. Anim. Sci. 57:355.
4. Hill, F. 1966. The solubility of intramuscular collagen in meat animals of various ages. J. Food Sci. 31:161.
5. Johnson, D.D., J.W. Savell, G.C. Smith, D.R. Gill, D.E. Williams, L.E. Walters, and J.J. Martin. 1984. Relationship of growth stimulants and breed groups on carcass characteristics and palatability of young bulls. J. Anim. Sci. 58:920.
6. Seideman, S.C., H.R. Cross, R.R. Oltjen, and B.D. Schanbacher. 1982. Utilization of the intact male for red meat production: A review. J. Anim. Sci. 55:826.

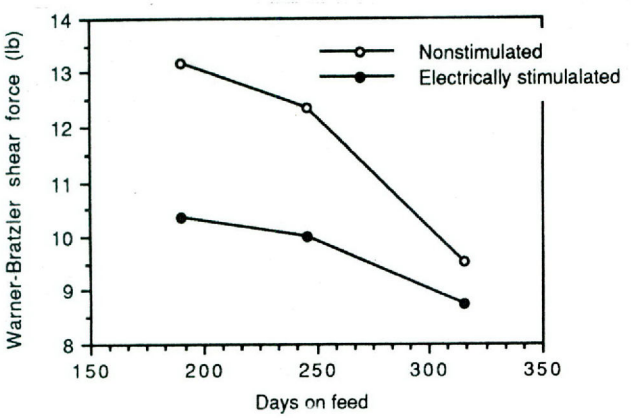



Figure 1. The interaction of slaughter endpoint and electrical stimulation on Warner-Bratzler shear force.

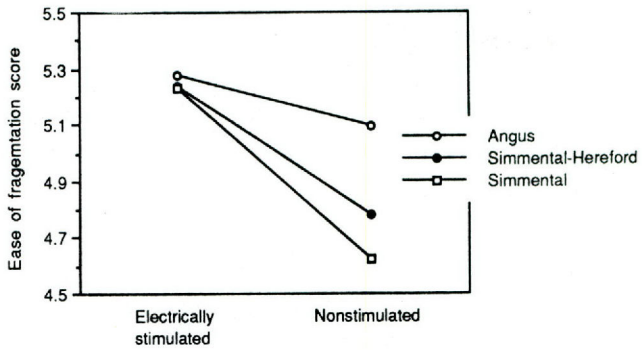



Figure 4. The interaction of electrical stimulation and breed type on ease of fragmentation scores.

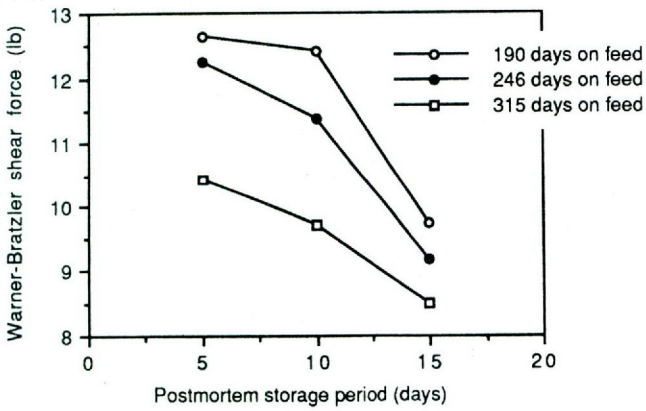



Figure 2. The interaction of postmortem storage period and slaughter endpoint on Warner-Bratzler shear force.

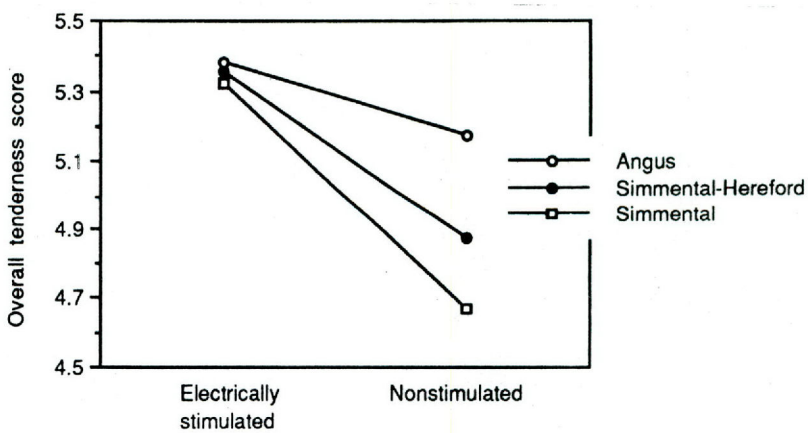



Figure 5. The interaction of electrical stimulation and breed type on overall tenderness scores.

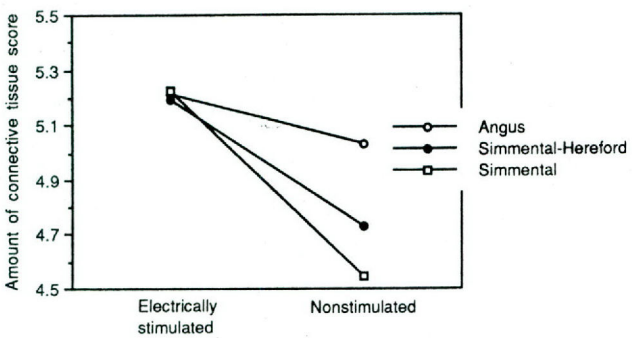



Figure 3. The interaction of electrical stimulation and breed type on amount of connective tissue scores.

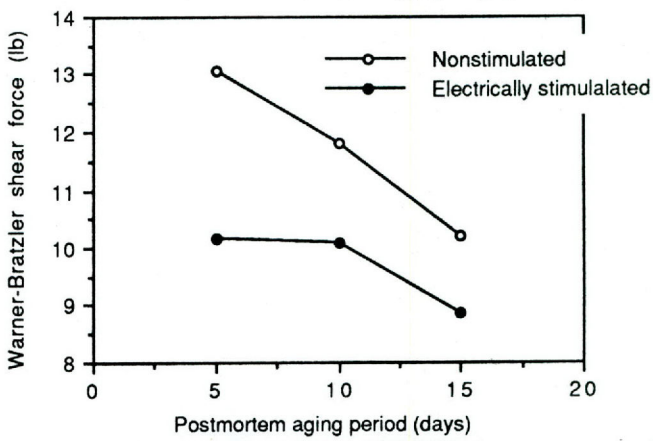



Figure 6. The interaction of postmortem storage period and electrical stimulation on Warner-Bratzler shear force.

TABLE 1. EFFECT OF TREATMENT ON PALATABILITY TRAITS

| | Steer | Intact | Intact Ralgro | Intact Synovex S |
|---|---|---|---|---|
| Warner-Bratzler shear force (lb) | 9.5 | 10.8 | 11.2 | 11.2 |
| Sensory trait[a] | | | | |
| Juiciness | 5.5 | 5.2 | 5.2 | 5.2 |
| Ease of fragmentation | 5.3 | 5.0 | 4.9 | 4.9 |
| Amount of connective tissue | 5.3 | 5.0 | 4.8 | 4.9 |
| Overall tenderness | 5.4 | 5.1 | 5.0 | 5.0 |
| Flavor intensity | 5.8 | 5.8 | 5.8 | 5.8 |
| Off-flavor | 2.5 | 2.5 | 2.4 | 2.4 |
| Collagen characteristics | | | | |
| Total collagen (mg/g) | 2.4 | 2.7 | 2.2 | 2.7 |
| Percent soluble collagen | 22.0 | 19.8 | 20.8 | 18.1 |

[a]Scored on a one- to eight-point scale (8 = extremely juicy, easy, little, tender, intense or nondetectable and 1 = extremely dry, hard, abundant, tough, bland or strong).

TABLE 2. EFFECT OF SLAUGHTER ENDPOINT ON PALATABILITY TRAITS

| | Days on feed | | |
|---|---|---|---|
| | 190 | 246 | 315 |
| Warner-Bratzler shear force (lb) | 11.7 | 11.2 | 9.0 |
| Sensory trait[a] | | | |
| Juiciness | 5.3 | 5.2 | 5.3 |
| Ease of fragmentation | 5.0 | 4.9 | 5.2 |
| Amount of connective tissue | 4.9 | 4.9 | 5.2 |
| Overall tenderness | 5.1 | 5.0 | 5.3 |
| Flavor intensity | 5.8 | 5.8 | 5.8 |
| Off-flavor | 2.4 | 2.4 | 2.5 |
| Collagen characteristics | | | |
| Total collagen | 2.7 | 2.7 | 2.2 |
| Percent soluble collagen | 20.3 | 19.0 | 21.2 |

[a]Scored on a one- to eight-point scale (8 = extremely juicy, easy, little, tender, intense or nondetectable and 1 = extremely dry, hard, abundant, tough, bland or strong).

TABLE 3. EFFECT OF BREED ON PALATABILITY TRAITS

| | Angus | Simmental-Hereford | Simmental |
|---|---|---|---|
| Warner-Bratzler shear force (lb) | 9.3 | 11.2 | 11.7 |
| Sensory trait[a] | | | |
| Juiciness | 5.3 | 5.3 | 5.3 |
| Flavor intensity | 5.8 | 5.8 | 5.8 |
| Off-flavor | 2.4 | 2.4 | 2.4 |
| Collagen characteristics | | | |
| Total collagen | 3.1 | 2.1 | 2.3 |
| Percent soluble collagen | 18.2 | 22.3 | 20.0 |

[a]Scored on a one- to eight-point scale (8 = extremely juicy, intense or nondetectable and 1 = extremely dry, bland or strong)

TABLE 4. EFFECT OF ELECTRICAL STIMULATION ON PALATABILITY TRAITS

| Sensory trait[a] | Stimulated | Nonstimulated |
|---|---|---|
| Juiciness | 5.2 | 5.3 |
| Flavor intensuty | 5.8 | 5.8 |
| Off-flavor | 2.5 | 2.4 |

[a]Scored on a one- to eight-point scale (8 = extremely juicy, intense or nondetectable and 1 = extremely dry, bland or strong).

# Recent Changes in the U. S. Beef Grading Standards

S.D. Shackelford, J.B. Morgan, D.S. Hale, J.W. Wise and J.W. Savell


## Summary

Recent changes in the Official United States Standards for Grades of Carcass Beef have led to dramatic shifts in the distribution of graded beef. The latest changes include the conversion of the name "U.S. Good" to "U.S. Select" and the uncoupling of quality and yield grades.


## Introduction

Before the name of the Good grade was changed to Select (November 23, 1987), packers generally chose to not grade (no-roll) most carcasses that met the specifications for this quality grade because there was not a specific market available for Good beef. Rather than selling this beef as U.S. Good, most packers found it was more profitable to combine this beef with lower quality (U.S. Standard) and sometimes poorer yielding (yield grade 4 and 5) beef. Although each packer has different specifications for what they will include in their boxed beef "no-roll" program, most of this beef was sold under the generic term of "no-roll" which simply meant that the beef had not been officially graded. Some retailers found that their consumers preferred leaner cuts of beef regardless of quality grade. Thus, these retailers chose to sell no-roll beef rather than selling Good beef. Cross and co-workers at Texas A&M University conducted the National Consumer Retail Beef Study (NCRBS; 1) and found that about one-half of consumers showed a clear purchase preference for beef of the Good grade (identified as Select in that study), even when it was priced higher than beef of the Choice grade, because of its superior leanness. The high level of consumer acceptance for Select beef in the NCRBS led several organizations to petition the USDA to change the name of Good to Select.

## Experimental Procedure

Data were obtained from USDA-AMS (Agricultural Marketing Service) estimates of beef slaughter and grading tonnage for this study. These estimates were for tonnage of beef produced (not number of carcasses). A major limitation to this study is that tonnage values are based on estimated (not actual) carcass weights.

## Results and Discussion

During the 12-week period before Good was changed to Select, only 1.7 percent of the graded steer and heifer carcasses were rolled Good (Figure 1). After the name change, some regional and national packers began taking advantage of the additional demand for Select by retailers and the percentage of carcasses graded Select quickly doubled and continued to increase through 1988 and early 1989.

On April 5, 1989, USDA quality and yield grading were uncoupled allowing packers the option of quality grading only and yield grading only. Before this time, if a packer graded a carcass it had to be rolled with both quality and yield grade designations. Although the tonnage of beef graded Choice increased after uncoupling, the percentage of cattle graded that were graded Choice decreased due to the surge in the frequency of cattle graded Select. Uncoupling has greatly increased the total percentage of carcasses that are graded. Much of this increase is due to packers electing to "yield grade only" carcasses that previously would have been no-roll.

In 1987, before the Good/Select name change and before yield and quality grades were uncoupled, 35.7 percent of steer and heifer carcasses were not graded. However, by the end of 1989, that percentage had decreased to 21.6 percent. Currently, approximately 90 percent of carcasses are either quality graded only, yield graded only, or quality and yield graded.

Data for 1989 reveal that 67 percent of cattle are graded for both quality and yield (Figure 2), 2 percent quality graded only, 12 percent yield graded only, and 21.6 percent no-roll. It is doubtful that packers are presently utilizing the "yield grade only" option as a marketing tool but rather are yield grading all cattle to improve sorting of carcasses for fabrication and to identify carcasses for 1/4 inch trim programs.

Although these changes in the beef carcass grading system may not have yet affected fed-beef pricing systems, they have undoubtedly changed packer-retailer relations. With time, the increased demand for yield grade 1 and 2, Select beef by retailers should result in increased packer demand for lean cattle that will meet this target.

Often industry leaders hold up Prime and Choice, yield grade 1 and 2 carcasses as the ideal. Twenty-five percent (Figure 3) of steer and heifer carcasses meet the ideal carcass endpoint of Choice or better and yield grade 2 or better (Choice, YG 1; Choice, YG 2; Prime, YG 1; Prime, YG 2). This is evidence of the cattle industry's ability to produce lean, high quality beef when proper selection and management techniques are utilized. In Figure 3, the "other" classification contains no-roll, yield graded only, quality graded only, and yield grade 4 and 5 beef. The "other"

classification should account for all beef that is inferior in quality and/or yield grade though not all the beef in the "other" class would be inferior. Thirty-nine percent of steer and heifer carcasses fell into the "other" classification indicating the continued need for carcass trait selection in the beef population. Also, there continues to be a partial void in carcass information, with one out of every three carcasses not identified according to palatability (quality grade) and/or leanness (yield grade).

## Literature Cited

1. Cross, H.R., J.W. Savell, and J. J. Harris. 1986. National Consumer Retail Beef Study. Proc. 39th Ann. Recip. Meat Conf. 39:112.

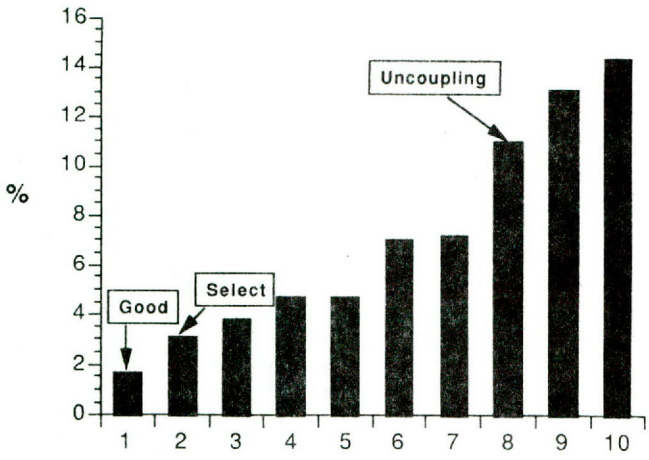



Figure 1. Select grading frequency. This figure shows the percentage of beef carcasses graded Select of the total population of beef carcasses that were quality graded. The ten periods shown across the bottom are twelve week long periods from August of 1987 (period 1) to December of 1989 (period 10). Period 1 was the last twelve weeks before Good was changed to Select. Period 8 was the first period after quality and yield grades were uncoupled.

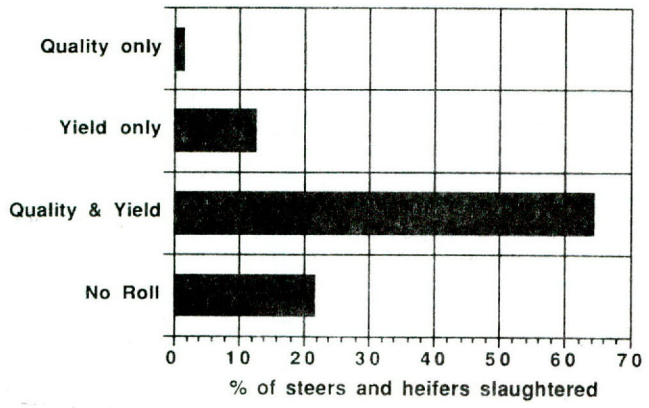



Figure 2. Grading frequency. This figure shows the percentage of steer and heifer carcasses which were not graded (No Roll), both quality and yield graded, yield graded only, or quality graded only for 1989.

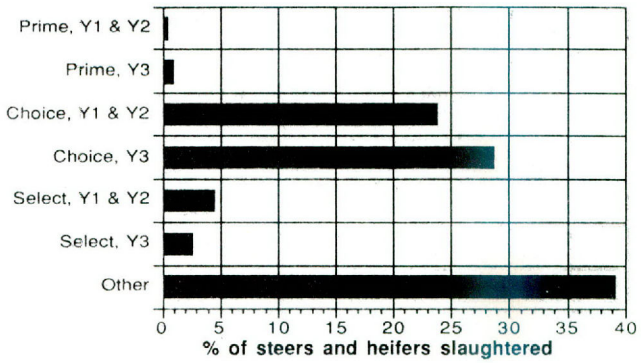



Figure 3. Steer and Heifer population. This figure shows the percentage of steers and heifers slaughtered in 1989 that were Prime, yield grade 1 or 2; Prime yield grade 3; Choice, yield grade 1 or 2; Choice yield grade 3; Select, yield grade 1 or 2; Select yield grade 3; and those carcasses that were not in the previously mentioned categories were combined into the "other" classification. The other classification contains no-roll, Yield grade only, quality graded only and yield grade 4 and 5 beef.

# Evaluation of the Effects of a Proposed Change in the Trim Specifications for Boxed Beef on Value-Based Marketing

R.M. Thallman and J.O. Sanders


## Summary

Value-based marketing has become a priority issue in the beef industry. Value-based marketing refers to the differentiation of the prices paid for a heterogeneous product (boxed beef, slaughter cattle, feeder cattle, or herd sires) based on the value of this product, as opposed to selling all of the product at a single, average price. In the beef industry, one of the most important factors affecting overall efficiency is leanness. It has been suggested that a reduction in the specifications for the maximum fat allowed on boxed beef would cause market signals that would result in a reduction in fat production in the livestock industry.

A computer model was developed to predict the effects of this proposal. The model results suggest that the stricter trim specifications on boxed beef should result in greater differentiation in the prices paid for slaughter cattle. However, a number of factors are involved in the price relationship between boxed beef and slaughter cattle. Several of these are discussed in detail.

The proposed change in specifications on boxed beef from a maximum of 1 inch to a maximum of 1/4 inch of trimmable fat is expected to have a positive effect on differentiation of value and efficiency of beef processing and distribution. However, several other changes in the industry will be required in order for value-based marketing to achieve its full potential.


## Introduction

The beef industry is faced with the problem of a naturally heterogeneous product. Greater consistency of the product should improve the position of beef with respect to other food alternatives. However, a number of factors interfere with market signals that could provide incentives for the industry to produce a more uniform product. These obstacles occur in all segments of the industry. Figure 1 describes steps that are necessary to implement value-based marketing at various levels and some of the benefits that could be derived from these changes.

It has been proposed that the trim specifications for boxed beef (primals and subprimals), upon which transactions between packers and retailers are based, be revised to reflect the recent reductions in the amount of fat present in the retail case. The proposal is that the maximum fat cover allowed on boxed beef be reduced from the current value of 1 inch to 1/4 inch.

## Experimental Procedure

A computer model has been developed to evaluate the effects of the proposed change in trim specifications. The model takes into account the effects of time-on-feed on slaughter weight, feed efficiency, dressing percent and the joint distribution of cutability and marbling score. The model is described in more detail in Thallman and Sanders (4). Three methods of value determination were considered.

The first scenario considered (CARC) assumes that cattle are valued at slaughter based on dressing percent, the percentage that grade USDA Choice (CH) or better, and the percentage that are USDA Yield Grade 3 (YG3) or better. It is assumed that the industry currently uses the CARC method of value determination for slaughter cattle because most cattle are sold live and most packer-buyers are evaluated primarily on the factors upon which CARC is based.

In the second scenario (1"TRIM), it is assumed that the price of slaughter cattle is equivalent to the carcass cutout value when carcasses are fabricated to boneless subprimals with 1 inch trim specifications. Since some cattle are traded using pricing methods that more accurately reflect cutout value (e.g., formula pricing or grade and yield trading), the industry is probably somewhere between CARC and 1"TRIM, but much closer to CARC. Significant changes in the method of pricing slaughter cattle would be required for the industry to move from CARC to 1"TRIM pricing schemes.

Cutout value was computed as follows. First, the slaughter mix was allocated to six marketing classes based on the distribution of yield grade and quality grade. The classes are Prime, Top Choice YG3 or better, Low Choice YG3 or better, Select YG3 or better, no roll and yield grades 4 and 5. Preliminary prices for each class were computed as deviations from the default cutout value of CH1-3 (USDA Choice, Yield Grade 1, 2, or 3) carcasses based on the proportions of carcasses in the various classes. The yield of each of 26 different carcass components (boneless subprimals trimmed to the appropriate level and by-products) was computed for each marketing class from the distribution of yield grades using regression equations from Griffin et al. (1). These regression

equations were pooled estimates from several breed and sex classes representative of the usual slaughter mix. The cutting style used to obtain the 26 carcass components is presented in Thallman and Sanders (4). For each class, the yield of each of these carcass components was multiplied by component price to obtain a cutout value for carcasses in that class. These cutout values were weighted by the percentages of carcasses in the classes (Ritchie and Anderson (2), Smith (3)) to obtain the average cutout value for the industry at a given time-on-feed.

The third scenario (1/4"TRIM), is identical to 1"TRIM except that value is based on subprimals trimmed to 1/4 inch. The prices of the trimmed subprimals were adjusted up so that the cost of retail cuts derived from the trimmed subprimals were equal to the cost of retail cuts derived from the same subprimals trimmed to 1 inch. Therefore, the preliminary cutout value was the same as under 1"TRIM. The extra value of fat trimmed at the packer instead of the retailer and the labor savings were then added to the preliminary cutout value to give the final cutout value.

The relationships between body composition and product value were determined on both a live weight and a carcass weight basis for the three methods of value determination described above.

## Results and Discussion

Figure 2 shows the relationship between product value and yield grade on a carcass weight basis for three methods of computing product value. Quality grade was held constant at Low Choice so that the relationships between cutability and value would be clearer. With constant quality grade, carcass value decreased as numerical yield grade increased in all three cases. However, it is apparent that the change in value is less for 1"TRIM and CARC than for 1/4"TRIM. Therefore, changing the trim specifications to 1/4 inch should result in the strongest signals from the packer to the feeder, if slaughter cattle prices were based on cutout value.

Figure 3 is analogous to Figure 2 except that it takes dressing percentage into account and expresses value on a live weight basis. When product is valued on a carcass grade basis, value increases with time-on-feed, because the higher dressing percent more than offsets the increased percentage of YG4s. However, relatively few carcasses are actually sold as carcass beef. If product is valued on the basis of boxed subprimals trimmed to 1 inch, live cutout value does not vary greatly with time-on-feed. If the product is trimmed to 1/4 inch, then cutout value decreases with time-on-feed. This is because at 1/4 inch trim, cutability has a greater effect than dressing percent on yield of high-priced subprimals from the live animal.

One of the most important aspects of value-based marketing is the ability of the marketplace to differentiate between the value of lean vs. fat product. Under the CARC scenario, only the percentage of YG4 and YG5 cattle contributes to this differentiation. Cattle enter the packing plant priced as if they were to be sold as carcasses, although they leave the plant as boxed beef. Therefore, fatter cattle with a higher dressing percentage are assumed to have greater value within a quality grade as long as yield grade does not exceed YG3. As a result, CARC is not effective in causing value-based marketing.

Under the 1"TRIM scenario, slaughter cattle are bought according to the way that they will be sold; that is, they are bought according to their predicted cutout value. Therefore, 1"TRIM resulted in greater differentiation of value than did CARC with respect to cutability. Although not widely discussed, leaner cattle produce carcasses with a higher value to the packer when boneless subprimals are sold, even among YG1, YG2, and YG3, when trimmed according to 1 inch IMPS specifications (Griffin et al. (1)). Note that the lower cutout value (on a carcass weight basis) almost exactly counteracts the increased dressing percentage when time-on-feed is increased. Therefore, in contrast with the CARC scenario, under the 1"TRIM pricing scenario, increased dressing percent is not a valid justification for feeding cattle longer (although improved quality grade may be).

The 1/4"TRIM scenario results in pricing cattle based on their yield of a product that is relatively close in composition to the retail product. Because of this, within quality grade, leaner cattle are priced higher and fatter cattle are priced lower under this scenario, than under 1"TRIM. Thus, the 1/4"TRIM scenario gives the greatest value differentiation.

Impediments to value-based marketing exist at many levels in the beef industry. Since most retail product is now sold boneless, trimmed to 1/4 inch or less of fat, the transaction from retailer to consumer is fairly efficient and the consumer receives a product that is reasonably consistent in composition. Retailers can predict retail product yield more accurately when they buy boneless subprimals trimmed to 1/4 inch than when they buy boxed beef that is trimmed to 1 inch and/or bone-in. Hence, the transaction between packers and retailers can more accurately reflect differences in real value under 1/4"TRIM.

One of the more challenging problems in value-based marketing is the lack of connection between the value of beef leaving the packing plant and the price of cattle coming into the plant. Although five different yield grades are available, price differentials normally occur only at the line between YG3 and YG4, resulting in two effective yield classes. This system implies that all carcasses of a given quality grade between YG 1.0 and YG 3.9 are worth the same amount of money. Since there are relatively few cattle in YG4-5, the distribution of a pen of cattle in these two yield classes does not provide a very accurate prediction of the mean cutability and hence of the carcass cutout value. This system was appropriate years ago when packers were selling carcass beef. However, now that most beef is sold as boneless

subprimals, "yield" should be defined as the weighted amounts of subprimals derived from a live steer or heifer and the appropriate measure for evaluating packer-buyers should be cutout value, which takes into account both quality grade and yield as defined above.

Hot fat trimming and instrument grading have been proposed as solutions to the problem of predicting cutout value and each has considerable merit, but they require significant changes in the marketing system and processing methods. The easiest solution is to simply use all of the yield grades that we already have. The distribution of YG1, YG2, YG3, YG4 and YG5 in a pen of slaughter cattle could be used to make a fairly accurate prediction of the mean yield grade of each pen of cattle. The mean yield grade can be used, along with the quality grade distribution to estimate the cutout value of the pen. Although the predictive power of yield grade can be criticized, it is the only tool that is currently in place to allow estimation of the yield component of cutout value. Some packers probably have these grade distributions available currently, and some others could obtain them by making some minor adjustments to data acquisition procedures and computer software.

By using the complete distribution of yield and quality grade data of each pen of cattle purchased, packers should be able to make a better prediction of the value of that pen of cattle when its boxed beef components leave the plant. If packer-buyers were paid based on the price they paid for a pen of cattle relative to the predicted cutout value of that pen, they would soon learn to buy cattle that produced a higher cutout value. Since slaughter cattle are usually sold in pens rather than as individuals, this approach could work quite effectively and would not require changes in carcass processing methods. Predictions of cutout value from the distribution of yield grade may not be as accurate as could be made with instrument grading and/or hot fat trimming, but they should be much more accurate than using only the percentage of YG4-5.

Some packers may currently be using buying systems that are better than the CARC scenario, but if this were the general case, we would see higher prices paid for lean vs fat pens of cattle. We believe that in today's market, there is an opportunity for some packers to widen their margins substantially by purchasing better than average cattle for average (or slightly above average) prices. Obviously, if enough packers adopted this strategy, the price spread between cattle with different estimated cutout values would begin to widen, and eventually it would approach (although it would probably never reach) the real difference in cutout value. In other words, the industry would achieve value-based marketing at the level of slaughter cattle.

The uniformity of pens of slaughter cattle is a critical issue. Feedlots mix desirable and undesirable cattle into the same pen. The end result is that the differences in average merit between pens are minimized. This certainly is one of the reasons that there are not larger differences in the prices paid for slaughter cattle. This situation serves to simplify price reporting and reduces the variation in cutout value between pens, removing the burden of value differentiation from the packer. This practice also results in inefficiencies of production and production of more undesirable (YG4-5 and No Roll) cattle than is necessary and it inhibits value-based marketing. In the poultry industry, yields and production parameters are predictable and prices pertain to a well defined product because the product is not only more consistent between marketing units, but is very uniform within marketing units as well. Intentional mixing of dissimilar cattle puts the beef industry at a competitive disadvantage with respect to both ultimate product uniformity and cost of production.

In addition to the effects on differentiation of value, reduction in the trim specifications from 1 inch to 1/4 inch should have several beneficial effects on the efficiency of processing and distributing beef. Under 1/4 inch trim, much of the excess fat on subprimals would be trimmed at the packing plant instead of in the back room of a retail store. This should allow the use of less expensive labor and a higher degree of mechanization in the fat removal process. Some of the fat trimmed in a retail store can be used in ground beef, but the rest of it has very little value. When fat is trimmed in a packing plant, however, it can be used or marketed in several alternative ways and, hence, it has more value. Removal of fat at the packing plant also reduces transportation and refrigeration expenses.

It has been suggested that fat reduction in the beef industry must eventually be accomplished through genetic improvement. Value-based marketing could ultimately provide incentives for seedstock producers to improve the genetic merit of their cattle for carcass merit. A number of tools are available for this purpose and other, more powerful, tools for genetic improvement are under development. However, selection for carcass merit will not be easy. As Figure 1 shows, value-based market signals must be passed through the retail, packing, feedlot, stocker, and cow-calf segments of the industry, before the seedstock producer has any incentive to incorporate carcass merit into his selection objectives.

A few breeders have begun to identify cattle that excel in carcass merit, in anticipation of the adoption of value-based marketing by the beef industry in the near future. However, if the industry fails to make the changes necessary for value differences to reach the seedstock producer, these breeders will abandon their efforts to improve carcass merit and will direct their efforts toward traits for which they are paid.

There will be stumbling blocks for value-based marketing at the interfaces between each of the industry segments. Differentiation of value at the level of boxed beef is an important first step toward value-based marketing, but it is only the first step.

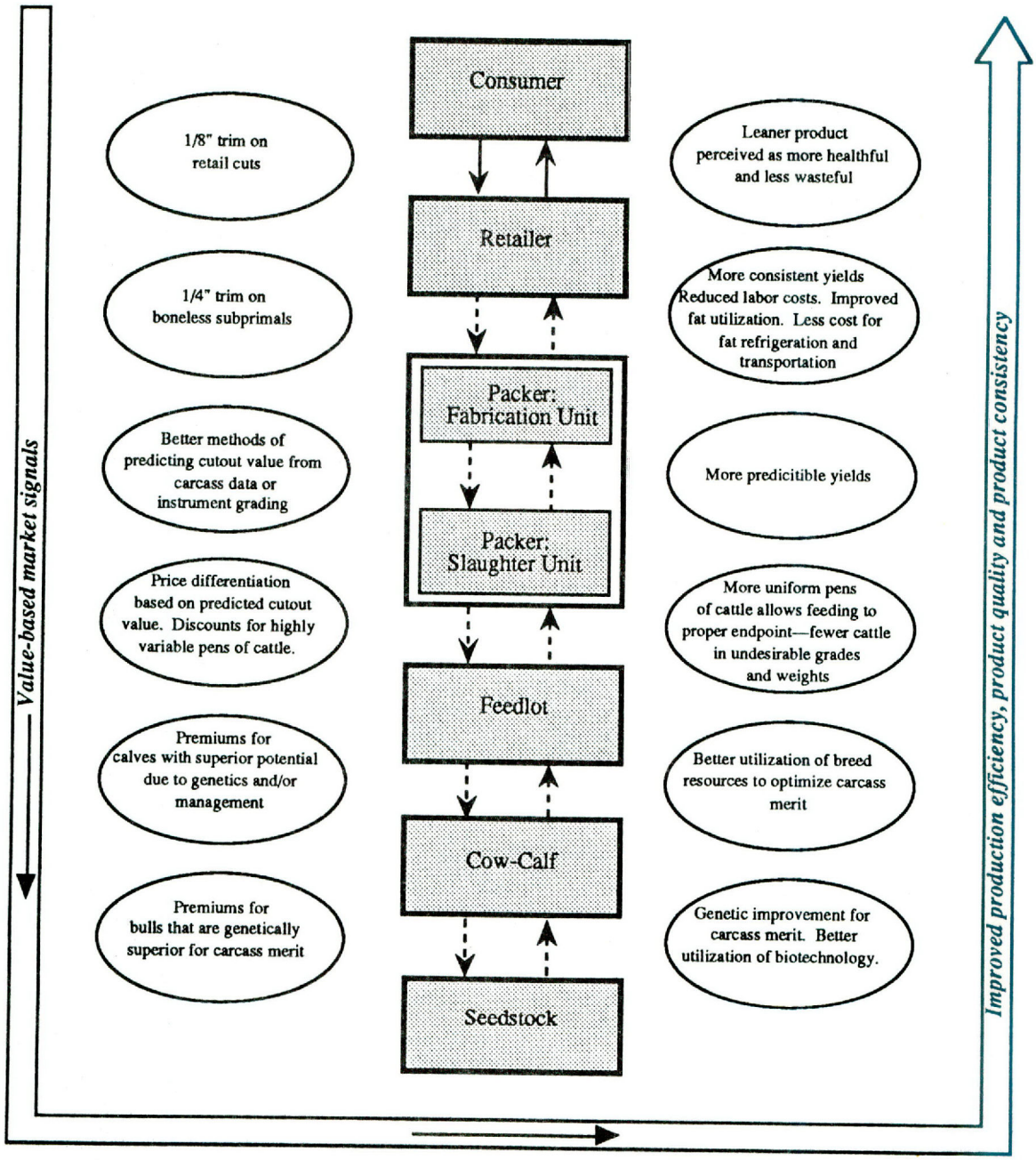



Figure 1. Relationships between causes and effects of value-based marketing. Note that the market signals on the left must occur in order, beginning with the consumer and ending with the seedstock producer. If any one of these signals does not occur, there is no incentive for any of the subsequent signals to be activated. Thus, the move toward value-based marketing must occur one step at a time and each step must occur in sequence. As each new step occurs, the industry becomes more efficient and/or produces a better product. The solid lines between the consumer and retailer indicate that the market signals at this interface are operating correctly. The remaining interfaces are not currently operating correctly.

## Conclusions

Changing the trim specifications on subprimals to 1/4 inch could enhance the differentiation of value with respect to composition. However, it can only do this if slaughter cattle are priced based on cutout value. The 1/4 inch trim specifications should provide additional incentives to do this. It would improve the consistency and predictability of yields at the retail level. This in turn could improve the retailer's attitude toward purchasing beef. Closer trimming at the packer level should also result in greater efficiencies and added profit potential for the industry.

There are a number of impediments to value-based marketing, and simply changing trim specifications should not be expected to cause value-based marketing to take effect. However, the change in trim specifications should contribute to value-based marketing and is not expected to have any negative effects on the industry. The change that would contribute most to value-based marketing is simply pricing slaughter cattle based on their predicted cutout value (at whatever the current trim specification is).

## Literature Cited


1. Griffin, D. B., J. W. Savell, and H. R. Cross. 1989. Determining composition of beef carcasses utilizing multiple primal and/or subprimal endpoints trimmed to various fatness levels. Final report to the Beef Industry Council of the National Livestock and Meat Board, the Cattlemen's Beef Promotion and Research Board and the California Beef Council. Meats and Muscle Biology Section, Department of Animal Science, Texas Agricultural Experiment Station, Texas A&M University, College Station.
2. Ritchie, H. and P. Anderson. 1988. Grab your opportunity to progress: Breed today's cows for tomorrow's carcasses. Beef, Spring 1988.
3. Smith, G. C. 1988. Removing the fat from beef - Where to, from here. Position paper, Texas A&M University, College Station.
4. Thallman, R. M., and J. 0. Sanders. 1990. Evaluation of effects of proposed beef industry changes on inputs and outputs of the industry. Final report prepared for the Value-Based Marketing Task Force of the Cattlemen's Beef Board (National Cattlemen's Association and the Beef Industry Council). Department of Animal Science, Texas A&M University, College Station.

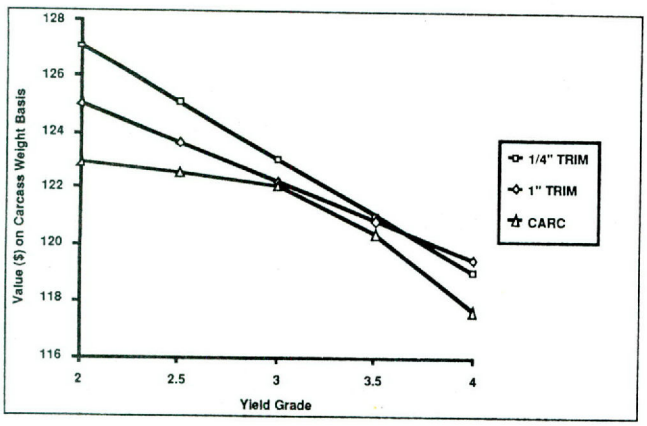




Figure 2. Differentiation of Value: Effect of Yield Grade on Value (Carcass Weight Basis). The horizontal axis represents a series of lots of carcasses that have the same quality grade distribution, but differ in average yield grade. The three lines represent three scenarios for value determination. The steeper slope of the line for 1/4"TRIM demonstrates that it results in the greatest value differentiation. 1"TRIM is intermediate, while CARC is the least efficient method of determining value differences. Note that under all three scenarios, the fatter carcasses are worth less.

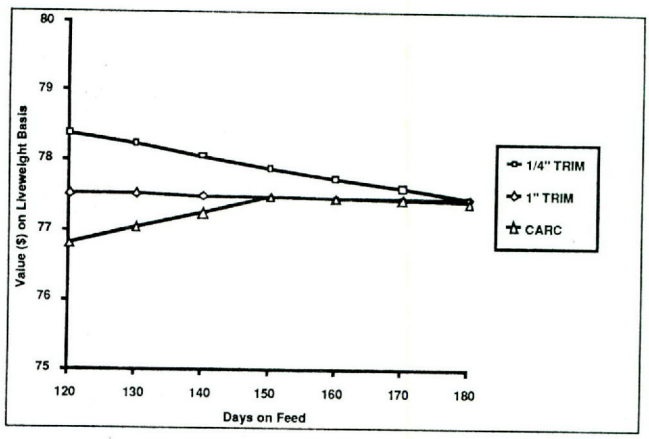
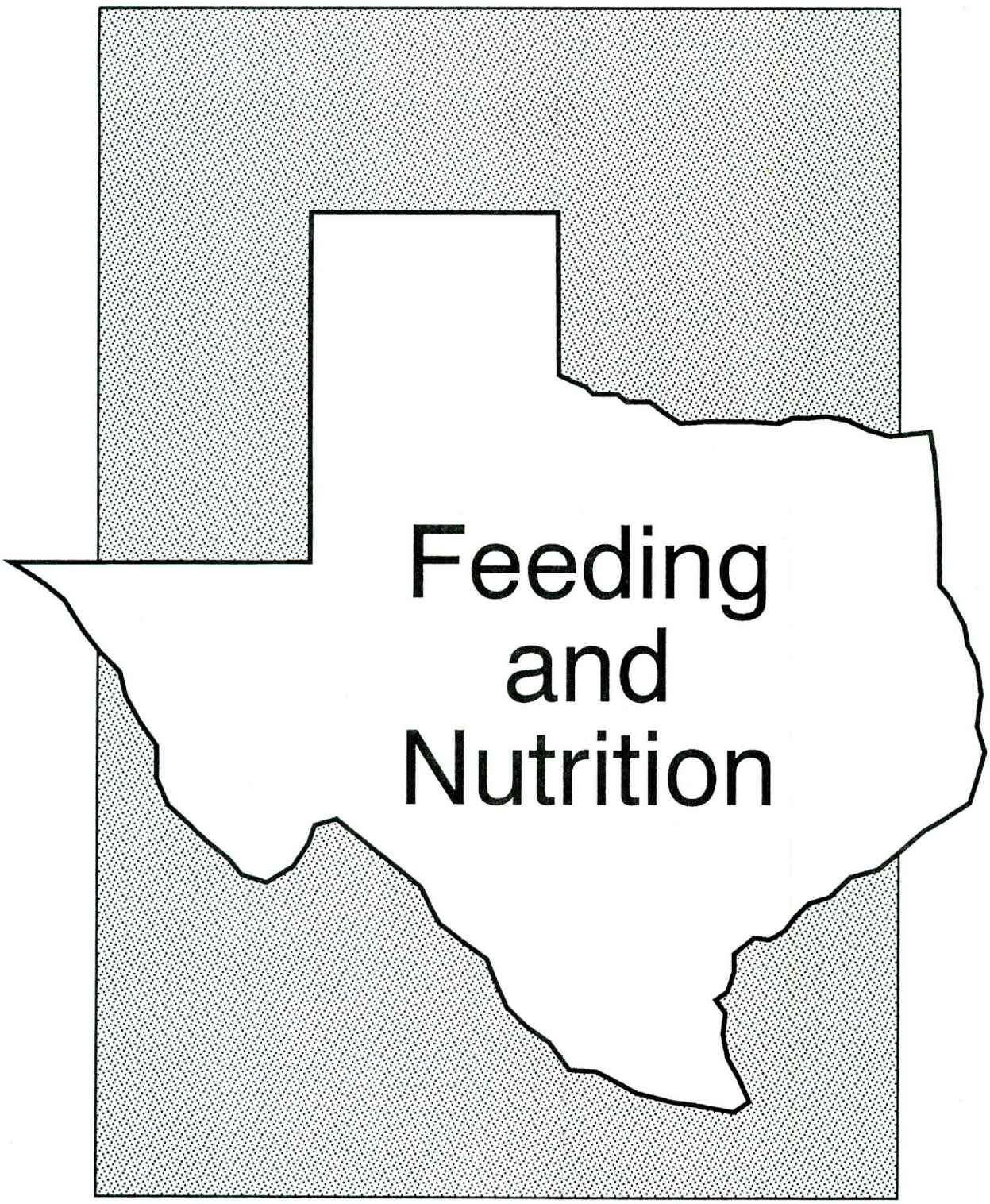



Figure 3. The Effects of Yield Grade and Dressing Percent on Value (Live Weight Basis) as Time-on-Feed Increases. This graph represents a pen of cattle valued at various alternative slaughter times. The effects of quality grade on cutout value have been removed so that the relationship between yield grade and dressing percent may be illustrated more clearly. Under the CARC pricing method, dressing percent has a greater effect than cutability until 150 days, when the percentage of YG4 begins to increase more rapidly. Under the 1"TRIM pricing method, cutability and dressing percent offset one another. Under the 1/4"TRIM scenario, cutability has a greater effect than dressing percent; and, therefore, at a given quality grade, feeding cattle longer to increase dressing percent is not justified.


Feeding
and
Nutrition

# Optimal Zeranol Levels for Enhancing Lean Retail Product

F.M. Byers, N.D. Turner, H.R. Cross, L.W. Greene
and G.E. Carstens

## Summary

Four experiments performed at four geographical locations (Idaho, Kansas, Illinois, Colorado) were conducted to assess the optimal level of zeranol (Ralgro®) for increasing carcass lean. Together, these experiments included 1,396 head of crossbred yearling cattle. All cattle within each experiment were fed for the same number of days, with the objective of assessing the impact of a single zeranol implant containing eight different dose levels on the quantity of lean retail product in cattle at a similar compositional endpoint. Cattle were implanted with doses of zeranol from 0 to 96 mg/animal, in 12 mg intervals, and were fed for up to 140 d.

Carcass characteristics (hot carcass weight, back fat, ribeye area, kidney, pelvic and heart fat percentage, and marbling score) were determined after a 24-h chill. Lean retail product weight and percentage, and yield grade were calculated from the carcass data collected. Rib sections (32/location) and carcass sides (four/location) were collected from selected cattle across treatments on each study for chemical analyses to validate lean retail product indicator equations for each location.

Implanting with 36 to 96 mg of zeranol increased ($P<.05$) hot carcass weight by 7.3 to 11.8 kg. Ribeye areas for the 36, 48, 60, 72, and 84 mg treatment groups were greater ($P<.05$) than for the control treatment. Kidney, pelvic and heart fat percentages were reduced ($P<.05$) from control values (2.37%) for all treatment groups by an average of 11 percent, except for the 48 mg level. Marbling score was similar among controls and all treatment levels of zeranol and averaged Low-Choice. The similar marbling score, combined with the reduction in kidney, pelvic and heart fat percentage indicated that the implants effected a change in site of fat deposition.

Retail product weight was similar for the control (212 kg) and 24 mg treatment groups, with greater ($P<.05$) amounts of lean retail product (4.2 to 7.6 kg more) for all other implant groups over controls. The increase in retail product was greatest for cattle receiving 48 (7.2 kg) to 72 mg (7.6 kg) of zeranol. Tenderness, shear force, and organoleptic values were similar for all groups. Zeranol at 36 to 84 mg as a single implant increased the quantity of lean retail product (especially for 48 to 72 mg), while maintaining marbling and organoleptic qualities of the beef produced.

## Introduction

Perception of the need to reduce caloric intake reflects the consumers recognition that excess energy consumption and its associated overweight conditions are national health problems. In no area is this more evident than in their selection of, and desire for, leaner beef products with less fat than provided in traditional beef. While leaner beef will assist in reducing intake of calories, it is also consistent with overall cattle industry objectives to reduce wasteful production of excessive carcass fat by developing new technologies and systems to efficiently produce leaner beef. While it is possible to alter beef composition using breeding, and in the future genetic engineering, it is important to develop more effective systems of growth regulation in all animals. Therefore, the focus of research must shift from rate of gain and feed efficiency to rate and efficiency of lean tissue growth if we are to accomplish the primary goal of enhancing lean beef production through conventional cattle feeding and management systems.

Previous research has indicated the ability of zeranol implants to increase average daily gains and modify carcass composition without greatly reducing product desirability (6). However, some research has indicated that the currently approved 36 mg dose/animal may not be sufficient to maximize the increase in average daily gain (3). It is important to establish the range of zeranol doses providing efficacy in enhancing not only average daily gain but also production of a highly marketable lean retail product.

This study was designed to allow assessment of the leanness response of steers to levels of zeranol and the impact of this growth regulator on lean retail product.

## Materials and Methods

Four experiments were conducted at different geographical locations. All cattle within each experiment were fed for the same number of days, with the objective of assessing the impact of zeranol dose on the quantity of lean retail product at a similar compositional endpoint.

The cattle were implanted with 0, 12, 24, 36, 48, 60, 72, 84, or 96 mg/animal, and were fed for about 140 days (depended on location), then slaughtered to

collect carcass data. Carcass characteristics (hot carcass weight, back fat, ribeye area, kidney, pelvic and heart fat percentage, and marbling score) were determined after a 24-h chill. Lean retail product weight and percentage, and yield grade were calculated from the carcass data collected. Retail product percentage was calculated as per the equation of Crouse and Dikeman (4): Retail product percentage = (73.6 - (6.5 * 2.54 * Adjusted fat thickness) + (0.087 * 6.45 * Ribeye area) - (1.23 * KPH) - (0.234 * Retail product marbling number). Retail product weight was calculated from retail product percentage and carcass weight. Yield grade was calculated using the equation of USDA (8): Yield grade = 2.5 + (2.5 * Adjusted fat thickness) + (0.2 * KPH) + (0.0038 * Hot carcass weight) - (0.32 * Ribeye area).

Rib sections were removed by trained personnel, using Hankins and Howe (5) procedures, from 32 head in each experiment and were transported to the Texas A&M Meat Science and Technology Center. The 32 head selected represented four cattle from each of the implant levels. The animals selected reflected the range in finish of cattle on each treatment. The 12th rib steak was removed from the 32 carcasses and it was prepared for taste panel evaluation. The taste panel consisted of seven trained panelists. Another steak was prepared to determine cooking loss and Warner-Bratzler shear forces using cores removed from the cooked steak.

Data were analyzed using the General Linear Models Procedures of SAS (7). The model included the main effects of location and treatment, and a location by treatment interaction with animal as the experimental unit. When the interaction was not significant, it was deleted and the data analyzed again using only the main effects. Cattle initial weight was included as a covariate in the model to remove the influence of initial weight on quantity of retail product. Using a covariate of initial weight resulted in a significant improvement in the models for only hot carcass weight and retail product weight. Therefore, the model for all other variables included only main effects. Least squares means were only separated when a significant (P<.05) model was generated for a main effect. Determinations of the non-linear response of retail product weight to zeranol dose was made using SAS GLM procedures. Least square means of retail product weight were used to fit linear-plateau models of Anderson and Nelson (1, 2).

## Results and Discussion

### *Carcass Characteristics*

There were no location and treatment interactions for hot carcass weight, actual fat thickness, ribeye area, kidney, pelvic and heart fat, marbling score, and retail product weight. Hot carcass weight was not increased with the 24 mg zeranol implant (Table 1). However, the other implant levels increased (P<.05) carcass weight from 7.3 to 11.8 kg over the controls. Actual fat thickness over the rib was 1.09 cm for the control carcasses, which was similar to the data for 24, 48, 72, and 84 mg treatment groups. The 36 and 96 mg treatment groups had the greatest (P<.05) fat covering, as compared to the 0 and 24 mg implant groups. These differences probably represent animal variability because no clear relationship between implant level and actual fat thickness is indicated. The control carcasses had the smallest ribeye area (76.0 $cm^2$), and the 24 and 96 mg treatment groups were not different from controls. Implanting with 36, 48, 60, 72, or 84 mg of zeranol increased (P<.05) ribeye area over controls. Kidney, pelvic and heart fat percentage was lower (P<.05) than controls for all implant groups, except for the 48 mg level. Marbling score was similar for all treatment groups, and none of the treatment means were lower than 400, which indicates a desirable (Low Choice) marbling rating. The similar marbling score, combined with the reduction in kidney, pelvic and heart fat percentage, indicated that the implants effected a change in the fat deposition sites, allowing a reduction in undesirable internal, organ fat while maintaining intramuscular fat needed for desirable cooking and flavor characteristics.

Lean retail product weight was similar for the control and 24 mg treatment group, and increased (P<.05) over controls with 36 to 96 mg zeranol. The 36, 48, 60, 72, 84, and 96 mg zeranol implants resulted in retail product weights which were 4.2, 7.2, 6.2, 7.6, 5.0 and 4.2 kg greater (P<.05), respectively, than the weights for the control group. The mean separation pattern indicates that the greatest retail product weight was produced when the 48, 60, 72 and 84 mg implants were used.

Non-linear models (Figure 1) and linear plateau models (Figure 2) were developed to establish the dose-response in quantity of retail product. The model for the quadratic fit was: Retail product, kg = 211.23 + .362*dose - .00225*$dose^2$, $R^2$ = .81, $S\hat{y}$ = 1.29. The linear plateau model was: Retail product, kg = 211.97 + .19*dose, $R^2$ = .82, $S\hat{y}$ = 1.15. This model was linear up to the 72 mg dose, at which point a plateau was observed in the response to subsequent levels. As is evident from the figures, both quadratic and the best linear plateau models indicate maximal response with 72 mg zeranol, with no additional response to greater levels.

Only the adjusted fat thickness, yield grade, and retail product percentage resulted in interactions between location and implant treatment (Table 1). Adjusted fat thickness over the rib was similar between the control and 24 mg implant groups, and was slightly greater for other treatments over controls. Retail product percentage was unaffected by zeranol implants and ranged from 66.3 to 67.1 percent. Implanting with 24 or 72 mg of zeranol had no effect on adjusted fat thickness, while other implants slightly increased external fat on the carcasses. Yield grade was not affected by any implant level.

### *Cooking Loss and Shear Force*

There were no differences in cooking loss for steaks from any implant group (Table 2). The percentage loss ranged from 21.9 to 23.5 percent for steaks from implanted cattle and was 22.0 percent for steaks from the control cattle. Cooking loss is composed of both moisture and fat. The shear force values were not different for any of the treatment groups. Tenderness decreases with increasing shear force values. The similar shear force values indicate zeranol likely did not alter characteristics of the muscle fibers.

### *Taste Panel Evaluation*

Implanting with zeranol did not modify the panelists perceptions of the steak quality. Juiciness was perceived to be similar for all treatment groups (Table 3). The ratings were similar for the control and 84 mg groups. All other implant levels produced numerically greater juiciness ratings than the controls. Muscle fiber tenderness was not affected by implanting with zeranol. Connective tissue amount was similar for all treatment groups. The perception of overall tenderness was not different for steaks from any implant group. Zeranol implants had no affect on steak flavor.

## Conclusions

Effective zeranol implant levels increased hot carcass weight and ribeye area, and reduced the kidney, pelvic and heart fat percentage. The 36 to 96 mg treatment levels enhanced lean retail product weight by 4.2 to 7.6 kg, and 72 mg was determined to be the plateau dose level. The cooking loss and shear force data did not show any treatment effects. Taste panel evaluations were not altered by treatment. Therefore, zeranol at the levels tested, enhanced production of lean retail product while maintaining flavor and tenderness of the steaks produced.

## Literature Cited


1. Anderson, R.L. and L.A. Nelson. 1975. A family of models involving intersecting straight lines and concomitant experimental designs useful in evaluating response to fertilizer nutrients. Biometrics 31:303.
2. Anderson, R.L. and L.A. Nelson. 1987. Linear-plateau and plateau-linear-plateau models useful in evaluating nutrient responses. Tech. Bull. 283. North Carolina Research Service, N.C. State Univ., Raleigh.
3. Cain, M.F., J. Henson, R.D. Williams, and P.G. Lemieux. 1986. Effect of 72 mg zeranol on gain and efficiency of feedlot steers. J. Anim. Sci. 63 (Suppl. 1) :398 (Abstr.).
4. Crouse, J.D. and M.E. Dikeman. 1976. Determinants of retail product of carcass beef. J. Anim. Sci. 42:584.
5. Hankins, O.G. and P.E. Howe. 1946. Estimation of the Composition of Beef Carcasses and Cuts. USDA. Tech. Bulletin 926.
6. Lemieux, P.G., F.M. Byers, G.T. Schelling, G.C. Smith, and T.R. Dutson. 1985. Carcass merit of steers receiving anabolic implants and fed forage and grain diets. J. Anim. Sci. 61 (Suppl. 1) :93 (Abstr.).
7. SAS. 1982. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.
8. USDA. 1976. Official United States standards for grades of carcass beef. Title 7, Ch. 28, Pt. 2853, Sections 102-107. Code of Federal Regulations, USDA, Washington, DC.

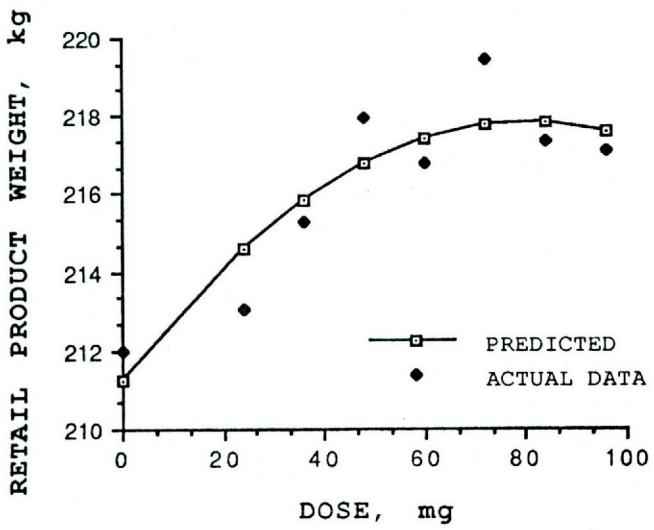




Figure 1. Non-linear response of retail product weight to zeranol dose.

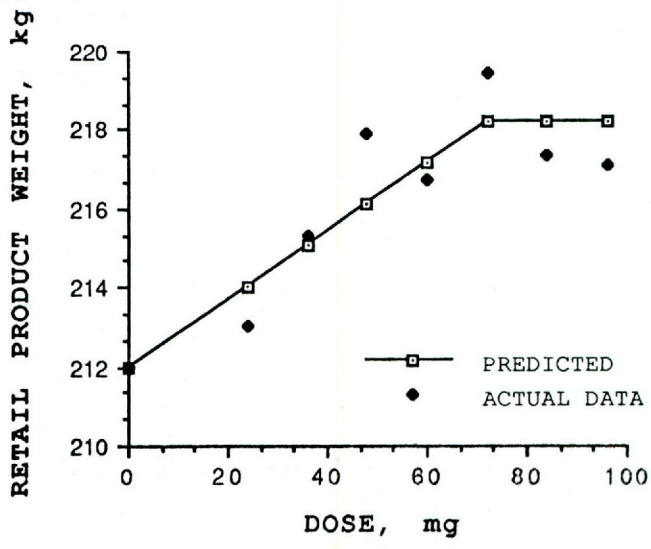



Figure 2. Maximum effective dose as predicted by linear plateau proceudres.

TABLE 1. CARCASS CHARACTERISTICS OF STEERS RECEIVING INCREMENTAL DOSES OF ZERANOL

| Item | Treatment 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | SE |
|---|---|---|---|---|---|---|---|---|---|
| Number | 172 | 172 | 172 | 174 | 175 | 178 | 178 | 175 | |
| Hot carcass weight, kg | 315.9$^{b}$ | 317.2$^{b}$ | 323.4$^{c}$ | 327.8$^{c}$ | 325.2$^{c}$ | 327.5$^{c}$ | 324.3$^{c}$ | 325.6$^{c}$ | 2.1 |
| Actual fat thickness, cm | 1.09$^{b}$ | 1.11$^{bc}$ | 1.19$^{d}$ | 1.16$^{bcd}$ | 1.18$^{cd}$ | 1.16$^{bcd}$ | 1.17$^{bcd}$ | 1.23$^{d}$ | .03 |
| Adjusted fat thickness[a], cm | 1.24$^{b}$ | 1.29$^{bc}$ | 1.34$^{cd}$ | 1.33$^{cd}$ | 1.34$^{cd}$ | 1.32$^{bcd}$ | 1.35$^{cd}$ | 1.39$^{d}$ | .03 |
| Ribeye area, $cm^2$ | 76.00$^{b}$ | 76.65$^{bcd}$ | 77.87$^{cd}$ | 77.68$^{cd}$ | 77.87$^{cd}$ | 77.87$^{d}$ | 77.81$^{cd}$ | 76.32$^{bc}$ | .58 |
| Kidney, pelvic, heart fat, % | 2.37$^{b}$ | 2.27$^{c}$ | 2.28$^{c}$ | 2.30$^{bc}$ | 2.25$^{c}$ | 2.25$^{c}$ | 2.27$^{c}$ | 2.22$^{c}$ | .03 |
| Marbling score | 410.3 | 404.3 | 401.3 | 401.2 | 400.9 | 403.9 | 408.4 | 402.2 | 6.0 |
| Yield grade[a] | 3.06 | 3.08 | 3.13 | 3.15 | 3.14 | 3.11 | 3.15 | 3.25 | .05 |
| Retail product weight, kg | 211.1$^{b}$ | 212.0$^{bc}$ | 215.3$^{cd}$ | 218.3$^{d}$ | 217.3$^{d}$ | 218.7$^{d}$ | 216.1$^{d}$ | 215.3$^{cd}$ | 1.5 |
| Retail product[a], % | 67.05 | 66.85 | 66.66 | 66.69 | 66.70 | 66.90 | 66.57 | 66.30 | .23 |

[a] Significance level of interaction between location and treatment were: Adjusted fat, P = .0329; Yield grade, P = .0019; Retail product weight, %, P = .0227.

[bcd] Mean within a row without a common superscript letter differ (P < .05).

TABLE 2. COOKING LOSS AND SHEAR FORCE VALUES OF 12TH RIB STEAKS FROM STEERS RECEIVING INCREMENTAL DOSES OF ZERANOL

| Item | Treatment 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | SE |
|---|---|---|---|---|---|---|---|---|---|
| Cooking loss, % | 21.96 | 23.08 | 23.50 | 22.37 | 21.89 | 22.84 | 23.05 | 21.94 | .81 |
| Shear force, kg | 7.01 | 6.63 | 6.82 | 6.57 | 7.12 | 6.76 | 7.03 | 6.90 | .27 |

TABLE 3. ORGANOLEPTIC PROPERTIES[a] OF 12TH RIB STEAKS FROM STEERS RECEIVING INCREMENTAL DOSES OF ZERANOL

| Item | Treatment 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | SE |
|---|---|---|---|---|---|---|---|---|---|
| Juiciness | 5.26 | 5.46 | 5.41 | 5.32 | 5.41 | 5.55 | 5.23 | 5.42 | .14 |
| Muscle fiber tenderness | 5.77 | 6.03 | 5.93 | 6.00 | 5.71 | 6.07 | 5.78 | 6.00 | .13 |
| Connective tissue amount | 6.76 | 6.81 | 6.69 | 6.78 | 6.73 | 6.80 | 6.63 | 6.77 | .09 |
| Overall tenderness | 5.79 | 5.99 | 5.91 | 6.02 | 5.73 | 6.09 | 5.76 | 5.98 | .13 |
| Flavor | 5.34 | 5.47 | 5.45 | 5.49 | 5.22 | 5.52 | 5.39 | 5.38 | .10 |

[a] A hedonistic scale was used where: Juiciness, 1 = extremely dry, 8 = extremely juicy; Muscle fiber tenderness, 1 = extremely tough, 8 = extremely tender; connective tissue amount, 1 = abundant, 8 = none; overall tenderness, 1 = extremely tough, 8 = extremely tender; flavor, 1 = extremely bland, 8 = extremely intense.

# The Role of Methane from Beef Cattle in Global Warming

F.M. Byers and N.D. Turner


## Summary

Global warming and the greenhouse effect are developing concerns of the consumer, and the contribution of the U.S. beef cattle industry to global warming from methane production has become a visible concern. To assess the magnitude of contributions of methane from cattle to global methane budgets and to potential global warming, methane production from each segment of the U.S. cattle industry was modeled with current animal numbers and methane yields (methane/GE) for respective classes of animals. Results indicate that beef cattle contribute the greatest fraction (72%) and that dairy cattle and dairy replacement heifers produce 28 percent of the methane from all cattle in the U.S. Of the methane produced in the beef cattle sector (2.87 million metric tons) of the U.S. cattle industry, the cow/calf sector is responsible for 75 percent, with stocker (14%) and feedlot (11%) segments responsible for the remaining 25 percent. Of the total annual methane production in the world from all sources, only 0.5 percent is from beef cattle in the U.S.

Production of methane/unit of product is also small compared to fossil greenhouse gas (carbon dioxide, carbon monoxide) production in contemporary activities. Therefore, methane would contribute less than 0.1 percent of the global warming from all sources world-wide. World-wide, the adoption of strategies such as grain feeding, and ionophores to reduce methane, or growth regulators to enhance lean tissue growth would reduce the methane/unit of beef produced. Hence, eliminating technologies that contribute to more efficient production of meat or milk production would directly increase the animal contribution to global warming by requiring production of more methane/unit of product, be it meat, milk, fiber, or draft power.


## Methane and Climate

Methane in the atmosphere has doubled in the last two to three centuries (16). Current projections indicate that the present rate of increase in methane is about 1 percent of current levels (1,8). Methane has an expected lifetime of about 10 yr in the troposphere (7). It is unknown whether the current increase in methane is due to increased emission, reduced destruction, or a combination of both effects (10). Destruction of methane depends on the presence of hydroxyls. Carbon monoxide from combustion of fossil fuels reduces the levels of hydroxyls in the atmosphere, reducing the rate of methane destruction. What is generally (but not universally) agreed upon is that the current increase in methane could contribute (perhaps up to one-third as much as the increase attributed to carbon dioxide) to any greenhouse effect occurring, and thus to global warming (7).

## Methane Sources

Many sources of methane exist (Figure 1), with those related to human activities accounting for about 70 percent of total annual production and/or release to the atmosphere, while natural sources account for the remaining 30 percent. Methane associated with human activity involves both biogenic and abiogenic sources. The largest abiogenic sources include methane released in the plume of flames during biomass burning, release from coal mines, venting and transmission losses of natural gas, and venting in oil exploration (9,11). These sources produce 33 percent of all methane produced world-wide.

Methane emissions from rice paddies account for the largest biogenic contribution of methane, which make up 21 percent of global emissions from human activity (4). Landfills are estimated to contribute 7 percent of global methane emissions. The sources listed so far account for 83 percent of total yearly methane production, leaving 17 percent directly associated with animals and their waste products.

### *Methane from Animals*

Methane gas is a product of anaerobic fermentation by microbes located in the pre-intestinal stomach compartments of ruminants, and in the lower digestive tract of all animals. Our current assessment indicates that about 7 percent of methane produced globally, is from beef, dairy, draft, and collateral (i.e., status, sacred, hobby) cattle world-wide. This differs somewhat from earlier (6,13,19) estimates. Estimates of 3.7 percent of the global methane have been generated for other ruminants (i.e., sheep, goats, buffalo, deer, bison, elk, camels, etc.) and both domestic and wild nonruminants (horses, pigs, elephants, etc.). Wastes held in lagoons from all types of animals (cattle, pigs, poultry) decay anaerobically and produce methane. Currently, animal wastes are estimated to contribute 2.7 percent of global emissions. Some of the methane from animal wastes is now captured and used as a household fuel source, as in small farms in developing countries, and as a commercial fuel source in large scale systems such as the type UNISYS currently has in place in Hawaii.

Methane produced in the digestive tract of the current 5.2 billion people (1990) accounts for 1 percent of world methane emissions (18). Termites, other insects and invertebrates (14,18,21) contribute the remainder of global methane, and this is conservatively estimated at 0.6 percent and 2 percent, respectively, for termites and for other fauna.

### *Methane Production by Cattle*

Of the 7 percent of global methane attributed to cattle, about 4.1 percent is from cattle in developed countries while 2.9 percent comes from cattle in developing countries. These statistics are based on using U.S. methane production values as a base for developed countries and modified methane yields for the livestock populations reported by Crutzen (6) for developing countries. Of the 4.1 percent of total annual methane production attributable to cattle in developed countries, 0.5 percent is from beef cattle in the U.S. Therefore, total elimination of beef cattle production in the U.S. would do little to solve the methane component of the global warming problem (Figure 2), and would have even less impact than elimination of termites world-wide. The same is true for most countries, since each by itself contributes little to global methane production. This is very different from the global warming scenario for carbon dioxide production from fossil fuel sources, where several developed countries are responsible for most of the problem.

With this perspective in mind, it is useful to consider the contribution to methane production from identifiable components of the U.S. cattle industry (Figure 3), to allow an assessment of where intervention, if appropriate, may be the most useful. Dairy cattle and their replacements account for 15 percent of the cattle in the U.S. and produce 28 percent of the methane. Beef cows contribute the greatest fraction, and are responsible for nearly half (46%) of all methane produced by cattle in the U.S. Beef cattle on stocker-growing programs and cattle on feed contribute 10 and 8 percent of methane produced, respectively. Of the methane produced in the beef cattle sector of the U.S. cattle industry, the cow/calf sector is responsible for 75 percent, with stocker (14%) and feedlot (11%) segments responsible for the remaining 25 percent. As is evident, most of the 2.87 million metric tons of methane produced by U.S. beef cattle is associated with the extensive cow/calf production component of the U.S. beef cattle system. Merit of the more intensively managed stocker and feedlot components in minimizing the amount of methane produced per unit of marketable retail product is illustrated in Figure 4. As is readily apparent, the amount of methane produced/unit increase in retail product is least for cattle on feed, and approximately double for growing cattle, and increases over 20-fold for retail product produced in calves in the suckling phase. Obviously, the opportunities to significantly alter methane production are quite different among different segments of the industry. However, some progress can be made in all phases of the industry with the uniform adoption of currently available technology and management practices.

Approximately one-fourth of the methane evolved to produce a carcass is associated with the beef cow during the last 160 d of gestation. Minimizing the interval from birth to calving for replacement heifers, pregnancy checking, and culling/rebreeding open cows are all effective in improving reproductive efficiency to minimize methane produced from unproductive animals. Balancing diets to eliminate serious nutrient deficiencies including energy, protein, and minerals that limit or impair production and reproduction will reduce methane produced/unit of animal product marketed. Providing an ionophore will also reduce methane through modification of rumen fermentation.

Similar opportunities exist in the 205-d phase from birth to weaning where another large fraction of the methane is produced. Most technology and management that results in increased rates of growth will reduce methane produced/unit of beef. Implanting calves with growth regulators will increase growth and reduce methane/unit of product. Also, providing a good quality escape protein and, if needed, energy to the calf to supplement milk when limited, and providing deficient macro and trace minerals to calves will improve growth and limit methane production. Providing ionophores to calves when nonmilk feed intake becomes significant (2 mo preweaning) will also reduce the amount of methane produced.

While methane production is already limited in the stocker and feedlot phases, opportunities do exist for further reducing its production. In the growing phase, implanting calves, feeding an escape protein source, balancing diets for all minerals and feeding ionophores will reduce methane produced/day and(or) per unit of beef produced. In the feedlot phase, the common use of high grain (i.e., >90%) diets, implants, ionophores, and balanced diets contribute to the minimal methane production during this phase, even though the cattle are the heaviest and consume the most feed/day during this period. Timely marketing to avoid over-finishing cattle will further limit methane produced/unit of marketable lean retail product. As is evident, although the U.S. beef cattle system is reasonably efficient and produces a minimal amount of methane/unit of retail product, opportunities consistent with good management techniques exist to further reduce methane production. Opportunities also exist to apply much of this same technology to other systems of beef production globally.

More improvement in methane/unit of food produced from ruminant livestock is possible in very extensively managed systems typically found in developing countries where food production from livestock is a byproduct of the economic unit, and animals are commonly fed food production byproducts and cereal

grain straws. These feedstuffs provide little more than a subsistence level of nutrients and result in little growth. In these systems, cattle may not reach marketable weights until they are 5 to 7 yr old. As a consequence, many more cows and growing cattle are needed to supply the same amount of animal protein than in more intensive systems. Methane produced in these systems/unit of retail product is five to seven times greater than in intensive systems similar to those in the U.S. Intervention in the yearly cycles of weight gain and weight loss following wet and dry seasons and periods of feed abundance and shortage with appropriate supplements and technology has the potential to reduce the interval to marketing by one to several years, and to substantially increase milk production/cow, greatly reducing methane production/unit of food (meat or milk) produced.

Previous estimates of methane production from livestock in the literature (6,7) suggested that livestock may account for ~15 percent of methane production, world-wide. These were overestimates for several reasons. The number of animals and their weight (size), especially in developing countries, is estimated with little precision. Even for the U.S. only census rather than production cycle data were used when in fact, many animals (i.e., feedlot cattle) do not spend a full year in that management category, and the numbers in any category cycle with season of the year and stage of the annual production cycle. Secondly, the daily methane production estimates from ruminants have been derived from methane production coefficients that are as much as 2.5-fold higher (i.e., for feedlot cattle) than actual methane production coefficients (2,3,15). Methane for all cattle on range (cow-calf-stocker) also has been calculated to be similar, although as many as 50 percent of the cattle on range are calves that are less than 6 mo of age and receive primarily milk, thereby producing very little methane. For animals in developing countries, methane was calculated to be as much as 9 percent of daily gross energy intake, where feedstuff digestibility would be low enough such that levels above 6 percent would be difficult if not impossible to achieve. For these reasons, the methane contribution of ruminants world-wide has been over estimated in most earlier published reports.

## Relative Contribution to Global Warming by Methane and Carbon Dioxide

Urban development and industrialization that has occurred in response to the eightfold increase in population since the 18th century to the current 5+ billion people, have increased atmospheric levels of greenhouse gases. This has caused the levels of both primary and trace greenhouse gases to increase in the last several centuries. Carbon dioxide levels have increased 25 percent in the last century, and by more than 10 percent in the last three decades (17). Carbon dioxide emissions from factories, vehicles and all other sources increased from less than 5 to over 5.5 billion metric tons in a single year (1986 to 1987) (5,12), and over 50 percent of this originated in the U.S., U.S.S.R., and China. The U.S. is responsible for 22 percent of the 5.5 billion tons. The largest contributors in the U.S. are electric power plants and vehicles, which are each responsible for >30 percent of carbon dioxide emissions (20).

Carbon dioxide release from deforestation has contributed as much as half of the atmospheric increase since 1800 and is responsible for 20 percent of current emissions (16). Dead organic matter in the soil holds two times as much total carbon dioxide as there is in the atmosphere, and dry soils release carbon dioxide on decomposition.

To put methane production by U.S. beef cattle in perspective with other sources of greenhouse gases, the methane produced in the course of producing a quarter-pound hamburger was modeled for cattle produced in an average (i.e., 18 mo) U.S. beef cattle system. Total methane produced is about 176 lb to produce an 1100 lb animal which results in about 480 lb of lean retail product. This results in about 40 g of methane for a quarter-pound hamburger. To put this in perspective, driving 6 miles each way to the store and back to purchase the sandwich in a well tuned car getting 25 miles/gal would result in production of 4200 g of carbon dioxide, or 100 times the amount of "greenhouse gas" as methane generated in the production of the beef. Thus ~4200 g of carbon dioxide were produced to drive to the store to obtain a burger for which 40 g of methane were evolved to produce. Since methane absorbs energy of the long infrared wavelength with about 20 times the effectiveness of carbon dioxide on a molecular basis, the net difference is over twofold more "potential" global warming from fossil fuel to propel the vehicle to purchase the sandwich than from methane in production of the beef per se.

We estimate total annual methane production from all of U.S. beef cattle production based on 33.6, 30.2 and 26.3 million cow/calf, stocker-replacement and fed cattle to be about 2.9 million metric tons (Terragrams, Tg) per year. This represents about 0.5 percent of the total estimated yearly tropospheric input of methane (550 million metric tons/yr) from all sources on earth, or about 15 percent less than a conservative estimate of methane produced annually by termites, which, like livestock, are difficult to count world-wide (14,18,21). In contrast, annual production of carbon dioxide from just the 110 billion gal of gas burned in vehicles in the U.S. each year totals about a *billion* metric tons.

## Conclusions

If beef cattle production systems in the U.S. were to revert back to extensive grazing systems used in developing countries, the methane/unit of beef produced would increase dramatically (as much as sevenfold) because several additional years are normally required to reach a market endpoint. Also, addition of a supplement and/or grain feeding component to

systems of beef production world-wide would reduce the current quantity of methane generated to produce the current levels of beef marketed, especially in developing countries.

World-wide, the adoption of technology (i.e., ionophores) to reduce methane or growth regulators to enhance lean tissue growth would reduce the methane/unit of beef produced. Hence, disallowing technology would directly increase the animal contribution to global warming by requiring production of more methane/unit of product, be it meat, milk, fiber, or draft power.

While global warming and the contribution from the greenhouse effect are certainly important issues to which our attention must be directed, the contribution by the U.S. beef cattle industry to annual global methane production (0.5% of total estimated production, 0.1% of all potential global warming) is not outstanding. Production of methane/unit of product is also small compared to fossil greenhouse gas production in contemporary activities. In keeping with these scenarios, however, it will be important to facilitate transfer of all available technology to enhance rate and efficiency of growth to reduce methane emissions from beef cattle production systems, in the U.S. and world-wide, to further limit the possible contribution of cattle to global warming.

## Literature Cited


1. Blake, D.R. and F.S. Rowland. 1988. Continuing world-wide increase in tropospheric methane, 1978-1987. Science 239:1129.
2. Blaxter, K.L. and F.W. Wainman. 1964. The utilization of the energy of different rations by sheep and cattle for maintenance and for fattening. J. Agric. Sci. 63:113.
3. Byers, F.M. 1974. The importance of associative effects of feeds on corn silage and corn grain net energy values. Ph.D. Dissertation. Colorado State Univ.
4. Cicerone, R.J. and R.S. Oremland. 1988. Biogeochemical aspects of atmospheric methane. Global Biogeochemical Cycles 2:299.
5. Clark, W.C. 1989. Managing Planet Earth. Scientific American 261 (3) :47.
6. Crutzen, P.J., I. Aselmann, and W. Seiler. 1986. Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. Tellus 38B:271.
7. Gibbs, M.J.,and J.S. Hoffman. 1989. Reducing Methane Emissions From Livestock: Opportunities and Issues. US EPA 400/1-89-002.
8. Graedel, T.E. and P.J. Crutzen. 1989. The changing atmosphere. Scientific American 261 (3):58.
9. Khalil, M.A.K. and R.A. Rasmussen. 1989. Constraints imposed by the ice core data on the budgets of nitrous oxide and methane. Proceedings of the 28th Liege International Astrophysical Colloquium, "Our Changing Atmosphere," Liege, Belgium.
10. Khalil, M.A.K. and R.A. Rasmussen. 1983. Sources, sinks, and seasonal cycles of atmospheric methane. J. Geophysical Res. 88:5131.
11. Klug, M.J. and C.A. Reddy. 1984. Current perspectives in microbial ecology. American Society for Microbiology Washington, D.C. Contribution of Biological Processes to the Global Budget of $CH_4$ in the Atmosphere. p 468.
12. Kozak, R. 1989. $CO_2$ emmisions jump more that 10 percent. Insight 5 (8/7/89) :56.
13. Lerner, J. and E. Mathews. 1988. Methane emissions from animals: A global high-resolution data base. Global Biogeochemical Cycles 2:139.
14. Rasmussen, R.A. and M.A.K. Khalil. 1983. Global production of methane by termites. Nature 301:700.
15. Rumpler, W.V., D.E. Johnson, and D.B. Bates. 1986. The effects of high dietary cation concentration on methanogenesis by steers fed diets with and without ionophores. J. Anim. Sci. 62:1737.
16. Schneider, S.H. 1989. The changing climate. Scientific American 261 (3) :70.
17. Schneider, S.H. 1989. The greenhouse effect: Science and Policy. Science 243:771.
18. Seiler, W. 1984. Contribution of biological processes to the global budget of CH4 in the atmosphere. *In*: Current Perspectives in Microbial Ecology. M. J. Klug and C. A. Reddy (Ed.). p 468. American Society of Meteorology.
19. Stevens, W.K. 1989. Methane from guts of livestock is new focus in global warming. The Environment. New York Times, 11/21/89.
20. USA must lead global-warming fight. 1989. USA Today, 11/15/89. p 12A.
21. Zimmerman, P.R., J.P. Greenberg, S.O. Wandiga, and P.J. Crutzen. 1982. Termites: A potentially large source of atmospheric methane, carbon dioxide, and molecular hydrogen. Science 215:563.

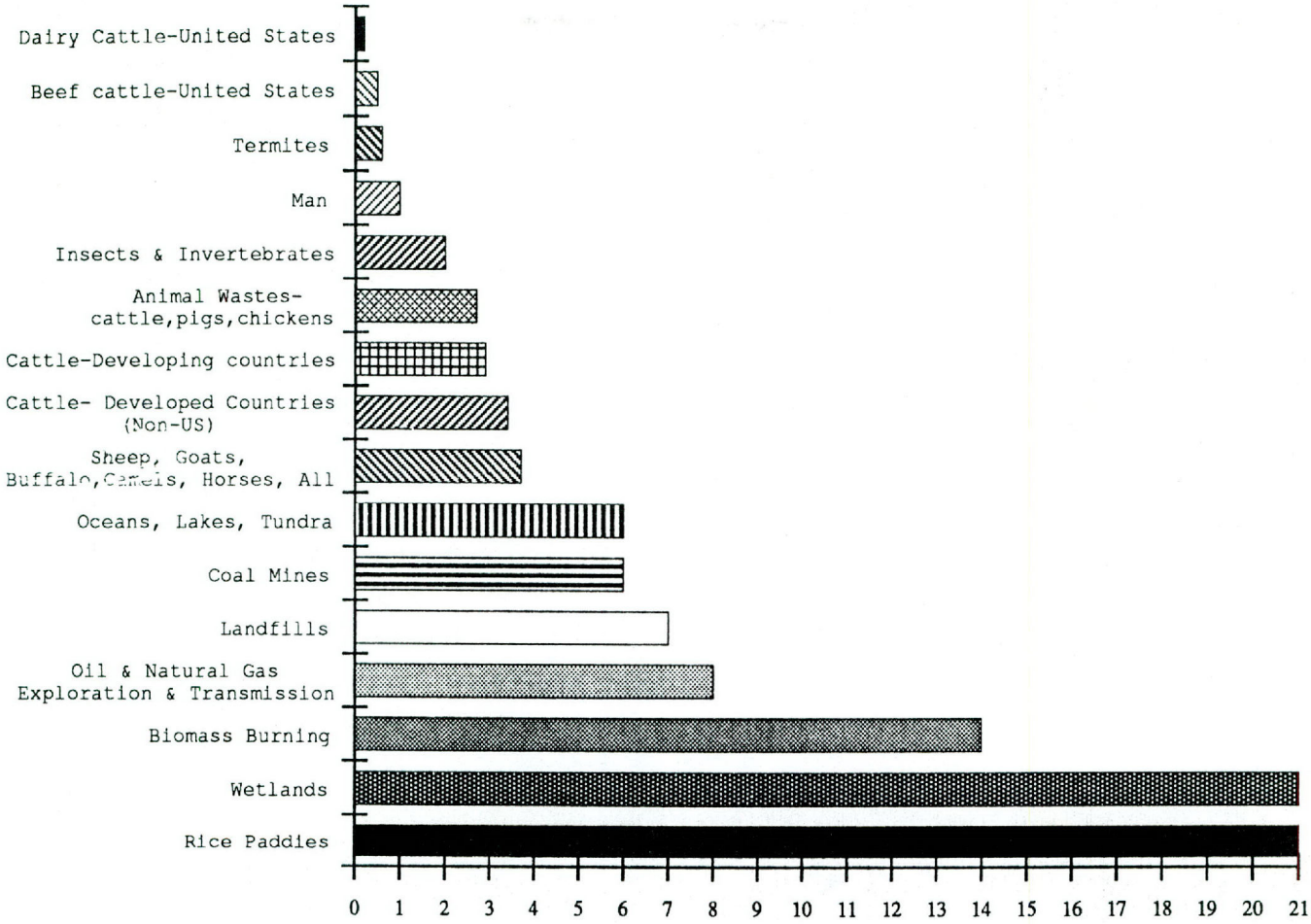



Figure 1. Percentage of world methane production.

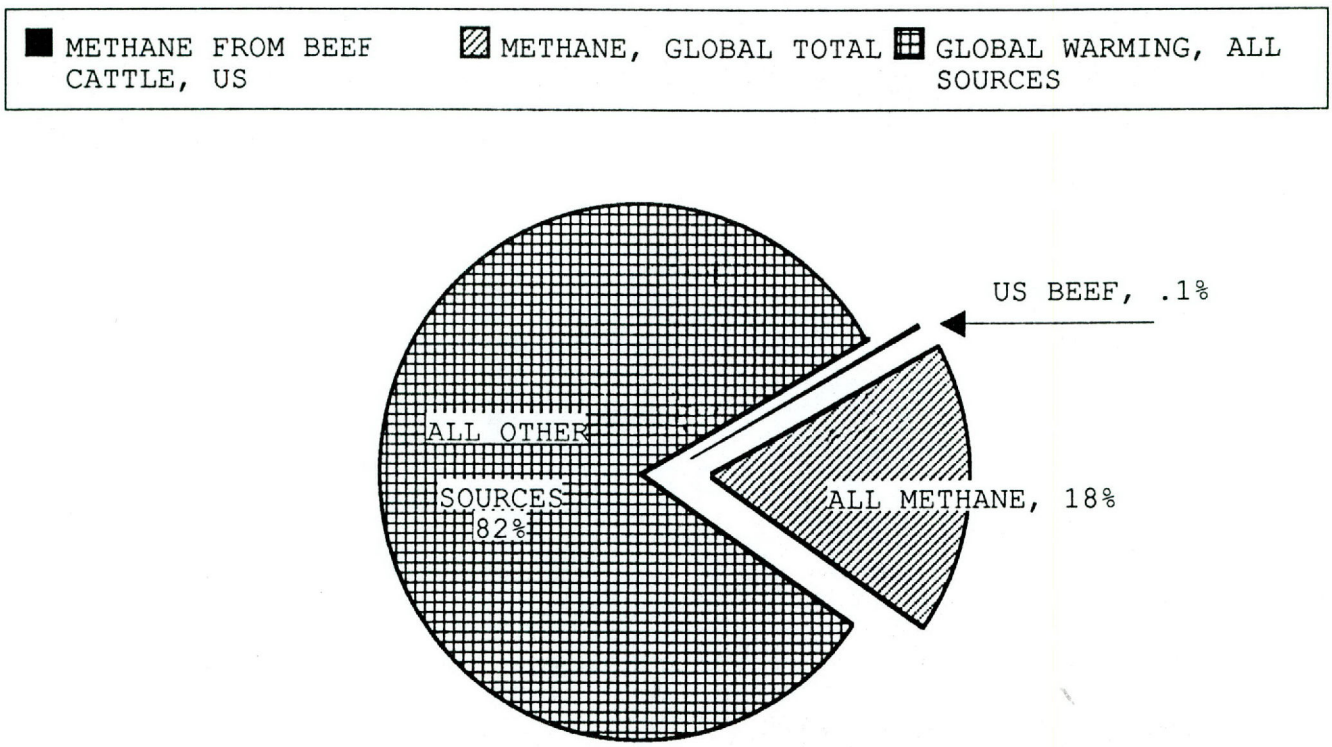



Figure 2. Contribution of U.S. beef cattle industry to global warming.

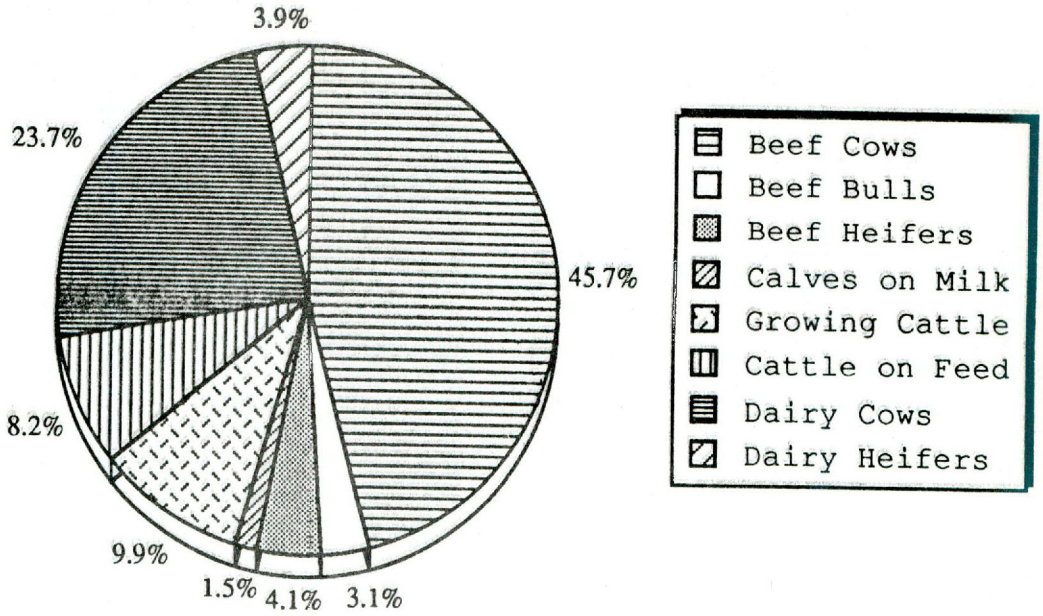



Figure 3. Percentage of U. S. Cattle methane production.

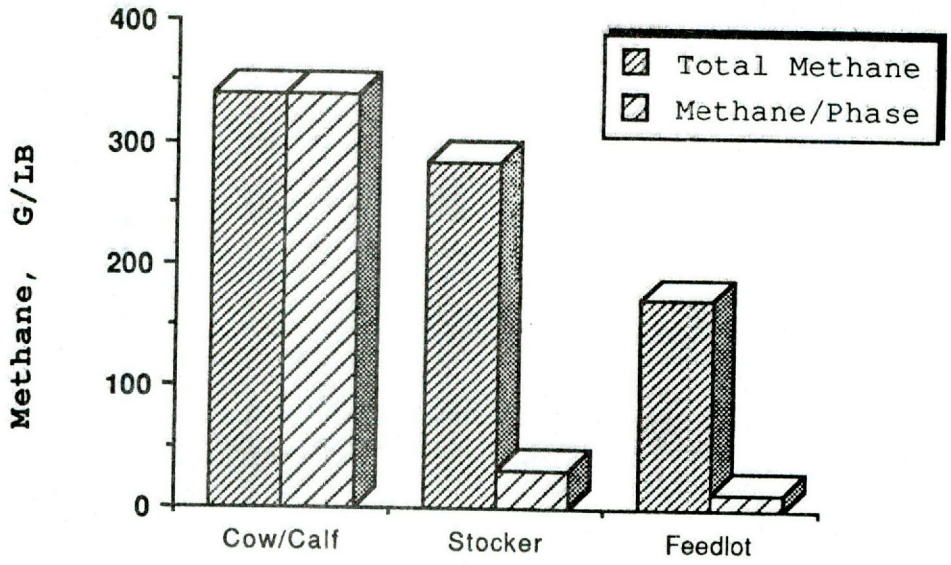



Figure 4. Methane produced per pound of retail product through phase of beef production.

# Performance of Yearling Heifers Fed Diets Containing Whole Cottonseed

M.C. Calhoun, J.E. Huston, D.N. Ueckert, B. C. Baldwin, Jr., S.W. Kuhlmann and B. S. Engdahl


## Summary

Cottonseed improved performance of yearling Hereford x Brangus heifers fed complete diets for 56 days prior to breeding. Overall for the 56-day study, live weight gain increased 12.5 percent (linear, P<.05) and feed/gain decreased 12.1 percent (linear, P<.10) as whole cottonseed increased from 0 to 30 percent of the diet. Cottonseed was readily eaten without evidence of sorting. Heifers on the diet containing 30 percent cottonseed consumed 6.7 lb of cottonseed per day. Corresponding free gossypol intakes were 16.6 g/day and 25.0 mg/lb live weight (LW)/day. There were no health problems during the study and no clinical signs of gossypol poisoning were observed. Subsequent reproductive performance was excellent regardless of cottonseed/gossypol intake and 95 percent of the heifers were diagnosed as pregnant. Cottonseed increased osmotic fragility of erythrocytes (percentage hemolysis in a buffered 0.6 percent saline solution) at 28 days (linear, P<.01) and 56 days (linear, P<.01) and decreased serum alkaline phosphatase levels at 56 days (linear, P<.01). Changes in these blood measurements indicated the capacity of the rumen to detoxify gossypol was exceeded, but there were no negative effects of cottonseed on growth or reproductive performance in this study.


## Introduction

Whole cottonseed is an excellent source of protein, energy, fiber and phosphorus and has been fed for many years to cattle in the Southwestern United States (4). It is used as a supplemental feed during fall and winter for range cattle, in growing and finishing diets for beef cattle and in diets of high producing dairy cattle. The actual amounts fed varies from year to year depending on availability and price, but in recent years about 25 to 30 percent of the available seed has been fed directly to livestock (8).

Cottonseed contains gossypol, a toxic polyphenolic, binaphthyl aldehyde (1). The gossypol content of cottonseed is affected by location, growing conditions and variety. Varieties grown throughout the cotton belt in 1989 contained 0.20 to 0.57 percent free gossypol (as fed basis). Mature cattle, sheep and goats tolerate 13.6 mg free gossypol/lb LW/day for periods greater than 100 days without clinical signs of gossypol poisoning or reduced reproductive performance. Although gossypol toxicity is rare in mature ruminants, it has been reported in Holstein cows fed 19.4 mg free gossypol/lb LW/day for 98 days, indicating the ability of the rumen to detoxify gossypol can be exceeded (7).

Increased osmotic fragility of erythrocytes in buffered saline has been observed when either cottonseed or cottonseed meal was fed to cattle (7) or sheep (2,3) and when cottonseed was fed to Angora goats (9). Osmotic fragility is very sensitive to gossypol intake and precedes gossypol-induced changes in other known physiological and biochemical measurements. Because of this, measurement of osmotic fragility may be useful in determining when the ability of the rumen to detoxify gossypol has been exceeded. This study was conducted to determine the value of cottonseed in a growing ration fed to yearling heifers prior to breeding and to examine changes in osmotic fragility and several other blood constituents.

## Experimental Procedures

Twenty yearling heifers (Hereford x Brangus) were selected from a group of 22 that were grazing pastures at the Carlsbad Research Area (Carlsbad, Texas). They were moved to Texas A&M University's Research Center at San Angelo and placed individually into pens (8' x 20'). On arrival at the Research Center they were weighed and adapted to a control diet (0% cottonseed, Table 1) during a 14-day preliminary period. Subsequently they were assigned at random to diets containing 0, 10, 20, and 30 percent whole, fuzzy cottonseed (Table 1). Five heifers were assigned to receive each diet for 56 days. During the 14-day adaptation period, the 0 percent cottonseed diet was fed at 2.5 percent of live weight. During the first 28 days of the comparison period, diets were fed at 3.0 percent of live weight. This was increased to 4.0 percent of live weight for the 29 to 56-day period.

Animals were weighed and bled at 0, 28, and 56 days during the study. Blood samples were collected by jugular venipuncture into vacuum tubes (15 ml plain tube for serum; 10 ml tube with heparin to be used for osmotic fragility of erythrocytes and hematocrit). Upon completion of the study, the heifers were returned to Carlsbad and bred.

Osmotic fragility of erythrocytes was determined as described by Nelson (10). Initially an osmotic fragility curve was constructed by determining percent-

age hemolysis of erythrocytes in buffered solutions varying from 0.40 to 0.75 percent saline (Figure 1). Subsequent measurements were made only with the solution containing 0.60 percent saline. Serum was frozen and sent to the Texas Veterinary Medical Diagnostic Laboratory in College Station for determination of total protein, albumin, globulin, calcium, phosphorus, glucose, total bilirubin, creatinine, creatine phosphokinase, alkaline phosphatase, lactic dehydrogenase, and aspartate aminotransferase.

The general linear models procedure of the Statistical Analysis System for personal computers and regression analysis were used in the statistical treatment of the data (13). Initial values were used in a covariance analysis to adjust final values of all blood measurements for differences in initial values.

## Results and Discussion

Performance of all the heifers was excellent during the 56-day study (Table 2). There were no health problems and no signs of gossypol poisoning were observed. Feed refusals were minimal during the first 28 days. Feed refusals were greater during the period from 29 to 56 days, but this occurred regardless of treatment and the heifers did not appear to be sorting out and leaving cottonseed. Percentage of cottonseed in the diets did not affect feed intake (Table 2). Coppock et al. (4) and Smith et al. (14) also reported cottonseed feeding did not affect dry matter intake of dairy cattle when included at up to 25 percent of the diet.

During the first 28-day period cottonseed level in the diet did not significantly affect live weight gain or feed efficiency. However, during the period from 29 to 56 days and overall for the 56-day study there were significant linear effects for live weight gain and feed/gain. Increasing cottonseed from 0 to 30 percent of the diet increased gains 30.4 percent ($P<.01$) and 12.5 percent ($P<.05$) and decreased feed/gain 20.5 percent ($P<.01$) and 12.1 percent ($P<.10$), respectively, for the periods 29 to 56 and 1 to 56 days. Increased gains and improved feed efficiency associated with feeding cottonseed are probably due to the higher energy values of diets containing cottonseed (Table 1). In contrast to the improvement in performance of growing cattle in this study when cottonseed was included at levels up to 30 percent of the diet, Preston et al. (12) reported that live weight gain and efficiency of gain were decreased when growing-finishing steers received diets with 20 percent or more of whole cottonseed.

Maximum cottonseed intake was 6.7 lb/day during the period from 29 to 56 days for heifers receiving 30 percent cottonseed. The corresponding free gossypol intakes were 19.7 g/day and 28.3 mg/lb LW/day (Table 3). These levels are similar to those considered safe for high producing dairy cows (4). However, the weight of a mature Holstein cow could easily be twice that of the heifers in this study.

There were linear increases in osmotic fragility of erythrocytes at 28 days ($P<.01$) and 56 days ($P<.01$) as the percentage of cottonseed in the diet increased. The response was greater at 56 days than at 28 days indicating a cumulative effect with time (Table 3). An increased response with time was also observed in early-weaned lambs (3) and 8 mo old Angora goats (9) consuming diets containing Pima cottonseed. Increased hemolysis of erythrocytes in buffered saline solutions has been observed with ruminants of various ages fed cottonseed, cottonseed meal, or gossypol acetic acid (2, 3, 7, 9). Thus, the response is believed due to the absorption of free gossypol and not to other toxic components of the cottonseed products being fed.

In contrast to the above results, Coppock et al. (5) and Hawkins et al. (6) did not observe an increase in erythrocyte hemolysis when lactating Holstein cows were fed cottonseed. The lack of response in the study by Coppock et al. (5) with cattle fed diets containing 30 percent cottonseed may have been due to the short feeding period (35 days). Hawkins et al. (6) fed lactating Holstein cows diets containing 18.5 percent whole cottonseed (dry matter basis) for 273 days which should have been long enough for an increase in erythrocyte hemolysis to have been observed. Free gossypol intake during this period averaged about 9.3 mg/lb LW/day. Apparently this level did not exceed the ability of these cows to detoxify gossypol.

The initial values for hematocrit and the serum constituents measured are summarized in Table 4. Final values adjusted by covariance for differences in initial values are presented in Table 5. The serum enzyme alkaline phosphatase was the only constituent for which there was a significant effect of cottonseed level. The reason for the decrease in this serum enzyme is unknown, but in studies with laboratory animals gossypol has been reported to affect a number of specific enzymes in mammalian systems (11). A similar decrease in alkaline phosphatase was also observed in the serum of Angora goats fed diets containing cottonseed for 132 days (9).

Reproductive performance was excellent when the heifers were bred. Nineteen of the 20 heifers were determined to be pregnant by palpation. The only open heifer had previously received the diet with 30 percent cottonseed, but in view of the small numbers involved this was not considered significant. Smith et al. (14) reported no apparent effect of feeding up to 6.4 lb of whole cottonseed dry matter per day on calving interval or on the incidence of displaced abomasum, ketosis, milk fever, or retained placenta in cows from commercial dairies. Likewise, Coppock et al. (4) concluded that there was no evidence of a detrimental effect of cottonseed on reproduction in the female. Williams et al. (15) reported positive responses in a number of reproductive parameters when whole cottonseed at levels of up to 30 percent of the dry matter was fed to beef cattle for short periods just prior to breeding.

## Literature Cited


1. Berardi, L.C., and L.A. Goldblatt. 1980. Gossypol. *In*: Toxic Constituents of Plant Foodstuffs. Ed. by I.E. Liener. Academic Press, New York. pp. 183-237.
2. Calhoun, M.C., J.E. Huston, B.C. Baldwin, Jr., S.W. Kuhlmann, B.S. Engdahl, and K.W. Bales. 1990. Effects of cottonseed meal source and dietary crude protein on performance of early-weaned lambs: with observations on gossypol toxicity. Tex. Agr. Exp. Sta. Prog. Rpt. 4790.
3. Calhoun, M.C., J.E. Huston, S.W. Kuhlmann, B.C. Baldwin, Jr., B.S. Engdahl, and K.W. Bales. 1990. Comparative toxicity of gossypol acetic acid and free gossypol in cottonseed meal and pima cottonseed to lambs. Tex. Agr. Exp. Sta. Prog. Rpt. 4779.
4. Coppock, C. E., J.K. Lanham, and J.J. Horner. 1987. A review of the nutritive value and utilization of whole cottonseed, cottonseed meal and associated by-products by dairy cattle. Anim. Feed Sci. Technol. 18:89-129.
5. Coppock, C.E., J.W. West, J.R. Moya, D.N. Nave, J.M. LaBore, K.G. Thompson, L.D. Rowe, Jr., and C.E. Gates. 1985. Effects of amount of whole cottonseed on intake, digestibility and physiological responses of dairy cows. J. Dairy Sci. 68:2248-2258.
6. Hawkins, G.E., K.A. Cummins, M. Silverio, and J.J. Jilek. 1985. Physilogical effects of whole cottonseed in the diet of lactating dairy cows. J. Dairy Sci. 68:2608-2614.
7. Lindsey, T.O., G.E. Hawkins, and L.D. Guthrie. 1980. Physiological responses of lactating cows to gossypol from cottonseed meal rations. J. Dairy Sci. 63:562-573.
8. Martin, S.D. 1990. Gossypol effects in animal feeding can be controlled. Feedstuffs 62 (33) :14-26.
9. Menges, W.L., G.R. Engdahl, C.J. Lupton, and M.C. Calhoun. 1991. Effects of feeding cottonseed on mohair growth and performance of Angora goats. Angelo State Univ., MIR Center Res. Rpt.
10. Nelson, D.A. 1979. Erythrocyte disorders. *In*: Todd, Sanford and Davidsohn's Clinical Diagnosis and Management by Laboratory Methods. (16th ed.). Ed. by J. B. Henrey. W. B. Saunders Co., Philadelphia. pp. 964-1035.
11. Nomeir, A.A., and M.B. Abou-Donia. 1985. Toxicological effects of gossypol. *In*: Male Fertility and its Regulations. Ed. by T.J. Lobl and E.S.E. Hafez. MTP Press Ltd., Boston. pp. 111-133.
12. Preston, R.L., S.J. Bartle, and D.C. Rule. 1989. Effect of whole cottonseeds in cattle finishing diets on growth, efficiency and body fat composition. Asian-Australasian J. Anim. Sci. 2:505-506.
13. SAS Institute Inc. 1985. SAS/STAT Guide for Personal Computers, Version 6 Edition, Cary, NC.
14. Smith, N.E., L.S. Collan, D.L. Bath, W.L. Dunkley, and A.A. Franke. 1981. Digestibility and effects of whole cottonseed fed to lactating cows. J. Dairy Sci. 64:2209-2215.
15. Williams, G.L., A.R. Morgan, and M.E. Wehrman. 1989. Effects of feeding high lipid supplements via whole cottonseed on reproduction in the cow and heifer. *In*: Use and Abuse of Cottonseed and Cottonseed Products in Cattle Diets: A 1989 Perspective. Tex. Agr. Exp. Sta. Information Rpt. 89-1.


TABLE 1. PERCENTAGES OF INGREDIENTS AND NUTRIENT COMPOSITION OF EXPERIMENTAL DIETS FED TO HEIFERS

| | % Whole cottonseed | | | |
|---|---|---|---|---|
| Ingredient | 0 | 10 | 20 | 30 |
| Sorghum grain, milo | 35.4 | 34.6 | 33.8 | 33.0 |
| Dehydrated alfalfa meal | 10.0 | 10.0 | 10.0 | 10.0 |
| Soybean meal | 12.0 | 8.0 | 4.0 | - - |
| Cottonseed hulls | 35.0 | 30.0 | 25.0 | 20.0 |
| Whole cottonseed | - - | 10.0 | 20.0 | 30.0 |
| Molasses | 5.0 | 5.0 | 5.0 | 5.0 |
| Calcium carbonate | 1.0 | 1.0 | 1.0 | 1.0 |
| Mono-dicalcium phosphate | .6 | .4 | .2 | - - |
| Vitamin-mineral premix[a] | 1.0 | 1.0 | 1.0 | 1.0 |
| Nutrient composition[b] | | | | |
| Dry matter, % | 89.3 | 89.5 | 89.6 | 89.8 |
| Total digestible nutrients, % | 66.7 | 69.8 | 73.0 | 76.2 |
| Crude protein, % | 14.1 | 13.9 | 13.8 | 13.6 |
| Calcium, % | .9 | .8 | .8 | .7 |
| Phosphorus, % | .4 | .4 | .4 | .4 |
| Free gossypol, ppm | 0 | 628 | 1253 | 1875 |

[a]The percentage composition of the premix was as follows: sodium chloride, 64.7; potassium chloride, 19.0; sulfur, 10.0; zinc oxide, .274; vitamin A (13.6 x $10^6$ IU/lb), .73; vitamin D (13.6 x $10^6$ IU/lb), .093; vitamin E (12.5 x $10^4$ IU/lb), .72; chlortetracycline, 3.0 and molasses, 1.5.
[b]Dry matter basis.

TABLE 2. PERFORMANCE OF YEARLING HEIFERS FED DIETS CONTAINING WHOLE COTTONSEED

| | % Whole cottonseed | | | | |
|---|---|---|---|---|---|
| Criterion | 0 | 10 | 20 | 30 | SEM[a] |
| Initial wt, lb | 595 | 602 | 643 | 585 | 21.7 |
| 1-28 days | | | | | |
| Live wt gain, lb/d | 2.4 | 2.4 | 2.4 | 2.5 | .22 |
| Feed intake, lb/d | 17.8 | 17.7 | 19.2 | 17.6 | .62 |
| Feed/gain | 7.5 | 7.9 | 8.4 | 7.1 | .81 |
| 29-56 days | | | | | |
| Live wt gain, lb/d[b] | 2.3 | 2.5 | 3.0 | 3.0 | .18 |
| Feed intake, lb/d | 25.2 | 24.0 | 27.0 | 25.9 | 1.02 |
| Feed/gain[b] | 11.2 | 9.9 | 9.0 | 8.9 | .72 |
| 1-56 days | | | | | |
| Live wt gain, lb/d[c] | 2.4 | 2.4 | 2.7 | 2.7 | .14 |
| Feed intake, lb/d | 21.5 | 20.8 | 23.1 | 21.7 | .80 |
| Feed/gain[d] | 9.1 | 8.6 | 8.6 | 8.0 | .44 |

[a]Standard error of the mean.
[b]Linear response (P<.01).
[c]Linear response (P<.05).
[d]Linear response (P<.10).

TABLE 3. FREE GOSSYPOL INTAKES AND OSMOTIC FRAGILITY OF ERYTHROCYTES OF YEARLING HEIFERS FED DIETS CONTAINING WHOLE COTTONSEED

| | % Whole cottonseed | | | | |
|---|---|---|---|---|---|
| Criterion | 0 | 10 | 20 | 30 | SEM[a] |
| Free gossypol intakes, | | | | | |
| mg/lb LW/d | | | | | |
| 1-28 days | 0 | 7.1 | 14.4 | 21.6 | .10 |
| 29-56 days | 0 | 8.7 | 18.3 | 28.3 | .30 |
| 1-56 days | 0 | 8.0 | 16.3 | 25.0 | .19 |
| g/day | | | | | |
| 1-28 days | 0 | 4.5 | 9.8 | 13.4 | .33 |
| 29-56 days | 0 | 6.1 | 13.7 | 19.7 | .57 |
| 1-56 days | 0 | 5.3 | 11.7 | 16.6 | .45 |
| Erythrocyte fragility[b] | | | | | |
| Initial | 5.0 | 11.2 | 4.7 | 7.9 | 3.6 |
| 28 days[c,d] | 8.6 | 9.4 | 10.7 | 12.6 | .87 |
| 56 days[c,d] | 7.7 | 10.4 | 14.0 | 20.2 | 2.54 |

[a]Standard error of the mean.
[b]Percentage hemolysis of erythrocytes in a buffered .6% salt solution.
[c]Significant linear response (P<.01).
[d]Adjusted by covariance for initial values.

TABLE 4. INITIAL VALUES FOR HEMATOCRIT AND SERUM CONSTITUENTS OF HEIFERS

| Item | Mean | SEM[a] |
|---|---|---|
| Hematocrit, % | 47.5 | ± .39 |
| Total protein, g/dl | 6.9 | ± .17 |
| Albumin, g/dl | 4.1 | ± .12 |
| Globulin, g/dl | 2.8 | ± .62 |
| Calcium, mg/dl | 10.6 | ± .19 |
| Phosphorus, mg/dl | 8.6 | ± .24 |
| Glucose, mg/dl | 92 | ± .85 |
| Urea nitrogen, mg/dl | 10 | ± .29 |
| Creatinine, mg/dl | 1.5 | ± .08 |
| Total bilirubin, mg/dl | 0.01 | ± .03 |
| Alkaline phosphatase, u/l | 141 | ± 1.6 |
| Creatine phosphokinase, u/l | 388 | ± 3.5 |
| Lactate dehydrogenase, u/l | 1080 | ± 2.1 |
| Aspartate aminotransferase, u/l | 56 | ± .62 |

[a]Standard error of the mean.

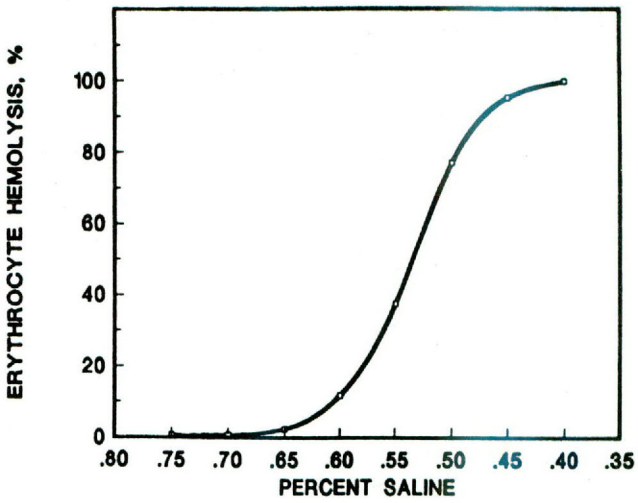



Figure 1. Osmotic fragility curve for erythrocytes of yearling Hereford x Brangus heifers.

TABLE 5. FINAL (56-DAY) VALUES FOR HEMATOCRIT AND SERUM CONSTITUENTS OF HEIFERS FED DIFFERING LEVELS OF WHOLE COTTONSEED IN THE DIET

| Item[a] | % Whole Cottonseed | | | | SEM[b] |
|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | |
| Hematocrit, % | 45.1 | 47.2 | 49.4 | 46.8 | 1.2 |
| Total protein, g/dl | 7.1 | 6.8 | 7.1 | 6.8 | .17 |
| Albumin, g/dl | 4.0 | 3.8 | 3.9 | 3.8 | .09 |
| Globulin, g/dl | 3.0 | 3.0 | 3.2 | 3.0 | .13 |
| Calcium, mg/dl | 10.6 | 10.4 | 10.6 | 10.2 | .14 |
| Phosphorus, mg/dl | 9.3 | 8.2 | 8.6 | 8.4 | .32 |
| Glucose, mg/dl | 90.1 | 87.2 | 85.7 | 82.8 | 3.4 |
| Urea nitrogen, mg/dl | 15.8 | 12.1 | 15.1 | 17.1 | 1.2 |
| Creatinine, mg/dl | 1.40 | 1.43 | 1.48 | 1.39 | .04 |
| Total bilirubin, mg/dl | .08 | .03 | .08 | .08 | .02 |
| Alkaline phosphatase, u/l[c] | 192 | 166 | 140 | 121 | 11 |
| Creatine phosphokinase, u/l | 608 | 335 | 262 | 251 | 121 |
| Lactate dehydrogenase, u/l | 1307 | 1236 | 1323 | 1221 | 54 |
| Aspartate aminotransferase, u/l | 72 | 74 | 77 | 72 | 2.6 |

[a]Covariance analysis was used to adjust all values for differences in initial values.
[b]Standard error of the mean.
[c]Significant linear response (P<.01).

# Efficacy of Selenium Supplementation to South Texas Stocker Calves

L.W. Greene and J.C. Paschal


## Summary

One hundred fourteen crossbred calves (avg wt 395 lb) were used to determine the effects of selenium supplementation on weight gain and whole blood selenium concentrations. Calves were blocked by sex (8 steers and 106 heifers) and randomly assigned to either a control or selenium treatment group. Selenium treated calves were dosed with 360 mg selenium as sodium selenite via a Dura Se®-120 bolus (Schering Animal Health, Schering Corporation, Kenilworth, NJ). Dura Se®-120 is designed to deliver 3 mg selenium/day for 4 months. Calves were weaned, vaccinated and weighed at the initiation of the study. Calves grazed wheat forages beginning January 4, 1990 for 105 d. Post grazing, calves were weighed,coat color (1=not faded, no coat discoloration, 9=faded coat, bleached) and quality scored (1=dull, long hair, 9=slick, shiny coat), and condition scored (1=thin, 9=fat). Whole blood selenium concentrations averaged 0.17 ppm at the initiation of the study. However, 35 percent of the calves had deficient whole blood selenium concentrations (0.15 ppm or less). Whole blood selenium concentrations were 47 percent greater (P<.01) in calves treated with selenium 105 d post treatment when compared to controls (0.28 vs 0.19 ppm, respectively). At the beginning of the study, all calves had a substantial amount of long-dead discolored hair over the entire body. Selenium treated calves had a greater (P<.08) coat quality score post grazing than controls. Calves treated with selenium were in better (P<.001) body condition (4.8) than control calves (4.3) post grazing. Calves in both treatment groups had similar (P>.10) weight gains throughout the study. Although calf weight gains were not significantly increased, selenium supplemented calves had a higher whole blood selenium concentration and visual body condition 105 d post treatment, which may have beneficial effects on immune function and stress tolerance if subjected to stress associated with the typical transition from grazing to the feedlot.


## Introduction

Mineral supplementation research studies have been difficult to conduct and have generated inconclusive results due to the lack of experimental techniques. Limited replication and low numbers of experimental units have been a major problem when conducting mineral supplementation research. Generally, the entire herd has to be considered as the experimental unit since all animals in the herd have access to the same mineral supplement. However, with the advent of trace mineral boluses designed to slowly release mineral into the rumen compartment of the stomach for a period of months, grazing mineral research can be adequately replicated and conducted.

Selenium is a trace mineral that has not been adequately researched in all areas of the United States. Soil and forage selenium concentrations in the northeastern, southeastern, and northwestern parts of the U.S. are well documented to be severely deficient. Without selenium supplementation to feeder cattle produced in these areas, animal production will not reach an optimum. However, at the other extreme, certain plants grown in the Dakotas, Nebraska, and Wyoming can accumulate significant quantities of selenium which, if eaten by livestock, create a selenium toxicity. Many other areas in the U.S. have been considered adequate in selenium, however, new evidence exists to suggest that these areas may vary greatly in their ability to supply adequate selenium for optimal livestock production. Previous data collected by our laboratory suggest that selenium supplementation may be needed to optimize animal production in certain areas of Texas. The objective of this project is to determine the efficacy of supplementing selenium to South Texas stocker calves.

## Experimental Procedures

One hundred six heifers and eight steers (average weight, 395 lb) were used in the study. Calves were sired by Simmental bulls and were out of Chianina x Angus or Angus dams. The study area included two pastures located on the Cannonade Ranch in Gonzales County, Texas. Calves were weighed individually and whole blood obtained in heparinized tubes for selenium analysis at the beginning of the study. Calves were grazed initially on a 90 acre pasture seeded with winter wheat and subsequently moved to an 111 acre pasture containing 80 acres of winter wheat and 31 acres of Coastal bermudagrass sod. At the initiation of the trial (January 4, 1990) calves were weighed, injected with 2 cc of VITAJECT ADE® and 4 cc of IVOMEC®, and vaccinated with 5 cc of IBR®, PI3, BRSV Cattle Master 4 + Vibrio-Lepto 5, and 5 cc of 7-way clotridial. Calves were randomly separated into two groups and assigned to either a control or selenium supplemented group. The selenium supplemented group was treated via orally

dosing with 360 mg selenium as sodium selenite using Dura Se® 120 boluses (Schering-Plough Corporation). On day 105 calves were removed from grazing pastures. Calves were individually weighed and whole blood samples obtained in heparinized tubes. Calves were coat color scored (1=normal, 5=gray, reddish, dun, 9=whole body faded, off color), coat quality scored (1=long, rough coat, 9=bloomy, bright), and body condition scored (1=thin, 9=fat). Calves were then housed in a single pen and started on a high concentrate diet. One calf was removed in early June due to health related reasons (selenium treatment group) and sold. Eighteen calves were sold on August 10 and the remaining 95 were sold on September 14. Data were analyzed using analysis of variance.

## Results and Discussion

Whole blood selenium concentrations are shown in Table 1 for steers and heifers at the beginning and end of the grazing period. Whole blood selenium concentration averaged 0.165 ppm at the beginning of the study and was not affected by sex. Our laboratory results indicate that the desirable concentrations of whole blood selenium is 0.15 ppm. Forty-one percent of the calves had whole blood selenium concentrations of 0.15 ppm or below at the initiation of the study. Whole blood selenium concentrations increased 75 percent ($P<.03$) from the January 4 sampling date to the April 19 sampling date when calves were treated with the Dura Se® 120 bolus, but not when maintained as a control. On the April 19 sampling date 19 (17 g) calves had whole blood selenium concentrations below the desirable level. However, of the calves with low selenium concentrations, 80 percent were calves not receiving the Dura Se® 120 bolus. There was an increase ($P<.01$) in whole blood selenium concentrations of 0.12 ppm compared to 0.02 ppm for controls when calves were treated with selenium. On April 19, selenium treated calves had a 48 percent increase ($P<.03$) in whole blood selenium concentrations compared to non-treated controls.

Initial calf weight averaged 395 lb (Table 2). At the termination of the grazing period, calf weight averaged 610 lb, an increase of 215 lb. Although not statistically significant due to the high degree of variation there was a 5 percent gain response (219 vs 212 lb) in favor of the calves that were dosed with Dura Se® 120. Average daily gain was similar to other studies of calves grazing small grain forages in this region; 2.1 and 2.0 lb/day for treated and control groups, respectively.

Coat quality, coat color, and body condition scores were recorded at the conclusion of the grazing period (Table 3). Coat color was not affected due to experimental treatment, but coat quality was improved ($P<.08$) when calves were given Dura Se® 120. General observations made at the time of sampling on April 19 suggested that treated animals had shed winter coats more readily than control calves. Although there was no difference in weight gain due to treatment, treated calves had better ($P<.002$) body condition scores than non-treated controls (4.8 vs 4.3).

As steers entered the feedlot, they were monitored for health related problems. There were no significant differences between treatment groups in herd health status. Four calves (two treated and two control) were moved to the sick pen and treated during the feedlot period with Naxel for 3 days and with penicillin on day 4 prior to returning to their original pen. A control calf was removed from the study prior to termination due to health and low performance. The final ending weight of calves was 981 lb with no apparent differences due to treatment. The calves used in this experiment were finished on the ranch where grazing occurred and were not sufficiently stressed to test the effect of selenium supplementation during grazing on subsequent health and performance in the feedlot. Additional studies are needed to determine the role of trace mineral supplementation during grazing on immune responsiveness of cattle when they enter the feedlot.

## Acknowledgments

Appreciation is expressed to Mr. Orval Wright, County Extension Agent, Gonzales, TX and Mr. John Thiele, Manager, Cannonade Ranch, Gonzales, TX for assistance in livestock management and data collection.

TABLE 1. EFFECT OF SELENIUM SUPPLEMENTATION ON WHOLE BLOOD SELENIUM CONCENTRATIONS IN STEER AND HEIFER CALVES GRAZING SMALL GRAIN FORAGES

| | Control | Selenium Treated | Probability Value |
|---|---|---|---|
| Sampling date, 1990 | ----------ppm--------- | | |
| January 4 | .17 | .16 | P < .31 |
| April 19 | .19[a] | .28[b] | P < .03 |
| Change | .02[a] | .12[b] | P < .01 |

[a,b]Means with different superscripts differ.

TABLE 2. EFFECT OF SELENIUM SUPPLEMENTATION OF STEER AND HEIFER CALF WEIGHTS WHILE GRAZING SMALL GRAIN FORAGES

| | Control | Selenium Treated | Probability Value |
|---|---|---|---|
| Sampling date, 1990 | | | |
| January 4 | 396 | 392 | P < .83 |
| April 19 | 608 | 611 | P < .74 |
| Total gain | 212 | 219 | P < .85 |
| Average daily gain | 2.0 | 2.1 | P < .85 |

TABLE 3. EFFECT OF SELENIUM SUPPLEMENTATION ON COAT QUALITY, COAT COLOR AND BODY CONDITION SCORES OF STEER AND HEIFER CALVES GRAZING SMALL GRAIN FORAGE

| | Control | Selenium Treated | Probability Value |
|---|---|---|---|
| Coat quality[a] | 4.2[d] | 4.6[e] | P < .08 |
| Coat color[b] | 5.4 | 5.2 | P < .84 |
| Body condition[c] | 4.3[d] | 4.8[e] | P < .002 |

[a]Coat quality, 1 = long, dead, rough coat, 9 = bloomy, bright, slick.
[b]Coat color, 1 = normal, 9 = whole body faded, off color.
[c]Body condition 1 = thin, 9 = fat.
[d,e]Means with different superscripts differ.

# Effects of Supplemental Sources of Energy or Protein for Calves Grazing Late Season Bermudagrass Pasture

T.M. Hill, S.D. Martin and W.C. Ellis


## Summary

Four supplements containing either corn plus urea, cottonseed meal, feather meal, or fish meal were individually fed to Brahman x Holstein heifers (average initial body weight of 268 pounds) grazing late season bermudagrass (7.7% crude protein). Forage organic matter intake was low (1.8% of body weight) and provided for less than 0.4 pounds of daily gain. All treatments met the requirement for ruminally degraded protein but only the fish meal and feather meal treatments approached the requirement for escape protein. The first limiting nutrient when young calves grazed poor quality bermudagrass was energy and the second limiting nutrient was escape protein.


## Introduction

Young, growing calves often do not achieve maximum gains while grazing summer forages. Maximum performance could be limited due to insufficient metabolizable nutrients to provide energy or protein. Various commercial supplements are available and often implemented in supplementation programs by Texas cattlemen. This study was designed to evaluate energy vs protein supplementation of lightweight growing calves that grazed late season bermudagrass.

## Experimental Procedure

The study was conducted in Brazos County during October and November of 1988 prior to any frosts. Animals grazed common bermudagrass and had constant access to shade and fresh water.

Four supplements (Table 1) consisting primarily of corn plus urea (CORN; 16% CP), solvent cottonseed meal (CSM), feather meal (FE) and Menhaden fish meal (FI) blended with molasses, minerals and lasalocid were fed to eight Brahman x Holstein heifers (mean initial body weight=268 lbs) in a two period, partial cross-over design. The high protein supplements (CSM, FE and FI; 34% CP) were fed at 0.5 percent of body weight and CORN was fed at 0.44 percent of body weight (both on a dry matter basis) to provide equal metabolizable energy intake from the supplements. The daily allotment of supplement was fed to individually penned heifers at 700 and 1700 h. One half the allotment was fed at 700 and the other half at 1700 h.

Four markers were constantly infused into the rumen of the calves via a peristaltic pump. The pump and liquid reservoirs were contained within a pack strapped to each animal's back. The markers used were Cobalt (Co III) - diethylenetrinitrilopentacetic acid (DTPA), Samarium (SM III) - DTPA, Ytterbium (Yb III) acetate, and Lanthium (La III) acetate. The liquid phase markers, Sm-DTPA and Co-DTPA, were within a common reservoir with $Na_2{}^{35}SO_4$ and $Na_2{}^{32}PO_4$, two isotopic markers used to label microbial protein. A second reservoir contained the indigestible flow markers, Yb and La acetates. These procedures are common to the procedures described in detail by Hill et al. (1). Additionally, ingestively masticated bermudagrass, collected via an esophageally cannulated steer was analyzed for indigestible neutral detergent fiber (INDF) along with digesta samples to estimate digestibility and intake of the forage.

Ruminal, duodenal, and fecal samples were collected from each animal at 700, 1200, 1700, and 2400 h on each of two consecutive days at the end of each 21 d grazing period. Microbial protein flow to the duodenum was determined by the ratio of trichloroacetic acid insoluble $^{35}S$ (TCAI $^{35}S$) to microbial protein (MP) in microbial preparations from ruminal particles to the ratio of TCAI $^{35}S$ to flow markers in whole duodenal digesta (2). Digesta samples were analyzed individually for flow and microbial markers, true protein, and ammonia. Digesta samples composited by animal within period were analyzed for neutral detergent fiber (NDF), INDF, total nitrogen, dry matter, and ash.

Statistical analysis of the data was as a partial cross-over design (as a split-split plot when appropriate) using the general linear model procedure of SAS (4). Logical contrast statements were used to separate possible treatment differences between 1) energy from corn vs energy from protein (CORN vs CSM, FE, FI), 2) ruminal degradable vs ruminal escape protein (CSM, FE, FI) and 3) unbalanced vs balanced amino acids of escape protein (FE vs FI).

## Results and Discussion

Forage composition is reported in Table 2. Forage true protein was low (7.3%), yet typical of unfertilized bermudagrass in late fall. Voluntary forage plus supplement intake is reported in Table 3. Organic matter intake (OMI) was low (mean of 1.8%

body weight) and tended to be greatest for FI supplemented animals; however, statistically the treatments did not differ (>.2). Although not statistically significant, intake differences of this magnitude (FI 25% greater than FE) appear to be significant from a production standpoint.

Ruminal digestibility of organic matter was low for all treatments, indicative of the high fiber content of late season bermudagrass. The ruminal digestibility of feed organic matter for CSM supplemented calves was lower (P<.05) than for FE and FI supplemented calves. When forage protein content is low, one generally expects ruminally degradable protein to stimulate ruminal digestion; however, it appears that ruminally degradable protein did not limit digestion. Ruminal ammonia concentrations averaged 11.6, 25.0, 14. 6 and 14.4 mg $NH_3$ Per 100 ml of ruminal fluid for CORN, CSM, FE and FI, respectively.

Total tract digestion appeared lowest for CSM and FE. Apparent organic matter digestion was lower (P<.05) for FE than for FI supplemented calves.

The protein flow to the duodenum (Table 3) had the following ranking: CORN <CSM <FE <FI. All contrast statements for protein flow to the duodenum were significant (P<.05). Microbial true protein flow to the duodenum did not differ (P>.10) due to supplement. Differences in total true protein flow to the duodenum can be attributed to true feed protein escaping ruminal degradation. True feed protein escaping ruminal degradation had the following ranking: CORN <CSM <FE = FI.

In a separate in situ study, the ruminal escape of CORN protein was determined to be 35 percent. Applying the value of 35 percent to the flow of escape of total feed protein to the duodenum observed in the current study, ruminal escape of bermudagrass forage protein was calculated to be 68 percent. Assuming 68 percent escape for bermudagrass protein to be unaffected by supplemental treatment, the escape fractions of the other supplemental protein could be calculated (Table 3). Ruminal escape of supplemental proteins within the high protein supplements had the following ranking: CSM < FI<FE. These values were generally lower than literature values (corn=58-73 percent; cottonseed meal=24-61 percent; fish meal=68-71 percent; reference 3). The literature values have generally been determined using high concentrate diets having a faster rate of passage and thus a shorter ruminal residence time. A shorter ruminal residence time would result in a greater fraction escaping due to less time for microbial degradation.

Figure 1 reflects the observed flux of energy and protein among the four treatments as a percentage of the requirements (3) met to achieve 0.44 pounds of daily gain. Requirements for metabolizable energy or escape protein were not met by any of the treatments, yet requirements for ruminally degraded intake protein were met by all treatments. Had urea not been included in the CORN supplement, ruminally degraded intake protein for CORN supplemented calves would have been less than 60 percent of the requirement to gain 0.44 pounds per day. The need to supplement ruminal escape protein such as FI or FE is apparent.

The bermudagrass was approximately 50 percent digestible and low in protein (less than 8%). Low consumption of this poor quality forage will restrict gains in these young calves. Animal performance will only be as great as the nutrient supply of first limiting nutrient. In this study, metabolizable energy was first limiting and thus the added protein supply to the duodenum via protein supplementation (CSM, FE and FI) will not maintain gains beyond the energy supply.

## Literature Cited


1. Hill, T.M., and W.C. Ellis. 1990. A simplified procedure for the simultaneous estimation of organically bound 35S, 32P and diaminopimelic acid and protein in ruminant digesta. Beef Cattle Research in Texas. pp. 132-135.
2. Hill, T.M., S.D. Martin, and W.C. Ellis. 1990. Use of continuously infused markers to estimate synthesis of microbial protein and ruminal escape dietary protein in grazing calves. Beef Cattle Research in Texas. pp. 136-144.
3. NRC. 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, DC.
4. SAS. 1985. SAS User's Guide: Statistics. SAS. Inst., Inc., Cary, NC.


TABLE 1. COMPOSITION OF SUPPLEMENTS USED IN THE EXPERIMENT

| | Supplements | | | |
|---|---|---|---|---|
| Ingredient | CORN | CSM | FE | FI |
| | ----------% dry matter---------- | | | |
| Cottonseed meal | | 73.5 | | |
| Feather meal | | | 38.6 | |
| Fish meal | | | | 47.2 |
| Corn | 77.0 | 7.3 | 40.3 | 35.8 |
| Molasses | 15.0 | 15.0 | 15.0 | 15.0 |
| Fish oil | 3.0 | 2.2 | 4.1 | |
| Salt | 2.0 | 2.0 | 2.0 | 2.0 |
| Urea | 3.0 | | | |
| | ----------g/lb---------- | | | |
| Limestone | .48 | 1.71 | 1.71 | |
| Dicalcium phosphate | | 1.17 | 2.02 | |
| Microminerals | 2.00 | .80 | .92 | .70 |

TABLE 2. FORAGE COMPOSITION FOR BOTH PERIODS OF THE EXPERIMENT

| Component | Period 1 | Period 2 |
|---|---|---|
| | --------% dry matter------- | |
| Organic matter | 93.7 | 93.0 |
| Neutral detergent fiber | 74.2 | 73.7 |
| Indigestible neutral detergent fiber | 30.1 | 32.1 |
| Crude protein | 7.6 | 7.9 |
| True protein | 7.3 | 7.3 |
| | ------% true protein------ | |
| Salivary insoluble protein | 93.6 | 88.0 |

TABLE 3. TOTAL ORGANIC MATTER INTAKE, DIGESTIBILITY, FLOW OF TRUE PROTEIN TO THE DUODENUM AND RUMINAL ESCAPE OF SUPPLEMENTAL PROTEIN

| Item | Supplements[a] CORN | CSM | FE | FI | SEM[b] |
|---|---|---|---|---|---|
| Organic matter | | | | | |
| Intake, % of body weight | 1.84 | 1.74 | 1.61 | 2.02 | .139 |
| Ruminal digestibility, % | | | | | |
| Apparent | 30 | 26 | 28 | 30 | 1.8 |
| Feed[c] | 39 | 36 | 38 | 39 | 1.2 |
| Total tract digestibility, % | | | | | |
| Apparent[d,e] | 57 | 50 | 49 | 57 | 1.4 |
| Duodenal true protein flow, % of body weight | | | | | |
| Total[c,d,e] | .200 | .213 | .241 | .265 | .0050 |
| Microbial | .107 | .107 | .103 | .118 | .0026 |
| Feed[c,d] | .093 | .106 | .138 | .147 | .0055 |
| Ruminal escape of supplemental protein % of intake | 35 | 23 | 45 | 47 | |

[a]Primary source of protein from supplements were: CORN = corn + urea; CSM = solvent cottonseed meal; FE = feather meal; FI = Menhaden fish meal.
[b]Standard error of the mean.
[c]CSM vs FE, FI ($P < .05$).
[d]CORN vs CSM, FE, FI ($P < .05$).
[e]FE vs FI ($P < .05$).

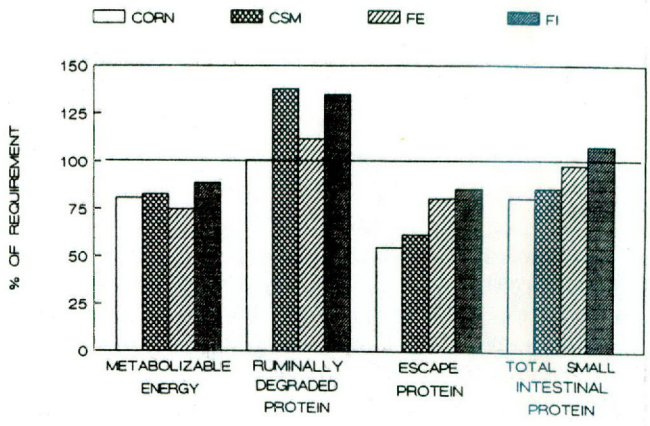



**Figure 1.** Flux of nutrients observed as a percentage of nutrients required by a 300 pound calf to gain .44 pounds daily. The actual gain is limited by the metabolizable energy or total small intestinal protein in the lowest supply relative to requirements.

# Effects of Supplemental Sources of Energy or Protein for Calves Grazing Ryegrass Pasture

T.M. Hill, S.D. Martin and W.C. Ellis


## Summary

Seven supplements containing minerals only, corn, cottonseed meal, blood meal, feather meal, fish meal, or condensed molasses with cottonseed meal were individually fed to Brahman x Holstein calves (average initial body weight of 444 pounds). The calves grazed ryegrass pastures (24.3% crude protein) during March, April and the first week of May in 1989. Forage organic matter intake (65% digestible) was increased by blood and fish meal supplements and depressed by cottonseed and feather meal supplements. Blood and fish meal supplements appear more effective in supplying required protein and essential amino acids that stimulate voluntary intake of forage.


## Introduction

Winter annual forages such as wheat, oats, ryegrass, and rye are highly digestible high protein forages. When a cattleman examines the composition of winter annuals he may not suspect the need for supplemental nutrients; however, past research has indicated that supplemental nutrients can increase gain. Due to the extensive ruminal protein degradation of winter annual forages, energy or starch supplementation has been suggested to more efficiently capture the ruminally degraded protein as microbial protein. Supplementing escape protein sources may be useful since research has indicated that the efficiency of microbial protein synthesis in calves grazing winter pasture is poor. The objective of this study was to evaluate various sources of supplemental nutrients for calves grazing ryegrass pastures to determine voluntary intake of forage, digestibility, and protein supply to the small intestine.

## Experimental Procedure

During March, April, and the first week of May 1989, seven Brahman x Holstein heifers with an initial average body weight of 444 pounds were given constant access to ryegrass pasture with fresh water and shelter. Six supplemental treatments were provided twice daily to the calves when they were individually penned at 7 am and 5 pm. These six treatments included a mineral mixture, dosed into the rumen (MIN; 72 g/d) and five meal-form, hand fed supplements. The five meal-form supplements included corn and minerals alone (CORN) or corn and minerals plus either cottonseed meal (CSM), blood meal (BM), feather meal (FE), or Menhaden fish meal (FI). A seventh treatment was a condensed molasses, commercial product (PDQ), fed ad libitum to one test animal and one companion animal in an adjacent ryegrass pasture. The meal-form supplements were fed at the rate of 0.35 percent of body weight (dry matter basis) split into two equal portions with one portion for each of the twice daily pennings. All supplements except PDQ provided equal mineral intake. All supplements except MIN and PDQ provided equal metabolizable energy intake and all supplements except MIN, CORN, and PDQ provided equal crude protein intake. Supplement compositions are shown in Table 1.

A particulate flow marker solution of Ytterbium acetate was constantly infused into the rumen of each via a pump strapped to each animal's back. The flow marker solution also contained $Na_2{}^{35}SO_4$ and $Na_2{}^{32}PO_4$, used to label microbial protein. A separate solution of Europlum acetate was pulse dosed into the rumen of each calf at 7 am and 5 pm daily to serve as an additional flow marker. The concentration of trichloroacetic acid insoluble $^{35}S$ (TCAI $^{35}S$) in microbial preparations made from duodenal liquid fractions in relation to the ratio of TCAI $^{35}S$ in whole duodenal samples was used to quantitate the concentration of microbial protein (2). Additionally, ingestively masticated bermudagrass collected using an esophageally cannulated cow was analyzed for indigestible neutral detergent fiber along with digesta samples to calculate digestibility and intake. Chemical analysis of forage and digesta was as described in (3).

There were three grazing periods arranged in a 3 x 7 Youden square design. Statistical analysis of the data was a Youden square using a split-split plot extension for sampling parameters when appropriate. Logical contrast statements were used to compare treatments based on the following:

1) mineral supplementation (MIN) vs all other supplements,
2) mineral supplementation (MIN) vs energy from corn (CORN)
3) energy from corn (CORN) vs energy from protein (CSM, BL, FE, FI, PDQ),
4) ad libitum protein (PDQ) vs meal-form protein (CSM, BL, FE, FI),
5) ruminal degradable (CSM) vs ruminal escape (BL, FE, FI) protein and
6) unbalanced amino acids (FE) vs balanced amino acids (BL, FI) of escape protein.

Analysis was accomplished using the general liner model on SAS (5).

## Results and Discussion

There was one missing data cell; however, all means are reported as numeric means. Intake of PDQ was measured to be 0.2 percent of body weight over the three grazing periods. Ad libitum intake of PDQ was less than intake of the meal supplements (0.35% of body weight). Since protein content of PDQ (28% CP) was less than the other protein supplements (37.5% CP), supplemental protein intake was also lower for PDQ than the other protein supplements.

Protein of the forage declined as fiber increased over the grazing periods (Table 2). Forage organic matter intake was apparently stimulated by the protein supplements with more favorable amino acid balance (BL and FI) and depressed by supplements with less favorable amino acid balance (FE, CSM, PDQ and possibly CORN) when compared to MIN (Figure 1). Numerically BL and FI supplemented calves had 19 and 5 percent greater organic matter intakes than MIN and CSM and FE supplemented calves had 21 percent smaller organic matter intakes than MIN.

Ruminal and total tract organic matter digestion appeared to be stimulated by all supplements; however, none of the contrast statements was significant. Apparent total tract digestibility of organic matter averaged 65 percent for combined treatments.

Protein flow to the duodenum (Figure 2) did not differ statistically due to treatment; however, numerical differences among treatments were large, which indicated very heterogenous outflow of total and microbial protein from the rumen. Numerically, the escape protein supplements provided the most protein to the duodenum. However, escape of the supplemental protein from the rumen was not the single cause for greater protein flow to the duodenum of calves receiving BL, FE, and FI. The ruminal escape of forage protein (19%) was calculated from the MIN supplemented calves and applied to calculate the escape of supplemental protein for the other treatments. The ruminal escape percentage for supplements considered to have high escape potential, BL, FE, and FI, were 56, 73, and 54, respectively, compared to 50 and 84 for CSM and PDQ, respectively. There was no great difference between CSM, BL, and FI ruminal escape values. However, total and escape true protein flow to the duodenum appeared greater for BL and FI than CSM due to greater forage intakes for BL and FI versus CSM. The low forage protein intake for FE supplemented calves was compensated by a large supplemental protein escape.

Ruminal escape values for the supplements were greater in the current study on ryegrass pastures relative to a previous study using the same heifers on bermudagrass pastures (3). The ruminal escape percentages for common supplements on bermudagrass were 23 (CSM), 45 (FE), and 47 (FI). The differences in ruminal escape of supplements common to the ryegrass and bermudagrass experiments may be primarily due to a faster rate of supplemental residue passage on ryegrass than bermudagrass (means were 11%/h vs 3%/h; data not shown).

Figure 3 depicts the percentage of requirements (4) met for 450 pound heifers to gain 2.2 pounds per day. The requirement for ruminally degraded protein was far exceeded. Escape protein requirements were met for BL, FE, and FI supplemented calves; however, the total small intestinal protein requirements were not met by any of the treatments. Metabolizable energy requirements were met by BL and almost met by FI supplemented calves.

Total small intestinal protein requirements were not met by any of the treatments because the efficiency of microbial protein synthesis was very low. Microbial efficiency did not differ due to supplement and averaged 6.4 g of microbial protein per 100 g of feed organic matter digested in the rumen.

The measurements taken in this experiment reflect differences in intake and protein flow that occur over the short term of about 2 weeks. These short term differences in forage intake are probably reflections of nutrient balances at the tissue level of protein to energy or among amino acids (1) supplied by BL and FI. Supplemental treatments appeared to have their greatest effect on forage intake. If these differences in forage intake observed persist over the entire grazing season, supplements BL and FI would be most advantageous. Ryegrass provides more ruminally degraded protein than required, so supplemental protein should be in the form of ruminal escape protein. It has been speculated that supplying supplemental energy sources would capture more of the ruminally degraded protein, increase microbial protein synthesis, and provide more protein to the duodenum. However, an increase in microbial efficiency was not observed and may be attributed to poor synchronization of supplemental energy with the forage protein degraded in the rumen. More information is needed concerning why microbial efficiency is low and how microbial capture of ruminally degraded protein can be improved in cattle grazing ryegrass.

## Literature Cited


1. Harper, A.E., N.J. Benevenga, and R. M. Wohlhueter. 1970. Effects of ingestion of disproportionate amounts of amino acids. Physiol. Red. 50:428.
2. Hill, T.M., and W.C. Ellis. 1990. A simplified procedure for the simultaneous estimation of organically bound $^{35}S$, $^{32}P$ and diaminopimelic acid and protein in ruminant digesta. Beef Cattle Research in Texas. pp. 132-135.
3. Hill, T.M., S.D. Martin, and W.C. Ellis. 1991. Effects of supplementing various sources of energy and protein to calves grazing late season bermudagrass pasture. Beef Cattle Research in Texas. In press.
4. NRC. 1985. Ruminant Nitrogen Usage. National Academy Press, Washington, D.C.
5. SAS. 1985. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

TABLE 1. COMPOSITION OF SUPPLEMENTS

| Item | Supplements MIN | CORN | CSM | BL | FE | FI | PDQ |
|---|---|---|---|---|---|---|---|
| | ----------% dry matter---------- | | | | | | |
| Cottonseed meal | - | - | 81 | - | - | - | 11.9 |
| Blood meal | - | - | - | 39.5 | - | - | .8 |
| Feather meal | - | - | - | - | 43 | - | - |
| Fish meal | - | - | - | - | - | 55.7 | - |
| Corn | - | 80.5 | - | 40.6 | 37.6 | 32.0 | - |
| Molasses | - | 10 | 10 | 10 | 10 | 10 | 67 |
| Salt | 17.8 | 2 | 2 | 2 | 2 | 2 | - |
| Other | - | - | - | - | - | - | a |
| Limestone | 26.3 | 3.0 | 6.2 | 2.7 | 3.4 | - | - |
| Dicalcium phosphate | 51.6 | 4.2 | .5 | 4.8 | 3.7 | - | 4.37 |
| Micromineral mix | 2.99 | .18 | .18 | .25 | .18 | .15 | - |
| Bovatec | 1.31 | .15 | .15 | .15 | .15 | .15 | - |
| Crude protein | - | 8.0 | 37.5 | 37.5 | 37.5 | 37.5 | 28.0 |

[a]Contained 1% of total dry matter of the following: 6.5% urea, .97% trace mineral mix, 3.18% meat scraps, 1.95% fish solubles, .71% soy oil, 1.36% lechithin, .97% hydrated lime, .28% Vitamin A, D & E mix.

TABLE 2. FORAGE COMPOSITION FOR EACH GRAZING PERIOD

| Item | Grazing period 1 | 2 | 3 |
|---|---|---|---|
| | ----------% of dry matter---------- | | |
| Crude protein | 27.6 | 25.0 | 20.3 |
| True protein | 23.5 | 20.5 | 15.8 |
| Neutral detergent fiber | 36.9 | 37.4 | 39.6 |
| Indigestible neutral detergent fiber | 7.4 | 11.7 | 13.1 |
| | ----------% of true protein---------- | | |
| Salivary insoluble true protein | 72.9 | 74.7 | 77.4 |

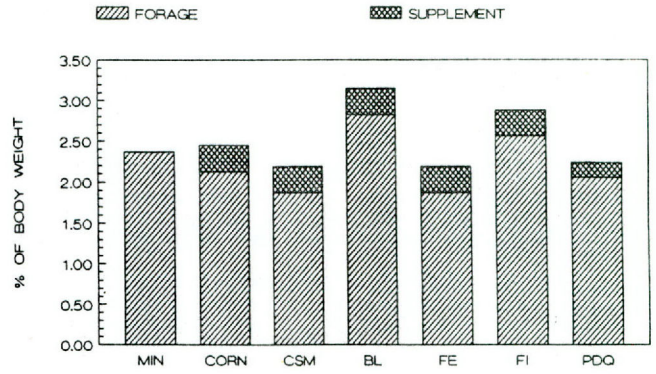



Figure 1. Voluntary intake of ryegrass and supplemental organic matter.

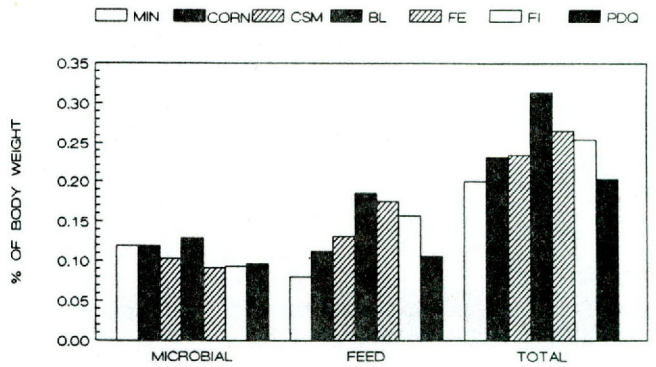



Figure 2. Microbial, feed and total true protein flow to the duodenum.

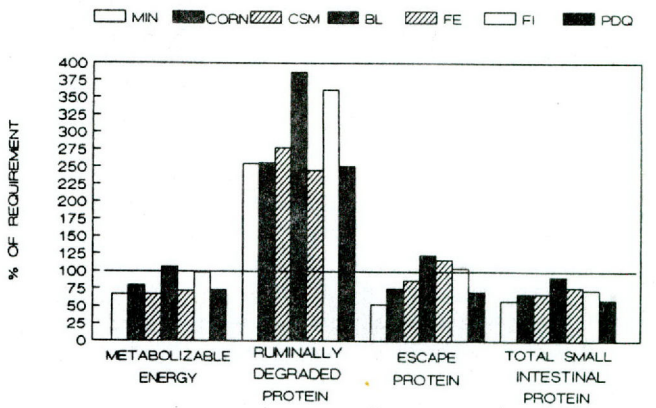



Figure 3. Flux of nutrients observed as a percentage of nutrients required by a 440 pound calf to gain 2.2 pounds daily. The actual gain is limited by the metabolizable energy or total small intestinal protein in the lowest supply relative to requirements.

# Metacarpal Characteristics of Steers and Heifers Implanted with Synovex S or H

L.A. Hurley, L.W. Greene, D.K. Lunt, F.M. Byers and G.E. Carstens


## Summary

Forty-seven steer and 48 heifer calves were used to determine the effect of an estrogenic anabolic agent upon feedlot performance and skeletal growth. Calves were blocked by sex and sire breed, and were assigned to either a control or implant treatment group. Implanted calves received Synovex C within 45 days of birth and were re-implanted with either Synovex S or Synovex H at weaning and at 84 and 169 days post weaning. Calves nursed cross-bred cows, grazing native and oat pastures. Stocker and feedlot phases lasted 169 and 124 days, respectively. During the stocker phase, calves grazed oat pastures. Calves were fed, ad libitum, a high concentrate corn based diet during the feedlot phase.

At slaughter, right and left metacarpals were excised. Measurements were made on the right metacarpal bones only. Metacarpal weights, lengths, cortical areas, medullary areas, thicknesses, widths, cross sectional areas, and breaking loads were measured. An interaction occurred between implant treatment groups and sex for bone weight (P<.08) and length (P<.07). Implanted steer metacarpal weights were 16.5 percent greater than implanted heifer metacarpal weights, and non-implanted steer metacarpal weights were 28.4 percent greater than non-implanted heifer metacarpal weights. Implanted steer metacarpal lengths were 1.9 percent greater than implanted heifer metacarpal lengths and non-implanted steer metacarpal lengths were 5.4 percent greater than non-implanted heifer metacarpal lengths. Metacarpal thicknesses were similar across treatment groups. Metacarpal widths were greater in steers vs heifers (1.71 vs 1.58 in, P<.0001) and medullary areas were similar for implant treatment groups and 11 percent greater (P<.09) in steers vs heifers.

Implanted cattle had greater cross sectional areas at the breaking point than did non-implanted cattle. The cross sectional areas were 15.4 percent greater (P<.0001) for steers compared to heifers. The cortical areas at the breaking point were smaller (P<.06) for implanted vs non-implanted cattle and larger (P<.0001) for steers vs heifers. The breaking loads were not affected by sex. Implanted cattle had greater (P<.02) metacarpal breakings loads than did non-implanted cattle (1420.5 vs 1266.2 lb, respectively). These data indicate anabolic implants alter bone characteristics in steers and heifers.


## Introduction

Anabolic implants have been used extensively in the beef cattle industry in order to maximize the performance of growing cattle on pasture or in the feedlot. It is well documented that anabolic agents enhance protein deposition while decreasing fat deposition in growing cattle. The effect of anabolic agents on bone growth has not been clearly established. Our laboratory, in previous studies, has shown that implanting with Synovex S increased bone breaking strength in steers (1) and implanting with Synovex S or H increased pelvic width, height, and resulted in a 13.1 percent (P<.05) increase in pelvic area opening (2). Implanting with zeranol increases the elasticity and cortical areas of steer metacarpal bones (3). The objective of this study was to investigate the effects of estrogenic anabolic implants on the physical characteristics of the metacarpal bones of growing steer and heifer calves.

## Materials and Methods

Forty seven steer and 48 heifer calves from the McGregor Research Center were used to study the effects of estrogenic anabolic implants on the physical characteristics of metacarpal bone. Calves were born to either Angus x Hereford or Zebu x Hereford cows sired by either Charolais or Saler bulls. Calves were blocked by sex and sire breed and randomly assigned to either a treatment (implant) or control (non-implant) group. Treated animals were implanted with Synovex C at 45 days of age and re-implanted with either Synovex S or H at weaning and at 84 and 169 days post weaning. Calves and cows were grazed on oat and native pastures until weaning. Post weaning, calves were grazed on oat pasture for 169 days and then placed in the feedlot. The feedlot phase lasted for 124 days and calves were fed a corn based diet, ad libitum. Metacarpals were excised at slaughter and were cleaned of all adhering tissue and frozen until measurements were made. Metacarpal weights, lengths, thicknesses, and widths were made on the intact bone. Metacarpal thicknesses and widths were measured at the midpoint of the intact bone. Bone breaking loads were measured as the weight required to cause bone fracture. Cortical areas, medullary areas, and cross sectional areas were measured in relation to the true point of breaking.

Data were analyzed by the General Linear Models Procedure of the Statistical Analysis System. The

model used in this analysis was: Y=treatment + sex + sire breed + two way interactions + three way interactions. When interactions were not significant, they were deleted from the model.

## Results and Discussion

Bone measurement data are presented in Table 1. A significant (P<.10) interaction existed between sex and implant treatment group for metacarpal weight and length. Non-implanted steers had 3.70 percent greater metacarpal weights than implanted steers; whereas, implanted heifers had 5.98 percent greater metacarpal weights than non-implanted heifers. Non-implanted steers had bone lengths that were 3.82 percent greater than implanted steers, and non-implanted heifers had 5.69 percent greater metacarpal lengths than implanted heifers. Implantation had no significant effect on bone thicknesses at the bone midpoint in steers, however, implanted heifers had 28.12 percent greater bone thicknesses at the bone midpoint than non-implanted heifers (0.48 vs 0.38 in, respectively, P>.29). Both implanted steers and heifers had greater bone widths at bone midpoints than did non-implanted animals. Although force was applied at the midpoint of the intact metacarpal bone, it did not necessarily follow that breakage occurred at that location. Therefore, measurements such as the cross sectional area, cortical area, and medullary area were taken at the point of breaking. Cross sectional areas at the point of breaking were larger for implanted steers than non-implanted steers (1.75 vs 1.66 $in^2$) and implanted heifers had larger cross sectional areas at the point of breaking than non-implanted heifers (1.52 vs 1.44 $in^2$). Implanted steers and heifers had greater cortical areas than did non-implanted animals of the same sex (1.28 vs 1.21 and 1.12 vs 1.01, respectively). Medullary areas were greater for both implanted steers and heifers (0.48 and 0.41 $in^2$, respectively). Implanted steers required 15.5 percent more breaking load than non-implanted steers and implanted heifers required 4.1 percent greater breaking load than non-implanted heifers. From these results, it can be concluded that while implantation with Synovex S or H does not result in larger, heavier bones, it does increase the metacarpal's ability to resist fracture. This effect may be due to the increase of the bone thickness and width which is reflected in the increase of cross sectional area of the bone at the point of breaking or to changes mediated by the implant in the chemical composition of the bone tissue or a combination of these factors. It is not known if these effects are exhibited throughout the skeletal system or if they are only short lived. Anabolic implants have been proven to increase the growth performance of young cattle. Implanting may also produce the added benefit of increasing the skeletal strength and the reduction of possible skeletal injuries in young growing cattle.

## Acknowledgments

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## Literature Cited

1. Heddins, C.E., L.W. Greene, K.K. Lunt, F.M. Byers, and G.T Schelling. 1988. Growth, mineral status and bone breaking strength of steers implanted with Synovex S. J. Anim. Sci. 66(Suppl. 1) :505.
2. Greene, L.W., D.K. Lunt, F.M. Byers, G.E. Carstens, and A.M. Rocha. 1989. Skeletal growth in calves implanted with Synovex. Beef Cattle Research in Texas, 1989. p. 62.
3. Turner, N.D., L.W. Greene, L.A. Hurley, and F.M. Byers. 1990. Influence of zeranol implants on the chemical and physical characteristics of third metacarpal bone from feedlot steers. J. Anim. Sci. 68(Suppl. 1) :314.

TABLE 1. METACARPAL BONES IMPLANTED WITH SYNOVEX C AND SYNOVEX S OR H

| Item | Steer | | Heifer | |
|---|---|---|---|---|
| | Control | Implant | Control | Implant |
| Wet weight, lb[ab] | 1.13 | 1.09 | .89 | .94 |
| Length, in[abe] | 8.77 | 8.44 | 8.33 | 7.88 |
| Thickness, in | .43 | .43 | .38 | .48 |
| Width, in[bd] | .66 | .69 | .61 | .63 |
| Cortical areas, $in^{2be}$ | 1.21 | 1.28 | 1.01 | 1.12 |
| Medullary areas, $in^{2}$ [c] | .45 | .48 | .40 | .41 |
| Cross sectional areas, $in^{2bd}$ | 1.66 | 1.75 | 1.44 | 1.52 |
| Breaking loads, lb[d] | 2785.45 | 3218.43 | 2739.57 | 2852.88 |

[a] Implant x sex interaction (P < .10).
[b] Affected by sex (P < .0001).
[c] Affected by sex (P < .10).
[d] Affected by implant (P < .05).
[e] Affected by implant (P < .10).

# Bovine Heat Shock Proteins as an Index of Susceptibility to Stress

D.T. Kochevar, J. Cooper and L. D. Moore


## Summary

The bovine heat shock or stress response was characterized using isolated lymphocytes, neutrophils, and macrophages from *Bos indicus* and *Bos taurus* cattle. Expression of the stress response in these isolated cell types is of particular importance to our understanding of stress and immune responsiveness in disease. *Bos indicus* animals are generally considered to represent a thermotolerant bovine population as compared to heat stress-sensitive *Bos taurus* animals. Using gel electrophoresis and immunoblotting of selected stress proteins, no significant differences were found between the overall pattern of heat shock protein expression in *Bos indicus* and *Bos taurus* cattle. Certain individuals within the *Bos indicus* group did have a greater capacity for specific heat shock protein expression as compared to unstressed levels in control cells. This, along with other preliminary data, suggests that certain genetic sub-types may have a greater potential for response to stress than others. Such sub-types did not predominate but were targeted for future investigation.


## Introduction

Heat shock proteins (hsps), or stress proteins, are a group of highly conserved cognate and inducible proteins present in all cells and organisms after exposure to various types of stress or injury (2). Members of all the hsp families are present in organisms at physiological temperatures and play major roles in normal cellular functions. Heat shock protein 70 (hsp70) is the focus of these studies because it may play a role in protection of cells from thermal and oxidative stress (3), antigen processing and presentation (7), and immunodominant antigenic stimulation (7). Basic knowledge of bovine stress proteins and genes, in particular hsp70, is important to our understanding of the bovine stress response and to our ability to predict and manipulate the stress and disease resistance profile of individual animals.

## Experimental Procedure

Using previously described techniques, bovine lymphocytes (4), neutrophils (6), and macrophages (5) were isolated from venous blood samples. Isolated cells were stressed by incubation for varying amounts of time in ethanol and/or incubation at 42°C. Experimentally stressed cells were metabolically labeled with $^{35}$S-methionine alone or in combination with $^{3}$H-leucine during the final hour of incubation. Cells were harvested, solubilized, and protein quantitated for analysis by sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS-PAGE). Autoradiograms of gels were densitometrically scanned to quantitate changes in protein banding patterns relative to non-stressed control cells. To verify the identity of hsp70 on one-dimensional separations, immunoblots of electrophoresed proteins were incubated with rat monoclonal anti-hsp70 primary antibody followed by alkaline phosphatase-conjugated second antibody and colorimetric development of the reaction product (1).

## Results and Discussion

Autoradiographic analysis of electrophoresed proteins revealed proteins of the following approximate molecular weights to be enhanced in heat shocked cells as compared to controls: 100kD, 70-72 kD doublet (lymphocytes); 70-72 kD, 28 kD (neutrophils); 110kD, 90kD, 78kD, 70kD, 46kD, 16kD (macrophages). Only the macrophages were double labeled with $^{35}$S-methionine and $^{3}$H-leucine and so more complete appreciation of low molecular weight protein bands was expected. Immunoblots of extracts from heat shocked and control neutrophils revealed the expected band at approximately 70kD. Although the primary antibody was capable of detecting other members of the human hsp70 family (eg. 72 and 68 kD proteins) a single 70 kD band was noted in bovine neutrophils. There were no significant differences between the overall pattern of heat shock protein expression in *Bos indicus* as compared to *Bos taurus* cattle. Certain individuals within the *Bos indicus* group were targeted for further investigation because of a greater capacity to enhance hsp70 expression over unstressed control levels. Further characterization of bovine hsps in each cell type is being accomplished using two-dimensional gel electrophoresis of double-labeled protein extracts and analysis of hsp70 mRNA expression.


## Acknowledgment

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## Literature Cited


1. Beisiegel, U., W. J. Schneider, J. L. Goldstein, R. G. W. Anderson, M. S. Brown. 1981. Monoclonal antibodies to the low density lipoprotein receptor as probes for study of receptor-mediated endocytosis and genetics of familial hypercholesterolemia. J. Biol Chem 256:11923.
2. Kochevar, D. T., M. M. Aucoin, and J. Cooper. 1990. Mammalian heat shock proteins: an overview with a systems perspective. Toxicology Letters. (In press)
3. Lindquist, S., and E. A. Craig. 1988. The heat-shck proteins. Annu. Rev. Genet. 221:631.
4. Mishell, B.B., and S. M. Shiigi. 1980. Selected Methods in Cellular Immunology. WH Freeman and Co., San Francisco, p. 8-117.
5. Roos, D., and M. deBoer. 1986. Purification and cryopreservation of phagocytes from human blood. Meth Enzymol 132:225.
6. Watson, E. 1989. In vitro function of bovine neutrophils against *Actinomyces pyogenes*. Am J. Vet Res 50:455.
7. Young, R.A. 1990. Stress proteins and immunology. Annu. Rev. Immunol. 8:401.

# Development and Validation of NIRS Equations to Predict Diet Quality of Free-Ranging Cattle Through Fecal Analysis

R.K. Lyons and J.W. Stuth


## Summary

Results indicate that prediction of diet in vivo digestible organic matter (DOM) and crude protein (CP) of free-ranging herbivores can be accomplished with fecal analysis by near infrared reflectance spectroscopy (NIRS) to a degree of accuracy equivalent to conventional laboratory methods used to analyze diet samples. Field validations completed to date suggest that there is a broad geographic base for applying the DOM and CP equations developed. However, these equations can be strengthened by including additional variation. The precision, potential accuracy, flexibility, and capability of NIRS for rapid analysis establish it as a viable animal monitoring technique of the future.


## Introduction

Presently there is no rapid reliable method of determining the diet quality of free-ranging herbivores. However, recent investigations indicate a potential for the application of near infrared reflectance spectroscopy (NIRS) in rangeland diet quality analysis (6,8). In addition, NIRS prediction of forage quality of free-ranging herbivores through fecal analysis appears to have potential for use both as a management and a research tool (2,4,8). The objective of this study was to investigate the potential of NIRS to predict diet in vivo digestibile organic matter (DOM) and crude protein (CP) content of free-ranging cattle of differing physiological stages through fecal analysis.

## Experimental Procedures

The study was conducted at the La Copita Research Area near Alice, Texas. The *Prosoais-Acacia* shrubland sites were characterized by a high diversity of forage species.

Five trials were conducted in 1988 and 1989. Esophageally fistulated steers were used to collect diet samples. Eight Brahman x Hereford non-fistulated cows at various stages of lactation and gestation were utilized to graze study plots and to generate fecal samples. Grazing pressure was used to create diets of two different forage quality levels during each trial.

Diet samples were dried immediately after collection at 60°C for 48 h and then ground in a Wiley mill to pass a 2-mm screen. Fecal samples were frozen and later dried at 60°C for 48 h and then ground in a Udy cyclone mill to pass a 1-mm screen to reduce particle size and ensure particle uniformity.

Digestibility of diet samples was determined by in vitro procedures using a 48-h fermentation (9) followed by neutral detergent fiber procedure (10). Forty-eight hour in vitro values were corrected to in vivo values by regression. Each diet sample was also analyzed for CP content by micro-Kjeldahl procedure (1) using the Hach system (5).

Prior to scanning with a Pacific Scientific NIR Scanner 4250, moisture was stabilized in each fecal sample (7). NIRS spectra generated from fecal material representative of known forage diets of varying nutritional quality were used as reference data to establish a calibration equation capable of predicting unknown diet quality. Prediction equations were developed by modified stepwise regression (11).

To validate calibration equations, five cross-geographical field validation trials were completed in 1989-90 at College Station. Diet samples were collected from areas to be grazed using esophageally fistulated steers. Non-fistulated cows were used to graze these pastures and generate fecal samples for NIRS analysis. Fecal samples were collected every 12 h from 24 h through 72 h following the initiation of grazing. Diet and fecal samples were prepared and analyzed as described for the calibration set. For each trial, the 12-h collection periods during which NIRS predictions most closely matched diet sample DOM and CP were used in calculation of correlation coefficients.

Selected validation samples were used to subsequently recalibrate NIRS DOM and CP equations. Validation samples from trials with DOM and CP values, which either expanded the range of the La Copita equations (LACEQA) or provided additional samples at data points lacking in the calibration data set, were selected for addition to the LACEQA and recalibration to develop expanded equations (EEQA).

Fecal samples were also collected during the winter of 1988-89 from five cooperating ranches in the Rio Grande Plain, Coastal Bend, and Post Oak Savanna vegetational regions of Texas to ascertain regional sensitivity of NIRS analysis and effectiveness of sample delivery systems. Forages grazed on these ranches included dormant native perennial grasses as well as small grain pastures.

## Results and Discussion

In terms of the standard error of calibration (SEC) values obtained, calibration for DOM was

deemed successful. Calibrations were not affected by physiological stage of the animals as indicated by the identical SEC of 1.7 for lactating and dry groups. The SEC for the best equation was 1.71. These values were nearly equivalent to the standard error of the laboratory method (SEL) of 1.68 indicating that the procedures used for preparation of samples for NIRS scanning introduced little error. In calibrations for percent CP (dry matter basis), the SEC (0.76) did not approach SEL (0.44) values as closely as the DOM equation. As with DOM, CP calibrations for the lactating and dry groups resulted in identical SEC values of 0.87. The SEC's obtained for DOM and CP in the present study were equivalent to or lower than values reported in other studies (2,3,6). The relationship between reference DOM and CP values and NIRS predicted values for the best equations is illustrated in Figure 1.

Using fecal material, Brooks et al. (2) reported a 0.88 $R^2$ for in vivo dry matter digestibility and Holechek et al. (6) reported a 0.84 $R^2$ for in vitro dry matter digestibility equations for prediction of extrusa. The $R^2$ values for CP equations in the present study were lower compared to values reported for other NIR applications, 0.99 (2) and 0.92 (6). The relatively low $R^2$ obtained in this study compared to other NIRS forage applications is at least partially due to limited data at extremes of the data set and possibly the narrower range of the data. The range in DOM for the calibration set was 54.6 to 65.3 percent, with only 12 samples below 56 percent DOM and only 4 samples above 64 percent. Similarly, the range for CP reference data was 6.9 to 12.9 percent, with only 8 samples below 7 percent CP and only 4 above 11 percent. Both a wider range and more even distribution of data as well as more samples at the extremes appears to be needed to improve this statistic.

Using the LACEQA, field validations resulted in a correlation coefficient (r) for diet DOM and closest matching NIRS predictions from fecal samples of 0.97 with a corresponding standard error (SE) of 1.54. Correlations for CP were 0.92 with a SE of 0.83. All CP diet values (4,5,13, and 17%) were outside the range of the LACEQA (6-12%). This may account for the fact that although CP correlations were high, accuracy of the predictions was low. For example, the closest match for the April validation trial diet CP of 17 percent was a prediction of 10.7 percent. Only diet DOM for April (67%) was outside the range of the LACEQA (54-65%). DOM predictions did not appear to be as sensitive to extrapolation as CP predictions as indicated by the close agreement between the April diet DOM of 67.3 percent and the closest prediction of 69.5 percent, even though these values were outside the range of the equation.

Recalibration of the LACEQA including samples from field validation trials resulted in improvement of the coefficient of determination for both DOM and CP. The $R^2$ for the EEQA DOM was 0. 80 compared to 0.73 for the best LACEQA DOM. An even greater improvement in the $R^2$, 0.92, was obtained with the EEQA CP compared to the best LACEQA CP of 0.73. No change was observed in the SEC for the EQA DOM, 1.66, compared to the LACEQA, 1.71. However, recalibration resulted in a slightly inflated SEC of 0.89 for the EEQA CP compared to 0.76 for the LACEQA.

Correlation for diet DOM with closest matching predictions (Fig. 2) was 0.99 with a SE of 0.56 using the EEQA. Similarly, the CP correlation using EEQA predictions (Fig. 2) was 0.99 with a SE of 0.32.

Examination of the NIRS predictions of cooperating ranch fecal samples provides further evidence of the feasibility of NIRS application to forage diet quality prediction through fecal sample analysis. Predictions for fecal samples from cattle grazing small grain pastures averaged 79 percent DOM and 25 percent CP (Fig. 3). These values are within expected ranges for small grain forages. Predictions from cattle grazing dormant perennial native grasses averaged 56 percent DOM and 8 percent CP (Fig. 3). Interestingly, predictions for dormant native grasses are similar to values observed in diet samples collected at the La Copita Research Area during the same time period.

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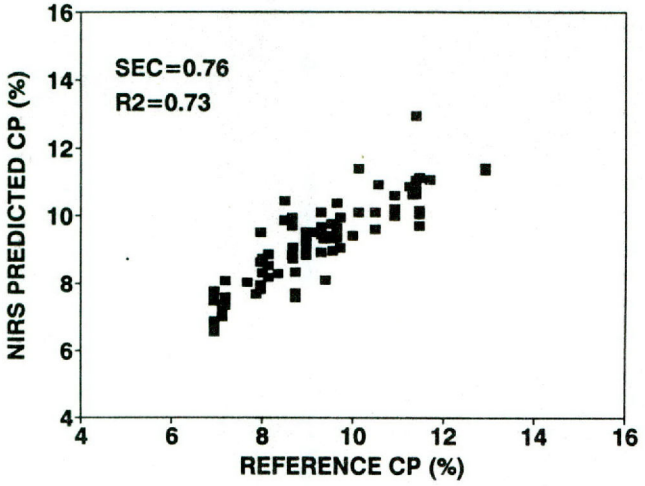
## Literature Cited

1. AOAC. 1975. Official methods of analysis (9th ed.). Assoc. Official Analytical Chem., Washington, D.C.
2. Brooks III, J., M. Anderson, and P.J. Urness. 1984. Infrared reflectance analysis of forage quality for elk. J. Wildl. Manage. 48:254.
3. Brown, W. F., J. E. Moore, W. E. Kunkle, C.G. Chambliss, and K. M. Portier. 1990. Forage testing using near infrared reflectance spectroscopy. J. Anim. Sci. 68:1416.
4. Coleman, S.W., J.W. Holloway, and J.W. Stuth. 1989. Monitoring the nutrition of grazing cattle with near-infrared analysis of feces. XVI Internat. Grassl. Congr. 26:881. Nice, France.
5. Hach Co. 1987. Feed analysis manual. Hach Company, Ames, IA.
6. Holechek, J. L., J. S. Shenk, M. Vavra, and D. Arthun. 1982. Prediction of forage quality using near infrared reflectance spectroscopy on esophageal fistula samples from cattle on mountain range. J. Anim. Sci. 55:971.
7. Lyons, R.K. 1990. Fecal indices of nutritional status of free-ranging cattle using near infrared reflectance spectroscopy. Ph.D. Dissertation. Texas A&M Univ., College Station.
8. Stuth, J.W., E. D. Kapes, and R.K. Lyons. 1989. Use of near infrared spectroscopy to assess nutritional status of cattle diets on rangeland. XVI Internat. Grassl. Congr. 26:889. Nice, France.
9. Tilley, J.M.A., and R.A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassld. Soc. 18:104.
10. Van Soest, P.J., and R.H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determinations of plant cell-wall constituents. J. Assoc. Off. Agr. Chem. 50:50.
11. Westerhaus, M.O. 1985. Equation development. In: Near infrared reflectance spectroscopy (NIRS) analysis of forage quality. USDA, ARS, Agricultural Handbook No. 643.



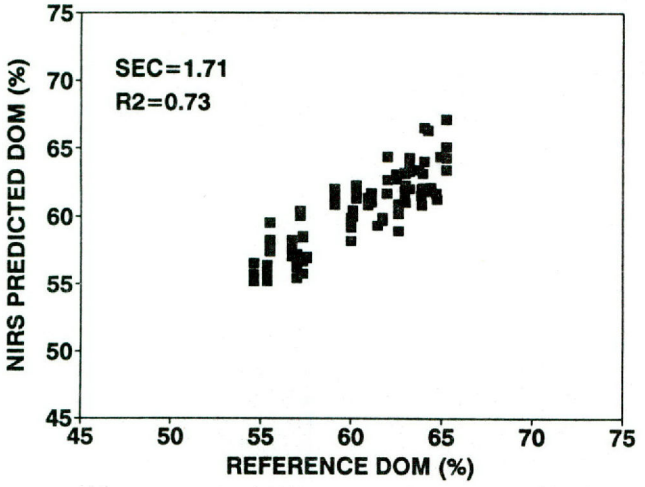
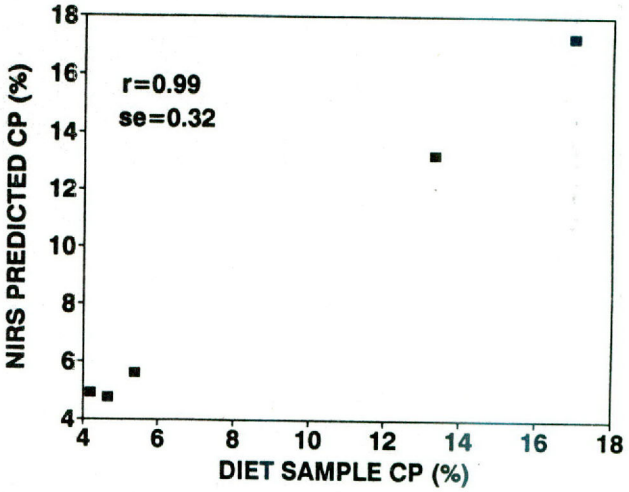




Figure 1. Reference in vivo corrected digestible organic matter (DOM) vs NIRS predicted DOM and reference crude protein (CP) vs NIRS predicted CP.



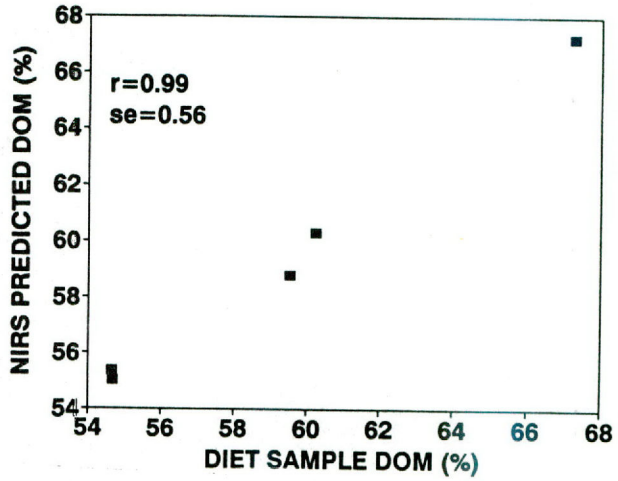




Figure 2. Correlations between diet in vivo corrected digestible organic matter (DOM) and closest matching diurnal NIRS predicted DOM and diet crude protein (CP) and closest matching diurnal NIRS predicted CP from fecal analysis for field validation trials.

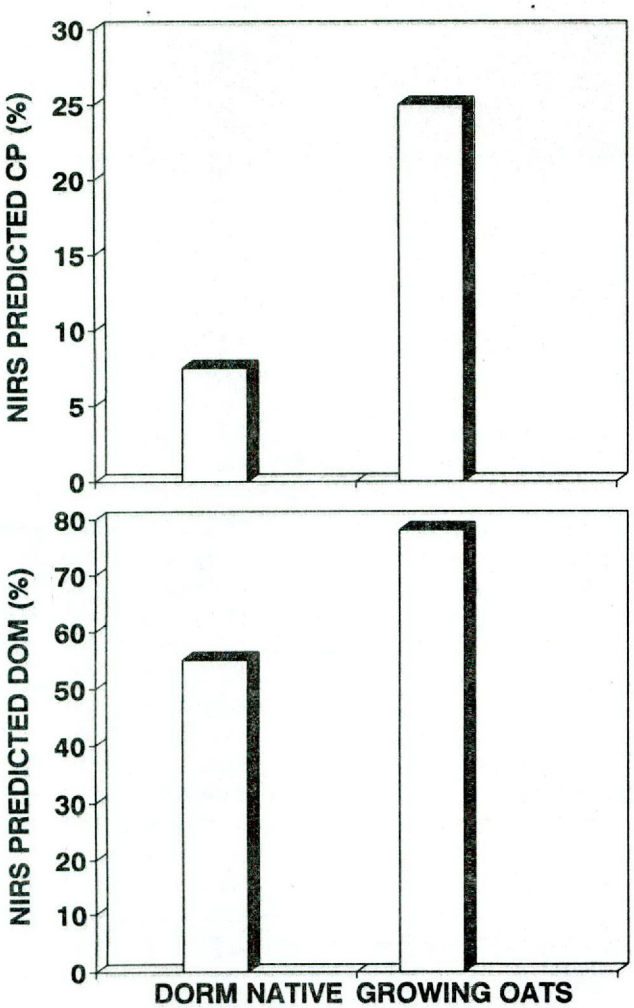



Figure 3. Comparison of NIRS predicted winter forage crude protein (CP) and in vivo corrected digestible organic matter (DOM) from fecal analysis.

# An Investigation into a Mechanism for Improved Forage Digestibility Resulting from a New Ammonia Treatment Process

N.D. Turner, C.M. McDonough, F.M. Byers, M.T. Holtzapple,
B.E. Dale and L. W. Greene

## Summary

Coastal bermudagrass hay and sugarcane bagasse were used to determine the effect of an ammonia fiber expansion process (AFEX) on physical structure. The AFEX process includes placing samples in a sealed chamber, pressurizing the chamber with liquid ammonia to achieve set pressure and temperature limits, and then rapidly releasing the pressure. The initial and final pressures for both samples used in this study were similar. Aliquots were removed at each level of treatment intensity (number of treatment times) to determine the degree of disruption that had occurred at that point in processing. AFEX treatment of Coastal bermudagrass removed the waxy coating on the surface of the samples, but did not cause considerable physical disruption when treatment intensity was low. However, as the severity of treatment increased, pieces of leaves and stems tended to bend and come apart, eventually forming small clusters of vascular bundles which spiralled together. This resulted in exposure of internal structures of the samples which would allow access to the fermentable nutrients by bacteria.

AFEX treatment of sugarcane bagasse caused clusters of vascular bundles to split apart at the ends of the sample. As the intensity of treatment increased, the number and length of splits into the sample increased. With extreme treatment intensity, sugarcane bagasse was curled, and split along the length of each piece similar to bermudagrass, with individual vascular bundles visible at the ends. These observations indicate that the intensity of AFEX processing will result in various degrees of structural disruption and that the degree of processing required to maximally increase digestibility will probably vary with the substrate used. This process would allow microbes greater access to structural carbohydrates in forages for fermentative digestion, enhancing the nutritive value of low quality feeds or byproducts for ruminant animals.

## Introduction

Ambient ammonia treatment of low quality feedstuffs has met with varied levels of success (3), and treatment did not always improve digestibility sufficiently to make the process economical. A consistent treatment whereby digestibility is maximized would allow processing of low quality forages and byproducts on an economically feasible basis. A new treatment process, Ammonia Fiber Expansion (AFEX), may provide a solution to this problem (1). It incorporates ammonia treatment with rapid release of pressure to achieve both a chemical and physical change in the sample over a short time frame. Therefore, the AFEX process would rapidly provide treated material that could be used almost as soon as it was produced. In contrast, ambient ammonia treatment usually requires weeks to maximize the response, which would demand large areas to keep treated materials prior to use; this increases the costs associated with ambient treatment. The primary goal of this research was to determine the effectiveness of the AFEX treatment and to establish the required intensity of treatment necessary to disrupt the structure of Coastal bermudagrass hay and sugarcane bagasse.

## Materials and Methods

A small amount of water (0.3 lb/lb of hay) was added to the dry Coastal bermudagrass and it was incubated for 20 minutes. Then 160 grams of the Coastal bermudagrass was placed in the 4-liter reaction chamber and liquid ammonia was added. Pressure was then applied until the desired temperature and pressure were obtained. The pressure was then rapidly released into a collection tank. The sample was recovered and allowed to air dry. An aliquot of treated Coastal was removed and the remainder was put through the process again, up to six times, to produce different levels of treatment intensity. Sugarcane bagasse was treated in the same manner, except that the water:bagasse ratio was reduced.

Representative control and treated samples from each processing intensity level were prepared for scanning electron microscopy. These were mounted on aluminum discs and vacuum dried for 48 hours at 40°C. Samples were coated with 200 Ångstroms of gold-palladium using a Hummer Sputter-coater, and were viewed on a JEOL T330A scanning electron microscope. The accelerating voltage was 15 mV.

Samples were viewed at 50 × to document any gross changes in external structure. Higher magnifications were used to determine what minute changes had occurred from the range of intensities of treatment for each feedstuff.

## Results

Control samples of Coastal bermudagrass had no overt disturbances in structure, except for those expected from preparing the sample for processing. These included only slightly rough edges and occasional breaks in the middle of pieces (Figure 1a). After the sample had been processed four times, the pieces started to bend along the length of the piece and curl up at the ends (Figure 1b). Large cracks extended down various lengths of the piece. At the highest level of treatment (processed six times) the sample consisted of smaller sections of stems and leaves, which were extensively curled and fragmented (Figure 1c). These low magnification (50 ×) pictures indicated there was considerable disruption of Coastal bermudagrass structure at the fourth intensity; the disruption increased even more with further processing. The changes in structure correlated with increased in vitro dry matter digestibilities (68 vs 85% in vitro dry matter digestibility for control vs treated, respectively) reported by Hagevoort et al. (2) for Coastal bermudagrass that had been treated at least three times.

Coastal bermudagrass that had received the fourth intensity treatment underwent a large degree of physical disruption (Figure 1d, 200 ×). In this picture, external structures have been pulled away, exposing internal structures to digestion by microbes. This type of structure modification is required if the more highly digestible contents of the hay are to be made available to bacteria prior to the smaller sample pieces exiting the rumen.

The "criss-cross" pattern (Figure 2a, see arrow) observed on Coastal bermudagrass is a waxy coating found normally on the surface. The AFEX treatment is apparently chemically extracting this waxy coating, because the criss-cross pattern is removed from samples that have been treated (Figure 2b). Removing the waxy coating may provide another route of access for bacteria during ruminal fermentation.

Sugarcane bagasse is the residual fiber from extracting sugar, which involves cutting and crushing the sugarcane. This causes considerable structural disruption (Figure 3a) as observed in the control samples. However, samples that have been treated four times have a much larger degree of longitudinal splitting of the pieces, especially near the ends, which resulted in small clusters of vascular bundles or single vascular bundles being separated from the bulk of the piece (Figure 3b). Samples that received the highest intensity treatment (six times) were broken down into small clusters of vascular bundles that curl and wind around the overall length of the pieces (Figure 3c). This amount of disruption would be necessary to allow bacteria access to the more readily fermentable carbohydrates contained within the internal structures of bagasse. These results suggest a mechanism responsible, in part, for the increase in in vitro dry matter digestibility (38 vs 55%) reported by Hagevoort et al. (2) for AFEX treated bagasse.

## Conclusions

These data indicate that the AFEX treatment is capable of causing physical disruption of the structure of both Coastal bermudagrass and sugarcane bagasse. The extent of disruption is related to the intensity of treatment. Therefore, it would be feasible to optimize this technique to maximize digestibility of forages and byproducts in a predictable manner. The economic feasibility of the AFEX process for large scale processing will be the focus of further research.

## Literature Cited


1. Dale, B.E. 1983. Biomass refining: Protein and ethanol from alfalfa. Ind. Eng. Chem. Prod. Res. Dev. 22:466.
2. Hagevoort, G.R., F.M. Byers, M.T. Holtzaple, J.H. Jun, L.W. Greene, and G.E. Carstens. 1990. Enhancing the nutritive value of forages with an ammonia fiber explosion (AFEX) technique. J. Anim. Sci. 68 (Suppl. 1) :584.
3. Turner, N.D., G.T. Schelling, L.W. Greene, and F.M. Byers. 1990. Modification of in vitro and in situ dry matter digestibility of forages with chemical treatment. J. Prod. Agric. 3:83.

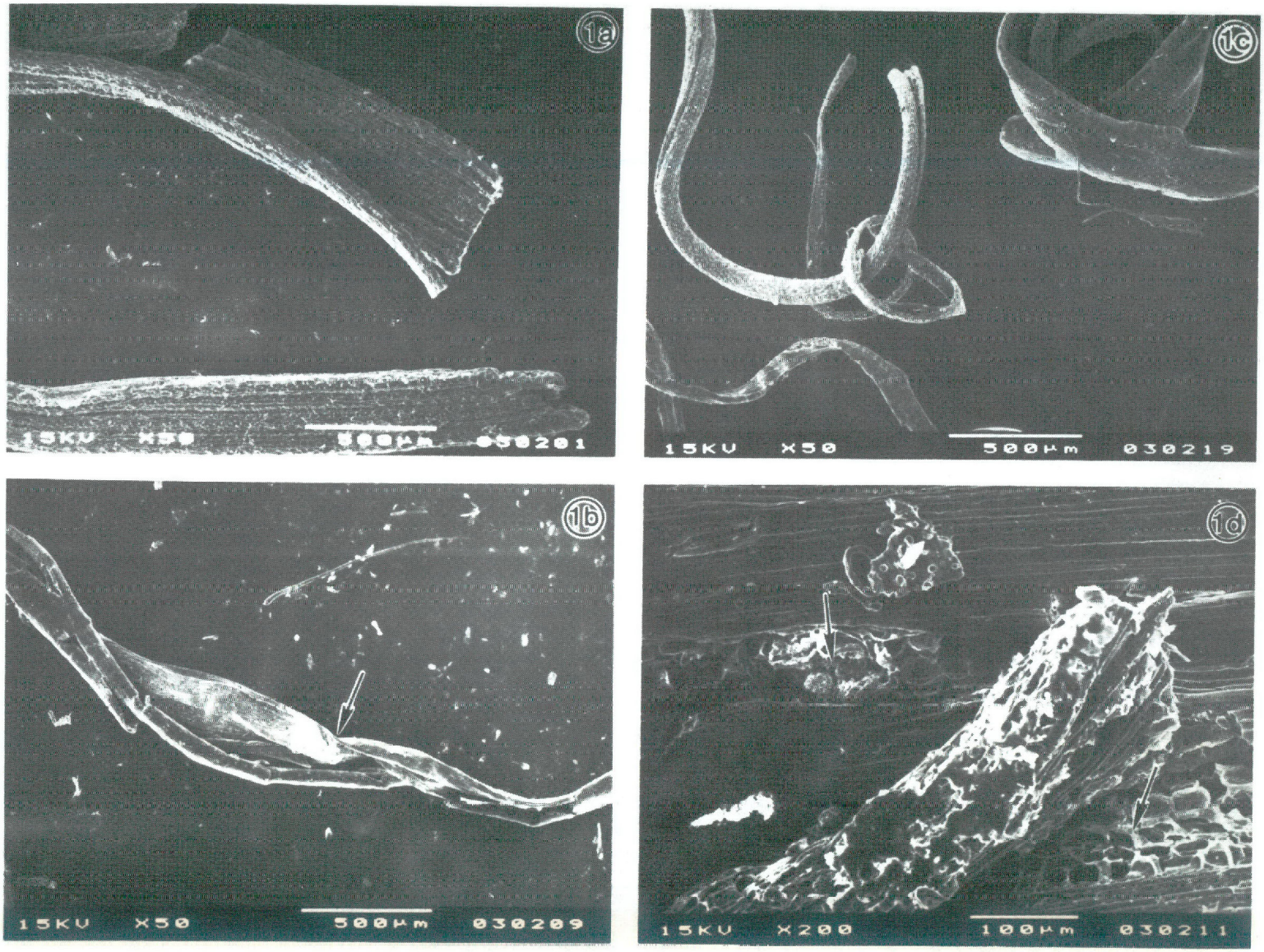



Figure 1. Coastal bermudagrass samples that received (a) no treatment, 50 ×, (b) 4 AFEX treatments, 50 ×, or (c) 6 AFEX treatments, 50 ×. The arrow in (b) points out the bending and splitting associated with treatment. With 4 treatments, the external structures (d, 200 ×) were fractured or removed, exposing the internal structures (arrows).

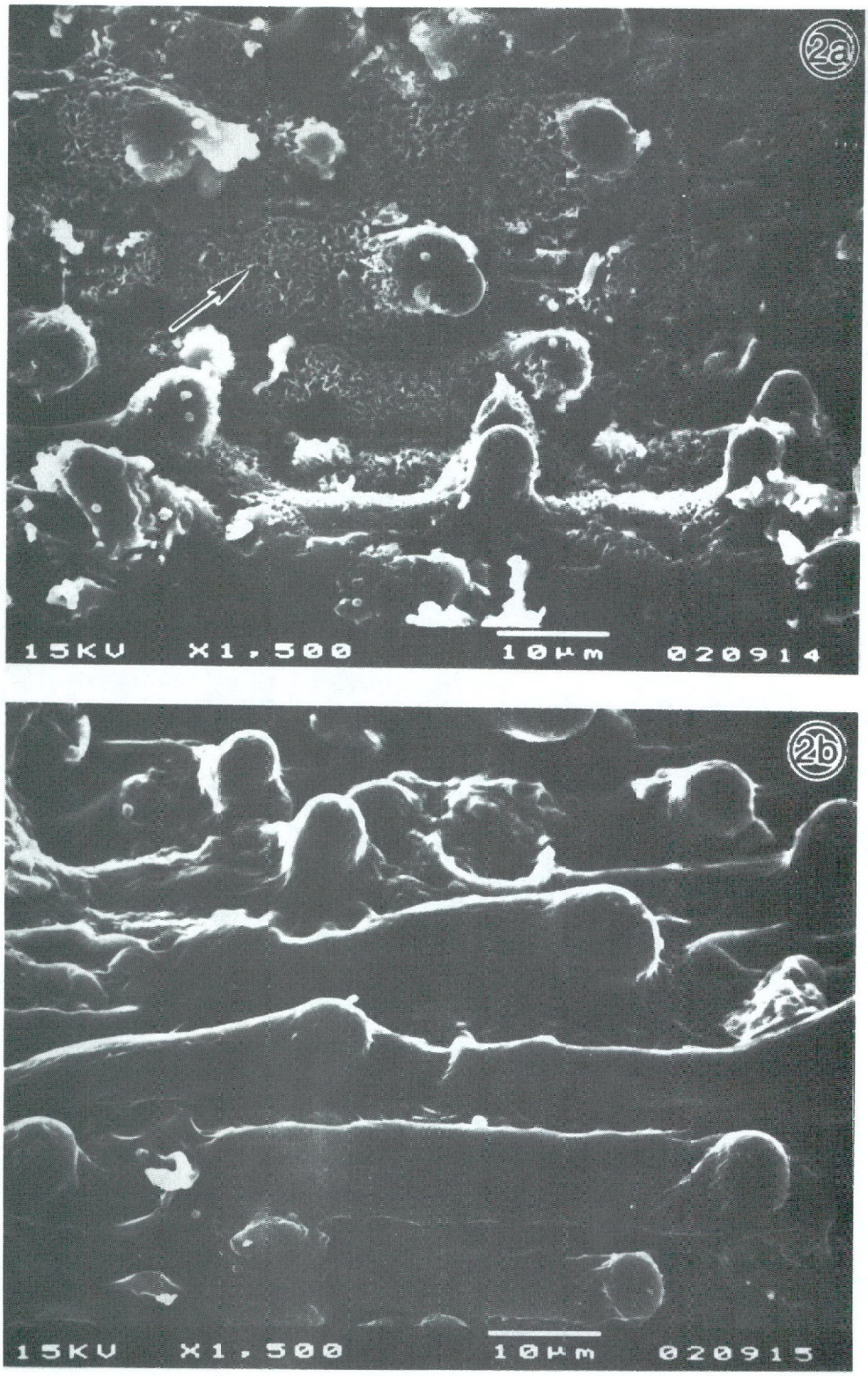



Figure 2. Coastal bermudagrass has a waxy coating on the surface (a, arrow, 200 x) which is removed by treatment (b).

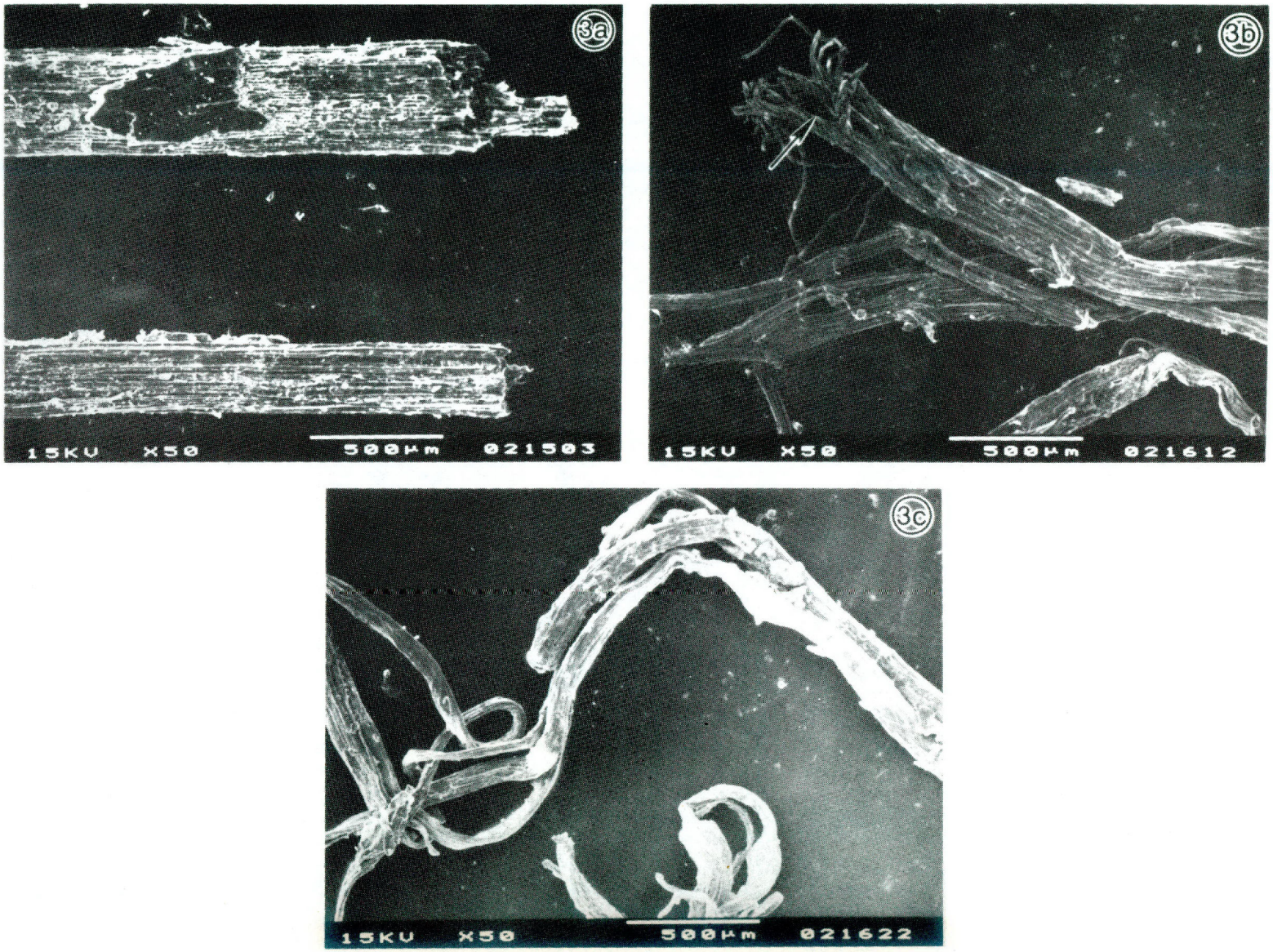



Figure 3. Sugarcane bagasse (50 ×) that received (a) no treatment, (b) 4 AFEX treatments, or (c) 6 AFEX treatments. The arrow (b) indicates fracturing that occurred at the ends.

# Influence of Zeranol Implants on the Chemical and Physical Characteristics of the Third Metacarpal Bone, Liver, and Soft Tissue from Feedlot Steers

N.D. Turner, L.W. Greene, L.A. Hurley and F.M. Byers


## Summary

The chemical and physical characteristics of the third metacarpal bones of feedlot steers, as well as liver and 9-10-11 rib section soft tissue composition were determined. One hundred and twenty-eight steers were selected from feedlot experiments conducted at four U.S. locations (Idaho, Kansas, Illinois, and Colorado; 32 from each location). The steers were selected to represent the range in weight and body composition of each treatment group within a location. The steers had been implanted with either 0, 24, 36, 48, 60, 72, 84, or 96 mg of zeranol when the experiments began. All the cattle within an experiment were fed for the same number of days (~ 140) and slaughtered at the same time. Third metacarpal bones and liver samples were collected at slaughter. Rib sections were obtained after a 24-hour chill. Bone breaking strength, elasticity, flexibility, and chemical composition were determined. Chemical composition was determined on liver and rib tissue.

Zeranol dose level had no effect on the chemical composition of bone, liver, or rib soft tissue. The load withstood by the bones up to flexure or at breaking was not affected by zeranol dose. However, elasticity of the bones at the breaking load increased linearly with zeranol dose. This is probably a result of increased cortical width of the bones from treated animals, as compared to the controls. These data indicate that steers receiving implants have modified bone metabolism which results in improved flexibility and ability to withstand stress, without modifying the ratio of bone in marketable tissues. Changes in structure and strength of the bones were evident at slaughter. These changes could result in reduced animal loss from broken bones and stress-related injuries in cattle.


## Introduction

Zeranol implants have been used for many years to improve growth rate in cattle (6). Another benefit of zeranol is that it produces a shift in body composition so that the quantity of lean retail product is increased (3). Lean retail product contains not only soft tissues, but also bone. Solis et al. (8) indicated that serum mineral concentrations were altered when large and small frame cattle were implanted with either estradiol/progesterone implants or those containing zeranol. Burnett and Reddi (2) demonstrated that both estrogen and progesterone affect long bone growth. Because zeranol has estrogenic activity and can affect body composition and mineral metabolism, it may also affect bone strength. Therefore, implanting with zeranol could reduce the incidence of bone breakage that can occur during cattle transport.

This research was conducted to determine the effect of incremental doses of zeranol on bone weight, dimensions, composition, mineral content, strength, and elasticity, as well as liver and rib soft tissue mineral concentrations.

## Procedures

The steers used for this study were a subsample of four feedlot experiments conducted at four locations (Idaho, Kansas, Illinois, and Colorado). Experiments were conducted in a completely randomized design, which included eight zeranol levels (0, 24, 36, 48, 60, 72, 84, and 96 mg). Thirty-two steers from each location were used (four steers/implant treatment group). Steers were implanted once with four or five pen replicates of each level at each location. At each location, steers from each treatment group were selected on the basis of weight and body composition to represent the range in each treatment group; one each from near the top and bottom of the range for each group and two above and below the average.

Metacarpal bones were removed from the right side of the animals at slaughter for each of three locations. A nonreconcilable identification error prevented use of bones from one experiment (Kansas), therefore the bone data represents observations from three experiments. The bones were frozen, transported to Texas A&M University, and were stored frozen until analyzed. Prior to testing, each bone was cleaned of all adherent tissues, weighed, measured for length, anterioposterior (AP), and later omedial (LM) diameters. The bones were broken using an Instron Testing Machine, and the force deformation curve was recorded. The broken bones were cut with a band saw at the point of breakage to expose the internal AP and LM diameters, which were measured with a dial caliper. Breaking load, breaking strength, and Young's Modulus of Elasticity were calculated from the force deformation curves and the bone dimensions using established procedures (4).

Bones were ground to prepare a homogenous sample for dry matter and ether extract analyses. The extracted bone was ground to a fine texture and ashed. Ashed bone samples were composited and used for mineral analyses. One-half gram samples of

ashed bone were dissolved in 10 ml of 3N HCl over low heat for 30 min. The dissolved samples were diluted and analyzed for calcium (Ca), phosphorus (P), magnesium (Mg), and zinc (Zn).

Livers were removed at slaughter and weighed. A 50 g sample of liver tissue was removed for analysis and stored at 4°C until freeze dried in preparation for analysis. After drying, the sample was ground with a laboratory mill, and an aliquot was wet-digested for analysis of Ca, Zn, Mg, P, and copper (Cu) content. Aliquots of the dried sample were used for determination of protein and ash content.

Samples of soft tissue from the 9-10-11 rib section (removed after a 24 h chill) were ground until homogenous. Protein content was analyzed using the mixed sample. Aliquots were dried and ether extracted in preparation for mineral analysis. The aliquots were combined and ground prior to analysis for minerals. Calcium, Mg, P, Zn, and Cu concentrations were measured after the samples were wet-digested.

Samples of muscle, liver, and bone were analyzed for Ca, Mg, Fe, Cu, and Zn using atomic absorption spectrophotometry (1). Phosphorus was measured using the colorimetric procedure of Fiske and Subarrow (5).

Data were analyzed using the GLM procedures of SAS (7). The model included main effects of location and treatment level and the interaction. If the interaction was not significant, it was deleted and the model analyzed again. Because initial and final weight of the cattle was variable, initial weight was used as a covariate to include variation due to initial weight. When treatment was not significant as a continuous variable, LSMEANS were generated (7) and separated using a protected Fischer's LSD (7).

## Results and Discussion

The mean hot carcass weight at each location was 309.8, 329.0, 312.9, and 341.9 kg. Zeranol levels of 36 mg or more increased in hot carcass weight (3), however, there was no effect of treatment on bone weight (0.82 vs 0.81 kg for control vs treated) or percent bone (15.7 vs 15.2% for control vs treated) in the 9-10-11 rib section.

Zeranol had no effect on wet weight, length, or external diameters of bones (Table 1). Because these steers were fed to a day-constant end-point, which was approximately 80 days past the effective delivery time of the implants, any effects on overall growth of the bones was probably not detectable. However, zeranol educed the internal (marrow cavity) diameters. The resulting cortical width (Table 1) was greater in steers receiving implants, and the change was positively correlated with zeranol dose (Figure 1).

Percentage of dry matter, ether extract, protein, and ash in the bones differed by location (Table 2), however, treatment had no effect on composition (Table 3). The covariate of animal initial weight was highly significant when the model contained only treatment. When the covariate was included in a model containing the effect of location, it was not significant, and location usually was highly significant. This indicates that the variation between locations attributable to initial weight reflected animal differences other than weight.

Ash content of Ca, P, Mg, or Zn did not change with zeranol implantation (Table 4) and the only differences detected were attributable to possible location effects (Table 5), such as diet. Zeranol implant effects last for a 90 to 100-day period. Any metabolic effects caused by zeranol that would change composition of bones could have returned to normal by 140 days after implantation. Therefore, if zeranol had changed mineral metabolism of these steers, the effect was absent by slaughter.

Force at the point of flexure or breaking was not affected by treatment level (Table 6). The point of flexure represents the force that the bone can resist before irreparable damage occurs. The cumulative force up to the point of breaking is the maximum load. These data indicate that these steers would have been equally able to resist a force applied to their bones. However, most acute, external forces applied to cattle are not sustained, but are rapidly applied as in kicking or being pushed up against an immovable object. Therefore, it is important to determine the ability to resist forces without permanent deformation considering the relative size of the area that would receive the force.

Young's Modulus of Elasticity represents the stiffness of the bone and incorporates, load, deformation prior to breaking or flexure, and the cortical area of the bone. Young's Modulus of Elasticity was affected by initial weight which influenced the size and area of the bone. Young's Modulus of Elasticity increased linearly with zeranol dose (Figure 2). These data indicate that zeranol has a beneficial affect on bone physiology and metabolism, which could improve bone strength and resistance to injury.

Stress incorporates the force resisted per $cm^2$ of bone. This variable would therefore, estimate if the animals were able to stand for long periods without developing bone deformations or abnormalities. Although not significant, there was an numerical increase in the stress resisted to flexure and breaking by steers implanted with zeranol.

There was no significant interaction between location and treatment for liver mineral concentrations. Only P and Zn were affected ($P<.09$) by treatment (Table 7). Analysis of rib soft tissue Ca content (Table 8) resulted in an interaction ($P<.05$) between location and treatment. All other interactions were not significant. Treatment had no effect on the concentration of any mineral in the rib soft tissue. The composition of liver and rib soft tissue are also probably similar because of the long feeding period after the effective dose delivery period for zeranol implants, which eliminated any metabolic differences in these rapidly metabolizing tissues.

## Conclusions

Zeranol does not increase hot carcass weight and lean retail product by increasing the quantity or percentage of bone in these carcass variables.

Zeranol did not affect chemical or mineral composition of bone, liver, or rib soft tissue. Any changes in mineral or chemical composition are probably not retained for a long period after the implant has ceased to deliver zeranol. External dimensions of third metacarpals were not affected by zeranol dose, however, because internal diameters were reduced, overall cortical width was increased in steers receiving zeranol. Breaking strength was not affected by treatment, however, elasticity increased linearly with zeranol dose. These characteristics could improve the ability of steers to resist the stress endured during shipping and should reduce bone breakage during transport.

## Literature Cited


1. Anonymous. 1972. Analytical Methods for Flame Spectrophotometry. The Varion Techtron Corp. Springvale, Vic., Australia.
2. Burnett, C.C. and A.H. Reddi. 1983. Influence of estrogen and progesterone on matrix-induced endochondral bone formation. Calcif. Tissue Int. 35:609.
3. Byers, F.M., N.D. Turner, H.R. Cross, L.W. Greene, and G.E. Carstens. 1990. Optimal growth regulator levels for enhancing carcass lean. Proc. West. Sect., ASCS. 41:422.
4. Crenshaw, T.D. 1986. Reliability of dietary Ca and P levels and bone mineral content as predictors of bone mechanical properties at various time periods in growing swine. J. Nutr. 116:2155.
5. Fiske, C.H. and Y. Subarrow. 1925. The colorimetric determination of phosphorus. J. Biol. Chem. 66:375.
6. Lemieux, P.G., F.M. Byers, and G.T. Schelling. 1990. Relationship of anabolic status and phase and rate of growth to priorities for protein and fat deposition in steers. J. Anim. Sci. 68:1702.
7. SAS. 1985. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.
8. Solis, T.C., L.W. Greene, F.M. Byers, and G.T. Schelling. 1987. Effect of anabolic implants on serum mineral concentrations in large and small frame steers. J. Anim. Sci. 65 (Suppl. 1):29 (Abstr.).


TABLE 1. EFFECT OF ZERANOL ON WEIGHT AND DIMENSIONS OF THIRD METACARPAL BONES OF STEERS

| | Zeranol dose, mg | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Item | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | SE |
| Wet weight, g | 480.9 | 455.2 | 452.7 | 448.5 | 461.4 | 470.7 | 453.9 | 480.4 | 15.8 |
| Length, cm | 20.8 | 19.9 | 20.1 | 20.2 | 20.3 | 20.4 | 20.0 | 20.1 | .27 |
| Weight/length, g/cm | 23.1 | 22.8 | 22.5 | 22.2 | 22.6 | 23.1 | 22.6 | 23.8 | .55 |
| Anterioposterior diameter, cm | 3.00 | 2.67 | 2.70 | 2.67 | 2.68 | 2.76 | 2.72 | 2.78 | .076 |
| Lateromedial diameter, cm | 4.22 | 4.19 | 4.16 | 4.15 | 4.27 | 4.12 | 4.10 | 4.33 | .080 |
| Anterioposterior cortical width, cm[a] | .84 | .72 | .77 | .76 | .76 | .80 | .78 | .78 | .042 |
| Lateromedial cortical width, cm[a] | .92 | .94 | 1.03 | .98 | 1.04 | .97 | .97 | 1.08 | .055 |
| Cortical width/AP diameter, cm/cm | 27.0 | 26.9 | 28.8 | 28.4 | 28.3 | 28.8 | 28.7 | 27.9 | .81 |
| Cortical width/LM diameter, cm/cm[b] | 21.6 | 22.4 | 24.8 | 23.6 | 24.3 | 23.0 | 23.8 | 25.0 | 1.14 |

[a] Linear implant effect ($P < .05$).
[b] Linear implant effect ($P < .06$).

TABLE 2. EFFECT OF LOCATION ON CHEMICAL COMPOSITION OF THIRD METACARPAL BONES FROM STEERS

| Item | Location | | | SE |
|---|---|---|---|---|
| | Idaho | Illinois | Colorado | |
| Dry matter, % | 78.9[a] | 82.0[b] | 83.6[b] | .70 |
| Ether extract[c], % | 19.0[a] | 15.3[b] | 15.7[b] | .73 |
| Crude protein[c], % | 17.8[a] | 20.0[b] | 19.3[ab] | .73 |
| Ash[c], % | 63.2[a] | 64.7[b] | 65.0[b] | .22 |

[ab] Means within a row without a common superscript differ ($P < .05$).
[c] Values are a percent of dry matter.

TABLE 3. CHEMICAL COMPOSITION OF THIRD METACARPAL BONES FROM IMPLANTED STEERS

| Item | Zeranol dose, mg | | | | | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | |
| Dry matter, % | 80.9 | 80.9 | 81.3 | 82.6 | 82.0 | 82.0 | 80.6 | 82.3 | 1.05 |
| Ether extract[a], % | 16.4 | 16.8 | 16.0 | 16.8 | 16.9 | 16.9 | 15.2 | 18.1 | 1.07 |
| Crude protein[a], % | 19.7 | 19.0 | 19.4 | 18.8 | 18.8 | 18.7 | 20.9 | 17.5 | .99 |
| Ash[a], % | 63.9 | 64.3 | 64.6 | 64.4 | 64.3 | 64.4 | 63.9 | 64.4 | .36 |

[a] Values are a percent of dry matter.

TABLE 4. MINERAL COMPOSITION OF THIRD METACARPAL BONES FROM IMPLANTED STEERS

| Item | Zeranol dose, mg | | | | | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | |
| Ash weight, g | 247.2 | 237.6 | 235.9 | 236.7 | 237.9 | 247.7 | 234.5 | 253.4 | 8.04 |
| Calcium, mg/g ash | 421.8 | 416.5 | 399.8 | 408.0 | 418.1 | 416.9 | 421.0 | 419.4 | 7.20 |
| Phosphorus, mg/g ash | 208.7 | 202.6 | 198.4 | 203.3 | 199.7 | 209.6 | 214.3 | 206.5 | 5.41 |
| Magnesium, mg/g ash | 6.51 | 6.63 | 6.99 | 6.68 | 6.64 | 6.65 | 6.58 | 6.73 | .11 |
| Zinc, µg/g ash | 78.9 | 84.5 | 81.2 | 86.4 | 76.5 | 85.2 | 82.4 | 86.9 | 4.89 |

TABLE 5. EFFECT OF LOCATION ON MINERAL CONTENT OF THIRD METACARPAL BONES FROM STEERS

| Item | Location | | | SE |
|---|---|---|---|---|
| | Idaho | Illinois | Colorado | |
| Ash weight, g | 227.4[a] | 269.1[b] | 227.5[a] | 5.92 |
| Calcium, mg/g ash | 403.2[a] | 411.8[a] | 430.5[b] | 5.45 |
| Phosphorus, mg/g ash | 204.8 | 207.6 | 203.7 | 4.10 |
| Magnesium, mg/g ash | 6.51[a] | 6.60[a] | 6.92[b] | .085 |
| Zinc, µg/g ash | 88.0[a] | 75.1[b] | 85.2[ab] | 3.70 |

[ab] Means within a row without a common superscript differ ($P < .05$).

TABLE 6. STRENGTH AND FLEXIBILITY CHARACTERISTICS OF THIRD METACARPAL BONES FROM IMPLANTED STEERS

| Item | Zeranol dose, mg | | | | | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | |
| Load at breaking, kg-cm | 1682 | 1575 | 1657 | 1616 | 1640 | 1645 | 1709 | 1732 | 64.8 |
| Load at flexure, kg-cm | 1020 | 906 | 965 | 1025 | 975 | 1042 | 1059 | 998 | 56.9 |
| Modulus of elasticity at breaking[a], kg/cm$^2$ | 819 | 1012 | 1114 | 1364 | 1396 | 1238 | 1335 | 1112 | 177 |
| Modulus of elasticity at flexure, kg/cm$^2$ | 1915 | 2001 | 2465 | 1878 | 2351 | 2083 | 2071 | 1863 | 338 |
| Stress at breaking, kg/cm$^2$ | 1393 | 1463 | 1494 | 1506 | 1478 | 1421 | 1538 | 1412 | 68 |
| Stress at flexure, kg/cm$^2$ | 845 | 844 | 872 | 970 | 880 | 898 | 961 | 811 | 61 |

[a] Linear implant effect ($P < .06$).

TABLE 7. CHEMICAL COMPOSITION OF LIVER TISSUE FROM IMPLANTED STEERS

| Item | Zeranol dose, mg | | | | | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | |
| Dry matter, % | 89.3 | 89.4 | 89.4 | 90.2 | 89.7 | 89.1 | 89.1 | 89.5 | .28 |
| Protein,[a] % | 70.8 | 72.0 | 74.8 | 72.6 | 74.6 | 72.2 | 74.2 | 73.7 | 1.47 |
| Ash,[a] % | 4.19 | 4.33 | 4.43 | 4.19 | 4.33 | 4.50 | 4.51 | 4.36 | .12 |
| Calcium, mg/g DM | .13 | .15 | .13 | .11 | .15 | .13 | .13 | .14 | .01 |
| Phosphorus,[b] mg/g DM | 12.8 | 13.3 | 14.0 | 13.0 | 13.4 | 13.7 | 13.4 | 13.7 | .31 |
| Magnesium, mg/g DM | .55 | .54 | .54 | .54 | .54 | .56 | .56 | .56 | .02 |
| Iron, mg/g DM | .19 | .18 | .21 | .22 | .19 | .21 | .22 | .20 | .01 |
| Copper, mg/g DM | .27 | .26 | .31 | .28 | .33 | .25 | .28 | .26 | .03 |
| Zinc,[b] mg/g DM | .13 | .13 | .15 | .13 | .15 | .14 | .13 | .14 | .01 |

[a] Values are a percent of dry matter.
[b] Implant effect ($P < .09$).

TABLE 8. CHEMICAL COMPOSITION OF 9-10-11 RIB SOFT TISSUE FROM IMPLANTED STEERS

| Item | Zeranol dose, mg | | | | | | | | SE |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 24 | 36 | 48 | 60 | 72 | 84 | 96 | |
| Water, % | 44.5 | 44.9 | 43.0 | 42.6 | 42.4 | 43.6 | 43.4 | 43.6 | 1.03 |
| Protein,[a] % | 14.2 | 14.5 | 13.8 | 14.0 | 13.6 | 14.5 | 14.2 | 14.0 | .37 |
| Ether extract,[a] % | 41.2 | 40.4 | 43.1 | 43.1 | 43.8 | 42.0 | 42.5 | 41.5 | 1.30 |
| Calcium,[b] mg/g DM | .35 | .40 | .40 | .46 | .38 | .41 | .37 | .41 | .03 |
| Phosphorus,[b] mg/g DM | 7.02 | 6.98 | 6.79 | 6.93 | 6.98 | 7.12 | 7.01 | 6.97 | .19 |
| Magnesium,[b] mg/g DM | .68 | .67 | .70 | .66 | .70 | .67 | .69 | .69 | .02 |
| Iron,[b] mg/g DM | .12 | .12 | .14 | .12 | .13 | .12 | .12 | .15 | .01 |
| Zinc,[b] mg/g DM | .17 | .16 | .16 | .17 | .17 | .18 | .17 | .17 | .06 |

[a] Values are on an as is basis.
[b] Dry, fat-free basis.

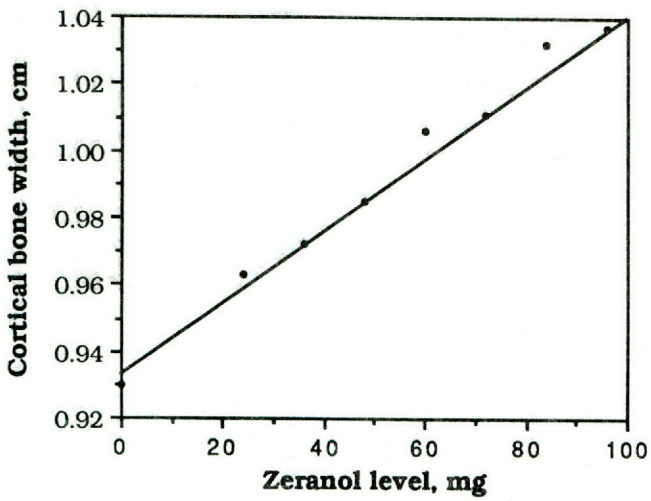



Figure 1. Relationship between zeranol dose and cortical bone width, including a covariate of initial steer weight.

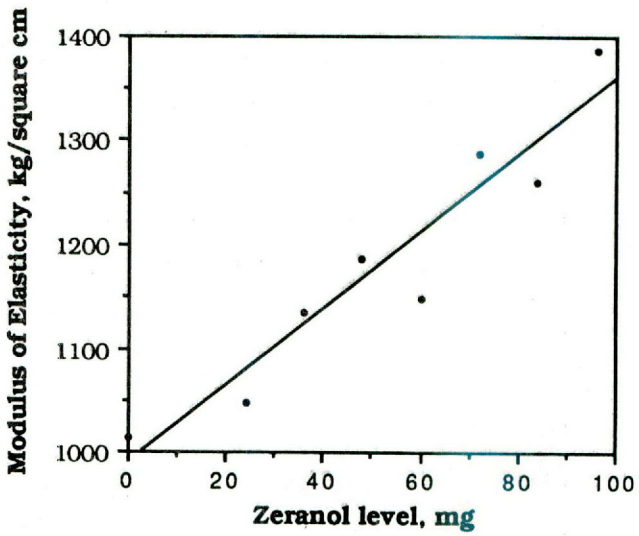



Figure 2. Effect of zeranol dose on Young's Modulus of Elasticity of third metacarpal bones of steers.

# Protein Metabolism of BC3H1 Muscle Cells in Culture in Response to Combinations of Anabolic Growth Regulators

C.N. Welch, F.M. Byers, J.M. Gunn, L.W. Greene and G.E. Carstens


## Summary

Protein synthesis and degradation were determined using BC3H1 cells grown in tissue culture receiving 0, $10^{-7}$ and $10^{-9}$ M levels of dexamethasone or zeranol singly or combined with estrogen, progesterone, testosterone, IGF-1, and growth hormone at $10^{-7}$ and $10^{-9}$ M. Estrogen with dexamethasone at $10^{-7}$ M decreased ($P<.05$) protein degradation. Treatment with $10^{-9}$ M dexamethasone and growth hormone increased ($P<.05$) protein synthesis, and increased ($P<.05$) protein accumulation. Progesterone with dexamethasone at $10^{-7}$ M tended to increase protein synthesis. Dexamethasone with testosterone at $10^{-7}$ M tended to increase protein degradation.

Estrogen with zeranol at $10^{-7}$ or $10^{-9}$ M increased ($P<.05$) protein degradation, which reduced ($P<.05$) accumulation as compared to the control. Protein synthesis decreased ($P<.05$) when $10^{-7}$M or $10^{-9}$ M growth hormone was added to cultures receiving $10^{-7}$ M or $10^{-9}$ M zeranol. Growth hormone at $10^{-7}$ M with $10^{-7}$ and $10^{-9}$ M zeranol tended to reduce protein accretion compared to the control. Progesterone, IGF-1, and testosterone added with zeranol had no effect on protein synthesis and degradation. Conversely, zeranol when combined with estrogen and growth hormone reduced accumulation. The results obtained with this cell line indicate that these growth regulators do not act independently and specific combinations of anabolic agents may differ in their ability to regulate protein growth.


## Introduction

The primary challenge in using anabolic agents is to manipulate protein metabolism to enhance growth of desired tissues. A relationship between anabolic agents and protein synthesis and degradation has been found (5). While the mechanisms through which anabolic agents increase or decrease muscle growth are unclear, the anabolic agents tested had a direct effect on protein muscle cells, which resulted in muscle anabolism. Changes in the rate of protein degradation can be as important as those of synthesis.

The current studies were undertaken to examine the effects of selected anabolic agents used singly and in combination on BC3H1 cell synthesis, degradation, and accumulation. An understanding of these relationships allow a more significant comprehension of the in vivo regulation of muscle growth and how exogenous growth promoters alter normal mechanisms to enhance protein accretion. The selected growth regulators (estrogen, testosterone, zeranol, progesterone, growth hormone and IGF-1) are anabolic agents widely used or produced naturally in ruminant meat animals.

## Experimental Procedures

### *Myoblast Cultures*

Muscle cell cultures are a valuable tool that allow the investigator to establish a relatively uniform synchronized cell population that may be grown without the influence of other tissues or organs (1). The BC3H1 cell line was selected based on its ability to proliferate and replicate (6,7) and its sensitivity. Cultures of BC3H1 myoblasts were prepared by plating myoblasts at $3.0 \times 10^4$ cells per well in Costar 24-well dishes (1.8 $cm^2$ surface area). The BC3H1 cells were cultivated for 72 h and maintained in Dulbecco's Modified Eagle Medium (DMEM) containing 20 percent bovine calf serum. The gas phase was 7 percent carbon dioxide in humidified air at 37°C in incubators. Fusion began on d 1 and by d 4 peak confluency (85%) was attained. Serum was added as a positive control but all treatments were evaluated in serum free media. No antibiotics were used. Comparisons were made between controls (no treatment) and the various treatments.

### *Measurement of Protein Synthesis*

Rates of protein synthesis were measured by determining the uptake of radioactivity ([$^3$H]leucine) into cell protein using the modified procedures of Gunn et al. (3). Estrogen, progesterone, testosterone, dexamethasone, zeranol, growth hormone, and IGF-1 at concentrations of $10^{-7}$ or $10^{-9}$ M were added to dexamethasone or zeranol at $10^{-7}$ or $10^{-9}$ M at the beginning of an 18 h synthesis period. A modified Lowry method (2) was used for protein determination and synthesis was expressed as cpm of radioactivity incorporated per mg of protein.

### *Measurement of Protein Degradation*

The basic method used for determination of degradation was the modified pulse-chase procedure of Gunn et al. (4). Percent degradation was expressed

as the percent protein degraded over a 4-h period and was calculated as follows:

$$\% \text{ Degraded} = \frac{\text{Media amino acids}}{(\text{Media amino acids} + \text{Media proteins} + \text{Cell Proteins})}$$

The measurement of radioactivity in media protein represents the leakage of protein from cells and is an indicator of cell viability.

### *Measurement of Accumulation*

Percent accumulation was calculated by subtracting percent degradation from percent synthesis and expressing it relative to control responses.

### *Statistical Analysis*

Protein synthesis, degradation, and accumulation measurements were statistically analyzed and means were compared using Fischers Protected LSD.

## Results and Discussion

Results for protein synthesis are in Table 1. When cells received dexamethasone ($10^{-9}$ M) and estrogen at $10^{-9}$ M synthesis was increased. Dexamethasone ($10^{-9}$ M) tended to increase degradation (Table 2). However, protein degradation decreased to control levels or below when the cells also received estrogen. Dexamethasone, at both levels, reduced protein accumulation (Table 3) compared to the control. A trend to reverse the effects of dexamethasone was found when higher levels of estrogen were added. Protein accumulation increased considerably when $10^{-7}$ and $10^{-9}$ M dexamethasone and estrogen were used.

An increase ($P<.05$) in protein synthesis was observed when $10^{-9}$ M growth hormone and dexamethasone were added to the cells. Protein degradation tended to decrease when cells were treated with dexamethasone and growth hormone at both levels. As a result, protein accumulation increased ($P<.05$) for cells treated with growth hormone and dexamethasone at $10^{-9}$M. A significant increase ($P<.05$) in protein synthesis was observed when $10^{-9}$ M dexamethasone was combined with $10^{-7}$ or $10^{-9}$ M IGF-1. Higher levels of dexamethasone decreased degradation while lower levels of dexamethasone increased degradation. Dexamethasone at $10^{-9}$ M combined with $10^{-7}$ and $10^{-9}$ M IGF-1 tended to reduce degradation. Protein accumulation was significantly enhanced ($P<.05$) when cells were treated with a combination of $10^{-9}$ M dexamethasone and either $10^{-7}$ or $10^{-9}$ M IGF-1.

Dexamethasone included at $10^{-7}$ M tended to increase protein synthesis in the progesterone experiment compared to the control. Protein synthesis was increased ($P<.05$) in cells treated with $10^{-7}$ M dexamethasone and progesterone. Dexamethasone did not affect protein degradation. However, in cells treated with dexamethasone at $10^{-7}$ M and progesterone at $10^{-7}$ or $10^{-9}$ M, protein degradation tended to increase. Treatment with $10^{-9}$ M progesterone combined with $10^{-7}$ M dexamethasone tended to reduce accumulation.

Although testosterone did not alter the effect of dexamethasone on synthesis at high levels ($10^{-7}$ M), low levels combined with dexamethasone tended to increase protein synthesis. Dexamethasone enhanced protein degradation at either level. Treatment with dexamethasone and testosterone at $10^{-7}$ M increased ($P<.05$) protein degradation. Protein accumulation was reduced with higher levels of dexamethasone. Both levels of testosterone combined with lower levels of dexamethasone tended to increase protein accumulation. Higher levels of testosterone ($10^{-7}$ M) tended to enhance the effect of dexamethasone.

Neither estrogen combined with zeranol nor the zeranol control had an affect on protein synthesis. Cells treated with zeranol and estrogen at $10^{-7}$ M and $10^{-9}$ M responded with increased ($P<.05$) protein degradation which then decreased ($P<.05$) accumulation. Overall, estrogen combined with zeranol enhanced the effect of zeranol.

Protein synthesis was decreased in cells treated with $10^{-7}$ M zeranol with $10^{-7}$ or $10^{-9}$ M growth hormone or $10^{-9}$ M zeranol combined with $10^{-7}$ M growth hormone ($P<.05$). While zeranol did not alter degradation, some combinations of growth hormone and zeranol increased degradation over controls. Protein accumulation was reduced when $10^{-7}$ and $10^{-9}$ M zeranol was combined with growth hormone.

Low level combinations of testosterone and zeranol reduced synthesis compared to controls. Testosterone at $10^{-7}$ M combined with zeranol at $10^{-9}$ M tended to increase protein degradation compared to the control, thus reducing accumulation.

Dexamethasone and zeranol generally reduced protein synthesis. Zeranol also tended to reduce protein synthesis. Protein degradation decreased ($P<.05$) when cells were treated with $10^{-9}$ M zeranol and $10^{-7}$ M dexamethasone. Combinations of $10^{-7}$ M dexamethasone and $10^{-9}$ M zeranol increased ($P<.05$) accumulation, thus enhancing the effect of zeranol. Cells treated with zeranol combined with IGF-1 and progesterone exhibited no effect on protein synthesis or degradation.

The BC3H1 cell line demonstrated varied responses to treatments with anabolic agents combined with dexamethasone and zeranol. Dexamethasone generally tended to reduce synthesis or enhance degradation, thus the individual treatment of the selected anabolic agents resulted in synergistic or antagonistic effects on dexamethasone's response. Estrogen, growth hormone, and IGF-1 tended to reverse the effect of dexamethasone, while progesterone and testosterone enhanced the effect of dexamethasone. The selected anabolic agents responded independently when combined with zeranol. Generally, zeranol tended to reduce synthesis. Estrogen, growth hormone and testosterone reduced overall accumulation, thus enhancing the effect of zeranol

on the cells. However, the dexamethasone treatment of cells treated with zeranol enhanced accumulation. Estrogen, testosterone, growth hormone, and dexamethasone generally enhanced the effects of zeranol.

## Conclusion

Combinations of anabolic agents and dexamethasone or zeranol produced a range of effects on cell function. These experiments indicate that BC3H1 cell cultures respond to anabolic agents and provide mechanisms to assess growth regulation. Studies with the BC3H1 cell line provide an avenue to assess protein synthesis or degradation responses to individual or combined anabolic agents to better understand how they may alter protein growth in cattle.

## Literature Cited


1. Allen, R.E. 1987. Muscle cell culture as a tool in animal growth research. Fed. Proc. 46:290.
2. Dulley, J.R. and P.A. Grieve. 1975. A simple technique for eliminating interference by detergent in the Lowry method of protein determination. Anal. Biochem. 64:136.
3. Gunn, J.M., J.B. Bodner, S.E. Knowles, and F.J. Ballard. 1983. Inhibition of protein breakdown by epidermal growth factor in IMR90 human fibroblasts and other mammalian cell lines. Biochem. J. 210:251.
4. Gunn, J.M., S.E. Clark, S.E. Knowles, M.F. Hopgood, and F.J. Ballard. 1977. Reduced rates of proteolysis in transformed cells. Nature 266:58.
5. Snochowski, M., K. Lundstrom, E. Dahlberg, H. Peterson, and L.E. Edquist. 1981. Androgen and glucocorticoid receptors in porcine skeletal muscle. J. Anim. Sci. 53:80.
6. Spizz, G., D. Roman, A. Strauss, and E. Olson. 1986. Serum fibroblast growth factor inhibit myogenic differentiation through a mechanism dependent on protein synthesis and independent of cell proliferation. J. Biol. Chem. 261:9483.
7. Wakelam, M.J. 1985. The fusion of myoblasts. Biochem. J. 228:1.


TABLE 1. ANABOLIC AGENT EFFECTS ON PROTEIN SYNTHESIS (%) IN BC3H1 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 18.41 | 18.36 | 16.69 | 18.92 | 17.23 | 16.77 | 28.99 | 12.11 |
| Progesterone | 23.68 | 27.25 | 29.51[b] | 26.32 | 23.80 | 25.16 | 25.64 | .62 |
| Testosterone | 25.67 | 26.51 | 24.82 | 26.46 | 23.11 | 28.16 | 27.40 | .83 |
| IGF-1 | 8.56 | 1.93 | 1.82 | 8.13 | 67.25 | 217.01[b] | 135.63[b] | 11.51 |
| GH | 10.96 | 10.49 | 10.11 | 8.26 | 7.04 | 12.05 | 46.36[b] | 1.49 |
| Regulator: | | ZERANOL | | | | | | |
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 18.42 | 20.09 | 20.01 | 17.41 | 18.85 | 17.30 | 18.44 | .45 |
| Progesterone | 20.59 | 18.06 | 17.81 | 19.34 | 20.55 | 19.12 | 18.43 | .36 |
| Testosterone | 20.17 | 21.66 | 21.38 | 21.47 | 20.98 | 21.01 | 16.76 | .73 |
| IGF-1 | 22.44 | 22.69 | 24.03 | 22.75 | 22.66 | 21.68 | 20.86 | .34 |
| GH | 26.66 | 26.10 | 24.25[b] | 24.35[b] | 24.91 | 24.93 | 24.49[b] | .22 |
| Dexamethasone | 13.21 | 16.72 | 15.60 | 12.56 | 13.06 | 13.52 | 12.62 | .55 |

[a]Values are the mean for three determinations and are contrasted to the control (no treatment) for each run. All cultures were exposed to regulators for a total of 18 h.

[b]Treatment differs from control ($P < .05$).

TABLE 2. ANABOLIC AGENT EFFECTS IN COMBINATION ON PROTEIN DEGRADATION (%) IN L6 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 50.3 | 51.2 | 49.9 | 51.5 | 51.2 | 50.9 | 50.0 | .7 |
| Progesterone | 33.1 | 36.9 | 39.1 | 34.7 | 35.8 | 44.0 | 38.0 | 3.8 |
| Testosterone | 41.2 | 44.0 | 45.0 | 37.3 | 44.4 | 52.9[b] | 50.3 | 3.2 |
| IGF-1 | 47.3 | 48.0 | 49.5 | 47.6 | 48.9 | 48.4 | 49.5 | .6 |
| GH | 52.3 | 52.7 | 55.2[b] | 52.5 | 55.8[b] | 53.2 | 55.1 | 1.0 |
| Zeranol | 43.1 | 43.9 | 42.5 | 42.9 | 40.6 | 43.3 | 42.2 | 1.0 |
| Regulator: | | ZERANOL | | | | | | |
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 51.0 | 49.9 | 49.2 | 49.6 | 49.0 | 50.8 | 49.7 | .7 |
| Progesterone | 57.9 | 53.4 | 53.9 | 55.7 | 54.8 | 52.4 | 53.5 | 1.3 |
| Testosterone | 56.2 | 54.6 | 56.4 | 53.8 | 54.6 | 54.0 | 53.7 | 1.2 |
| IGF-1 | 52.7 | 52.6 | 53.6 | 55.9 | 51.2 | 50.8 | 54.1 | .8 |
| GH | 38.1 | 43.1[b] | 45.4[b] | 43.3[b] | 45.3[b] | 41.0[b] | 43.2[b] | .9 |

[a]Values are the mean for three determinations and are contrasted to the control for each run. All cultures were exposed to regulators for a total of 18 h.

[b]Treatments differ from control ($P < .05$).

TABLE 3. ANABOLIC AGENT ON PROTEIN ACCUMULATION (%) IN BC3H1 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | -41.96 | -2.06 | 9.89 | -.40 | -3.54 | 1.02 | 20.32 | 12.12 |
| Progesterone | -24.03 | 3.95 | 1.85 | -13.16 | .08 | 1.38 | 2.97 | 2.01 |
| Testosterone | -16.63 | -.62 | -3.32 | -.52 | -4.54 | .79 | .09 | .92 |
| IGF-1 | -32.61 | 8.85 | 8.69 | 2.72 | 34.15 | 248.12[b] | 165.02[b] | 15.06 |
| GH | -30.35 | 1.65 | -3.70 | -.62 | -10.46 | -3.85 | 36.78[b] | 2.27 |
| Regulator: | | ZERANOL | | | | | | |
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | -27.05 | -1.29 | -3.97 | -6.41[b] | -3.86 | -6.67[b] | -7.11[b] | .58 |
| Progesterone | -26.88 | -.93 | -2.21 | -1.28 | -.98 | -.47 | -1.88 | .60 |
| Testosterone | -26.66 | 1.99 | 1.17 | -.43 | .86 | -17.61 | -4.47 | 2.50 |
| IGF-1 | -19.87 | 1.84 | 1.73 | .85 | 1.09 | .20 | .40 | .38 |
| GH | -13.53 | -1.70 | -3.83[b] | -3.06 | -1.17 | -3.37[b] | -2.61 | .39 |
| Dexamethasone | -28.07 | 5.54 | 4.62 | 1.82 | 3.68 | 10.15[b] | 2.46 | .96 |

[a]Values are calculated means using the formula: %Synthesis - %Degradation = %Accumulation and the values are expressed as the differences from the control for each run. All cultures were exposed to steroids for a total of 18 h.

[b]Treatment differs from controls ($P < .05$).

# Protein Synthesis, Degradation, and Accumulation Response in an L6 Myoblast Cell Culture System with Anabolic Agents

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## Summary

Non-differentiated L6 myoblasts were used to determine protein degradation and synthesis using 0, $10^{-7}$ and $10^{-9}$ M levels of dexamethasone or zeranol combined with estrogen, progesterone, testosterone, IGF-1, and growth hormone at $10^{-7}$ or $10^{-9}$ M. Estrogen, testosterone, and growth hormone added to dexamethasone increased protein synthesis. Inhibition of protein degradation with the combined anabolic agents appeared to be additive for zeranol combined with growth hormone while others (estrogen, testosterone, and growth hormone) were not additive. Results from this study support the concept of interactions of anabolic agents in net protein accretion in live animals.


## Introduction

Anabolic agents are used in the beef production industry in order to increase growth rate, feed conversion efficiency and the lean meat yield of carcasses. Thus, while the value of anabolics for meat production is well established, little is known about the direct effects these substances have on muscle cell growth of meat animals. An understanding of these factors in cellular and molecular terms would permit greater manipulation of animal function to optimize lean meat production.

Muscle cell culture techniques have been used for several years in research on muscle growth and development. Several types of culture systems have been devised, including primary cultures from embryonic or postnatal muscle and myogenic cell lines. By investigating the response to anabolic and catabolic agents in non-differentiated myoblasts, an understanding of in vivo regulation of muscle growth can be achieved, as well as determining the effect of exogenous growth regulators on normal mechanisms which enhance protein accretion to develop leaner animal products.

## Materials and Methods

Non-differentiated L6 myoblasts were used to determine protein degradation and synthesis using 0, $10^{-7}$ and $10^{-9}$ M levels of dexamethasone or zeranol combined with estrogen, progesterone, testosterone, IGF-1, and growth hormone at $10^{-7}$ or $10^{-9}$M. The cells were cultivated for 72 h and maintained in Dulbecco's Modified Eagle Medium (DMEM)[2] containing 10 percent bovine calf serum and 0.2 percent glucose and glutamine. Serum was included as a positive control but all treatments were evaluated in serum free media. No antibiotics were used in the media. Three multiwells for each concentration of treatment were used for each experiment.

### *Measurement of Protein Synthesis*

Rates of protein synthesis were measured by determining the uptake of radioactivity (5 μCi [$^3$H]leucine) into cell protein using the modified procedures of Gunn et al. (2). A modified Lowry method (1) was used for protein determination, and synthesis was expressed as counts per minute (cpm) of radioactivity incorporated per mg of protein.

### *Measurement of Protein Degradation*

The basic method used for determination of degradation was the modified pulse-chase procedure of Gunn et al. (3). Percent degradation was expressed as the percent protein degraded over a 4-h period and was calculated as follows:

$$\% \text{ Degradation} = \frac{[^3\text{H}] \text{ Media amino acids}}{[^3\text{H}] \text{ in Media amino acids} + \text{Cell proteins} + \text{Media proteins}}$$

The measurement of radioactivity in media protein represents the leakage of protein from cells and is an indicator of cell viability.

### *Accumulation*

Accumulation was calculated by subtracting percent degradation from percent synthesis, and the data for all treatments are expressed relative to the control for each experiment.

### *Statistics*

Protein synthesis, degradation, and accumulation were statistically analyzed (ANOVA) and means were compared using Fisher's Protected LSD when the main effect of treatment was significant.

## Results and Discussion

An increase ($P<.05$) in protein synthesis (Table 1) was observed when $10^{-7}$ M estrogen and dexamethasone were added to the cells. Dexamethasone, at both levels, tended to slightly increase protein degradation. Estrogen added with dexamethasone did not alter protein degradation (Table 2). Protein accumu-

lation (Table 3) was increased (P<.05) when dexamethasone and estrogen were combined at $10^{-7}$ M. However, estrogen and dexamethasone were not expected to increase protein synthesis.

Treatments of dexamethasone at both levels tended to increase overall protein synthesis. Dexamethasone and progesterone tended to increase protein synthesis. Overall protein accumulation increased in response to combinations of progesterone and dexamethasone.

Dexamethasone combined with testosterone at all levels, increased (P<.05) protein synthesis compared to controls. All levels of testosterone tended to increase (P<.05) protein degradation, particularly for $10^{-9}$ M dexamethasone and $10^{-7}$ M testosterone. Protein accumulation tended to decrease when low levels ($10^{-9}$ M) of dexamethasone were combined with testosterone, and was enhanced when high levels $10^{-7}$ M) of dexamethasone were combined with testosterone.

An increase (P<.05) in protein synthesis was observed when $10^{-7}$ M dexamethasone was combined with $10^{-9}$ M IGF-1. Lower levels of dexamethasone treated with $10^{-7}$ and $10^{-9}$ M IGF-1 decreased (P<.05) protein synthesis. Dexamethasone combined with IGF-1 tended to increase degradation. Protein accumulation was reduced (P<.05) when $10^{-7}$ M dexamethasone and IGF-1 were combined, and when $10^{-9}$ M dexamethasone with $10^{-7}$ or $10^{-9}$ M IGF-1 were included. It has been postulated that growth hormone may change muscle growth by regulating levels of IGF-1 which then acts directly on satellite cells to stimulate proliferation of muscle.

Either level of dexamethasone combined with $10^{-7}$ M growth hormone reduced protein synthesis. However, both levels of dexamethasone with $10^{-9}$ M growth hormone increased (P<.05) protein synthesis when compared to the control. Dexamethasone and growth hormone at $10^{-7}$ M increased (P<.05) protein degradation in myoblast cultures. As a result, protein accumulation tended to be reduced the greatest at $10^{-7}$ M levels of dexamethasone and growth hormone.

Dexamethasone had no effect individually or when combined with zeranol on protein synthesis. Combinations of zeranol and dexamethasone did not affect protein degradation.

Zeranol with $10^{-7}$ and $10^{-9}$ M estrogen tended to increase protein synthesis. Estrogen combined with zeranol had no effect on protein degradation. Protein accumulation tended to be enhanced with estrogen-zeranol combinations compared to the control. Since zeranol and estrogen are both growth regulators in animals, an increase in accumulation in muscle cells parallels animal response.

High levels of zeranol combined with progesterone tended to decrease protein synthesis while low levels of dexamethasone combined with progesterone tended to increase protein synthesis. Zeranol individually and combined with progesterone at $10^{-9}$ M in cells, tended to decrease protein degradation. However, $10^{-7}$ M zeranol combined with $10^{-9}$ M progesterone enhanced degradation over the control. The combination of progesterone combined with $10^{-7}$ M zeranol reduced protein accumulation.

Testosterone at $10^{-9}$ M combined with $10^{-7}$ M zeranol and $10^{-7}$ M testosterone combined with $10^{-9}$ M zeranol increased (P <.05) protein synthesis. Testosterone combined with zeranol did not effect protein degradation. Overall, testosterone combined with zeranol enhanced protein accumulation.

Protein synthesis increased (P <.05) with $10^{-9}$ M zeranol combined with $10^{-7}$ and $10^{-9}$ M growth hormone. Protein degradation was increased (P <.05) when $10^{-7}$ and $10^{-9}$ M growth hormone was added with either level of zeranol. As a result, $10^{-7}$ M zeranol with $10^{-9}$ M growth hormone and $10^{-9}$ M zeranol and growth hormone greatly reduced protein accumulation.

High levels of zeranol combined with IGF-1 tended to decrease protein synthesis while low levels of zeranol and IGF-1 tended to increase protein synthesis. Protein degradation was enhanced with most levels of zeranol combined with IGF-1. Protein accumulation was decreased for $10^{-7}$ M zeranol with $10^{-7}$ and $10^{-9}$ M IGF-1.

## Conclusions

Observations that dexamethasone exerts a regulatory effect on protein degradation were confirmed using the L6 cell line. Estrogen, testosterone, and growth hormone added to dexamethasone increased protein synthesis. The potentiation for inhibition for protein degradation observed with the combined anabolic agents appeared to be additive for zeranol combined with growth hormone while others (estrogen, testosterone, and growth hormone) were not additive.

The mechanism for the inhibition or enhancement of protein synthesis and degradation by growth regulators is not known with certainty in live animals, but evidence with muscle cells in culture indicates responses depend on the combination of regulators present. Results from this study, support the concept of interactions of anabolic agents in net protein accretion in live animals.

## Literature Cited


1. Dulley, J.R. and P.A. Grieve. 1975. A simple technique for eliminating interference by detergent in the Lowry method of protein determination. Anal. Biochem. 64:136.
2. Gunn, J.M., J.B. Bodner, S.E. Knowles, and F.J. Ballard. 1983. Inhibition of protein breakdown by epidermal growth factor in IMR90 human fibroblasts and other mammalian cell lines. Biochem. J. 210:251.
3. Gunn, J.M., S.E. Clark, S.E. Knowles, M.F. Hopgood, and F.J. Ballard. 1977. Reduced rates of proteolysis in transformed cells. Nature 266:58.

TABLE 1. ANABOLIC AGENT EFFECTS IN COMBINATION ON PROTEIN SYNTHESIS (%) IN L6 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 14.9 | 15.6 | 21.0[b] | 16.6 | 14.8 | 16.8 | 16.0 | 1.0 |
| Progesterone | 19.2 | 28.2 | 27.5 | 29.3 | 30.6 | 32.0 | 32.0 | 3.1 |
| Testosterone | 10.2 | 17.9[b] | 19.6[b] | 16.8[b] | 18.0[b] | 19.0[b] | 18.2[b] | 1.6 |
| IGF-1 | 27.0 | 23.5[b] | 25.0 | 24.2[b] | 27.0 | 24.0[b] | 24.0[b] | .9 |
| GH | 22.7 | 23.7 | 22.6 | 24.9[b] | 24.2 | 22.0 | 26.3[b] | .6 |
| Zeranol | 33.2 | 32.8 | 31.6 | 32.8 | 33.3 | 33.7 | 33.5 | 1.6 |

| Regulator: | | ZERANOL | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 24.4 | 29.2 | 27.2 | 28.7 | 29.9 | 28.2 | 27.7 | 1.4 |
| Progesterone | 20.0 | 19.7 | 18.5 | 18.0 | 17.9 | 19.2 | 18.7 | .6 |
| Testosterone | 23.1 | 25.2 | 26.0 | 28.8[b] | 28.5[b] | 27.9[b] | 26.5 | 3.2 |
| IGF-1 | 23.3 | 19.9 | 23.8 | 21.7 | 23.3 | 22.1 | 23.9 | 1.4 |
| GH | 23.6 | 25.2 | 28.2 | 17.7 | 26.4 | 32.5[b] | 38.8[b] | 2.7 |

[a]Values are the mean for three determinations and are contrasted to the control (no treatment) for each run. All cultures were exposed to regulators for a total of 18 h.

[b]Treatment differs from control ($P < .05$).

TABLE 2. ANABOLIC AGENT EFFECTS ON PROTEIN DEGRADATION (%) IN BC3H1 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 60.37 | 62.38 | 48.76[b] | 61.28 | 62.73 | 57.71 | 50.63 | 1.34 |
| Progesterone | 47.72 | 47.34 | 51.70 | 63.52 | 47.76 | 47.82 | 46.73 | 1.99 |
| Testosterone | 42.31 | 43.77 | 44.78[b] | 43.62 | 44.29[b] | 44.01 | 43.95 | .21 |
| IGF-1 | 41.17 | 25.69 | 25.74 | 38.03 | 65.71 | 1.49 | 3.22 | 5.04 |
| GH | 41.31 | 39.19 | 44.16 | 39.23 | 47.85 | 38.51 | 39.93 | 1.36 |

| Regulator: | | ZERANOL | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | 45.47 | 48.43 | 51.04[b] | 50.87[b] | 49.76[b] | 51.02[b] | 52.59 | .39 |
| Progesterone | 47.47 | 45.87 | 46.90 | 47.49 | 48.42 | 46.47 | 47.18 | .35 |
| Testosterone | 46.84 | 46.23 | 46.87 | 48.56 | 46.78 | 65.29 | 47.89 | 2.41 |
| IGF-1 | 42.31 | 40.73 | 42.17 | 41.76 | 41.45 | 41.36 | 40.81 | .24 |
| GH | 40.19 | 41.33 | 41.62 | 40.94 | 39.61 | 41.83 | 40.64 | .23 |
| Dexamethasone | 41.29 | 39.25 | 39.06 | 38.82 | 37.70 | 31.44[b] | 38.23 | .78 |

[a]Values are the mean for three determinations and are contrasted to the control for each run. All cultures were exposed to regulators for a total of 18 h.

[b]Treatments differ from control ($P < .05$).

TABLE 3. ANABOLIC AGENT EFFECTS IN COMBINATION ON PROTEIN ACCUMULATION (%) IN L6 MYOBLAST CULTURES[a]

| Regulator: | | DEXAMETHASONE | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | -35.3 | -.3 | 6.4[b] | .4 | -1.1 | 1.2 | 2.2 | 1.5 |
| Progesterone | -13.9 | 5.2 | 2.3 | 8.5 | 8.6 | 1.9 | 7.9 | 5.4 |
| Testosterone | -30.9 | 4.8 | 5.5 | 10.4[c] | 4.5 | -2.9 | -1.2 | 3.5 |
| IGF-1 | -20.4 | -4.2[b] | -4.2[b] | -3.1[c] | -1.5[c] | -4.0[b] | -5.1[b] | 1.1 |
| GH | -29.6 | .6 | -3.0 | 2.1 | -2.0 | -1.6 | .8 | 1.3 |
| Zeranol | -9.9 | -1.2 | -.9 | -.1 | 2.6 | .4 | 1.2 | 1.9 |

| Regulator: | | ZERANOL | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Regulator level: | | -7 M | | | -9 M | | | |
| Agent level: | C | 0 | -7 M | -9 M | 0 | -7 M | -9 M | SE |
| Estrogen | -26.5 | 5.8[c] | 4.6[c] | 5.6[c] | 7.4[c] | 3.9 | 4.5[c] | 1.8 |
| Progesterone | -37.9 | 4.2[c] | 2.6 | .2 | 1.0 | 4.7[c] | 3.1 | 1.6 |
| Testosterone | -33.1 | 3.7 | 2.7[c] | 8.0 | 7.0[c] | 6.9[c] | 5.9[c] | 2.2 |
| IGF-1 | -29.4 | -3.3 | -.4 | -1.8 | 1.5 | .7 | -.8 | 1.8 |
| GH | -14.5 | -3.4 | -2.7 | -11.1[b] | -4.4 | -6.0 | -10.0[b] | 3.1 |

[a]Values are expressed as the differences from the control for each run. All cultures were exposed to steroids for a total of 18 h.

[b]Treatment differs from control ($P < .05$).

[c]Treatment differs from control ($P < .10$).

# Effects of Stocking Rate and Supplemental Feeding on Adult Beef Cows on Rangeland in the Edwards Plateau Region of Texas

J.E. Huston and P.V. Thompson


## Summary

A study was conducted at the H. D. Winters Ranch, Brady, Texas, to determine the effects of stocking rate and supplemental feeding on adult beef cows. Beef cows were combined with flocks of sheep and goats (2:1:1 on animal unit basis) and stocked at 20 (low), 15 (medium) and 10 (high) acres per animal unit (AU) on native rangeland. Sheep and goats were treated the same in all pastures. Supplemental feed treatments were imposed on cows using Calan feeding gates so that all feed treatments were fed to individual cows at each stocking rate. Feed treatments included a control (no supplemental feed), and low (.66 lb crude protein, CP, and 2 megacalories, Mcal, of digestible energy, DE), medium (.66 lb CP and 4 Mcal DE) and high (.66 lb CP and 8 Mcal DE) feeding per day. Weight and condition changes generally were larger as stocking rate increased. Fall-to-spring weight and condition losses were greater but spring-to-fall gains were also greater as stocking rate increased. Feeding decreased weight and condition fluctuations, but feeding at a low level was generally as effective as feeding at higher levels. Trends were noted for conception rates and calf weaning weights, which were not statistically significant. The nature of the study precluded carryover effects of feed treatments. Therefore, it is suggested that weight and condition changes be considered indicative of reproductive performance expectations.


## Introduction

The rangelands of the Edwards Plateau region of Texas are effectively used by grazing multiple ruminant species that include cattle, sheep, goats, and white-tailed deer. Each species uniquely relates to the vegetation and the animal: forage association forms the match and mismatch that leads to a level of productivity. For cattle, the fluctuating nutrient content of range vegetation (1) offers periods of excess but also imposes periods of deficiency. Spring to mid-fall (the frost-free period) generally provides greater than required levels of nutrients. During the cold-dormant season, nutrients are at relatively low concentrations in typical range vegetation. The animal system is equipped to some extent to function under such cyclic highs and lows in diet quality and responds with a level of productivity. Two management strategies that can influence diet quality, thus productivity, include adjustments in stocking rate and supplies of supplemental nutrients. This report includes partial and preliminary findings from a study to quantify effects of stocking rate and supplemental feeds on adult beef cows.

## Experimental Procedure

Rangeland on the H. D. Winters Experimental Ranch near Brady, Texas, is typical of a large portion of the Edwards Plateau region. The herbaceous vegetation is primarily warm-season, perennial grasses but includes several species of forbs and legumes and a few species of winter-growing plants (3). Also, the landscape is sprinkled with species of oak (both deciduous and evergreen) and various other shrubs and trees. Rainfall tends to be bimodal (spring and fall) and averages about 22 inches annually. Typically, the breeding season for cattle is during the spring and calving begins in January. Stocking rates range from 30 to 50 AU per section (approximately 10 to 20 acres per AU) with a mixture of cattle, sheep, goats, and white-tailed deer.

Three variable sized pastures that were described previously (3) were stocked with adult Hereford x Brangus cows, Rambouillet sheep, and Angora goats at a ratio of 2:1:1 on an animal unit basis. The three pastures were stocked at rates of 20 (low), 15 (medium) and 10 (high) acres per animal unit during the fall of 1987. During the first 12 months, the animals were treated identically and no experimental treatments were imposed. In the fall of 1988, the cows in each pasture (stocking rate) were assigned randomly to four supplemental feed treatments that included a negative control (no supplemental feed) and three feed levels (Table 1). Feeding began on December 1 and was terminated March 22, 1989. In the fall of 1989, nonpregnant cows were removed and replaced with pregnant cows of similar age from an auxiliary herd. All cows were re-randomized to feed treatment, and the experimental procedure was repeated during 1989-90. All sheep and goats were treated the same in all three pastures.

Response data included fall and spring weights and condition scores (1 to 9 scale), calf weaning weights (Oct.) and conception (Oct.). The data were analyzed by orthogonal contrasts as follows:

| | |
|---|---|
| Stocking Rate: | Low vs medium, high |
| | Medium vs high |
| Supplemental Feeds: | Control vs low, medium, high |
| | Low vs medium, high |
| | Medium vs high |

The error term used assumed a completely random model and tests for significance were at the .05 level of probability.

Feeding levels were prescribed for the individual cow according to body weight and condition. However, the feeding levels approximated the equivalent described in Table 1.

## Results and Discussion

The 2 years, 1988-89 and 1989-90, were completely different climatically. The winter of 1988-89 provided ample dormant forage. However, the growing season of 1989 was very dry and very little forage was accumulated. Cows were thin at the onset of winter, 1989, and forage was generally limited. The growing season, 1990, was blessed with excellent growing conditions. Such extremes are typical of year-to-year changes in the Edwards Plateau region.

The data were pooled for the 2 years because of the absence of a clear stocking rate × feeding rate interaction. The data were also pooled for the main effects of stocking rate (Table 2) and feeding treatments (Table 3).

Stocking rate had significant effects on cow weight. Cows at the low stocking rate lost less weight than those at the higher stocking rates (P<.05). On the other hand, cows at the high stocking rate, which lost the most weight from fall to spring, gained more weight between spring and fall compared with those stocked at the lower rates (P<.05). Changes in body condition tended to follow weight changes, but because of high variability, the differences were not statistically separable. Likewise, calf weaning weights were not different.

Feeding affected cow weight and condition changes. Whereas unfed cows (control) lost 21.9 percent of their fall weight by spring, feeding reduced the weight loss to between 10.1 percent and 14.7 percent (P<.05). Also, the cows fed at the low level lost less weight than those fed at higher levels (P<.05). Fed cows tended to gain less weight between spring and fall compared with control cows (approached significance) and cows fed at higher levels of energy (medium and high) gained more weight than low-fed cows (P<.05). Condition changes were reduced by feeding (P<.05). Fed cows tended to wean heavier calves (NS, approached significance).

Overall, the data indicate that both stocking rate and feeding have marked effects on cow weight and condition changes and perhaps minimal effects on weaning weights. In this study, cows that received adequate protein and phosphorus at a minimal feeding level performed as well as and perhaps better than those fed elevated levels of energy. Elevated energy feeding may have adversely altered ruminal microflora and/or foraging patterns. Data yet to be analyzed on forage intake may clarify this effect.

Conception data were not adequate to clearly show treatment effects. However, conception is a discrete yes/no response and possible carryover effects were not allowed. It is likely that tendency to breed would have surfaced as a treatment response if the cows had been held on the respective treatments over years. Because weight and condition changes are related to conception (2), it is suggested that these response data are indicative of the effects of stocking rate and feeding on reproductive likelihood.

## Literature Cited


1. Huston, J.E., B.S. Rector, L.B. Merrill, and B.S. Engdahl. 1981. Nutritional value of range plants in the Edwards Plateau region of Texas. Texas Agri. Exp. Sta. Bul. B-1357.
2. Lusby, K.S. 1990. Review of protein, energy and body condition effects on beef cattle reproduction. Beef Cattle Science Handbook 24:1.
3. Rector, B.S. 1983. Diet selection and voluntary forage intake by cattle, sheep and goats grazing in different combinations. Ph.D. Diss., Texas A&M Univ., College Station, Texas. 173 pp.


TABLE 1. FEED SUPPLEMENTS, AVERAGE FEEDING RATES AND APPROXIMATE SUPPLY OF NUTRIENTS IN A STOCKING RATE - SUPPLEMENTAL FEEDING STUDY WITH ADULT COWS ON RANGELAND

| | Supplemental Feed Treatments | | | |
|---|---|---|---|---|
| Item | Control | Low | Medium | High |
| Supplement ingredients, % | | | | |
| Cottonseed meal | -- | 93 | 44 | 7.0 |
| Sorghum grain (milo) | -- | -- | 52 | 89.5 |
| Molasses | -- | 3 | 3 | 3.0 |
| Urea | -- | 1 | -- | -,- |
| Mono-dicalcium phosphate | -- | 3 | 1 | 0.5 |
| Salt (sodium chloride)[1] | + | + | + | + |
| | | 100 | 100 | 100.0 |
| Feeding rate[2], lb/d | -- | 1.56 | 2.86 | 5.07 |
| Approximate nutrient supply[2] | | | | |
| Crude protein, lb/d | -- | .66 | .66 | .66 |
| Digestible energy, Mcal/d | -- | 2 | 4 | 8 |
| Phosphorus, g/d | -- | 10 | 10 | 10 |

[1]Salt was provided free-choice to all cattle.
[2]Feeding rates and approximate nutrients provided for a cow weighing 1000 lb and having a body condition score of 5.

TABLE 2. EFFECTS OF STOCKING RATE ON WEIGHT AND CONDITION CHANGES, CALF WEANING WEIGHTS AND CONCEPTION IN ADULT BEEF COWS ON RANGELAND IN THE EDWARDS PLATEAU REGION OF TEXAS[1]

| Item | Stocking Rate[2] | | |
|---|---|---|---|
| | Low | Medium | High |
| Number of cows | 17 | 46 | 14 |
| Cow wt, lb | | | |
| Fall | 1091 | 1091 | 1086 |
| Spring[3] | 974 | 916 | 880 |
| Fall | 1053 | 1028 | 1069 |
| Wt change, % of fall wt | | | |
| Fall to spring[3] | -10.7 | -16.0 | -19.0 |
| Spring to fall[3] | 7.1 | 10.2 | 17.4 |
| Fall to fall | -3.6 | -5.8 | -1.6 |
| Condition score change[4] | -.94 | -1.13 | -1.37 |
| Calf weaning wt, lb | 617 | 581 | 603 |
| Conception, pregnant/total | 17/17 | 41/46 | 13/14 |

[1]Study conducted at H. D. Winters Ranch at Brady, Texas, during 2 years.
[2]Stocking rates were 20, 15 and 10 acres per animal unit for low, medium and high stocking rates, respectively
[3]Orthogonal contrasts (P<.05)
Spring wt, low > medium and high
% wt change:
Fall to spring, low < medium and high
Spring to fall, high > medium
[4]Condition scores were assigned on a 1 to 9 scale.

TABLE 3. EFFECTS OF SUPPLEMENTAL FEEDING ON WEIGHT AND CONDITION CHANGES, CALF WEANING WEIGHTS AND CONCEPTION IN ADULT BEEF COWS ON RANGELAND IN THE EDWARDS PLATEAU REGION OF TEXAS[1]

| Item | Feeding Treatments[2] | | | |
|---|---|---|---|---|
| | Control | Low | Medium | High |
| Number of cows | 22 | 19 | 17 | 19 |
| Cow wt, lb | | | | |
| Fall | 1058 | 1107 | 1087 | 1113 |
| Spring[3] | 826 | 995 | 936 | 949 |
| Fall[3] | 984 | 1066 | 1067 | 1060 |
| Wt changes, % of fall wt | | | | |
| Fall to spring[3] | -21.9 | -10.1 | -13.9 | -14.7 |
| Spring to fall[3] | 14.9 | 6.3 | 11.9 | 9.9 |
| Fall to fall | -6.9 | -3.7 | -1.9 | -4.8 |
| Condition score change[3,4] | -1.53 | -.88 | -1.24 | -.83 |
| Calf weaning wt, lb | 571 | 604 | 580 | 619 |
| Conception, pregnant/total | 20/22 | 18/19 | 16/17 | 17/19 |

[1]Study conducted at H. D. Winters Ranch at Brady, Texas, during 2 years.
[2]Feed treatments described in Table 1.
[3]Orthogonal contrasts (P<.05)
Spring wt, control < fed groups
Fall wt (end of year), control < fed groups
% wt changes:
Fall to spring, control > fed groups
low < medium and high
Spring to fall, control > fed groups
Condition score changes, control > fed groups
[4]Condition scores were assigned on a 1 to 9 scale.

# A Comparison of Supplemental Feeds for Adult Beef Cows Grazing Native Rangeland in the Edwards Plateau Region of Texas

J.E. Huston, K.W. Bales and D.W. Spiller


## Summary

Supplemental feed treatments were compared during two consecutive years in adult beef cows grazing native rangeland in the Edwards Plateau region of Texas. Treatments included a control (Control; no supplemental feed) and three supplements: a cottonseed meal-containing supplement (CSM), a feather meal-containing supplement (FM), and a commercial feed block (PDQ), each containing approximately 28 percent crude protein. The CSM and FM supplements were fed at prescribed levels, by use of Calan individual animal feeding gates, to provide 42 percent of protein requirements and uniform amounts of energy and phosphorus. The PDQ blocks were fed individually also in Calan gates but were offered free-choice. Feeding began during late fall and was discontinued in early spring each year. Intake of the PDQ block averaged .9 lb/day and ranged from 0.18 to 2.13 among the individual cows receiving the block. Cows receiving the CSM and FM treatments lost less weight between fall and spring than those on the Control and PDQ treatments ($P<.05$). A similar pattern was observed for condition score (1 to 9 scale) but the differences were not statistically significant. The cows tended to compensate during the spring to fall period for previous weight loss, and by the fall, weights among treatment groups were not significantly different. Treatment effects were not statistically different for calf weaning weight or conception rate. Overall, the CSM and FM supplements were equal and the control and PDQ treatments were comparable. The PDQ block was consumed variably among cows and at a relatively low average daily rate. The excessive weight loss in the cows fed PDQ may have been less if consumption level had been higher.


## Introduction

Range vegetation in the southern Edwards Plateau region of Texas is comprised mostly of native perennial grasses having a spring-to-fall growing season. Adult beef cows consuming diets derived from the vegetation will gain weight during the growing season and lose weight during the winter. Weight fluctuation is not harmful to productivity under most circumstances unless cow condition (fatness) drops so low as to adversely affect reproduction. Cows that reach good condition in the fall (condition score 5 to 6 on a 1 to 9 scale) can lose up to 15 percent of the fall weight by spring including weight of conceptus, and still have good conception. Thin cows (condition score <5) should lose less weight (<15%) to assure good reproductive performance. Under usual conditions, cows that do not receive any supplemental feed can lose 20 percent or more of fall weight by spring and have low or delayed conception.

## Experimental Procedure

The study was conducted at the Frances Hill Ranch lease in western Edwards county between Sonora and Rocksprings, Texas. Diets, during the winter months, are derived typically from cold-dormant, warm-season grasses that are low in protein (2), limited amounts of Texas wintergrass (*Stipa leucotricha*) and various forbs and shrubs. Nutrient contents of cattle diets at the Hill Ranch have been estimated at 6 percent crude protein, 45 percent total digestible nutrients (TDN) and 0.1 percent phosphorus, but can vary depending on environmental conditions (3). Conditions during a 2-yr study period averaged near normal.

Sixty Brangus cows were used during each of two consecutive years of the study as experimental animals. Pregnant cows were assigned randomly to experimental treatments (Table 1) during the fall (yr-1). After 1 yr, open cows were culled and replaced with similar pregnant cows from an auxiliary herd, and the new herd was again assigned randomly to experimental treatments. The cows were grazed in 15-head herds in each of four similar pastures. In each pasture, twelve cows were trained to eat from Calan feeding gates to accommodate individual animal feeding. All cows were bred to Hereford bulls during a 75-d breeding season (April 1 to June 15).

Experimental treatments included a control (Control; no supplemental feed) and three supplemental feeds (Table 1). Two supplements were formulated and fed at levels to provide 42 percent of daily protein requirements for pregnant beef cows (4) with the primary protein contribution from either cottonseed meal (CSM) or hydrolized feather meal (FM). The CSM and FM supplements were fed three times per week during the winter months. Feeding levels were prescribed on an individual animal basis and adjusted for weight and body condition. However, target and actual supplement intake levels are reported as averages for the experimental groups (Table 2). A third feed supplement (PDQ), having approximately the same protein content (Table 1), was provided free-choice on an individual cow basis by use of the Calan gates. Each feed was provided to

an equal number of cows in each pasture, and three cows in each pasture (untrained cows) were not fed (Control).

Consumption rate was of special interest since the PDQ block was fed free-choice. PDQ blocks (tubs) containing approximately 75 lb of feed were weighed and placed in the feeders at the beginning of the feeding period. Consumption was monitored visually and when feed remaining in a tub fell below approximately 5 lb, the old tub was weighed and replaced with a tub containing a new supply of feed. All tubs were weighed at termination of the feeding period.

Data were analyzed by analysis of variance according to a randomized block design with four experimental treatments and four blocks (pastures). Mean separation was according to the Studentized Range Test (5). Variables analyzed included weight and condition changes and calf weaning weight (Table 3). Conception rates are reported in Table 3 but were not subjected to statistical test.

## Results and Discussion

Data from individual animals were deleted when the cows refused to consume feed at adequate levels, failed to operate the Calan gates properly, or when problems occurred which were not associated with the experimental treatments. Therefore, of the 24 cows assigned to each experimental treatment, 22, 22, 16, and 19 supplied data for the Control, CSM, FM, and PDQ groups, respectively. In yr-1, only 4 of 12 cows adequately consumed the FM supplement, apparently because of palatability. However, the supplement was readily consumed by all 12 cows during yr-2.

The PDQ was consumed at a relatively low and variable rate (Table 2). As a result, crude protein intake from the PDQ supplement averaged only 0.25 lb/d, less than 40 percent of the amount consumed by cows fed the CSM and FM supplements. The structure of the Calan gates made feeding from the PDQ tubs slightly more difficult than if the tubs were placed on the ground. How much this may have affected consumption rate is not known. Also, consumption was variable among cows fed PDQ ranging from 0.18 to 2.13 lb/cow/day. However, similar variability in supplement intake has been demonstrated in cows fed more traditional supplements daily as a group (1).

Body weight losses (fall to spring) were less for cows fed CSM and FM supplements than for Control cows and cows fed PDQ ($P<.05$; Table 3). Cows appeared to compensate during the spring to fall period and by fall, weights were similar. Changes in body condition score (fall to spring) showed a consistent pattern with weight change, but because of considerable variability, the differences were not significant. Also, conception rates and calf weaning weights showed only small differences.

Weight losses of Control cows were somewhat typical for the region. The cows were thinner in the fall (about 1 condition score) than is normally expected but conception was greater than usual. Perhaps this was because animals were rerandomized after yr-1 and cows were not held on the control treatment for both years. What often occurs in range cattle during periods of limited feed availability is that conception occurs, but after a long post calving interval. Therefore, the probability of failure to conceive is greatly increased if cows are in poor nutrient condition during consecutive years. Because the cows were rerandomized after yr-1, the value of the weaning weight and conception data, both of which are affected by calving date, was decreased. Therefore, it is suggested that the weight and condition score data are more reflective of the effects of the experimental treatments.

Both CSM and FM supplements decreased winter weight loss of cows to acceptable levels (Table 3). The PDQ block was not an acceptable supplement under conditions of this study, probably because of less than optimal intake. It is likely that consumption level of PDQ and resulting productivity would be greater under a more conventional feeding practice. However, variability of intake of PDQ among individual cows may be greater than desired.


## Acknowledgments

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## Literature Cited


1. Huston, J.E., F.M. Byers, D. Cooper, and L.M. Schake. 1987. Feeding frequency and variations in supplement and forage i ntake in cows grazing dormant rangeland. Tex. Agric. Exp. Sta. PR-4477.
2. Huston, J.E., B.S. Rector, L.B. Merrill, and B.S. Engdahl. 1981, Nutritional value of range plants in the Edwards Plateau region of Texas. Tex. Agric. Exp. Sta. B-1357.
3. Huston, J.E. and Don Spiller. 1981. Effect of monensin on rate-of-gain in stocking calves grazing dormant, native rangeland in West Central Texas. Tex. Agric. Exp. Sta. PR-3762.
4. NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, D.C.
5. Snedecor, G.W. and W.G. Cochran. 1956. Statistical Methods (5th Ed.). The Iowa State University Press. Ames, Iowa.


TABLE 1. SUPPLEMENTAL FEED TREATMENTS IMPOSED ON ADULT COWS GRAZING NATIVE RANGELAND IN THE EDWARDS PLATEAU REGION OF TEXAS

| | Experimental treatment[a] | | | |
|---|---|---|---|---|
| Item | Control[b] | CSM | FM | PDQ[c] |
| Feed ingredients, % | | | | |
| Alfalfa meal | | 10 | 10 | |
| Sorghum grain (milo) | | 30.6 | 56 | |
| Cottonseed meal | | 54 | 0 | |
| Feather meal | | 0 | 27.2 | |
| Mono-dicalcium phosphate | | 1.4 | 2.8 | |
| Molasses | | 4 | 4 | |
| | | 100.0 | 100.0 | |
| Estimated nutrient contents | | | | |
| Crude protein (CP), % | | 28 | 29 | 28 |
| Digestible energy (DE), Mcal/lb | | 1.4 | 1.4 | |
| Phosphorus (P), % | | .94 | .97 | |

[a]Feed treatments included Control, CSM (indicated mixture), FM (indicated mixture) and PDQ Block (free-choice).
[b]Control group given access to salt free-choice.
[c]PDQ blocks provided by Positive Feed, Inc., were estimated to contain 28% CP and were offered free-choice. No estimates of DE and P contents were made.

TABLE 2. TARGET AND ACTUAL INTAKES OF SUPPLEMENTAL FEEDS OFFERED INDIVIDUALLY TO ADULT COWS GRAZING NATIVE RANGELAND IN THE EDWARDS PLATEAU REGION OF TEXAS

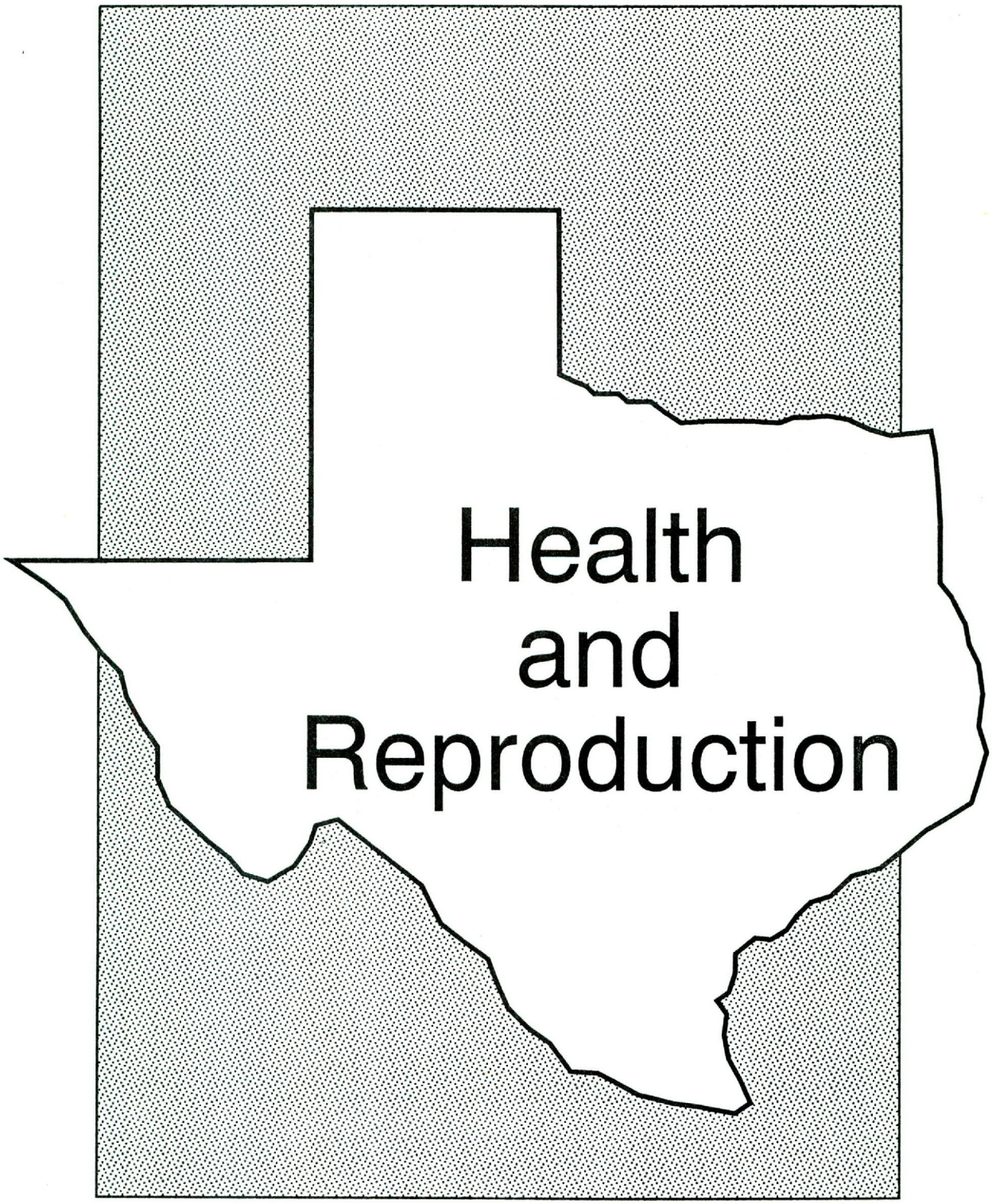
| Item | Feed supplements[a] | | |
|---|---|---|---|
| | CSM | FM | PDQ |
| Target intake | | | |
| Supplement, lb/d | 2.47 | 2.39 | 2.46 |
| CP, lb/d | .69 | .69 | .69 |
| DE, Mcal/d | 3.34 | 3.37 | |
| P, g/d | 10.54 | 10.53 | |
| Actual supplement intake | | | |
| Average, lb/d | 2.46 | 2.37 | .90 |
| Range | | | |
| Low | | | .18 |
| High | | | 2.13 |
| SD | | | .52 |
| Nutrient intake | | | |
| CP, lb/d | .69 | .69 | .25 |
| DE, Mcal/d | 3.33 | 3.35 | |
| P, g/d | 10.50 | 10.44 | |

[a]The CSM and FM supplements were offered in prescribed amounts to provide 42% of total protein requirements (4). The PDQ blocks were offered free-choice, and the indicated target intake is the consumption level required to provide the same protein offered in the CSM and FM supplements.

TABLE 3. EFFECTS OF SUPPLEMENTAL FEED TREATMENTS ON COW WEIGHTS AND CONDITION, CALF WEANING WEIGHTS AND COW CONCEPTION RATES IN THE EDWARDS PLATEAU REGION OF TEXAS

| Item | Feed treatment | | | |
|---|---|---|---|---|
| | Control | CSM | FM | PDQ |
| Number of cows | 22 | 22 | 16 | 19 |
| Cow weights, lb | | | | |
| Fall | 1039 | 1056 | 1051 | 1051 |
| Spring | 845 | 930 | 931 | 866 |
| Fall | 978 | 1001 | 1072 | 982 |
| Weight change, % of fall wt | | | | |
| Fall to spring | -18.7[a] | -11.9[b] | -11.3[b] | -17.7[a] |
| Spring to fall | 13.1 | 7.1 | 13.5 | 11.6 |
| Fall to fall | -5.7 | -4.8 | 2.2 | -6.1 |
| Cow condition score | | | | |
| Fall | 4.7 | 4.5 | 4.3 | 4.4 |
| Spring | 3.1 | 3.3 | 3.3 | 3.0 |
| Condition change | | | | |
| Fall to spring | -1.6 | -1.2 | -1.0 | -1.4 |
| Calf weaning wt, lb | 557 | 568 | 589 | 571 |
| Conception, pregnant/total | 19/22 | 19/22 | 16/16 | 16/19 |

[ab]Treatment means not sharing a common superscript are different ($P < .05$).


Health
and
Reproduction

# Effects of Freeze or Hot-Iron Branding of Crossbred Cattle on Some Physiological Indicators of Stress

D.C. Lay, Jr., T.H. Friend, R.D. Randel, C.L. Bowers, K.K. Grissom and O.C. Jenkins


## Summary

Twenty-seven crossbred calves (1/2 Simmental, 1/4 Hereford, 1/4 Brahman) averaging 257±11 d of age were either hot-iron branded (H), freeze branded (F), or served as a sham (S). Calves were blocked for temperament, weight, and sex; and randomly assigned to day and order in which treatments were applied. To reduce stress from handling at treatment time, each calf was herded through the squeeze chute daily for 5 d prior to the experiment. Jugular cannulae were established in each calf 1 d prior to application of treatment. Blood samples and heart rate were obtained at -5, -3, 0, 0.5, 1, 3, 5, 10, 15, and 20 min after application of the treatments. Mean plasma epinephrine concentrations were higher for H calves at time 0.5 than for either S or F calves (P<.001). Epinephrine, expressed as a proportion of the mean of the pre-branding concentrations, also differed between treatments, with H having higher epinephrine concentrations at time 0.5 than either S or F calves (P<.028). Heart rate expressed as a proportion of the pre-branding mean differed between treatments at time 0.5, with F calves being higher than S calves (P=.10) but not H calves (P>.50). Despite the 5 d acclimation period, handling and restraint elevated plasma hormone concentrations and heart rate, possibly masking some treatment effects. The expression of a higher epinephrine response by H calves indicates a higher momentary pain sensation that lasted less than one minute.


## Introduction

In 1966, cryo-branding, commonly referred to as freeze branding, was introduced as a painless alternative to hot-iron branding (3). However, freeze branding often appears to elicit a strong avoidance response by the animal being branded. Due to the lack of scientific studies comparing these two methods of branding and a current interest in using freeze branding instead of hot-iron branding (1), there is a need for a scientific study comparing these two methods of branding. Although there is little doubt that stimuli resulting in skin damage are painful (2), the objective of this study was to determine whether there is a difference in the degree of pain perceived by cattle when branded with either a hot or freeze iron.

## Procedure

Twenty-seven 9-mo-old crossbred (1/2 Simmental, 1/4 Hereford, 1/4 Brahman) cattle weighing 570 ± 62 (SD) lb were assigned to one of three treatments (N=9 per treatment): 1) hot-iron branded (H), 2) freeze branded (F), or 3) sham (S). The calves were blocked for temperament, weight, and sex as they were assigned to treatments. Between treatments, calves were blocked for time of day and order of treatment, to balance for any diurnal or order effects. All subjects were taken from similar pasture environments in an attempt to form a group with similar past experiences. The calves were weaned immediately prior to a 5 d training period in which they were acclimated to being quietly processed through and restrained in a squeeze chute with a head gate. None of the animals had prior experience in this chute except for the 5 d training period. The training period eliminated having to use force to get the calves into the head gate for their treatments and hopefully decreased the calves' stress response due to restraint.

Jugular cannulae were established in each calf at 14 to 20 h prior to application of treatments. To prevent the possibility of the calves associating the location where the treatments were applied with the stress of cannulation, the calves were cannulated in a different squeeze chute and handling facility than where they received their treatment. The cannula was flushed with a 2 percent NaEDTA solution, sealed off and taped to each subject's neck until the next day when a 8 ft extension was added prior to treatment. Blood samples (10 ml) were drawn into syringes containing 0.1 ml of a 10 percent NaEDTA solution at the intervals indicated in Table 1. Blood samples were then placed in an ice bath and centrifuged at 32 to 41°F within 2 h of sampling. The plasma was frozen at -13°F until the laboratory procedures could be completed.

Heart rate was monitored by using a transmitter, attached to surface electrodes which were glued on the animal, to transmit a pulse to a computer controlled receiver. The computer recorded each heart beat on a per min basis. Heart rate was continuously recorded for 30 s, starting at the time each blood sample was drawn (Table 1).

In preparation for branding, square patches of hair were clipped in corresponding areas on both

hind quarters of each calf prior to cannulation. Hot-iron branded cattle were branded with a 3.4 in high brand of the letters "TS" on the clipped site using a conventional electric brander at approximately 970°F for 5 s (8). The freeze-branded group was branded on the clipped site immediately after the application of a liberal amount of methanol (95%). The brand was an 3.4 in high letter "TS" applied for 17 s, using a 3/8 inch rounded face copper/bronze brander with liquid nitrogen as the coolant. Application of the brander for 17 s is recommended for these age calves to produce a regrowth of white hair (5). Applying the brander for 40 s or longer would have resulted in a scar similar in appearance to a hot-iron brand that has no hair regrowth. The sham treatment calves were handled identically to the branded calves, except that a 3.4 in letter "TS" iron at room temperature was held on the clipped area for 10 seconds.

Cortisol concentrations were determined on duplicate samples using commercially produced RIA kits. Samples were re-assayed if the duplicates differed by more than 5 percent. The intra-assay CV for cortisol was 16 percent.

Data were analyzed utilizing the GLM procedure (7), as a randomized block experiment, blocked for time (time of day samples were taken) and order (sequence in which animals were sampled). For each calf, the mean for samples -5 and -2 were divided into each subsequent sample to get a response to treatment at each sampling time. This proportion of the pre-branding mean was then subjected to least square means analysis (7) with treatment, time, and their interactions as main factors. The differential temperature was subjected to a repeated measures (day) analysis using least square means (7).

## Results

Informal observations indicated that the calves varied in their behavioral response to treatments. Hot-iron branded calves immediately lurched away from the iron repeatedly, occasionally falling down on their knees. Freeze branded calves did not react to the brander for approximately the first 8 s, after which they reacted similarly to the H calves. Sham branded calves usually did not move, except for occasionally moving away from the brander on initial contact.

All calves responded to treatments with increasing plasma cortisol concentrations during the 25 min study (Figure 1, P=.0001). Cortisol analyzed as a proportion of the pre-branding mean was not significantly different between treatments (P=.20).

Hot-iron branded calves had mean plasma EPI concentrations that were elevated at 0.5 min post-branding (Figure 2) over either the S or the F calves (P<.001). When EPI data were analyzed as proportions of the pre-branding mean, EPI was still greater in H than either the F or S (P=.026 and .028, respectively) at 0.5 min post-branding. Treatment differences, however, disappeared within 1 min post-branding.

Freeze branded calves had mean plasma NOR concentrations that were elevated above either the S or H calves at 20 min post-branding (Figure 3, P=.07). However, when analyzed as a proportion, F calves had lower proportions than the S calves (P=.05) at 20 min post-branding.

Four animals, 2 H and 2 F calves, were dropped from heart rate analysis due to their missing 2 or 3 critical (immediately after branding) values. The missed heart rates were caused by the calves dislodging the electrodes due to jumping and struggling when branded. Hot-iron branded calves had lower mean heart rates at 3 min post-branding (Figure 4) than either S or F calves (P<.07) and H calves had lower heart rates at 5 min post-branding than F calves (P=.04).

When heart rate was analyzed as a proportion of the pre-branding mean, time was significant (P=.0001) due to the over-all decrease in heart rate during the 25 min sampling period. Heart rates increased at 0.5 min post-branding for H and F and remained elevated until approximately 1 min post-branding. All calves' heart rates decreased below the pre-branding mean by 10 min post-branding. At 0.5 min post-branding, F and H calves tended to have higher heart rates than S calves (P=.098 and .16, respectively).

## Discussion

For the 25 min sampling period, cortisol concentrations across treatments ranged from approximately 20 to 35 ng/ml. Since cortisol values for branding and restraint are similar to mere restraint (Figure 1), as indicated by the S calves, the stress due to restraint may be masking or reducing the sensitivity of the characters measured in this study. Restraint clearly elevated the cortisol response of the calves regardless of treatment.

The greater EPI concentrations in H calves indicates a greater pain sensation since EPI is increased with psychological stress, whereas NOR is thought to increase more with physical stress (4,6). The trend for NOR to be elevated at 30 s and 1 min post-branding (P<.16) for the F calves may reflect the longer period that the freeze brander was applied.

Both F and H calves had a similar increase in heart rate response to branding (Figure 4). The relatively high pre-treatment heart rates obtained in this experiment were probably due to the stress of restraint combined with possible effects of breed differences.

Due to handling and restraint, the calves in this study exhibited increased plasma concentrations of cortisol and catecholamines as well as an elevated heart rate. Both hot-iron and freeze branded calves showed an escape avoidance reaction to branding, but a higher EPI response by the H calves at 0.5 min post-branding indicates a greater momentary pain sensation. A study using tame cattle could elucidate some important factors not obvious from studying

the relatively untamed cattle used in this experiment.

Freeze branding is often proposed as a painless alternative to hot-iron branding, although there are no scientific data to support that contention. The freeze and hot-iron branded cattle in this study showed an escape avoidance reaction to branding; however, only the hot-iron branded cattle had a physiological response indicative of pain. Freeze branding may be an alternative to hot-iron branding as a possible method to reduce momentary pain, and to reduce hide damage that decreases hide value at slaughter. Increased expense, time required to perform the procedure, difficulty in procuring a suitable coolant in remote areas, and the initial poor visibility of the brand, will likely continue to limit the use of freeze branding.

## Literature Cited


1. Animal Welfare Institute. 1986. Federal judge condemns hot-iron face branding. The Animal Welfare Institute Quarterly. 35 (1) :1.
2. Dantzer, R. 1986. Assessing pain by studying neuroendocrine responses. *In* (Ed.) I.J.H. Duncan and V. Molony. Agriculture, Assessing Pain in Farm Animals. p 39. Commission of the European Communities, Luxembourg, Brussels.
3. Ferrel, R.K. 1966. The freeze-branding technique. Proc. Freeze Brand Seminar. p 5. Washington State Univ.
4. Goldstein, D.S. 1986. Sample handling and preparation for liquid chromatography and electrochemical assays for plasma catecholamines. *In*: A.M. Krstulovic (Ed.) Quantitative analysis of Catecholamines and Related Compounds. p 176. Halsted Press, New York.
5. Kirkeide, M.A., and J. Johnson. 1982. Freeze Branding. Circular AS-501 Revised. Cooperative Extension Service, North Dakota.
6. Leblanc, J., J. Cote, M. Jobin, and A. Labrie. 1980. Effects of physical and mental stress on plasma catecholamines and cardiovascular parameters. *In*: E. Usdin, R. Kvetnansky, and I.J. Kopin (Ed.) Catecholamines and Stress: Recent Advances. p 255. Elsevier North Holland Inc. New York.
7. SAS Institute Inc. 1985. SAS, Version 5 Edition, Cary NC:SAS Institute Inc.
8. Thomas, O.O. 1978. Management of cows and their calves during the summer from the end of the breeding season to weaning. *In*: C.C. O'Mary and I.A. Dyer (Ed.) Commercial Beef Cattle Production. p 209. Lea and Febiger. Philadelphia.


TABLE 1. TIME OF BLOOD SAMPLING AND OTHER EVENTS RELATIVE TO WHEN THE CALF RECEIVED TREATMENT

| Event | Time (min) |
|---|---|
| Calf enters squeeze chute | -15 |
| Commence blood & heart rate samples (30 sec) | -5 |
| | -2 |
| Brander applied | 0 |
| | .5 |
| | 1 |
| | 3 |
| | 5 |
| | 10 |
| | 15 |
| Final Sample | 20 |

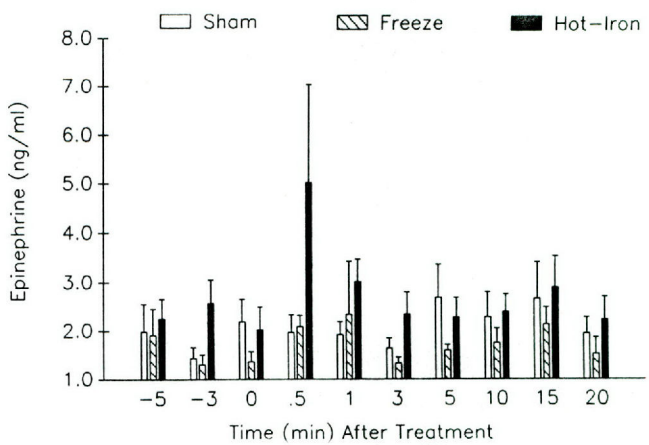



Figure 2. Mean (±SE) Epinephrine response to treatments. Treatments were administered at time 0.

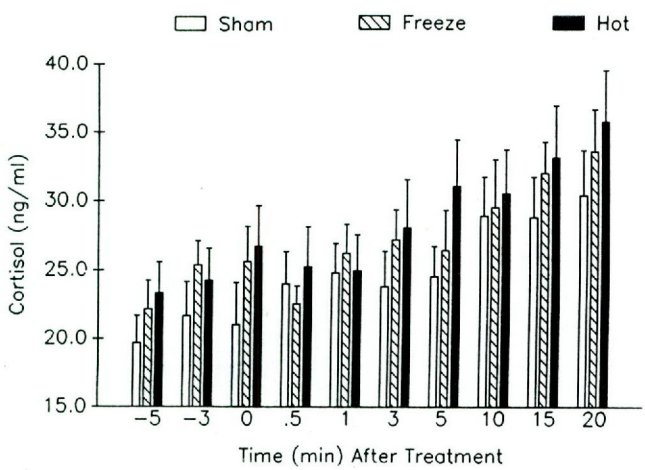



Figure 1. Mean (±SE) cortisol response to treatments. Treatments were administered at time 0.

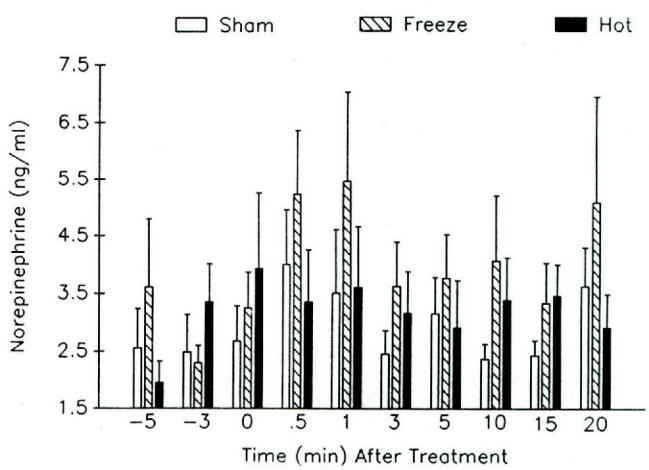



Figure 3. Mean (±SE) Norepinephrine response to treatments. Treatments were administered at time 0.

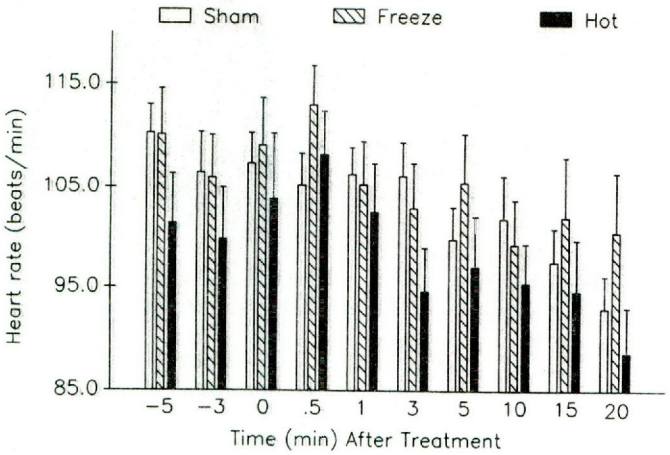



**Figure 4. Mean (±SE) heart rate response to treatments. Treatments were administered at time 0.**

# Serving Capacity and Fertility in Brahman Influenced Bulls: a Selective Review

A. Rocha, D.W. Forrest, D.E. Hawkins, B.B. Carpenter and L.R. Sprott


## Summary

Results on serving capacity (SC) of Brahman-influenced bulls are reviewed. Breeding activity was greater with SC tests using nonrestrained, estrual heifers (in heat) than with tests using nonestrual, restrained females. Brangus bulls were successfully tested for serving capacity (SC) as yearlings. Simbrah bulls responded to the tests by 15 to 17 mo of age. Santa Gertrudis bulls (mean age of 16.5 mo) achieved low numbers of intromissions and ejaculations during SC tests. At 20 mo of age, the response of Santa Gertrudis bulls was satisfactory, and the breeding proficiency did not increase with additional age or with sexual experience. When used in combination with a breeding soundness examination, the SC tests were efficient in detecting bulls with acceptable levels of fertility but need to be improved to discriminate between bulls that have apparent or actual low libido. High serving capacity bulls increased the number of calvings occurring early in the calving season.


## Introduction

In beef cattle production systems based on natural mating, the fertility of the bull influences the conception rate of the cows served by the bull. Thus, methods to predict the fertility of bulls are of paramount importance. The most widely used method to evaluate breeding potential of bulls is the breeding soundness examination (BSE), by which bulls are classified based on seminal quality and genital development (9). It is well documented that there is large variability in bull serving capacity (1) and that breeding proficiency is not correlated with either semen quality or testicular development (2, 11, 19, 21). Heritability of libido within breed for beef bulls has been calculated as 0.59±0.16 (4). Libido score, measured in several tests, as well as measured in bulls tested as yearlings and as mature animals, was highly repeatable (20, 22). In single-sire breeding groups, the pregnancy rate achieved by low libido *Bos taurus* bulls was lower than that achieved by bulls with high libido, despite both groups having similar testicular development and semen quality (20, 21). High serving capacity bulls achieved more services and bred more heifers than low serving capacity bulls in a multiple-sire breeding situation (16). Serving capacity also influenced the number of calves produced by individual bulls in multiple-sire breeding groups (12).

Methods to evaluate mating ability based on serving capacity have been developed based primarily on the performance of *Bos taurus* bulls. *Bos indicus* and *Bos indicus*-cross bulls exhibited less breeding activity than *Bos taurus* bulls in serving capacity tests (8, 13). A wide variation in libido was reported for Simbrah, Santa Gertrudis, and Beefmaster bulls (26).

Brahman-influenced breeds are extensively used for beef production in Texas. Thus, it is important to understand 1) the usefulness of techniques to assess serving capacity in the different Brahman-influenced bulls and 2) the relationship between serving capacity and reproductive performance. In this review, data on performance of Brahman-influenced bulls in SC tests and fertility trials are presented.

### *Serving Capacity Tests*

Osborne et al. (24) was the first to develop a method to assess bull libido using estrogenized (in heat), unrestrained females. Later, Blockey (1) developed a method to assess serving capacity of *Bos taurus* bulls using five bulls and three estrual females in a pen for a 7.5 h observation period. A shorter duration test (30 minutes) was also used by Blockey (3) where bulls were sexually stimulated by observing other bulls mounting females for at least 10 minutes, and then tested by a 30-minute exposure to nonestrual, restrained heifers. However, it is known that Zebu bulls have a tendency to only mount estrual females, and it has been suggested that Zebu bulls may not exhibit their inherent mating ability in the presence of restrained females (7). Crichton and Lishman (13) reported that Brahman and Brahman-influenced bulls achieved fewer services than *Bos taurus* bulls in a test with restrained females. The estrual condition of the stimulus cows influenced the breeding response of Santa Gertrudis bulls (15). For further understanding of the influence of type of test on serving capacity of *Bos indicus* influenced bulls, two tests adapted for "on farm" use were developed (14). A stanchion test consisted of placing five nonestrual heifers in a breeding stanchion, while the pen test utilized eight heifers in estrus that were allowed free mobility in a pen. A group of bulls (n=5) was tested for 30 minutes in the stanchion and in the

pen test, after being subjected to sexual stimulation by observing mating activity of the preceding bull group. The total numbers of mounts, intromissions, and ejaculations were recorded for each bull.

Twenty-eight virgin Santa Gertrudis bulls (20-24 mo of age) were evaluated during three stanchion and three pen tests as described above (17). Mean number of mounts did not differ between the pen and stanchion tests (5.0 vs 5.8). However, mean numbers of intromissions and ejaculations were greater ($P<.01$) for bulls during evaluation in the pen test than in the stanchion tests (2.09 vs 0.69 and 0.66 vs 0.32).

### *Influence of Age, Breed, and Sexual Experience on Serving Capacity*

In *Bos taurus* bulls, libido scores obtained at 16 mo and at 40 mo of age were highly correlated (0.71). Furthermore, fertility at 16 mo was highly correlated (0.90) with fertility at 40 mo of age (22). No differences were found in libido of Hereford and Angus bulls between age groups (10). However, bulls in tropical Australia exhibited higher libido scores as age increased from 15 to 30 mo (6).

The influence of age and sexual experience on serving capacity was studied using twenty 32-mo-old, sexually experienced and thirty-four 20-mo-old, virgin Santa Gertrudis bulls (5). There were differences ($P<.05$) among bulls in the number of mounts, intromissions, and ejaculations performed. However, neither age nor sexual experience ($P>.05$) influenced the number of mounts, intromissions, or ejaculations achieved. This is in agreement with data on Afrikaner bulls (*Bos indicus*-influenced Sanga cattle) where libido did not improve between 16 and 28 months of age or with sexual experience (23).

When Santa Gertrudis bulls (n=30) were evaluated at 16.5 mo of age, a low level of breeding activity was exhibited (25). The cumulative mean numbers of mounts, intromissions, and ejaculations achieved in two tests using nonrestrained heifers were 6, 0.8, and 0.3, respectively. Only mean number of mounts differed ($P<.01$) among bulls.

Eight yearling Simbrah bulls, subjected to two stanchion tests, did not display any breeding behavior. Three months later the bulls were retested and the means±SE were 4.3±2.0, 1.4±2.0, and 0.63±0.38 for numbers of mounts, intromissions, and ejaculations, respectively (25).

Mean numbers of mounts, intromissions, and ejaculations performed by eleven Brangus bulls (11 to 12 mo old) in two stanchion tests were 14, 1.4, and 0.8 and 12.3, 1.1, and 0.6 for the first and second test, respectively. Five bulls did not exhibit either intromission or ejaculation in the two tests. No differences ($P>.05$) were found among individuals for the number of mounts, intromissions, or ejaculations performed (B.B. Carpenter, unpublished data).

Beefmaster (n=10), Santa Gertrudis (n=13), and Simbrah (n=8) bulls aged from 18 to 36 months joined with beef females treated with Syncro-mate B for estrus synchronization, performed a mean number of 24 services in a 33-h period (26). However, a wide range in libido among bulls was noted.

### *Serving Capacity and Fertility*

Three high (minimum of five ejaculations in three tests) and three low libido (total of zero to one ejaculation in three tests) Santa Gertrudis bulls were used in single-sire breeding herds at a bull to female ratio of 1:50 for a 60-day breeding period (18). Pregnancy rates (88%, 83%, and 78%) were similar among herds joined with high serving capacity bulls. Pregnancy rates differed ($P<.05$) among herds served by low serving capacity bulls (94%, 70%, and 36%). The number of pregnancies occurring in the first 25 days of the breeding season was higher in heifers mated to high serving capacity bulls (62%) than in heifers mated to low serving capacity bulls (45%).

Three high libido (one to three ejaculations) and three low libido (zero ejaculations) Simbrah bulls were joined for 6 wk with 30 to 38 cows in single-sire breeding herds (25). Mean pregnancy rates of cows joined with high and low libido bulls were 78 percent and 52 percent, respectively ($P>.05$). High libido bulls produced consistently acceptable pregnancy rates (74%, 76%, and 83%) but low libido bulls produced variable pregnancy rates (0%, 65%, and 92%).

## Conclusions

Copulatory activity was greater in Santa Gertrudis bulls evaluated with nonrestrained, estrual females than with restrained, nonestrual females. Breed type is one of the factors that influences the age at which serving capacity can be evaluated. Brangus, Simbrah, and Santa Gertrudis bulls have been successfully tested at 11 to 12 mo, 15 to 17 mo, and 20 to 24 mo, respectively.

The serving capacity tests used (in conjunction with a BSE) were efficient in detecting bulls with acceptable levels of fertility. However, the tests failed to completely discriminate between bulls that have an apparent or actual low libido. Thus, methods to test serving capacity of Brahman-influenced bulls need to be modified to allow a more accurate separation between apparent and actual low serving capacity. Development of methods for selection of Brahman-influenced bulls for serving capacity at an early age and with greater accuracy (possibly based on detection of hormone concentrations at a critical period) would facilitate assessment of libido.

## Literature Cited


1. Blockey, M.A. de B. 1976. Serving capacity - a measure of serving efficiency of bulls during pasture mating. Theriogenology 6:393.
2. Blockey, M.A. de B. 1978. The influence of serving capacity of bulls on herd fertility. J. Anim. Sci. 46:589.
3. Blockey, M.A. de B. 1981. Modification of a serving capacity test for beef bulls. Appl. Anim. Ethol. 7:321.
4. Blockey, M.A. de B., W.M. Straw, and L.P. Jones. 1978. Heritability of serving capacity and scrotal circumference in beef

bulls. Abstr. No. 92, 70th Annual Mtg. Am. Soc. Anim. Sci., East Lansing,

5. Carpenter, B.B. 1990. Serving capacity and social dominance in the bull: Assessment and effects on fertility at pasture. M.S.Thesis. Texas A&M University, College Station.
6. Chenoweth, P.J. 1979. Studies on aspects of the reproductive function of young beef bulls in central Queensland. Ph.D. Thesis, University of Queensland, Australia.
7. Chenoweth, P.J. 1981. Libido and mating behavior in bulls, boars and rams. A review. Theriogenology 16:155.
8. Chenoweth, P.J. and H.G. Osborne. 1975. Breed differences in the reproductive function of young beef bulls in central Queensland. Australian Vet. J. 54:463.
9. Chenoweth, P.J. and L. Ball. 1980. Breeding soundness evaluation in bulls. *In*: D.B. Morrow (Ed.). Current Therapy in Theriogenology. p. 330-339. W.B. Saunders Co., Philadelphia.
10. Chenoweth, P.J., P.W. Farin, E.R. Mateos, G.P. Rupp, and J.E. Pexton. 1984. Breeding soundness and sex-drive by breed and age in beef bulls used for natural mating. Theriogenology 22:341.
11. Chenoweth, P.J., P.W. Farin, E.R. Mateos, G.P. Rupp, and J.E. Pexton. 1988. Relationships between breeding soundness and sex drive classifications in beef bulls. Theriogenology 30:227.
12. Coulter, G.H. and G.C. Kozub. 1989. Efficacy of methods used to test fertility of beef bulls used for multiple-sire breeding under range conditions. J. Anim. Sci. 67:1757.
13. Crichton, J.S. and A.W. Lishman. 1985. Libido evaluation of virgin beef bulls. S. Afr. J. Anim. Sci. 15:22.
14. Forrest, D.W. 1989. Serving capacity and reproductive performance in Brahman-influenced bulls. Beef Cattle Science Handbook. L.S. Pope (Ed.). Lang Printing Incorporated. Bryan, Texas.
15. Garcia, M.C., S.M. McDonell, and R.M. Kenney. 1986. Bull sexual behavior tests: Stimulus cows affects performance. Appl. Anim. Behav. Sci. 16:1.
16. Godfrey, R.W. and D.D. Lunstra. 1988. Influence of serving capacity and single or multiple sires on pasture mating of beef bulls. J. Anim. Sci. 66 (Suppl. 1) :235. (Abstr.).
17. Hawkins, D.E., B.B. Carpenter, L.R. Sprott, J.R. Beverly, H. Hawkins, N.R. Parish, and D.W. Forrest. 1988a. Copulatory activity of Santa Gertrudis bulls in two types of serving capacity test. J. Anim. Sci. 66 (Suppl. 1) :235. (Abstr.).
18. Hawkins, D.E., B.B. Carpenter, L.R. Sprott, J.R. Beverly, H. Hawkins, N.R. Parish, and D.W. Forrest. 1988b. Proportion of early-conceiving heifers is increased by high serving capacity bulls. J. Anim. Sci. 66 (Suppl. 1) :246. (Abstr.).
19. Henney, S.R., G.J. Killian, and D.R. Deaver. 1990. Libido, hormone concentrations in blood plasma and semen characteristics in Holstein bulls. J. Anim. Sci. 68:2784.
20. Lunstra, D.D. 1984. Changes in libido-fertility relationships as beef bulls mature. J. Anim. Sci. 59 (Suppl. 1) :351. (Abstr.).
21. Lunstra, D.D. 1986. Libido and serving capacity of beef bulls, p 20. Proc. Beef Improvement Federation Annual Meeting.
22. Lunstra, D.D., B.B. Laster, and R.D. Schanbacher. 1979. Libido-fertility relationships in yearling beef bulls. J. Anim. Sci. 49 (Suppl. 1) :315. (Abstr.).
23. Maree, C., N.H. Casey, and I.E. Jacobi. 1989. The non- significant effect of feeding level, growth rate and age on libido of young Afrikaner bulls. J. S. Afr. Vet. Ass. 60:143.
24. Osborne, H.G., G.L. Williams, and D.B. Galloway. 1971. A test for libido and serving ability in beef bulls. Australian Vet. J. 47:465.
25. Rocha, A. 1990. Sexual behavior in the bull: Assessment by seminal vesicle size and response to gonadotropin releasing hormone. M.S. Thesis. Texas A&M University, College Station.
26. Williams, G.L. 1988. Breeding capacity, behavior and fertility of bulls with Brahman genetic influence during synchronized breeding of beef females. Theriogenology 30:35.


Extension
Reports

# Internal and External Parasite Control in Range Beef Cattle

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## Summary

Data from 951 cows and 905 calves over a 3-year period were analyzed to determine the effect of control of internal and certain external parasites on cow/calf performance. Cattle grazed native range on the Swen R. Swensen Cattle Company ranch in Throckmorton County in North Central Texas where the average annual precipitation is 26 inches. Treatment stocking rates for mature, winter calving cows ranged from moderate (16 a/au) to heavy (9 a/au).

Herds on various grazing regimens were stratified by age and randomly assigned to one of three treatments: 1) Ivomec® injection; 2) a pour-on of trichlorfon (Neguvon®); and 3) untreated. Cattle were treated in early June each year. Cows and calves were weighed in June, August, and October. Cows were weighed again in December and their backs inspected for the presence of cattle grubs. Analyses of variance for fecal egg counts, cow weight change, and calf gains were conducted by use of a SAS general linear procedure.

Worm egg counts were extremely low all years for all treatment groups. There were no significant differences in absolute cow weight change from the time of treatment in June, to calf weaning in October, or to pre-calving in December. There was also no significant treatment effect on calf gain from treatment to weaning. During the 3 years, the percentage of cows in each treatment group with one or more grubs was 0, 30, and 54 percent for Ivomec®, pour-on, and control groups, respectively. Corresponding average grubs per infested cow were 0, 3.05, and 6.78. Under the conditions of this study, treating for internal parasites failed to provide any significant performance or economic advantage in either cow weight change or additional pounds of calf weight. However, Ivomec® did provide complete control of all cattle grubs.


## Introduction

It is well documented that internal parasites can be a major problem in beef cattle production in areas where favorable moisture and environmental conditions exist. The southeastern states including eastern portions of Texas fall into this category. However, there is also substantial evidence that cattle in semi-arid and arid range country benefit little from the control of internal parasites.

Producers raising cattle in the warm, humid, higher rainfall regions adhere to a recommended internal parasite treatment program. Ranchers in the arid and semi-arid western part of the state seldom treat for internal parasites. There is a large area of ranch lands that falls into a marginal category, from the standpoint of recommendations for managing internal parasites. The amount and varied distribution of rainfall and the acres required per animal unit (AU) do not fit the patterns favorable for internal parasite infection. However, favorable conditions may prevail occasionally which would propagate damaging populations of internal parasites. These climatic variations make it difficult to develop economic recommendations for the management of internal parasites.

Certain external parasites, the cattle grub in particular, appear to be more consistently widespread. Recommendations for their control can be applied state-wide. This study was conducted to provide information on the performance of cows and calves grazing rangeland in a 26" average rainfall area that were treated for certain internal and external parasites.

## Experimental Procedure

The cattle in this study belonged to the Swen R. Swensen ranch in Throckmorton County and were a part of the Texas A&M Experimental Ranch. Cattle were assigned to four grazing regimens of varied stocking rates and grazing frequencies for the duration of the experiment. Stocking rates varied from moderate (16.5 a/au) to heavy (9 a/au). The cows were multi-aged Angus x Hereford bred to Charolais bulls to calve from January to March. Within each grazing block, the cows were stratified by age and randomly assigned to one of three treatment groups. The treatments for both the cow and her calf consisted of: 1) Ivomec® injection at 1 ml/110 lbs body weight; 2) a normal dosage of the pour-on trichlorfon (Neguvon®); and 3) control cattle receiving no chemical treatment. The cows were re-randomized to treatment groups each year of the study.

Fecal material was collected from randomly selected cow/calf pairs in each treatment group within each herd. The same cows and calves were sampled on each collection date. Samples were collected prior to the respective treatments in June, at the August weighing, and in October when the calves were

the findings in this study, even though a different product was used for internal parasite control. The work reported by Waggoner et al. (2) also found no benefit in weight gain of stocker cattle treated for internal parasites.

Table 5 reports the effectiveness of the treatments on cattle grub control. There were no grubs detected in cows treated with Ivomec® over the 3 year period. Approximately 30 percent of the pour-on treatment and 54 percent of the control cattle exhibited grub infestation. The ineffectiveness of the pour-on treatment was unexpected and it is not known whether these results are due to improper product management, rain after application, or product failure.

Ranchers in regions of the state that receive low to moderate (26 inches or less) annual average precipitation may not benefit from routine treatment for internal parasites. In this study treating for internal parasites failed to exhibit any significant economic advantage in either the cow weight change or additional calf weight gain.

It appears that mature cows maintained in this environment have the ability to tolerate normal parasitic loads encountered without measurable losses in performance. It should be emphasized, however, that sufficient internal parasites are present, even under these range conditions, to provide the opportunity for a parasite buildup under favorable environmental conditions, which could result in potential economic losses.

Because of the many variables affecting parasite numbers and the damage they cause, there is no clear-cut management program for this region. It should be emphasized that parasites are opportunists. Low to moderate parasite level by itself may not affect performance. However, coupled with stress, diseases, or inadequate nutrition, parasites can contribute significantly to the animals' health and performance even in this region.

TABLE 1. WORM EGGS[1] PER GRAM OF FECAL MATERIAL FOR COWS BY TREATMENT

| | TREATMENTS | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROLS |
| YEAR I[2] | | | |
| June | 3.78[a] | 2.32[a] | 4.09[a] |
| October | 12.69[a] | 23.44[ab] | 35.92[b] |
| YEAR II | | | |
| June | 4.38[a] | 3.20[a] | 2.27[a] |
| August | 0.82[b] | 2.60[a] | 0.97[b] |
| October | 0.74[a] | 1.29[a] | 0.96[a] |

[1] Expressed as log transformation geometric mean.

[2] Means on the same line with a common superscript are not significantly different.

TABLE 2. WORM EGGS[1] PER GRAM OF FECAL MATERIAL FOR CALVES BY TREATMENT

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROLS |
| Year I[2] | | | |
| June | .93[a] | 0.77[a] | 0.96[a] |
| October | 1.47[b] | 3.63[ab] | 5.06[a] |
| Year II | | | |
| June | 5.60[a] | 2.73[a] | 2.92[a] |
| August | 5.49[b] | 28.15[a] | 27.65[a] |
| October | 8.90[a] | 17.9[a] | 13.56[a] |
| Year III | | | |
| June | 10.21[a] | 10.18[a] | 10.31[a] |
| August | 9.24[b] | 71.29[a] | 55.09[a] |
| October | .82[a] | 1.04[a] | 1.05[a] |

[1] Expressed as log transformation geometric mean.

[2] Means on the same line with a common superscript are not significantly different.

## Acknowledgments

Appreciation is expressed to Dr. Tom Craig and his staff, Department of Veterinary Pathobiology, College of Veterinary Medicine, for internal parasite egg counts and analyses.

This study was partially supported by Merck and Company, MDS, Ag-Vet, Rahway, NJ.

## Literature Cited

1. Houston, J.E., and Jerry Cowley, 1986. Internal parasites control in stocker cattle in West Texas. Beef Cattle Res. in Texas TAES PR-4498.
2. Waggoner, J.W., S. L. Applegate, and W. R. Jolley. 1988. Effect of internal parasite control on the performance of range cows. Proceedings, Western Section, Am. Soc. Anim. Sci. 39:55.

TABLE 3. THREE YEAR AVERAGE COW WEIGHT CHANGE BY TREATMENT FOR ALL HERDS COMBINED

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROL |
| Grazing Period June - Oct. wt. change lbs. | + 30[a] | + 26[a] | + 25[a] |
| June - Dec. wt. change lbs. | + 81[a] | + 80[a] | + 74[a] |

[1] Absolute cow weight change

[2] Means on the same line with a common superscript are not significantly different.

TABLE 4. TWO YEAR AVERAGE CALF GAIN BY TREATMENT FOR HEIFER AND STEER CALVES COMBINED ACROSS ALL HERDS

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROL |
| Average gain[1] lbs. | 205[a] | 201[a] | 200[a] |

[1] Calf gain on native pasture for an average of 115 days.

[2] Means on the same line with a common superscript are not significantly different.

the findings in this study, even though a different product was used for internal parasite control. The work reported by Waggoner et al. (2) also found no benefit in weight gain of stocker cattle treated for internal parasites.

Table 5 reports the effectiveness of the treatments on cattle grub control. There were no grubs detected in cows treated with Ivomec® over the 3 year period. Approximately 30 percent of the pour-on treatment and 54 percent of the control cattle exhibited grub infestation. The ineffectiveness of the pour-on treatment was unexpected and it is not known whether these results are due to improper product management, rain after application, or product failure.

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Because of the many variables affecting parasite numbers and the damage they cause, there is no clear-cut management program for this region. It should be emphasized that parasites are opportunists. Low to moderate parasite level by itself may not affect performance. However, coupled with stress, diseases, or inadequate nutrition, parasites can contribute significantly to the animals' health and performance even in this region.

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| | TREATMENTS | | |
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| June | 4.38[a] | 3.20[a] | 2.27[a] |
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[2] Means on the same line with a common superscript are not significantly different.

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| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROLS |
| Year I[2] | | | |
| June | .93[a] | 0.77[a] | 0.96[a] |
| October | 1.47[b] | 3.63[ab] | 5.06[a] |
| Year II | | | |
| June | 5.60[a] | 2.73[a] | 2.92[a] |
| August | 5.49[b] | 28.15[a] | 27.65[a] |
| October | 8.90[a] | 17.9[a] | 13.56[a] |
| Year III | | | |
| June | 10.21[a] | 10.18[a] | 10.31[a] |
| August | 9.24[b] | 71.29[a] | 55.09[a] |
| October | .82[a] | 1.04[a] | 1.05[a] |

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TABLE 3. THREE YEAR AVERAGE COW WEIGHT CHANGE BY TREATMENT FOR ALL HERDS COMBINED

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROL |
| Grazing Period June - Oct. wt. change lbs. | + 30[a] | + 26[a] | + 25[a] |
| June - Dec. wt. change lbs. | + 81[a] | + 80[a] | + 74[a] |

[1] Absolute cow weight change

[2] Means on the same line with a common superscript are not significantly different.

TABLE 4. TWO YEAR AVERAGE CALF GAIN BY TREATMENT FOR HEIFER AND STEER CALVES COMBINED ACROSS ALL HERDS

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROL |
| Average gain[1] lbs. | 205[a] | 201[a] | 200[a] |

[1] Calf gain on native pasture for an average of 115 days.

[2] Means on the same line with a common superscript are not significantly different.

TABLE 5. THREE YEAR SUMMARY OF CATTLE GRUB NUMBERS BY TREATMENT AND YEAR FOR ALL HERDS COMBINED

| | TREATMENT | | |
|---|---|---|---|
| | IVOMEC® | POUR-ON | CONTROL |
| Year I | | | |
| No. of Cows | 145 | 135 | 41 |
| No. with Grubs | 0 | 36 | 18 |
| % of Cows with Grubs | 0 | 27 | 43 |
| Grubs per Infested Cow | 0 | 2.75 | 4.0 |
| Year II | | | |
| No. of Cows | 95 | 93 | 95 |
| No. with Grubs | 0 | 19 | 45 |
| % of Cows with Grubs | 0 | 20 | 47 |
| Grubs per Infested Cow | 0 | 3.0 | 5.7 |
| Year III | | | |
| No. of Cows | 112 | 167 | 102 |
| No. with Grubs | 0 | 62 | 65 |
| % of Cows with Grubs | 0 | 37 | 64 |
| Grubs per Infested Cow | 0 | 3.16 | 7.5 |
| Three Year Summary (985 Head) | | | |
| No. of Cows | 352 | 395 | 238 |
| No. of Cows with Grubs | 0 | 117 | 128 |
| % with Grubs | 0 | 30 | 54 |
| Grubs per Infested Cow | 0 | 3.05 | 6.78 |

# Relationships of Internal Pelvic Area to Other Body Measurements in Yearling Heifers

B.B. Carpenter and L.R. Sprott


## Summary

Internal pelvic dimensions may not be obtained as readily as other body measurements such as height, weight, or external measurements of the pelvis. Therefore, it would be useful to know the relationships among these measurements and whether they could be used to predict internal pelvic area of yearlings. Crossbred heifers (n=66) were measured as weanlings and yearlings for body weight, hip height, and external pelvic dimensions. They were measured as yearlings for internal pelvic dimensions. Only yearling body weight was a significant factor in predicting yearling pelvic area ($P<.001$, $R^2=.366$). The correlation between these two factors was moderate ($r=.59$, $P<.001$). Thus, larger heifers tended to have larger pelvic openings.


## Introduction

Though less important than calf birth weight, large pelvic openings have been associated with lessened dystocia in first- calf heifers (1, 2). Internal pelvic area can be measured with specialized equipment, and direct measurement is the most accurate means. However, it has been reported (3) that heifer body weight is highly associated with internal pelvic area and Siemens et al. (5) reported moderate correlations between external pelvic measurements, hip height, and internal pelvic area in 698 yearling heifers.

This trial examined the relationship of internal pelvic area to body weight, hip height, and external pelvic dimensions.

## Experimental Procedure

Measurements were taken in Brahman crossbred heifers (n=66). External pelvic measurements (hook and pin width) were taken with a non-metallic, non-stretch surveyor tape. Hip heights were measured with a grid and/or a steel tape. Body weight was measured with a balance type Paul's scale. A Rice pelvimeter was used to measure internal pelvic width and height in 0.25 cm increments. Internal pelvic area was defined as pelvic width × pelvic height. Measurements used for this analysis were taken at weaning and again at yearling age.

Data were analyzed with a forward elimination regression model (4) in which internal pelvic area was the dependent variable. Independent variables initially included were: weaning and yearling weights, hip heights, and pelvic dimensions. Also included were ratios of yearling weight:height, hip height:hook width, and pin width:hook width. The final model was tested with residual plot analysis. Associations between factors were determined with Pearson's correlation coefficients.

## Results and Discussion

Larger heifers tended to have larger internal pelvic areas as evidenced by the moderate to moderately high correlation coefficients relating pelvic area to weight, height, and external pelvic measurements (Table 1). Note also that these factors were positively correlated with yearling weight and that the coefficients were generally higher (Table 2).

Regression analysis revealed that of the independent variables modeled, yearling weight was the best predictor of yearling internal pelvic area ($P<.001$, $R^2=.366$). Other independent variables were eliminated. Figure 1 shows the square centimeters of pelvic area predicted for this group of females, based on their yearling weights.

Selection of the heaviest heifers will favor those with the largest internal pelvic areas. Also, *within* breed types, selection of these heifers will favor the oldest, and thus most sexually mature individuals. This is an important consideration when breeding heifers for their first calves. However, note that in this group of heifers, not all variation in pelvic area was accounted for by variation in yearling body weight.


## Acknowledgments

The authors would like to thank Broseco Ranches, Mt. Pleasant, Texas, for providing animals and facilities. The efforts of the management staff: Dr. Tom Woodward, Mr. Walter Carter, and Mr. Lawerence Wingate are appreciated.


## Literature Cited


1. Bellows, R.A., R.E. Short, D.C. Anderson, B.W. Knapp, and O.F. Parish. 1971. Cause and effect of relationships associated with calving difficulty and birth weight. J. Anim. Sci. 33:407.
2. Deutscher, 1988. Pelvic measurements for reducing calving difficulty. Cooperative Extension Service, University of Nebraska. Bulletin No. G88-895.
3. Price, T.D., and J.N. Wiltbank, 1978. Predicting dystocia in heifers. Theriogenology 9:221.
4. SAS, 1988. SAS User's Guide. SAS Inst. Cary, NC.
5. Siemens, M.G., R.J. Lipsey, A.L. Siemens, D.W. Vogt, and C.G. Carlton. 1987. Phenotypic correlations involving internal pelvic measurements and linear body measurements in yearling heifers. J. Anim. Sci. 65:440(Suppl. 1).

TABLE 1. CORRELATION COEFFICIENTS FOR YEARLING PELVIC AREA VS. OTHER BODY MEASUREMENTS

| | pelvic area | | pelvic area |
|---|---|---|---|
| wean wt | .56 | wean hook wd | .48 |
| yearl wt | .59 | yearl hook wd | .35 |
| wean hip ht | .36 | wean pin wd | .41 |
| yearl hip ht | .35 | yearl pin wd | .35 |

TABLE 2. CORRELATION COEFFICIENTS FOR YEARLING WEIGHT VS.OTHER BODY MEASUREMENTS

| | yearling wt | | yearling wt |
|---|---|---|---|
| wean wt | .67 | wean hook wd | .71 |
| yearl wt | .87 | yearl hook wd | .43 |
| wean hip ht | .62 | wean pin wd | .55 |
| yearl hip ht | .30 | yearl pin wd | .34 |

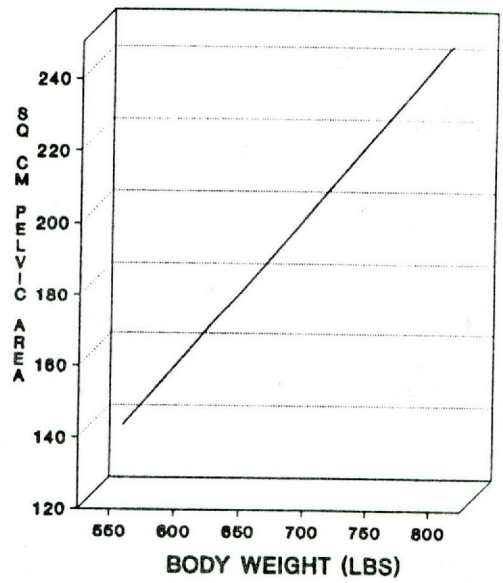


Figure 1. Yearling pelvic area ($cm^2$) restricted by yearling body weight (lb).

# Synovex-C in Replacement Heifers: Effects on Pelvic Dimensions, Hip Height, Body Weight, and Reproduction

B.B. Carpenter and L.R. Sprott


## Summary

Suckling heifers (n=82) given a single Synovex-C implant (I) at 40 to 90 days of age, or left as unimplanted controls (C) were evaluated at weaning and again as yearlings for body weight, hip height, and external pelvic dimensions. They were further evaluated as yearlings for internal pelvic dimensions and reproductive rates. Implanted heifers had greater body weights and hip heights at weaning ($P<.05$). As yearlings, these differences persisted ($P<.05$). Mean internal pelvic area was also larger ($P<.001$) in I vs. C heifers (200.6 vs 171.7 $cm^2$, respectively). Pregnancy rates after a 3 month breeding season did not differ ($P>.44$). Thus, Synovex-C given to suckling heifers appears to have the potential to increase body size at weaning and yearling age, and to increase yearling internal pelvic area without adversely affecting reproductive performance.


## Introduction

There is evidence that growth implants given to suckling heifers may increase precalving internal pelvic area (2, 3, 10). Maternal pelvic area can interact with calf birth weight to affect calving difficulty or dystocia.

Calving difficulty in beef heifers is a familiar but complex problem which can be attributed to a multitude of factors. Some of these are: birth weight of the calf, sex of the calf, length of gestation, breed of sire, heterosis, genotype, nutrition of the dam prior to parturition, age at parturition, pelvic area of the dam, abnormal presentation, and failure of the cervix to dilate (6, 7, 8). Rice and Wiltbank (7) attributed 50 percent of all dystocias to a disproportion between the maternal pelvic opening and birth weight of the calf. It is well documented that the single most important factor affecting dystocia is calf birth weight, whereas pelvic area of the dam has been found to be second in importance (1). Pelvic area by itself however, may not influence dystocia at all (5); implying that dystocia can result from an interaction of several factors.

The objective of this trial was to determine effects on subsequent growth, reproduction, and yearling pelvic area resulting from administration of Synovex-C to suckling heifers. Data on dystocia and rebreeding rates will be collected as they become available.

## Experimental Procedure

Brahman crossbred suckling heifers (n=82) were blocked by weight class (150-175; 176-200; 201-225; 226-250; 250-275 lb) and randomly allotted to treatment (I=single Synovex-C implant; C=non implanted control). External pelvic measurements (hook and pin width) were taken with a non-metallic, non-stretch surveyor tape. Hip height was measured with a grid and/or a steel tape. Body weight was measured with a balance type scale. A Rice pelvimeter was used to measure pelvic height and width in 0.25 cm increments. Internal pelvic area was calculated by multiplying pelvic height by width. Yearling reproductive performance was determined by pregnancy status after a 3 month breeding season. External skeletal and weight measurements were taken at three periods: 1) at trial initiation (calfhood), 2) at weaning, and 3) prior to breeding (yearling). Internal measurements were taken in yearlings only.

Data were analyzed with a split plot GLM model for repeated measures (9). Weight, hip height, hook width, and pin width were dependent variables. Treatment, individual within treatment, period, and treatment × period were tested as independent variables. Data with only one observation (i.e. yearling pelvic dimensions) were analyzed with t-tests. Z-tests for proportional data (4) were used to analyze pregnancy rates.

## Results and Discussion

Body weight data is shown in Table 1. Calves began the trial with equivalent weights. Preweaning growth (weight gain) was higher in I vs C calves, producing higher average weaning weights. Growth from weaning to yearling did not differ between I and C heifers, yet average yearling weights remained higher for I heifers, indicating that the initial weight gains realized from calfhood implants persisted through yearling age. Table 2 shows a similar pattern for hip heights.

External pin widths did not differ between treatments. External average hook widths were greater for I vs C heifers at weaning and yearling age (Table 3). Internal pelvic heights and widths were

greater in I vs C heifers. Therefore, I heifers had 28.9 $cm^2$ more pelvic area than did C heifers (Table 4). In all heifers, yearling body weight and hip height were positively correlated with pelvic area (.59 and .35, respectively; P<.004).

Pregnancy rates after a 3 month breeding season were 78.9 percent in I heifers and 77.4 percent in C heifers and did not differ (P=.447).

It appears that Synovex-C given to suckling heifers can increase internal pelvic area at one year of age without adversely affecting reproductive performance. Whether or not these heifers will continue to have larger pelvic openings as 2-yr-olds (prior to calving) and, any associated decrease in actual dystocia due to implanting, remains untested in this trial. Furthermore, dystocia is unquestionably influenced by calf birth weight and the potential benefits of a large pelvic opening could still be negated by a calf of unsuitable birth weight. Selection of larger heifers which, *within breed types*, also tend to be the most s exually mature, can also increase the group's average pelvic area since there is a positive association of internal pelvic area with body weight and height.

**Table 1. Least squares mean weights (lb).**

| | Implanted | | Control |
|---|---|---|---|
| Beginning Calf Weights | 196.7[a] | vs | 202.1[a] |
| Weaning Weights | 545.9[a] | vs | 509.1[b] |
| Growth: Calf to Weaning | 349.2[a] | vs | 307.9[b] |
| Yearling Weights | 663.0[a] | vs | 619.3[b] |
| Growth: Weaning to Yearling | 108.0[a] | vs | 110.9[a] |
| Total Growth: Calf to Yearling | 463.3[a] | vs | 417.0[b] |

[a,b] Differ across columns (P<.05).

**Table 2. Least squares mean hip heights (inches).**

| | Implanted | | Control |
|---|---|---|---|
| Beginning Calf Hip Hts. | 34.5[a] | vs | 34.8[a] |
| Weaning Hip Hts. | 44.6[c] | vs | 44.0[d] |
| Growth: Calf to Weaning | 10.0[a] | vs | 9.2[b] |
| Yearling Hip Hts. | 47.6[a] | vs | 46.7[b] |
| Growth: Weaning to Yearling | 2.8[a] | vs | 3.2[a] |
| Total Growth: Calf to Yearling | 13.0[a] | vs | 12.2[b] |

[a,b]Differ across columns (P<.05).
[c,d]Differ across columns (P<.10).

**Table 3. Least squares mean hook widths (inches).**

| | Implanted | | Control |
|---|---|---|---|
| Beginning Calf Hook Widths | 11.64[a] | vs | 11.64[a] |
| Weaning Hook Widths | 16.44[a] | vs | 15.96[b] |
| Yearling Hook Widths | 18.12[c] | vs | 17.16[d] |

[a,b]Differ across columns (P<.05).
[c,d]Differ across columns (P<.002).

**Table 4. Yearling internal pelvic dimensions (cm).**

| | Implanted | | Control |
|---|---|---|---|
| Internal pelvic width | 12.8[a] | vs | 11.7[b] |
| Internal pelvic height | 15.7[a] | vs | 14.6[b] |
| Internal pelvic area (wd X ht) | 200.6[a] | vs | 171.7[b] |

[a,b]Differ across columns (p<.001).

## Acknowledgments

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## Literature Cited

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2. Corah, L., L.R. Sprott, G. Francis, and G. Kiracofe. 1980. Effects of various levels of Ralgro on reproductive performance of yearling heifers. Cattleman's Day Rep., Kansas State University, Manhattan.
3. Lawrence, J.R., J. C. Allen, R.C. Herschler, and T.A. Miller. 1985. Synovex implants: Re-implantation and fertility in beef heifers. Agri-practice. 6(4) 13.
4. Microstat, 1978. Ecosoft, Inc. Indianapolis, IN.
5. Naazie, A., M.M. Makarechian, and R.T. Berg. 1989. Factors influencing calving difficulty in beef heifers. J. Anim. Sci. 12:3243.
6. Price, T.D. and J.N. Wiltbank. 1978a. Dystocia in beef cattle a review and implications. Theriogenology 9:195.
7. Price, T.D. and J.N. Wiltbank. 1978b. Predicting dystocia in heifers. Theriogenology 9:221.
8. Rice, L.N. and J.N. Wiltbank. 1972. Factors affecting dystocia in beef heifers. J. Amer. Vet. Med. Assoc. 161:1348.
9. SAS, 1986. SAS System For Linear Models. SAS Inst. Inc. Cary, N.C.
10. Staigmiller, R.B., R.A. Bellows, and R.E. Short. 1983. Growth and reproductive traits in beef heifers implanted with zeranol. J. Anim. Sci. 55:527.

# Social Dominance and Its Influence on Reproductive Performance of Bulls in Multiple-Sire Breeding Groups

B.B. Carpenter, D.W. Forrest, A. Rocha,
L.R. Sprott, J.W. Holloway and B.G. Warrington

## Summary

Angus and Braford bulls of satisfactory serving capacity and breeding soundness were evaluated in Angus/Braford pairs for dominant (D) and subordinant (S) social relationships. Following social dominance testing, Angus/Braford bull pairs (n=4) were placed in breeding pastures for 60 d. Number of calves sired by each bull was influenced by an interaction of bull social ranking with the number of cows to which each bull pair was exposed (P<.05). Dominant bulls sired more calves in small herds whereas S bulls sired more calves in large herds. These results indicate that social interactions and size of the breeding herd among bulls can influence breeding performance.

## Introduction

Reproductive performance in the bull can be affected by several factors. Physical soundness, semen quality, and desire/ability to mate (serving capacity) are known to affect fertility. However, few studies have quantified the effects of social ranking among bulls on reproductive performance. Social dominance associated with age has been shown by some researchers to influence a bull's pasture mating fertility (1, 5, 8). Furthermore, Ologun et al. (9) reported that high sex drive appeared to be independent of social dominance. We hypothesized that, when bulls of equivalent semen quality and serving capacity were paired, the dominant bull would sire a majority of the calves. Therefore, the objective of the present study was to evaluate the effects of social dominance in pairs of bulls of similar semen quality and serving capacity on fertility during pasture mating.

## Materials and Methods

Three year-old Angus and $F_1$ Braford bulls (n=19) were evaluated for breeding soundness and serving capacity (2). Those bulls with satisfactory serving capacity and breeding soundness scores were retained and randomly paired across breeds for social dominance testing. All bulls had been raised together during the previous year. Dominance (D) and submissiveness (S) were assessed when bulls were placed together in a pen and allowed to compete for food and/or water — a restricted resource (7). Activities were recorded on video tape and the ratio of competitive events initiated to those won, lost, or tied were calculated. Winning was defined as an event wherein one bull yielded to another (3).

Dominant bulls were paired with S bulls for pasture mating during a 60 day breeding season. Pasture size ranged from 1490 to 2260 acres. Each pair consisted of one Angus and one Braford bull in order to allow identification of a given sire's progeny based on phenotypic characteristics. Number of cows per pasture ranged from 22 to 39. Four pastures were used and females were allotted to each pasture based on estrous cyclicity.

Statistical analysis involved covariate and correlation analysis (10). In the model, number of calves sired was the dependent variable. Social dominance (D or S) and sire breed were the independent variables with number of cows functioning as the covariate.

## Results and Discussion

During the serving capacity tests, the four Angus bulls had higher (P<.05) total mean number of ejaculations than did the four Braford bulls (9.3 vs. 3.0 respectively; range 1 to 13). However, previous studies (4, 6) indicate that copulatory behaviornot be as readily displayed by Bos indicus as by Bos taurus bulls during a serving capacity test. Therefore, comparisons across breed types may not be appropriate due to differences in mating behavior. One ejaculation in either of two serving capacity tests was the "threshold" of activity used to define satisfactory display of serving capacity in this group of bulls and, with the exception of one bull, all others had more than one ejaculation. This criterion appeared to be adequate since neither number of ejaculations nor number of mounts was significantly correlated with the number of calves sired. Likewise, body weight of the bull was not significantly correlated with number of calves sired.

Among the eight bulls evaluated, the number of calves sired per bull ranged from 6 to 24. This was not influenced by breed (percentages shown in Table 1) but was, however influenced by an interaction of sire dominance value with the covariate (number of cows in the breeding pasture). Figure 1 illustrates this interaction; with both actual and predicted number of calves sired per bull charted. Note that at lower cow numbers, D bulls are predicted to sire more

calves, possibly due to competition for fewer females. Conversely, S bulls are predicted to sire more calves at higher cow numbers. Also note, that these predictions are based on data obtained from only four bulls in each dominance class.

These results do not support the hypothesis that the D bull of a pair will sire more calves than the S bull. Further studies are warranted to investigate the interrelationships between size of the breeding herd and social interactions among bulls.

## Acknowledgments

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## Literature Cited

1. Blockey, M.A. deB. 1979. Observations on group mating of bulls at pasture. Appl. Anim. Ethol. 5:515.
2. Blockey, M.A. deB. 1981. Further Studies on the serving capacity test for beef bulls. Appl. Anim. Ethol. 7:337.
3. Blockey, M.A. deB, and A.D. Lade. 1974. Social dominance relationships among young bulls in a test of rate of weight gain after weaning. Aust. Vet. J. 50:435.
4. Chenoweth, P.J., and H. G. Osborne. 1975. Bred differences in the reproductive function of young beef bulls in Central Queensland. Aust. Vet. J. 51:405.
5. Coulter, G. H., and G. C. Kozub. 1989. Efficacy of methods used to test fertility of beef bulls used for multiple-sire breeding under range conditions. J. Anim. Sci. 67:1757.
6. Crichton, J.S., and A.W. Lishman. 1985. Libido evaluation of virgin beef bulls. S. Afr. J. Anim. Sci. 15:1.
7. Kelly, K.W., J.J. McGlone, and C.T. Gaskins. 1980. Porcine aggression: Measurement and effects of crowding and fasting. J. Anim. Sci. 50:336.
8. Makarechian, M., and A. Farid. 1985. The relationship between breeding soundness evaluation and fertility of beef bulls under group mating at pasture. Theriogenology 23:886.
9. Ologun, A. F., P.J. Chenoweth, and P.J. Brinks. 1981. Relationships among production traits and estimates of sex-drive and dominance value in yearling bulls. Theriogenology 15:379.
10. SAS, 1986. SAS System For Linear Models. SAS Inst., Inc., Cary, NC.

TABLE 1. PERCENTAGE OF CALVES SIRED BY EACH BREED REPRESENTED IN THE BULL PAIR

| PASTURE | ANGUS | BRAFORD |
|---|---|---|
| 1 | 65% | 35% |
| 2 | 41% | 59% |
| 3 | 45% | 55% |
| 4 | 67% | 33% |

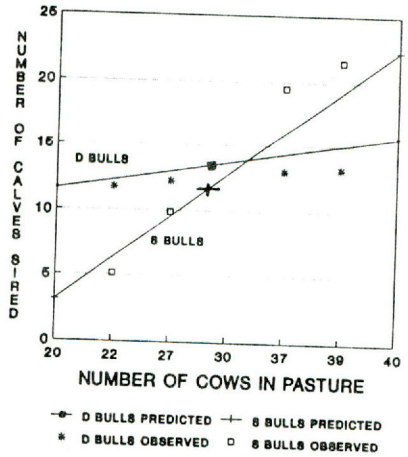


Figure 1. Predicted and observed number of calves sired by dominant (D) and subordinate (S) bulls exposed to varying numbers of cows in the breeding pasture.

# The Effects of Fenbendazole Preventive Parasite Treatment on Gains in Beef Cattle

C.G. Charanza, L.L. Boleman, B.B. Carpenter, J.J. Cowley, R.D. Grooms, J .W. McNeill, J.C. Paschal, T.R. Troxel and J.W. Turner

## Summary

Field data trials performed in various Texas counties by the Texas Agricultural Extension Service were analyzed to determine the effects of strategic deworming programs with fenbendazole on gains of stocker cattle as well as calves in cow/calf operations. The trials were separated into three different management groups: stocker cattle, cow/calf systems using split-pasture protocol, and cow/calf systems using other experimental methods referred to as demonstrations. Gains standardized to the average trial length of each management group were analyzed to determine the effectiveness of strategic deworming programs.

The stocker group was examined using both trial averages and individual calf records. In the stocker group analysis, fenbendazole-treated calves showed a 15.3 lb advantage over control animals during a 131-day period. Similarly, in the stocker individual analysis, calves treated with fenbendazole gained 17.0 lb more than the control calves over the same 131-day period. In the cow/calf split-pasture protocol system, calves treated with fenbendazole gained 24.1 lb more than those receiving no treatment over a 190-day period.

Data from cow/calf systems using experimental methods other than split-pasture protocol could not be analyzed because of the tremendous differences in experimental methods that were used, but comparison of this data showed higher gains in fenbendazole-treated calves than in the control group. Results from this study indicated that weight gains can be significantly increased over time by using fenbendazole preventive parasite treatments.

## Introduction

Internal parasite control in beef cattle has changed drastically in recent years. Previously, parasite treatments were basically therapeutic, being administered only to animals with obvious signs of parasite infection. By the time clinical symptoms were observed in the infected animals, a tremendous amount of production efficiency had already been lost. Characteristically, the majority of economic losses from internal parasites have been subclinical. Herrick (8) has estimated that losses of $25 to $200/animal could result from subclinical infections in the absence of parasite control. Preventive parasite programs of strategically timed deworming offer the best solution to the problem of production inefficiency in beef cattle. Research has established that strategic deworming is effective in killing very high percentages of internal parasite species (1, 5, 7, 9, 10). Elimination of these parasite species has resulted in increased reproductive efficiency (3), increased milk production (8), and increased weight gains (1, 4).

Subclinical parasite infections affecting animals grazing improved pastures and experiencing a rapid growth rate should be a primary concern of producers. These animals can easily lose 50 lb or more during one season due to subclinical levels of parasites (2). Calf gain is one of the most economically important factors in a beef cattle operation. Since young cattle are primarily affected by internal parasites and since calves represent a large portion of income for beef producers, it is necessary to further analyze the effects of strategic deworming on calf weight gains in beef cattle systems. In particular, it is important to determine if the weight gains are consistent throughout various counties in Texas and if strategic deworming is a beneficial management practice for producers.

## Materials and Methods

Field data trials from various counties in Texas were analyzed to quantitatively assess the effect of fenbendazole preventive parasite treatment on calf weight gains in stocker and cow/calf enterprises. Trials with fenbendazole-treated animals and control animals were chosen for statistical analyses. These trials were independent and contained weight measurements based upon using the animal as the experimental unit. The trials were separated into three different management groups for analyses: stocker cattle, cow/calf systems using split pasture protocol, and cow/calf systems using other experimental methods referred to as demonstrations.

### *Stocker cattle*

Stocker cattle trials from five counties in Texas were analyzed to determine the benefits of deworming programs using fenbendazole preventive parasite treatment. Six field data trials were examined to determine if a single statistical analysis could be

performed. Since management systems were similar and each trial consisted of treatments at initiation of grazing, the trials were combined for analysis.

Stocker cattle gains could not be compared by using average daily gains directly because of differences with regard to lengths of trials and environmental conditions of trial locations. Instead, gains were examined on a trial basis using a standardized trial length obtained by averaging the number of days of the stocker trials (131 days). The standardized length of days was multiplied by the composite average daily gain of animals within each trial to standardize gains for 131 days. These calculations enabled quantitative comparisons of the average gains of the trial groups in the statistical model. Main effects that were evaluated for the standardized weight gain included the trial number and the treatment used.

Stocker cattle gains were also examined on an individual basis as opposed to the trial basis previously described. This independent analysis was performed in order to account for more variability in the model. A 131-day standardized gain was also used to compare control and treatment animals in this analysis. Standardized gains were calculated for 174 animals. Main effects that were analyzed for the standardized weight gains included the trial number, the treatment used, and the trial × treatment interaction.

### *Cow/calf systems using split-pasture protocol*

Gains of treated and untreated calves in cow/calf production systems were also analyzed. Standardized gains of calves in six trials using split-pasture protocol were examined to determine the effects of strategic parasite treatment using fenbendazole over the average trial length of 179 days. In split-pasture protocol, a strategically timed seasonal control program using an anthelmintic is compared to a program using no treatment. Healthy cows are allotted to two equal groups and are randomly assigned to the treatment or control group. Two permanent pastures comparable in size, forage composition, and stocking capacity are used for the two treatment groups. One pasture contains the control animals, while the other contains the animals treated with anthelmintic prior to or early in the calving season. Approximately 60 days after placement onto pastures, all calves in this second group are also treated with anthelmintic. By maintaining the two herds on separate pastures for the entire grazing season, recontamination in the treated herd is prevented.

Data from trials in four different Texas counties were analyzed to determine the effects of fenbendazole treatment in split-pasture systems. Three of six trials were eliminated because the trials did not fit the requirements of the analysis. Frio County trials used pastures as the experimental units and could not be analyzed with the other trials which used animals as experimental units. The Gonzales County trial had a significant bull effect that favored the fenbendazole treatment group. Fenbendazole-treated calves had been sired by a bull that was noted for having calves with much higher growth rates than the control group. The three remaining trials were used in a statistical analysis based on 190-day standardized gains, the average length of these trials.

### *Cow/calf systems referred to as demonstrations*

Trials from cow/calf production systems using experimental methods other than split-pasture protocol were examined separately due to the major differences in treatment regimes. These trials could not be analyzed together due to the tremendous range of treatment levels and the variation of experimental design. Calf gains standardized to 109 days were compared descriptively to ascertain the effects of fenbendazole treatment on animal performance.

## Results and Discussion

### *Stocker cattle*

Strategic treatment of stocker cattle with fenbendazole at initiation of grazing increased calf gains over a 131-day period in several Texas counties. Table 1 shows the improvement in weight gains that was achieved by using fenbendazole treatment to interrupt parasite life cycles. Sex, location, climate, management systems, and the availability of forage could have contributed to the variability in gains since these factors were specific for each trial.

The stocker group analysis of variance (Table 2) indicated that the trial contributed significantly to the variability in stocker gains over 131 days ($P<.01$). This may have resulted from differences in calf sex, management, and environment. Treatment was also significant in the stocker group analysis ($P<.05$). According to least-square means in Table 3, a 15.28 lb advantage to deworming stocker cattle with fenbendazole was realized over 131 days. These results are supported by trials of Bergstrom et al. (1), although the magnitude of difference between treatment groups was greater than the gains documented in their findings. Similarly, the stocker individual analysis of variance (Table 4) indicated that trial and treatment effects in stockers over 131 days was highly significant. This is supported by the least-square means for treatment in Table 5, which showed a 17.0 lb advantage to strategic deworming over 131 days. Therefore, strategic deworming programs in stocker systems would be beneficial to producers who want to increase gains over a grazing period.

### *Cow/calf systems using split pasture protocol*

The three Texas trials analyzed in this group showed higher gains in fenbendazole-treated animals over 179 days (Table 6), however the treatment effect was not significant in the three trials that were analyzed (Table 7). Trial effects were significant

possibly due to the same factors as those discussed for stockers ($P<.05$). A difference was found in the least-square means for treatment between fenbendazole and control groups, although it was not significant (Table 8). The gain advantage of fenbendazole over controls was 24.1 lb over 190 days. Although this difference was not significant, Bumgarner et al. (4) have produced evidence of highly significant mean weight differences between treatment and control groups. Dewormed calves had a 50.4 lb. advantage in weaning weight over a 205-day period. No difference was detected by Bumgarner with regard to location, but treatments were administered in the same geographical area of Missouri.

### *Cow/calf systems referred to as demonstrations*

These systems could not be combined for a single analysis group. Gains were compared descriptively over a 109-day period (Table 9). Both large and small gains in the fenbendazole group above the controls were present.

The variability of gains in this analysis as well as that of the others could indicate that the fenbendazole treatment effect is not as large in some locations or in some animal production systems. Additionally, it could indicate that the parasite infection levels are not as high in some areas of Texas as in different parts of the state.

In all three management groups that were analyzed, performance of fenbendazole-treated animals over controls was greater in systems with less variability in management and fewer environmental differences (i.e., stocker programs). Absolute performance of animals treated with fenbendazole was consistently greater than controls. Management practices to control parasite infections such as rotation of pastures, barnyard and feed bunk sanitation, and the availability of clean water and adequate nutrition could reduce the effect of deworming treatment in specific trials. Differences between treatment animals and controls would not be as great due to the reduction of parasite contamination in systems using these management practices.

The major implication of this study is that strategically timed deworming can result in consistently high gains of calves in most areas of Texas. If ranchers used programs of deworming that effectively interfere with the life cycles of internal parasites, they would increase production efficiency and, more than likely, increase profits in their beef cattle herds.

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## Literature Cited

1. Bergstrom, R.C., S.L. Etherton, and M.A. Macdanold. 1984. Controlling concurrent infections of trichostrongylids and coccidia in weaned calves. Vet. Med. and Sm. Anim. Clin. 79:1210.
2. Bliss, D.H. 1987. Cost effective deworming programs. Anim. Health and Nutr. 42:19.
3. Bolender, R., and S. Lowry. 1986. Effects of deworming on profitability in cow/calf operations. Mod. Vet. Pract., April, p. 352.
4. Bumgarner, S. C., M.A. Brauer, R.M. Corwin, E .A. Thomas, and G. H. Myers. 1986. Strategic deworming for spring-calving beef cow/calf herds. J. Amer. Vet. Med. Assoc. 189:427.
5. Ciordia, H., J.A. Stuedemann, and H.C. McCampbell. 1983. Efficacy of fenbendazole against tapeworms in calves. Am. J. Vet. Res. 44:1091.
6. Herrick, J.B. 1987. Will the livestock industry capitalize on available dewormers? Anim. Health and Nutr. 42:5.
7. Malone, J.B., J.C. Williams, M. Lutz, N. Fagan, M. Jacocks, E. Jones, K. Marbury, and E. Willis. 1990. Efficacy of concomitant early summer treatment with fenbendazole and clorsulon against Fasciola hepatica and gastro-intestinal nematodes in calves in Louisiana. Am. J. Vet. Res. 51:133.
8. Myers, G.H. 1988. Strategies to control internal parasites in cattle and swine. J. Anim. Sci. 66:1555.
9. Williams, J.C., J.W. Knox, M.S. Marbury, M.D. Kimball, S.W. Scheide, T.G. Snider, and M.U. David. 1984. Efficacy of fenbendazole against inhibited larvae of Ostertagia ostertagi in yearling cattle. Am. J. Vet. Res. 45:1989.
10. Yazwinski, T.A., T.E. Greenway, W. Tilley, and H. Featherstone. 1983. Efficacy of fenbendazole against gastrointestinal nematode larvae in cattle. Vet Med. and Sm. Anim. Clin. 78:1899.

TABLE 1. INCREASED PRODUCTION PERFORMANCE IN STOCKER CATTLE FOLLOWING PREVENTIVE PARASITE CONTROL PROGRAMS INCLUDING FENBENDAZOLE TREATMENT

| Location (County) | Weight Improvement, lbs./hd over 131 d | A.D.G. Improvement, lbs./hd/d |
|---|---|---|
| Brazos | 11.8 | .09 |
| Donley | 24.9 | .19 |
| Ector | 11.8 | .09 |
| McCulloch | -1.3 | -.01 |
| McCulloch | 13.1 | .10 |
| Milam | 31.4 | .24 |

TABLE 2. ANALYSIS OF VARIANCE FOR WEIGHT GAIN OF STOCKER CATTLE OVER 131 DAYS (GROUP ANALYSIS)

| Source | D.F. | Sum of Squares |
|---|---|---|
| Trial | 5 | 5907.63 ** |
| Treatment | 1 | 700.74 * |
| Error | 5 | 328.13 |

**P<.01 *P<.05

TABLE 3. LEAST-SQUARE MEANS AND STANDARD ERRORS BY TREATMENT FOR WEIGHT GAINS OVER A 131-DAY PERIOD IN STOCKER CATTLE TREATED WITH FENBENDAZOLE (GROUP ANALYSIS)

| Treatment | Weight Gain, lbs. |
|---|---|
| Control | 100.22 ± 3.31 |
| Fenbendazole | 115.50 ± 3.31 |

TABLE 4. ANALYSIS OF VARIANCE FOR WEIGHT GAIN OF STOCKER CATTLE OVER 131 DAYS (INDIVIDUAL ANALYSIS)

| Source | D.F. | Sum of Squares |
|---|---|---|
| Trial | 5 | 71476.07 ** |
| Treatment | 1 | 11044.11 ** |
| Trial x Treatment | 5 | 5218.23 |
| Error | 162 | 141061.14 |

**P<.01 *P<.05

TABLE 5. LEAST-SQUARE MEANS AND STANDARD ERRORS BY TREATMENT FOR WEIGHT GAINS OVER A 131-DAY PERIOD IN STOCKER CATTLE TREATED WITH FENBENDAZOLE

| Treatment | Weight Gain, lbs. |
|---|---|
| Control | 100.41 ± 3.64 |
| Fenbendazole | 117.37 ± 3.06 |

TABLE 6. INCREASED PRODUCTION PERFORMANCE IN COW/CALF HERDS (USING SPLIT-PASTURE PROTOCOL) FOLLOWING PREVENTIVE PARASITE CONTROL PROGRAMS INCLUDING FENBENDAZOLE TREATMENT

| Location (County) | Weight Improvement, lbs./hd. over 179 d | A.D.G.Improvement, lbs./hd./d |
|---|---|---|
| Brazos | 21.5 | .12 |
| Brazos | 9.0 | .05 |
| Caldwell | 37.6 | .21 |
| Frio * | 39.4 | .22 |
| Frio * | 21.5 | .12 |
| Gonzales * | 32.2 | .18 |

* Eliminated from statistical analysis

TABLE 7. ANALYSIS OF VARIANCE FOR WEIGHT GAIN OF CALVES OVER 190 DAYS IN COW/CALF SYSTEMS USING SPLIT-PASTURE PROTOCOL

| Source | D.F. | Sum of Squares |
|---|---|---|
| Trial | 2 | 5885.50 * |
| Treatment | 1 | 868.81 |
| Error | 2 | 232.24 |

**P<.01 *P<.05

TABLE 8. LEAST-SQUARE MEANS AND STANDARD ERRORS BY TREATMENT FOR CALF WEIGHT GAINS OVER A 190-DAY PERIOD IN COW/CALF SYSTEMS USING FENBENDAZOLE TREATMENT WITH SPLIT-PASTURE PROTOCOL

| Treatment | Weight Gain, lbs. |
|---|---|
| Control | 418.63 ± 6.22 |
| Fenbendazole | 442.70 ± 6.22 |

TABLE 9. INCREASED PRODUCTION PERFORMANCE IN COW/CALF HERDS (USING DEMONSTRATION TREATMENTS) FOLLOWING PREVENTIVE PARASITE CONTROL PROGRAMS INCLUDING FENBENDAZOLE TREATMENT

| Location (County) | Weight Improvement, lbs./hd. over 109 d | A.D.G. Improvement, lbs./hd./d |
|---|---|---|
| Ector | 23.0 | .26 |
| Gonzales | 4.7 | .05 |
| Hays | 43.0 | .24 |
| Hopkins | 37.0 | .39 |
| Jefferson | 20.0 | .24 |

# Prickly Pear Cactus: An Important Rangeland Resource

C.W. Hanselka and J.C. Paschal


## Summary

Prickly pear cactus is an excellent natural resource that can be used for emergency or drought supplementation of beef cattle. Prickly pear is extremely variable in nutritional value depending on species and variety, age of the plant, season, and plant part. It is low in protein and phosphorus content, moderate in energy content measured as total digestible nutrients (TDN), but high in water, vitamin A, fiber, and ash. Most prickly pear diets require additional supplementation of protein and phosphorus for balancing nutrient intake.


## Introduction

Rangeland is the primary natural resource used for a variety of enterprises. It is a renewable resource that can regenerate indefinitely under favorable conditions. Much of the success or failure of a ranching operation on rangelands depends upon the management decisions regarding this resource. Range resources must be effectively produced, harvested, and converted to saleable products. It is the manager's responsibility and task to choose and implement the right practices at the right time based on the goals of the enterprise.

A recent survey of feeding trials conducted periodically since the early 1900s still has not adequately defined the role of prickly pear in livestock diets (10). Prickly pear is still an important emergency feed resource for ranchers in South Texas for both beef cows and stockers. However, the nutrient content of prickly pear is often less than that required by an animal other than a dry or early bred beef cow and, it is doubtful that prickly pear has a significant place in modern feed rations. There is a need, however, for nutritional and feeding information, which could be very useful in areas or countries with less intensive methods of livestock production.

The increasing economic importance of wildlife and wildlife habitat to Texas ranchers has shifted many former undesirable plants into the desirable column. One example is the prickly pear cactus. This species provides and excellent example of a plant that offers opportunities for manipulation to meet management objectives.

### *Forage Resource*

The prickly pears are a group of flat-stemmed cacti with jointed pads which occupy between 25 and 35 million acres in varying densities in all parts of the state except northeast Texas (8). The cacti easily root from pads scattered by animals or machinery, and mechanical brush control efforts have inadvertently done much to spread and intensify cactus populations. Grass herbage production has been shown to be two to three times greater in the absence of prickly pear on good sites. However, prickly pear will also grow on sites that will not support a high level of grass production (e.g. saline, shallow gravelly hills, etc.).

Many wildlife species, particularly in South Texas, depend upon prickly pear for food, water, and cover. Much of the annual diet of white-tailed deer (1) and the bulk of the diet of the javelina is prickly pear cactus. Prickly pear is also rated as an important food and cover plant in South Texas for Northern bobwhite quail (7). Many other species of birds and mammals also use the prickly pear as food or cover.

Prickly pears are also food producing cacti for humans. The fruits or tunas are large and sweet and are eaten raw, prepared as jelly or candied. The young, tender pads, called "nopalitos", are eaten in salads and omelets or as a garnish. Domestic production, at the present, is relatively small and large amounts of nopalitos and tunas are imported into the U.S. annually from Mexico.

Livestock throughout South Texas, Mexico, and Central and South America are often fed prickly pear or "Mexican Alfalfa" either as a primary sustenance food or an emergency feedstuff (2). Feeding prickly pear, however, has several disadvantages. "Pear eaters" may result from feeding livestock singed pear as the livestock may continue to eat prickly pear with spines after "burning" has stopped. This can result in external and internal injuries causing the animals to remain in poor condition throughout the year. Death losses are high from these injuries during screwworm outbreaks. Livestock may also tear off pads and scatter them over the pasture, spreading the plant.

Sheep in the Edwards Plateau of Central Texas are particularly affected by eating pear. The small spines cause a swelling of the lips and tongue that is locally called "pear mouth" and the seeds may also become compacted in the rumen. Blockage can become complete, eventually killing the animal.

## Nutritional Value

Prickly pear is very high in moisture content and consequently low in dry matter (4). As a result, it

takes very large amounts of prickly pear (100-200 lbs per animal unit (A.U.) daily) to satisfy minimal nutrient requirements. This high level of water in the diet may increase the rate of passage through the digestive system and could cause the scouring often seen in cattle fed singed prickly pear. This increased rate of passage also reduces nutrient absorption. It is advisable to feed some hay or have a dry pasture that the cattle can utilize to increase the level of dry matter intake. Cattle may appear to bloat on prickly pear but a more likely cause is the distension of the rumen from the large amounts consumed.

Crude protein levels are generally low (5-14%) (6) in prickly pear, especially when fed on the plant "as is" or after singeing. Prickly pear is generally too low in crude protein to adequately maintain cattle other than a dry pregnant cow, except during early spring growth (6). As a result, it is recommended that a good protein supplement be added to the diet of cattle fed prickly pear. Additional supplemental protein and/or hay also reduces the incidence of pear or fiber balls in the rumen by increasing fiber digestibility. A non-protein nitrogen source might also be utilized in a prickly pear ration.

Prickly pear is moderate to low in TDN (30-46%) (6). Since energy is often the first limiting nutrient on rangeland, is needed in the greatest amount, and has a significant effect on reproduction, prickly pear should be considered as a "good feed", albeit a slightly unbalanced one.

Prickly pear is generally very high in fiber and ash (5), both of which are responsible for digestive upsets. Indigestible fiber often causes "fiber" or "pear balls" and the high ash content aggravates the scours as a laxative effect. This appears to be a result of the high levels of magnesium, potassium, and sodium salts in prickly pear but this has not been established. The problem of scours can be reduced by increasing dry matter intake with lower quality feedstuffs such as cottonseed hulls, hay, or dry, brush pasture.

Prickly pear is extremely variable in mineral content, with some minerals exceeding requirements (5). These levels sometimes border on toxic levels, and may create other mineral imbalances with both macro and micro elements. It is low in phosphorus and will meet a dry pregnant cow's requirement usually only in the spring (9). Pear is very high in calcium (5-7%), further aggravating the calcium: phosphorus ratio imbalance seen on South Texas rangelands (5). A 12% calcium:12% phosphorus mineral should be used as a supplement for cattle fed prickly pear. Prickly pear is also very high in vitamin A, often found in limited quantities on drought-prone rangelands.

The cost of supplementing with prickly pear was approximately $.60 per head per day in 1983 and 1984. This compared very favorably with the cost of feeding hay ($1.58/head/day in 1983 and $1.84/head/day in 1984). A Texas Agricultural Extension Service survey of South Texas ranchers in 33 counties in 1989 indicates that almost one-fifth of the ranchers burn and feed prickly pear as an emergency feed for their cattle at an average cost of $.22/head/day. Most ranchers indicated that a tank containing 2 gallons of propane could be used to burn enough pear to feed 8-10 cows in 20-30 minutes depending upon the quality of the pear and the skill of the burner. Other ranchers have developed elaborate methods of burning large quantities of pear at once using mobile burners or harvesters.

## Landowner Attitudes

Land manager attitudes toward prickly pear have varied but generally prickly pear has been viewed as a mixed blessing (8). South Texas producers generally believe prickly pear to have positive values for livestock and wildlife but other regions rate it somewhat lower. Prickly pear is not perceived to cause a serious livestock health problem except on the Edwards Plateau.

Only 16 percent of individual landowners in Texas practice any control measures for prickly pear. The main reasons for non-control were relatively light stands of pear and the high cost of treatment. Texas land managers generally feel that a 50-75 percent reduction in prickly pear would have no effect on range livestock production but would have a negative influence on wildlife habitat.

If some prickly pear control is necessary, the rancher must determine how much, where, in what configuration, and what control methods are most appropriate to their management plans. In areas where prickly pear is viewed as a problem, an array of tools have been used to control it. These have ranged from grubbing with a heavy hoe, and early attempts included 2,4-D and 2,4,5-T, various mechanical treatments, and combinations of mechanical and chemical treatments.

A land manager may want to increase prickly pear in his pastures for an emergency feed. Mechanical methods such as railing or discing will scatter pads and encourage establishment. Some producers in South Texas are planting prickly pear in rows in small pastures to facilitate singeing the spines and for control of the amount fed to livestock. Some are experimenting with fertilizer regimes to encourage optimum production. Recent research has indicated that total biomass production can be increased five-fold and nutrient quality boosted significantly with the addition of fertilizer (3).

## Conclusions

The advantages of feeding prickly pear include the reduction of costs of emergency feeding during droughts and winter; lessening of soil erosion on poor condition ranges; protection of grasses on overstocked and poor condition ranges; and several wildlife food and habitat benefits. Disadvantages include the fact

that prickly pear itself is not a high quality livestock feed; singeing pear today is an expensive process; "pear-eaters" often result from feeding the plant; total forage production is lessened on pear ranges; and that animal health problems can occur.

There is a lack of current research evaluating prickly pear in South Texas specifically as it relates to the ranching industry as a supplemental emergency feed for beef cattle in terms of ration formulation, feed methods, and the economics of feeding. As a result, each individual manager must decide how to respond to this rangeland plant.

## Literature Cited


1. Arnold, L.A. Jr., and D.L. Drawe. 1979. Seasonal food habits of white-tail deer in the South Texas plains. J. Range Manage. 32: 175-178.
2. Benavides, T. 1985. Integrating resources for profitable ranching. *In*: L.D. White, D. Guynn, and T. Troxel (Ed. ), Proc. of the 1985 Intl. Ranchers Roundup. pp. 276-285.
3. Gonzalez, C.L. 1989. Potential of fertilization to improve nutritive value of prickly pear cactus (*Opuntia lindheimeri* Engelm.). J. Arid Environ. 16:87-94.
4. Griffiths, D. 1905. The Prickly Pear and Other Cacti as Food for Stock. USDA-Bur. of Plant Industry, Bull. No. 74. 55 p.
5. Griffiths, D., and R.F. Hare. 1908. Prickly pear and other cacti as food for stock. New Mex. Agr. Exp. Stat. Bull. 60.
6. Holloway, J.W., and L.W. Varner. 1985. Meeting the nutrient requirements of beef cattle. *In*: L.D. White, D. Guynn, and T. Troxel (Eds. ), Proc. of the 1985 Intl. Ranchers Roundup. pp. 276-285.
7. Lehman, V. W. 1984. Bobwhites in the Rio Grande Plain of Texas. Tex. A&M Univ. Press, College Station, 371 p.
8. Lundgren, G.K., R. E. Whitson, D.N. Ueckert, F. E. Gilstrap, and C.W. Livingston. 1981. Assessment of the Prickly Pear Problem on Texas Rangelands. Tex. Agr. Exp. Stat. MP-1483. 22 p.
9. Meyer, M.W., and R.D. Brown. 1985. Seasonal trends in the chemical composition of ten range plants in South Texas. J. Range Manage. 38:154-157.
10. Paschal, J.C. 1989. Nutritional value of prickly pear for livestock. *In*: C.W. Hanselka and J.C. Paschal (Eds.) Developing Prickly Pear as a Forage, Fruit, and Vegetable Resource. pp. 31- 49.

# South Texas Ranching - A Profile

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## Introduction

Ranchers in South Texas and elsewhere are working to survive in an increasingly competitive and complex market. To remain successful, ranchers must have continual access to information on ever-improving production, marketing, and management practices that is relevant to their own unique set of ranching circumstances. Little of this type of information is currently available in an integrated, useable form for the specific economic, technical, and social environment of South Texas ranchers.

The Texas Agricultural Extension Service initiated an integrated resource management program in 1988 called Comprehensive Ranch Management for Profit (CRMP) to provide the types of information that ranchers need to help them remain competitive. The CRMP staff is a group of subject matter specialists in range, wildlife, livestock, and agriculture economics-management, county agents, and their directors in Extension Districts 12 (South Texas), 13 (Southwest Texas), and 14 (Gulf Coast). For CRMP to be effective in delivering the appropriate information, it was necessary to develop a clear understanding of the composition and structure of the South Texas ranching industry, current enterprises and enterprise combinations, and current production, management, and marketing practices. Therefore, a mail survey of South Texas ranchers was conducted to obtain this background information and determine possible profit opportunities for ranchers in this region.

## Methods and Study Area

Survey questionnaires were mailed to 1,850 South Texas ranchers in 33 counties in the 3 Extension districts in January 1989 (Fig. 1). These ranchers were randomly selected from county lists of producers on file with the Texas Beef Industry Council in Austin. These lists had been used in the beef check off referendum. The survey sample was stratified by county (18% of each county list), with a minimum of 30 producers selected from each county to provide an adequate sample size for analysis at the county level. Each rancher received a questionnaire in counties with less than 30 persons on the county list. The CRMP staff cooperated with County Extension Agents and District Extension Directors during the development of the county lists and in subsequent phases of the survey. All counties in Districts 12 (11 total) and 14 (16) were included in the survey as well as the 6 lower counties of District 13. This sampling included all the counties in the area generally designated the Rio Grande Plains of South Texas.

Each selected rancher was mailed a 4-page survey instrument which included a cover letter explaining the purpose of the survey and 22 survey questions, including a request for the results of the survey. The questionnaire consisted of 21 questions concerning rancher background and income, and livestock, wildlife, recreation, and range management practices. A stamped, self-addressed envelope to be used by the respondents for returning completed questionnaires was included. Each questionnaire was coded to provide confidential identification. This was used for follow-up mailings to non-respondents and allowed the CRMP staff to contact ranchers for the personal interviews.

Approximately 2 weeks after the first mailing, a reminder postcard was mailed to each non-respondent to emphasize to them the importance of the survey and to indicate that their questionnaire had not been received. A final mailing was sent to the remaining non-respondents which was identical to the initial mailing two weeks later.

The Personal Computer Statistical Analysis System (PC-SAS) was used to analyze data from the useable questionnaires. Descriptive statistics were obtained for each county, Extension district, selected resource zones, and the overall South Texas region for use in county and district educational programming and to compare trends from earlier surveys of this area.

## Results and Discussion

Of the 1,850 ranchers who received survey questionnaires, 1,012 (55%) of them responded by returning the questionnaire. Some of the questionnaires were not useable in the study because of rancher retirement, ranch sale, ranch location, occupational changes, livestock liquidation, and other reasons. Approximately 800 of the questionnaires were used in the analyses.

Demographic information about South Texas ranchers obtained through the survey indicated an average age of 58 years, 13 years of education, cow herd size of 200, and 2,290 acres owned. Some of these statistics, such as age and education, remained

fairly constant across all areas of South Texas. Other parameters, such as ranch and herd size and management practices, varied considerably from county to county. For example, the normal stocking rate for the 33-county region was 9.5 acres/animal unit (AU), but the individual county averages ranged from 2.6 acres/AU to 23.2 acres/AU. Therefore, many of the region-wide results are of limited usefulness. It is more meaningful to compare results by county and by similar resource areas (groups of counties with like resources).

The survey region was separated into three "Resource Zones" that were arbitrarily chosen and based upon differences in rainfall, vegetation, and livestock stocking rates. The three resource zones will be referred to as the Western, Central, and Eastern zones (Fig. 2). The following discussion will focus on similarities and differences among the three regions as indicated by the survey results, as well as possible reasons for such differences. In addition, only selected results from the survey are included in the following discussion. For the complete results or more information on the survey method, contact the authors at the Corpus Christi Research and Extension Center.

## Size and Scope

The differences in climate, soil, and vegetation among the three resource zones directly influence the size and kinds of ranching operations in each region. The survey results showed that ranch size in the South Texas region increased from the northeast to the southwest (Eastern=1,041 acres, Central=1,442 acres, Western=6,058 acres). This region is primarily a beef cattle production area with approximately 92 percent of the ranchers in each resource zone having cow-calf operations with only 10-15 percent grazing stocker cattle, primarily steers. Spanish goats are raised by less than 1 percent of the ranchers in the Eastern and Central zones, but this increases to 4 percent in the Western zone. The average number of cows owned in each resource zone parallels the increase ranch size (Eastern=136, Central=181, Western=373). Ranches in the Eastern and Central zones reported an average of 33 percent of their pastures as brushy range. The Eastern zone ranches also reported 28 percent of their acreage as improved pasture while Central zone ranches contained 38 percent of their acreage as improved pasture. Ranches in the Western zone average 66 percent brushy range but only 19 percent in improved pasture.

## Range and Pasture Management

The normal stocking rates for the three resource zones are 6.8 acres/AU (Eastern), 9.1 acres/AU (Central), and 16.6 acres/AU (Western). All regions of South Texas appeared to be significantly affected by the 1988-89 drought which is shown by a dramatic decrease in stocking rates in 1988 across all resource zones compared to normal reported stocking rates. The Eastern zone appeared to be most affected with a 35 percent decrease in stocking rates. The Central and Western zones had a 21 and a 19 percent decline in stocking rates. The drought was certainly as severe in the Central and Western zones, if not more so, as in the Eastern zone so other factors, including a lower normal stocking in these zones, may have lessened the impact of the drought on stocking rate.

When considering factors that influence stocking rate decisions, there were no major differences among the three resource zones. Ranchers in each region rated range condition and forage quantity as the most important considerations, followed by past experience. Economics was a moderate influencing factor, while the least important factors were the influences of a neighbor or agency.

A slightly higher percentage of ranchers in the Central zone (88%) indicated that they used some form of grazing system when compared to the other two zones surveyed (81 and 82%). There were small differences among the three regions in the percent of ranchers using short duration (31-33%) or continuous grazing (23-26%). However, the number of ranchers using a 4 pasture - 1 herd system was greater in the Central zone (33%) than in the Eastern (26%) and Western (22%) zones.

When considering the average percent of each ranch that was treated with a specific brush management technique, there were no major differences between the three resource zones for prescribed burning, roller chopping, discing, chaining, or bulldozing to reduce brush cover. Grubbing (12.5%) and aerial herbicide treatments (15%) were more popular on ranches in the Central zone, while ranches in the Western zone root-plowed an average of 17 percent of their acreage compared to 7 percent in the Eastern resource zone. Shredding (52-54%) and soil-applied herbicides (16-23%) were among the most common brush management practices used in the Central and Eastern resource zones. These differences in brush management practices are affected by ranch size, rainfall, and previous brush management strategy.

More than 38 percent of ranchers in South Texas use winter pastures (an 83 to 139% increase over previous surveys) as a nutritional management practice. As one might expect, use of winter pastures is much more prevalent in the Central and Eastern zones (42 and 43%) compared to the Western zone (24%). This difference is directly related to lower amounts of precipitation and erratic rainfall patterns typical of Southwest Texas in the Western zone. One unique nutritional management practice that has been utilized by many South Texas ranchers for decades is burning prickly pear cactus. After the spines are burned away, "pear", combined with a protein supplement and hay, provides an adequate maintenance ration for dry cows during drought. This is a common practice in the Western zone (40%) compared to the percent of ranchers that burn pear in the Central (22%) and Eastern zone (7%). The primary reason for this difference is that droughts

are more frequent in the southwestern regions of South Texas, resulting in shortages of forage. Also, prickly pear decreases in abundance from the Western to the Eastern zone.

### Livestock Management

Results from the livestock management section of the survey produced important information on production, nutrition, reproduction, and marketing practices. For example, more than 65 percent of the ranchers in each South Texas region evaluate their bulls for breeding soundness to help insure a high calf crop percentage. The use of this reproductive management practice has improved by 38 to 150 percent since earlier surveys in 1982 and 1984, respectively. Continued emphasis through Extension programming should help expand the use of this important management tool. Forty-six percent of the ranchers in South Texas pregnancy test their cow herd which has increased by 59 and 84 percent from the levels reported from earlier surveys. This figure is lowest in the Western zone (41%) which can probably be attributed to the increased difficulties involved with "working" cattle on larger, more extensive operations.

Animal and herd health management practices declined slightly compared to the earlier surveys, which is indicative of a drought situation such as in 1988. These are often the first practices to be stopped or reduced during drought to compensate for the increase in supplemental feed costs. Seventy-eight percent of the ranchers in the South Texas region have a herd health vaccination program which is similar to the 81 and 82 percent reported in the earlier surveys. The number of ranches using external parasite control decreased to 71 percent from 87 and 76 percent compared to earlier surveys in 1982 and 1984, while internal parasite control increased slightly to 66 percent compared to 40 and 61 percent reported in 1982 and 1984, respectively. As one might expect, internal and external parasite control is more common (70 and 74, and 72 and 78%, respectively) in the higher rainfall areas (Eastern and Central) than in the Western zone (54 and 59%, respectively). Overall, most ranchers know that herd health management practices should be utilized for the control of diseases and parasites during the lifetime of the animal with annual and sometimes monthly treatment. The use of these and other management practices should not be reduced during a drought, especially a prolonged one, since the cattle remaining in the herd are usually the most productive or genetically superior individuals.

Marketing techniques have changed for cattle producers since the 1982 and 1984 surveys of this area. The percentage of ranchers who sell on the ranch has more than doubled from 9 and 13 percent, respectively, to 27 percent in 1988. This marketing method is less popular in the Eastern zone (22%) than in the Central and Western zones (34 and 35%). However, the numbers of ranchers who market their cattle through the local auction barn (94%) is unchanged. This may be because the auction marketing method is the most common in Texas due to their proximity and convenience of selling time. Less common methods of selling cattle include direct sale to a local packing operation (6%), market reports service (9%), video marketing (2.5%), and the futures market (2%). These results indicate a need for increased educational emphasis on futures and options, and the need for producers to become more aware of market conditions since only 1 of 10 ranchers receive any type of market report.

### Wildlife and Recreation Management

Across the South Texas region, 28 percent of the ranchers reported that they lease their land for hunting. However, there was a wide variation in the percent of hunting leases among the three resource zones. More than 52 percent of ranchers in the Western zone lease for hunting, compared to 26 percent in the Central zone and only 19 percent in the Eastern zone. A likely reason for the contrast is a greater abundance of wildlife habitat (brush) and a greater number of game animals such as quail and deer from the East to the West. Also, the smaller landholdings to the northeast are more likely to be used for family recreation than larger landholdings in the southwestern region. Of those ranchers that lease for hunting, season leases (87%) were by far the most common, followed by package hunts (13%), and day leases (9%). This may be due to the fact that season leases, although usually less profitable than the latter two types of hunting agreements, require the least input by the landowner.

The three major wildlife species that are hunted in the South Texas region are white-tail deer, bobwhite quail, and mourning and white winged dove. Deer are hunted more often than any other species in the Eastern (62%) and Western zones (82%). Dove hunting is more popular in the Central zone (70%), followed by deer (63%) and quail (63%) hunting. Javelina (58%) and feral hogs (50%) are important game species in the Western region.

Whether or not ranchers lease for hunting, many of them apply management practices to improve wildlife in their operation. The most important management practices in the Western zone are maintaining harvest records (50%) and brush management to enhance wildlife habitat (49%). Supplemental feeding, wildlife watering facilities, population surveys, and harvest quotas are also important in this region. In the Central zone, supplemental feeding (44%) is the most common management practice, followed by wildlife watering facilities (31%), and brush management (30%). Wildlife management does not seem to be a high priority in the Eastern zone. The most common management practice was supplemental feeding (29%), followed to a lesser degree by brush management, water facilities, and harvest records. These results are in agreement with the current low priority placed on hunting leases and

wildlife management in the Eastern zone compared to the Central and Western zones.

A few recreation enterprises other than hunting were considered important on some South Texas ranches. Nature photography, camping, and artifact collecting were additional sources of income for some ranchers in the Western zone. Nature photography, camping, and bird-watching were important recreation enterprises in the Central region, while camping and bird watching were the most common enterprises in the Eastern zone.

### Financial Management

A few general questions on income and computer usage revealed some interesting patterns of record keeping and financial management by South Texas ranchers. The survey indicated that about 21 percent of ranchers own a computer but only 12 percent (55% of those owning them) use them in their ranch business. Ranchers in the Western zone reported the highest computer use (16%) while Eastern zone ranchers used computers the least (10%). This difference is related to the increased need for computerized record-keeping systems on the larger ranch operations in the southwestern region. At any rate, it certainly indicates a need for educational efforts to determine exactly who does need a computer and how should it be used to enhance ranch profitability.

About 67 percent of ranchers use a profit and loss statement, and about 25 percent use either a balance sheet or cash flow statement as a financial management tool. This pattern was similar across all regions of South Texas. The operating statement is relatively popular because it is used to produce the Schedule F for tax purposes. The balance sheet and cash flow statements are probably used for loan documentation purposes. Fortunately, many ranchers realize the importance of financial management in ranching survivability and profitability, but this is an area where increased educational emphasis by Extension personnel could greatly benefit ranch efficiency.

The percent of the total income that is derived from the ranch business was similar across all regions of South Texas. The percent of income from the ranch business ranged from a low of 39 percent in the Central zone to a high of 47 percent in the Western zone. Only 13 percent of the ranchers in South Texas derive 100 percent of their income from the ranch business. This value is lowest in the Central zone (10%), highest in the Western zone (17%), and similar to that of the Central zone in the Eastern zone (12%). These numbers indicate that non-ranch income is extremely important to South Texas producers.

Nearly 77 percent of the respondents had a gross income in 1988 that was less than $50,000. This is relatively low for "gross" income, but it does represent a slight increase in gross income reported in this survey for 1986 and 1987. Among the three resource zones, the Western region showed the highest income level with 32 percent of the ranchers grossing more than $50,000, followed by the Central zone (26%) and the Eastern zones (18%).

Only 33 percent of South Texas ranchers are certain that their children will operate the ranch when the rancher retires. Two-thirds believe that their children will not take over the ranch, or they are uncertain about the future of the ranch operation. Since the average age of South Texas ranchers is 58 years of age, they probably have less than 10 years to plan for retirement and for transfer of their ranch to new management. The children of a 58 year old rancher are probably in their 30s, and it is not likely that they will leave their current jobs to come home and operate the ranch if they have not already indicated a desire to do so. This certainly represents one of the more significant statistics uncovered by this survey and may represent an area previously not well covered in Extension program efforts.

### Summary

Ranchers in South Texas will likely experience increasing challenges in the ranching industry through the 1990s. It is becoming increasingly important that ranchers concentrate on maintaining or increasing profits through more effective management of production and marketing and to plan who will follow in their footsteps. Fortunately, the CRMP survey has begun to clarify some strengths and weaknesses of the South Texas ranching industry. The results of the survey are applicable for ranchers in making decisions on enterprise selections and in determining appropriate management practices. Additionally, this survey has provided Texas A&M Extension personnel with valuable information on educational programs that are needed to support ranching survivability and profitability in Texas. More detailed information is needed on successful production and marketing techniques, including enterprise economics, to help reverse the present trend of decreasing profits in ranching.

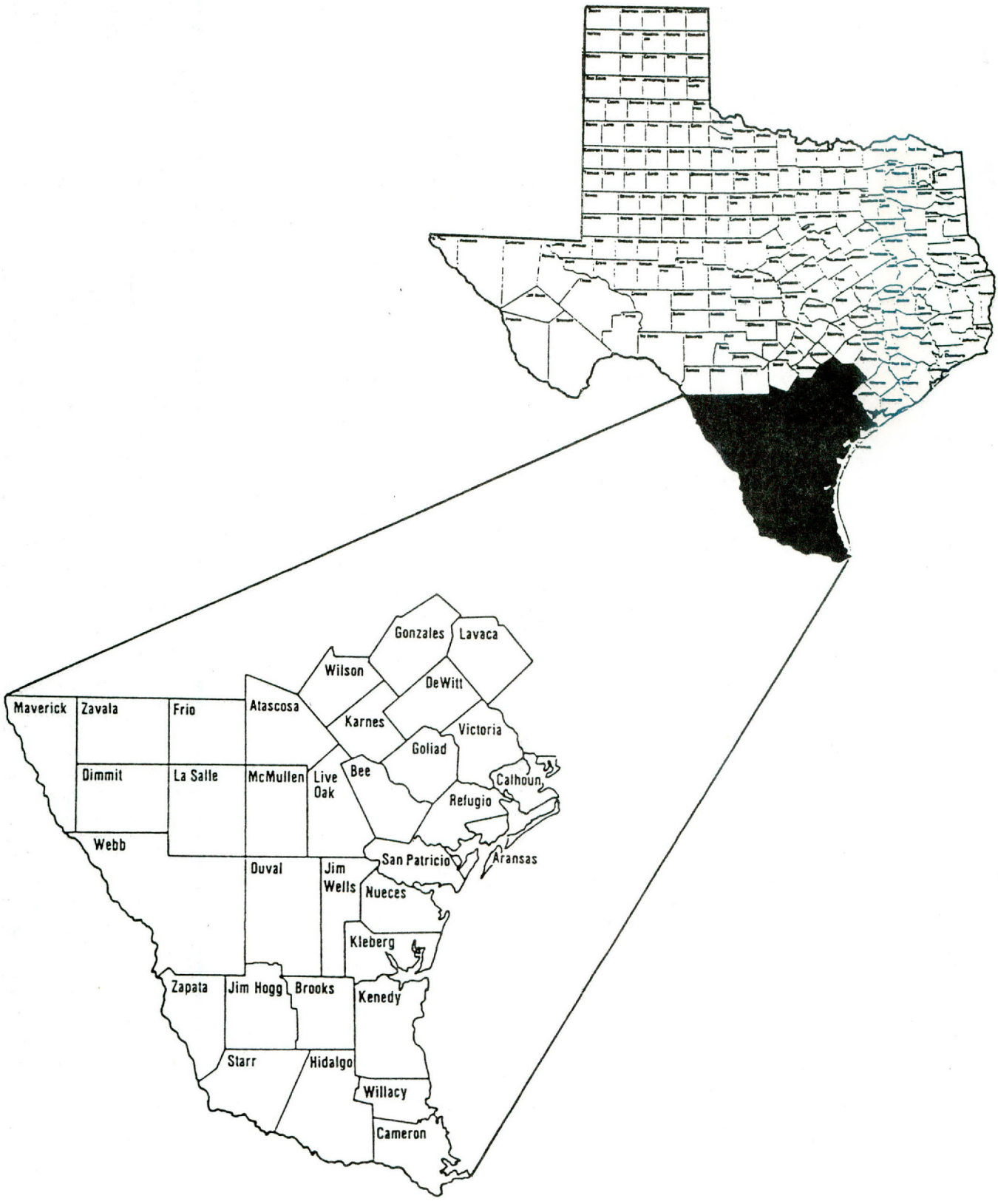


Figure 1. The 33 South Texas counties included in the CRMP survey.

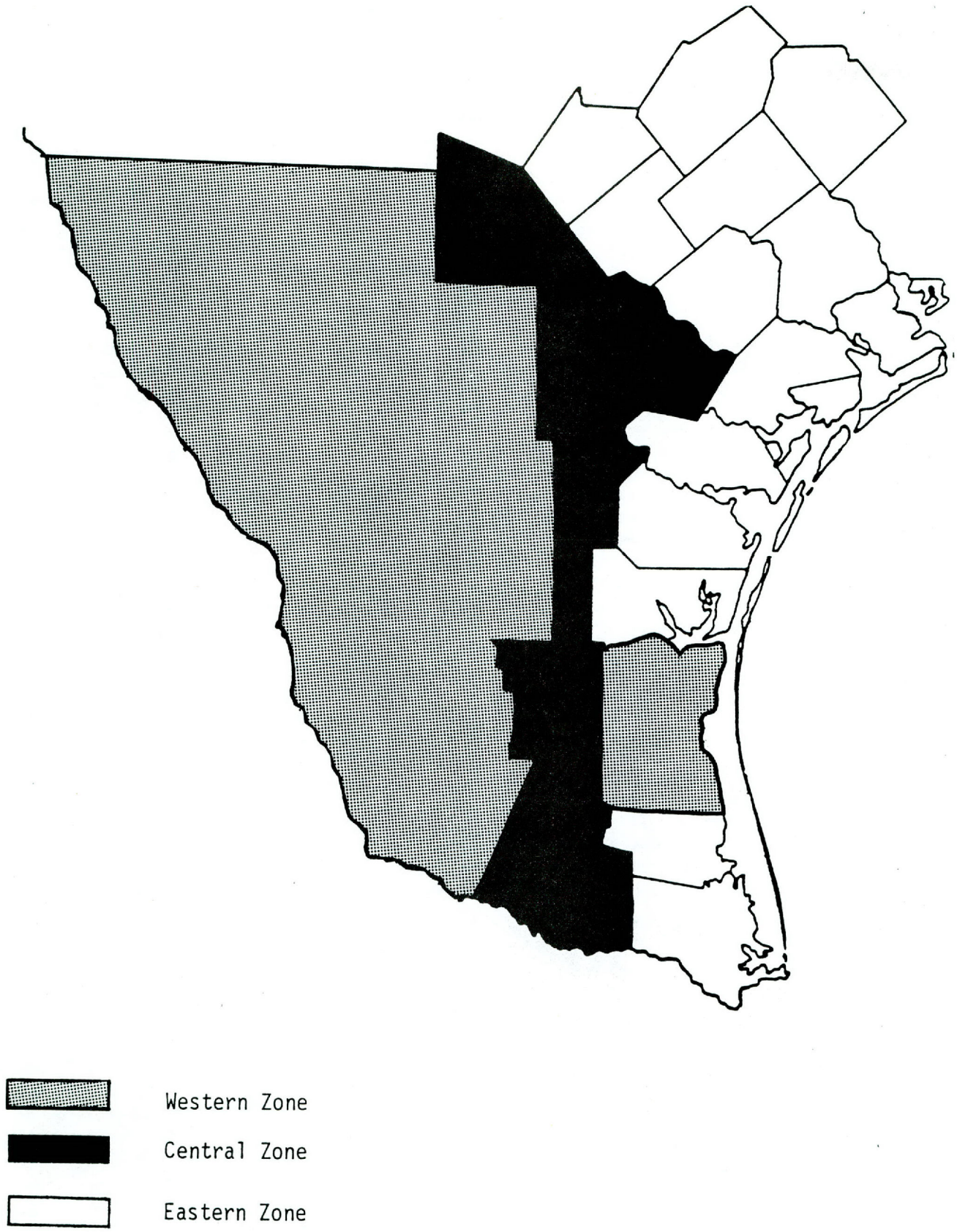


Figure 2. The three "resource zones" based upon differences in rainfall, soils, and vegetation and created to provide more meaningful analysis of the CRMP survey results.

# The Effect of Fenbendazole on the Control of Nematode Parasites and on Preweaning Average Daily Gain

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## Summary

The objectives of this study were to determine the effects of fenbendazole treatment on nematode parasite control and on the average daily gains of preweaning beef calves. In Experiment 1, seven pastures containing commercial cows were randomly assigned to one of two treatment groups. Cows and calves in Group 1 received no treatment and served as controls. Cows in Group 2 received fenbendazole 45-60 days prior to calving. The calves in Group 2 received fenbendazole at approximately 90 days of age. Fecal samples were collected and calf weights were recorded. Group 2 cows had a lower fecal egg count (P<.025) than Group 1 cows (4.2±1.24 vs 7.8±2.45 eggs/gram). In addition, the calves from Group 2 had a lower (P<.05) fecal eggs/gram count (22.1±4.70) than Group 1 calves (63.7±20.2). Differences in preweaning average daily gain were not significant, but gains were higher for the Group 2 calves (1.53 vs 1.31 lb).

In Experiment 2, there were three treatment groups. Groups 1 and 2 were repeated as described in Experiment 1 except that cows received fenbendazole in deworming blocks. Cows and calves in Group 3 received the same fenbendazole treatment as in Group 2 cows and calves except the cows in Group 3 received a second treatment at the time of calf treatment (90 days postpartum). A treatment × time interaction was detected (P<.08) in the cow fecal egg counts. The Group 1 egg counts started with a relatively low value (5.4±3.47) and had increased by weaning (24.7±11.88) whereas the Groups 2 and 3 egg counts started higher (17.3±5.52 and 22.2±3.80) and were reduced by weaning (6.4±4.91 and 1.3±.99). The calf pre-treatment fecal egg counts for Group 1 were 102.1±16.02 eggs/gram and Groups 2 and 3 were 17.2±2.09 and 12.5±2.38 eggs/gram. Differences in calf preweaning average daily gain were not significant but were slightly higher for the treated calves.

In conclusion: 1) cattle in Southwest Texas appear to have nematode parasites, 2) calves that were born to cows that had been treated with fenbendazole prior to calving had a lower eggs/gram count at approximately 90 days of age than calves born to cows that had not been treated prior to calving, 3) no significant improvement in calf preweaning average daily gains were detected but gains tended to be higher for the treated calves, and 4) the deworming fenbendazole blocks were just as effective in reducing nematode fecal eggs as fenbendazole administered as a suspension.


## Introduction

Throughout Southwest Texas internal parasite control in beef cow/calf herds has been considered to be an unnecessary management practice. Beef cows were not thought of as being completely free of internal parasites but rather their level of infection was not intensive enough to cause reduced animal performance. Therefore, without the clinical signs of internal parasite infection (anemia, diarrhea, poor growth rate, and anorexia) treatment was generally believed to be nonessential.

It is now known that internal parasitism in cattle can be divided into three categories with regard to the parasites' effect on the host; infection, economic, and clinical (2). It has been suggested that the losses in productivity due to inapparent infections (economic category) probably far exceed those due to obvious disease or death (clinical category) (5). Of the three categories, economic parasitism is the most difficult to assess (2). The beef cow looks healthy and without untreated controls to compare performance, one would never know the true economic impact.

Parasite treatment philosophy for beef cattle has changed in recent years. Recognition of economic losses without clinical evidence has caused an interest in preventive programs rather than waiting until animals are suffering obvious effects of parasite infection (5). In Southwest Texas, beef cows under native range management infrequently show any clinical evidence of internal parasite infection. Controlled studies, however, had not been conducted to determine if beef cows were experiencing economic losses due to parasite infection. Therefore, the objectives of these studies were: 1) to determine the nematode infestation level in Southwest Texas Beef cows and calves, 2) to determine the effect of fenbendazole treatment on nematode parasite levels, and 3) to determine the effect of fenbendazole treatment and parasite loads on the preweaning average daily gain of suckled beef calves.

## Experimental Procedure

Two experiments were conducted over a three year period to evaluate the effects of fenbendazole treatment on cow and calf fecal egg counts and calf preweaning average daily gains. Each experiment

was initiated and completed within one beef cattle production year.

### *Experiment 1*

Seven pastures (18 to 26 cows per pasture), which were being grazed by mature crossbred (1/4 to 1/2 Brahman x English breeds) beef cows, were assigned to one of two treatment groups. Three pastures were randomly assigned to the control group (Group 1) and four pastures were randomly assigned to a fenbendazole treatment group (Group 2). The pastures were assigned in such a way to minimize the effect of pasture variation (size, stocking rate, etc.). The cattle were similarly managed under a spring calving program. Throughout the entire experimental period, cows remained in their respective pastures and were never mixed with another group of cows or moved into another pasture.

All cows in Group 2 were treated with fenbendazole (5 mg/kg) 45-60 days before the beginning of the calving season. Approximately 90 days following the end of the calving season, all calves that were born within Group 2 were also treated with fenbendazole. Fenbendazole (suspension) was administered to each individual animal (cows and calves). No cows or calves in Group 1 received any fenbendazole (Table 1).

At the time of the cow fenbendazole treatment (45-60 days before the beginning of the calving season), fecal samples were randomly collected. Fecal samples from the cows were also collected at the time of calf treatment approximately 90 days after the calving season. Fecal samples within a pasture were selected at random to determine fecal worm egg counts. The collection schedule and the number of fecal observations within each pasture are summarized in Table 2.

All calves within each pasture were identified by an ear tag. At the time of calf treatment and at weaning, fecal samples were collected from calves (Table 2). Calf fecal samples within each pasture were collected at random and identified by the ear tag number. At weaning, the same calves within each pasture were re-sampled. All calves were individually weighed at the time of treatment and at weaning. Weights were recorded and average daily gains were calculated.

### *Experiment 2*

Seven pastures grazed by commercial crossbred beef cows (18 to 26 cows per pasture) were assigned to one of three treatment groups. The pastures were assigned as described in Experiment 1 (size, etc.). Three pastures were randomly assigned to the control group (Group 1) and two pastures each were randomly assigned to treatment groups (Group 2 and Group 3). Groups 1 and 2 received the same treatment schedule as described in Experiment 1. Group 3 received the same treatment as Group 2 except an additional fenbendazole treatment was administered to the cows at the time of calf treatment (approximately 90 days postpartum: Table 3).

In Experiment 2, Fenbendazole was administered to the cows 45-60 days before calving season by feeding of deworming blocks. In order for the cows in the treatment pastures (Group 2 and 3) to accept the deworming block, all salt and mineral blocks were removed from the pastures. Starter blocks were then placed in each treatment pasture. Once the starter blocks were readily being consumed, the starter blocks were replaced with deworming blocks. All deworming blocks were over 90 percent consumed in 5 to 7 days. Fenbendazole in suspension was used to individually deworm the cows (Group 3) and calves (Groups 2 and 3) at approximately 90 days following the end of the calving season.

Fecal samples from the cows and calves were collected in the same manner and at the same time periods as described in Experiment 1. Additional cow samples were collected 8 to 12 days following the time of cow fenbendazole treatment (45-60 days before the beginning of the calving season) and at weaning (Table 4).

All calves were individually weighed at the time of treatment and at weaning. Weights were recorded and average daily gains were calculated.

### *Fecal Analysis*

All fecal samples for both experiments were examined within seven days of collection to determine fecal egg counts. The samples were analyzed by the Wisconsin double centrifugation sugar flotation technique for the recovery of helminth ova. Five grams of feces per animal were examined. Resultant slides were scanned with an Olympus tri-nocular microscope. In order to insure accuracy the hi-dry objective was employed and representative ova were measured with an eyepiece micrometer.

### *Data Analysis*

In both experiments, the pastures served as replicates or experimental units. The treatments were randomly assigned to each pasture, and therefore, all cattle within each pasture received the same treatment. Individual fecal worm egg counts (cows and calves) and calf average daily gains served as sampling units. Therefore, the data (eggs per gram and average daily gain) within each pasture were averaged to obtain a data value for the pasture. The number of sampling units per pasture for the cow and calf fecal worm egg counts for each experiment is listed in Tables 2 and 4. Because every calf was ear-tagged, all calves or sampling units were weighed in order to obtain the pasture or experimental unit average daily gain value. The change of pasture fecal worm egg counts over time were analyzed by split-plot analysis of variance (3). Standard errors of the difference between treatment and time were determined from the error mean squares method (7). The average daily gain data was analyzed by analysis of variance (7).

## Results and Discussion

Cows in Southwest Texas are infected with nematodes. After reviewing the control and pretreatment cow fecal samples, 12.7 percent of the samples had no nematode eggs, 62.7 percent had an egg count between 1-20 eggs/gram, 7.5 percent had 21-50 eggs/gram, 12.7 percent had an egg count between 51-100 eggs/gram, and only 4. 5 percent of the samples were between 101-250 eggs/gram. This data agrees with other reports from Texas (1) as well as fecal worm egg counts from arid and semiarid regions (4). For some species of nematode the most severe damage can be caused by the immature stages rather than by the adult worm. Thus, cattle can exhibit clinical signs of parasitism having few or no parasite eggs in their feces (2). In these studies, however, no cows or calves showed any clinical signs of parasitism.

### *Experiment 1*

Table 5 summarizes the fecal egg counts from the commercial cows. The analysis disclosed an overal l significant (P<.025) treatment effect. The average ±S.E. eggs/gram for the Group 1 and Group 2 cows were 7.8±2.45 and 4.2±1.24. There was not a significant time effect or treatment × time interaction (P>.10). Therefore, cows that received fenbendazole had lower levels of parasite infection than the cows that did not receive fenbendazole.

The average eggs/gram for the calves is shown in Table 6. There was a significant treatment effect (P<.05) plus a tendency toward a treatment × time interaction (P<.1). The calves that were born from cows that had been treated prior to calving and were treated themselves had a lower overall fecal eggs/gram count than control calves (22.1±4.7 vs. 63.7±20.2). It is very interesting to note that by weaning time there were no significant differences in the calf fecal egg counts. The control calves counts went from 92.1±35.23 eggs/gram at approximately 90 days of age to 35.2±10.95 eggs/gram at weaning whereas the treated calves eggs/gram count went from 17.3±8.91 to 26.9±2.49. These changes in fecal egg counts were the reasons for the slight treatment × time interaction. This data does support the concept that calves born to cows that had been dewormed prior to calving have lower nematode infection at 90 days of age compared to calves born to cows that were not dewormed prior to calving. At least most of that advantage, however, appears to be lost by weaning time (8).

There was no difference (P>.10) in the average daily gain performance between the Group 1 calves and the Group 2 calves. The average daily gains for these groups were 1.31±0.13 lbs and 1.53±0.25 lbs, respectively.

### *Experiment 2*

The average cow eggs/gram values are shown in Table 7. Although the main effect of fenbendazole treatment was not significant (P>.10), the treatment × time interaction was approaching significance (P<.08). It is interesting to note that the cows in Group 1 had a lower pretreatment eggs/gram count than the cows in Group 2 and 3 (5.4±3.47, 17.3±5.52 and 22.2±3. 80, respectively). This data suggests that fecal egg count differences reflect parasite pasture contamination differences as a result of previous grazing history. The Group 2 and 3 pastures were evaluated and there were no observable reasons why the cows in those pastures had a higher parasite load when compared to the cows in the Group 1 pastures.

Even though the cows in Group 2 and 3 had a higher fecal egg count, it appears that the fenbendazole blocks successfully dewormed those cows. The Group 2 and 3 eggs/gram values for pretreatment and post treatment periods were 17.3±5.52 ; 1.4±1.08 and 22.2±3.80; 2.9±2.26, respectively. The eggs/gram count for the Group 1 cows remained unchanged throughout this time period. Cows can be effectively dewormed with the fenbendazole deworming blocks. One key to the successful use of the deworming blocks is that the cattle must consume the block within a 3 to 10 day period. Therefore, using the starter blocks to train the cattle to accept the deworming block is very important.

By approximately 90 days postpartum, it appeared that the average fecal eggs/gram count in the Group 3 cows were on the increase (2.9±2.26 to 12.3±9.77). This may or may not be accurate due to the large standard errors. By increasing the number of replications, this trend could be better evaluated. This trend, however, may be supported because the cows in Group 3 pastures had a higher worm egg count at pretreatment, suggesting a higher pasture contamination. Nevertheless, Group 3 cows received a second treatment of fenbendazole (suspension) which is probably the reason for the lower average fecal eggs/gram count at weaning (1.3±0.99).

The treatment × time interaction (P<.08) can be explained by the fact that Group 1 cows started with a low pretreated average fecal egg count and by weaning the egg count increased (5.4±3.47 to 24.7±11.88, ); whereas, the cows in Group 2 and 3 started with high pretreatment average egg counts and by weaning the egg counts were reduced (17.3±5.52 to 6.42±4.91 and 22.2±3.80 to 1.3±0.99). Further study is needed on these trends because replications were limited.

Although the main effect of treatment was not significant (P<.10) for the calf fecal egg counts, there was a significant treatment × time interaction (P<.005). As documented in Experiment 1, the initial average eggs/gram count of the calves that were born to cows that had been dewormed prior to calving (Group 2 and 3) were lower (17.2±2.09 and 12.5±2.38) than the average fecal egg counts of calves that were born to cows that had not been dewormed prior to calving (102.1±16.02, Group 1, Table 8). The pre-treatment fecal egg counts in Experiment 1 were very similar to those of Experiment 2. The pretreated fecal egg counts for Group 2 increased from 17.2 + 2.09 to the

time of weaning (132.2 + 2.59). This average eggs/gram count is much higher than any of the weaning counts from Experiment 1. One possible explanation may be that Group 2 pastures had a higher parasite contamination. This assumption is supported by the high pretreatment cow average eggs/gram counts for Group 2 pastures. More studies are needed before this conclusion can be determined. Meanwhile, the Group 3 calf average fecal egg counts started low and remained low. It might be suggested that the Group 3 calf eggs/gram counts should have increased by weaning time much like the Group 2 calves. Group 3 cows had very similar pretreatment average egg counts as Group 2. This would support the higher parasite pasture contamination argument. The Group 3 cows, however, received a second treatment of fenbendazole at approximately 90 days postpartum. This second treatment probably helped keep the pasture parasite load down, thus reducing the calf infection rates when compared to Group 2 calves.

Even with the difference detected with cow and calf average fecal egg counts, there were no significant differences detected (P>.10) for the average daily gain of the preweaning suckled beef calves. The average daily gains for the calves in Group 1, 2, and 3 were 1.79±0.22 lb, 1.91±0.04 lb and 1.80±0.12 (respectively). There were no differences observed in body condition of the cows or calves in either experiment.

Reproductive performance has been reported to be improved as a result of strategic deworming programs (6, 8, 9). In Experiments 1 and 2, cows were not managed in such a way that reproductive data could have been collected and analyzed. The owner of the cattle, however, observed what he believed to be a shorter calving interval in the cows that received fenbendazole. Future studies should be designed so that reproductive data can be collected to evaluate the owner's subjective observations.

Eighty-two percent of the cows sampled had less than 50 worm eggs per gram of feces. If a cow had an infection level of 50 eggs/gram she would shed about 46,000 worm eggs per kilogram of feces. With a cow producing 14 kg of feces per day, a 100 cow herd could shed 64,000,000 worm eggs every day on the pasture. One would think that the pasture contamination would eventually build up so that cattle performance would be reduced. This apparently does not occur or it hasn't been reported. Perhaps the weather in Southwest Texas plays a role to keep the pasture parasite load down or the stocking rates (one animal unit to 22-30 acres) help reduce pasture contamination.

Fenbendazole did reduce fecal egg counts in both cows and calves. Fenbendazole treatment was successful in the two routes administered in this study (suspension or deworming blocks). For most cattle operations, the deworming blocks offer a convenient way to worm cattle without the high cost of labor and the additional stress on the animals.

As a result of both experiments, it is quite apparent that treating cows prior to calving will result in calves with a lower parasite load at approximately 90 days of age. Our experiments did not show a significant difference in performance as a result of the lower parasite concentrations early in the life of the calf. Average daily gain improvements, however, did tend to favor the calves from the fenbendazole treatments groups. A positive cost and return relationship is very important when evaluating a yearly deworming program. Cows and calves may need to be dewormed more often, less often, or not at all, depending upon pasture contamination. When evaluating deworming programs, pasture differences must be taken into consideration.

## Acknowledgment

The authors would like to express their appreciation to Dr. Gil Myers and Hoescht-Roussel Agri-Vet Company for their support for this demonstration, and to Mr. J.T. Neal, Jr. for the use of the cattle.

## Literature Cited

1. Bliss, D.H. 1989. The prevalence of parasite contamination on spring pastures for cow/calf herds in Texas as determined by fecal worm egg counts. Texas Veterinarian Medical Journal. May-June.
2. Craig, T.M. 1988. Impact of internal parasites on beef cattle. J. Anim. Sci. 66:1565-1569.
3. Gill, J.L., and H.D. Hafs. 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33:331.
4. Kvasnicka, W., R. Torell, L. Krysl, A. Miller, V. Higbee, W. Peterson, D. Torell, D. Bliss, and G. Myers. 1990. Prevalence of parasite contamination on great basin pastures and ranges from cow/calf herds as determined by fecal worm egg counts. J. Anim. Sci. 68 (Supp. 1) :196 (Abstr.).
5. Myers, G.H. 1988. Strategies to control internal parasites in cattle and swine. J. Anim. Sci. 66:1555-1564.
6. Pate, F.M., and E.J. Richey. 1988. Response of brood cows and calves to fenbendazole wormer. J. Anim. Sci. 66 (Supp. 1) :82 (Abstr.).
7. Steel, R.G.D., and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York.
8. Stuedemann, J.A., J. Ciordia, G.H. Myers, and H.C. Mc Campbell. 1989. Effect of a single strategically timed dose of fenbendazole on cow and calf performance. Veterinary Parasitology, 34:79-86.
9. Vatthauer, R.J., H.E. Hanke, J.C. Schlotthauer, B.E. Stromberg, and D.L. Haggard. 1986. Deworming effects on beef cows and calf weight gains, pregnancy and fecal egg counts. J. Anim. Sci. 63 (Supp.1) :4000 (Abstr.).

TABLE 1. FENBENDAZOLE TREATMENT SCHEDULE FOR EXPERIMENT 1

| Treatment Group | Pasture Number | Fenbendazole Treatment: Cows prior To Calving [a] | Fenbendazole Treatment: Calves following Calving [b] |
|---|---|---|---|
| Group 1 (Control) | 1 | No | No |
| | 2 | No | No |
| | 3 | No | No |
| Group 2 (Treatment) | 1 | Yes | Yes |
| | 2 | Yes | Yes |
| | 3 | Yes | Yes |
| | 4 | Yes | Yes |

[a] 45-60 days prior to the calving season
[b] approx. 90 days following the end of the calving season

TABLE 2. COW AND CALF FECAL COLLECTION SCHEDULE FOR EXPERIMENT 1

| Treatment Group | Pasture Number | Fecal Collection Periods: Prior to Treatment | 90 Days Postpartum | | Weaning Time |
|---|---|---|---|---|---|
| | | Cows | Cows | Calves | Calves |
| Group 1 (Control) | 1 | 6 [a] | 6 | 6 | 6 |
| | 2 | 6 | 6 | 6 | 6 |
| | 3 | 6 | 6 | 6 | 6 |
| Group 2 (Treatment) | 1 | 8 | 8 | 8 | 6 |
| | 2 | 8 | 8 | 8 | 4 |
| | 3 | 8 | 8 | 8 | 6 |
| | 4 | 8 | 8 | 8 | 8 |

[a] Indicates the number of samples per pasture

TABLE 3. FENBENDAZOLE TREATMENT SCHEDULE FOR EXPERIMENT 2

| Treatment Group | Pasture Number | Fenbendazole Treatment: Cows prior To Calving [a] | Fenbendazole Treatment: Calves following Calving [b] | Fenbendazole Treatment: Cows Following Calving [b] |
|---|---|---|---|---|
| Group 1 (Control) | 1 | No | No | No |
| | 2 | No | No | No |
| | 3 | No | No | No |
| Group 2 | 1 | Yes | Yes | No |
| | 2 | Yes | Yes | No |
| Group 3 | 3 | Yes | Yes | Yes |
| | 4 | Yes | Yes | Yes |

[a] 45-60 days prior to the calving season
[b] approx. 90 days following the end of the calving season

TABLE 4. COW AND CALF FECAL COLLECTION SCHEDULE FOR EXPERIMENT 2

| Treatment Group | Pasture Number | Fecal Collection Periods: Prior to Treatment | 8-12 Days After Treatment | 90 Days Postpartum | | Weaning Time | |
|---|---|---|---|---|---|---|---|
| | | Cows | Cows | Cows | Calves | Cows | Calves |
| Group 1 (Control) | 1 | 6 [a] | 6 | 6 | 6 | 6 | 6 |
| | 2 | 6 | 6 | 6 | 6 | 6 | 6 |
| | 3 | 6 | 6 | 6 | 6 | 6 | 5 |
| Group 2 | 1 | 8 | 8 | 8 | 6 | 6 | 6 |
| | 2 | 8 | 8 | 8 | 8 | 8 | 7 |
| Group 3 | 3 | 8 | 8 | 8 | 8 | 8 | 7 |
| | 4 | 8 | 8 | 8 | 8 | 8 | 8 |

[a] Indicates the number of samples per pasture

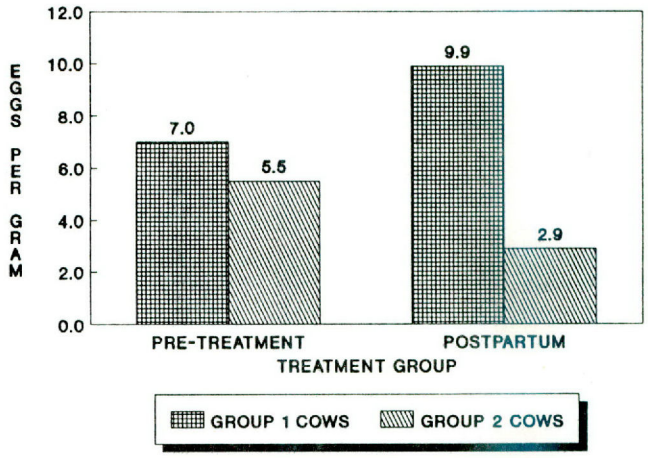


Table 5. The mean fecal egg counts before treatment and at 90 days postpartum for the cows in Experiment 1. Standard error of the difference between two treatment means for a given time period is 2.4. Standard error of the difference between two time means for one treatment group is 3.1. Treatment effect (P<.025).

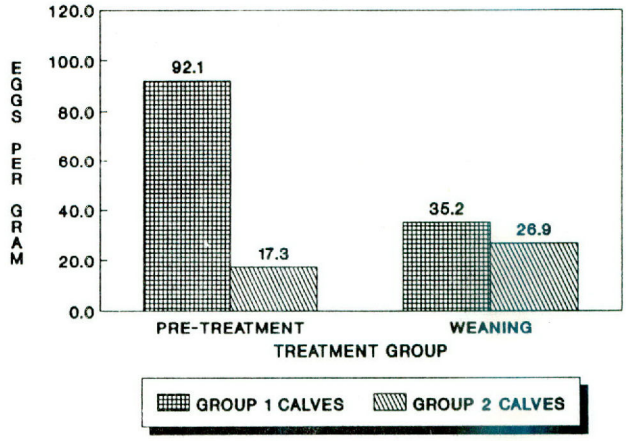


Table 6. The mean fecal egg counts before treatment and at weaning for the calves in Experiment 1. Standard error of the difference between two treatment means for a given time period is 15.5. Standard error of the difference between two time means for one treatment group is 15.7. Treatment effect (P<.05); Treatment × Time (P<.10).

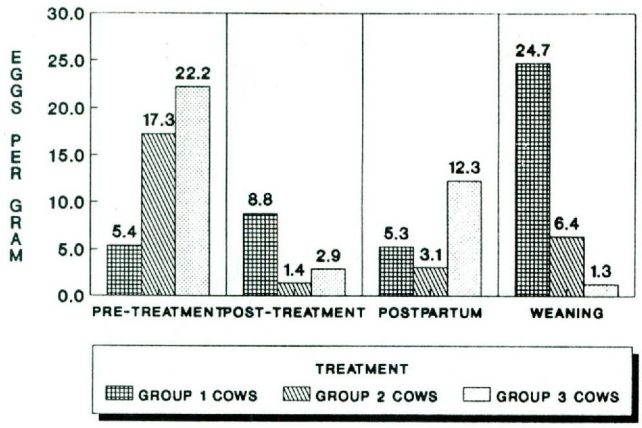


Table 7. The mean fecal egg counts before treatment, post-treatment, 90 days postpartum and at weaning for the cows in Experiment 2. Standard error of the difference between two treatment means for a given time period is 3.5. Standard error of the difference between two time means for one treatment group is 3.4. Treatment x Time (P<.08).

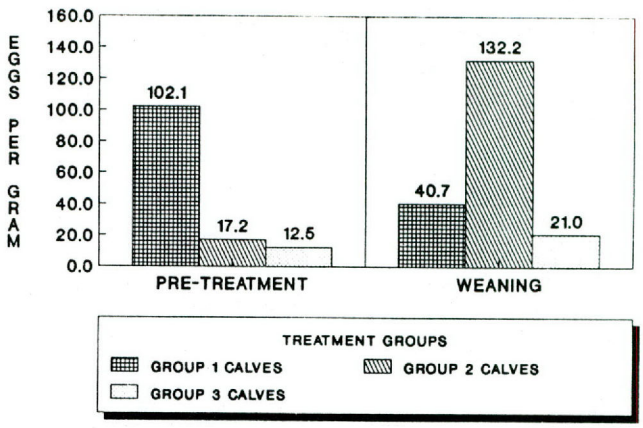


Table 8. The mean fecal egg counts before treatment and at weaning for the calves in Experiment 2. Standard error of the difference between two treatment means for a given time period is 14.9. Standard error of the difference between two time means for one treatment group is 7.5. Treatment x Time (P<.005).


Progress
Reports

# Effects of Varying Levels of Dietary Free Gossypol on Reproductive Hormone Secretion, Fertility, and Incidence of Gossypol Toxicity in Beef Heifers

M.L. Gray, L.W. Greene, R.D. Randel and G.L. Williams


## Summary

Gossypol is a toxic substance found in the pigment glands of most varieties of the cotton plant. It is also a natural plant insect repellent and has antifertility effects in male animals. The presence of gossypol in cottonseed meal and whole cottonseed has limited their use in the diets of poultry and other non-ruminant animals. It has been assumed that ruminants have the ability to completely detoxify gossypol in the rumen; however, recent studies have shown that gossypol toxicity can occur in cattle consuming large quantities of cottonseed meal or whole cottonseed. These effects have included microscopic damage to testicular tissue in bulls, suggesting the possibility that fertility might be impaired.

To date, very little research has been performed to determine potential toxic effects of feeding large quantities of gossypol-containing feed to the beef cow. The objectives of this study were to determine the effects of varying levels of dietary free gossypol on certain blood, metabolic, and reproductive parameters in sexually mature beef heifers. Thirty-six heifers were randomly allotted to 6 levels of dietary free gossypol (n=6/group). Daily rations, fed for 62 days, yielded levels of 0, 0.4, 1.7, 3.3, 8.2, and 16.3 grams of gossypol, with energy and protein equal across groups. Cottonseed meal was the primary source of free gossypol (0.25%) in all gossypol-containing diets, except the 16.3 gram diet, which also utilized whole cottonseed. The quantity of gossypol in the two highest doses was supplied by 7 lb whole cottonseed meal per day (8.2 grams) or 4.6 lb cottonseed meal plus 5.0 lb whole cottonseed (16.3 grams), respectively.

Red blood cell fragility, a sign of gossypol toxicity, was seen in samples obtained from heifers receiving 8.2 and 16.3 grams of gossypol after day 42. Increased plasma concentrations of a liver enzyme, sorbitol dehydrogenase, were also found in blood samples obtained from heifers receiving the two highest doses of gossypol on day 42. Potassium ion concentrations tended to be lower in heifers receiving 16.3 grams of gossypol on day 62. Body weights, body condition scores, pregnancy rates, and plasma progesterone concentrations were not affected by gossypol treatments. Blood plasma concentrations of luteinizing hormone were inexplicably elevated in the highest dose group. High levels of gossypol fed in the current study for 2 months did not impair reproduction in heifers, although some other clinical signs of toxicity were apparent.

# Metabolic Hormone Changes in Beef Cows Fed Whole Cottonseed as a Fat Supplement

R.A. Spoon, T.H. Welsh, Jr. and G.L. Williams


## Summary

Previous work at this location suggests that feeding high fat supplements, such as whole cottonseed, to beef cows after calving can have significant effects on reproductive potential. These effects appear to be controlled through an increase in the intestinal production and transfer of cholesterol to the ovary. As a result, the concentration of cholesterol within ovarian structures (follicles) is dramatically increased, hormonal steroid production is enhanced and the development of ovarian follicles to the medium-size classification is hastened. Cows that ovulate seem to resume normal cycling earlier and, therefore, have an increased opportunity to become pregnant.

The objective of this study was to determine the effects of increased dietary fat intake on certain metabolic hormones in cows in optimal and thin body condition. It is possible that some of the effects of high fat diets previously observed may have occurred, at least in part, through changes in insulin or growth hormone secretion.

Forty-one beef cows were fed to either maintain excellent body condition before calving, or to lose weight and body condition before calving, resulting in condition scores at parturition of 6 (optimal) or 4 (low). After calving, cows in each group were fed either a normal fat supplement (no whole cottonseed) or a high fat supplement (7.4 lb whole cottonseed). Energy and protein intake were held constant and were equal between the two groups. Blood serum concentrations of insulin, growth hormone and free fatty acids were determined on days 17, 19 and 37 post-calving.

High fat supplements (whole cottonseed) increased average serum insulin concentration but had no consistent effect on growth hormone concentrations. The pattern of growth hormone secretion, which may be more important than actual concentration, still remains to be characterized. Whole cottonseed diets lowered blood levels of free fatty acids, indicating a sparing effect on body energy reserves. Our experiments suggest that diets which increase cholesterol synthesis and availability also increase insulin secretion in cattle. Since insulin has previously been shown to enhance the function of cultured ovarian cells, it is suggested that whole cottonseed diets or other high fat supplements may improve reproductive performance in cattle through events mediated, in part, by insulin. These effects are not controlled by an increase in dietary energy intake, but rather a shift in lipid or fat metabolism.

# Mating According to Estrus vs Timed Mating in Early Responding Beef Cows after Estrous Synchronization

L.R. Sprott, B.B. Carpenter and J.E. Hill

Cows that are estrous synchronized with Syncro-Mate-B® can either be artificially inseminated according to estrus detection or time (mass) mated at 48 hrs after implant removal. Among those cows that respond to treatment, some will exhibit estrus within 24 hrs of implant removal, and there is some question as to whether early response in these particular cows may be untimely thereby lowering the total number of conceptions in a traditional time mating program.

The purpose of this trial was to determine if insemination according to estrus in the early responding cows, followed by time mating in the remainder of the herd, could increase the total number of conceptions during the synchrony period. Brangus cows (112 head) were treated with Syncro-Mate-B® 11 days prior to the start of breeding. At implant placement, cows were allotted by ovarian status (presence of a corpus luteum) into two groups. At implant removal, the groups were separated to allow for estrus detection in group 1 (n=59) or no detection in group 2 (n=53).

Estrus detection in group 1 was performed at 12 and 24 h after implant removal, and cows showing estrus in those periods were artificially inseminated 12 h after being detected in estrus. The remainder of group 1 was time mated at 48 hrs after implant removal. Estrus detection was not performed for cows in group 2, and they were time mated at 48 hrs after implant removal. Both groups were inseminated by one of two experienced technicians using semen from one bull. By 12 hrs after implant removal, none of the cows in group 1 exhibited estrus, but 13 of 59 exhibited estrus by 24 hrs and were inseminated at 36 hrs after implant removal. There was no difference in conception rate between technicians. The percent of cows conceiving during the synchrony period (48 hrs after implant removal) was 54 and 58 percent ($P>.05$) for groups 1 and 2, respectively.

These data indicate that the total number of conceptions did not increase as a result of mating according to estrus in early responding cows that would have otherwise been mated in a traditional time mating program. Nevertheless, the choice of inseminating according to estrus in early responding cows or waiting for time mating may be influenced by semen cost and the expected value of potential offspring from a particularly valuable female.

# Role of Teat Stimulation by the Suckling Calf in Delay of Rebreeding Activity in Beef Cows

G.L. Williams, J.L. Cutshaw, P.A. Silveira and W.R. McVey, Jr.


## Summary

Efficient reproduction in the beef cow herd is dependent upon the ability of cows to resume estrous or "heat" cycles within 45 days post-calving and to conceive within 85 days post-calving on an annual basis. Failure to achieve these targets contributes to long calving intervals and a nation-wide net calf crop averaging only 70-75 percent.

The objectives of studies reported here were to determine the role of sensory nerves within the teat in mediating suckling-induced delay of first estrus in the dam. Previous research in this laboratory and in others has shown that suckling suppresses lower brain activity that controls secretion of pituitary luteinizing hormone. This hormone is necessary for normal ovarian function. Weaning the calf for 2-6 days results in a dramatic increase in the rate of secretion of luteinizing hormone, followed by ovulation (egg release). In Experiments 1 and 2, we used cows that had ovaries removed on day 5 after calving followed by treatment with an estrogen implant to stabilize function of the pituitary. Cows were then weaned, control suckled every 6 hours, or weaned and stimulated with thermal or electrical devices every 6 hours for 4 days. Chronic stimuli were intended to superactivate nerves in the teat (specific site) or tail (non-specific control site).

Weaning, control suckling or weaning plus stimulation was performed on days 17-21 postcalving. Chronic superstimuli did not prevent the rise in luteinizing hormone secretion in stimulated-weaned animals. Therefore, these animals behaved exactly like weaned animals that were not stimulated. In a third experiment, we surgically disconnected nerves to the udder prior to calving and compared hormonal secretion and reproductive patterns to suckled and weaned cows. These variables were not affected by denervation, resulting in denervated cows performing like suckled animals. Luteinizing hormone was suppressed and ovulation was delayed. Preliminary results of a fourth study suggest that the maternal bond may be an important factor in the occurrence of suckling-induced delay of ovulation and estrus; however, tactile stimulation of the teat itself does not appear to be important.

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