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EVALUATION OF F_1 COWS SIRED BY BRAHMAN, BORAN, AND TULI FOR REPRODUCTIVE AND MATERNAL PERFORMANCE AND COW LONGEVITY

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Summary

Birth weight (BW) (n = 1,051) and weaning weight (WW) (n = 973) of their calves, calving rate (CR) (n = 1,170), weaning rate (WR) (n = 1,161), and cow weight at palpation (PW) (n = 1,333) were evaluated from 1994 to 2004 in 143 F_1 cows sired by Brahman (B), Boran (Bo), and Tuli (T) bulls and out of Hereford and Angus cows. The mouth scores of these females, as scored in 2004, when the cows were 11 to 12 yr of age, were also analyzed. Adjusted means for BW for calves out of these 143 females were 78.5 lb, 77.8 lb, and 78.3 lb and were not significantly different. Significant differences were found among the adjusted means for weaning weight of calves out of these cows, with values of 512 lb, 484 lb, and 458 lb. Adjusted means for calving rate for B, Bo, and T sired cows were .90, .93, and .90 and no significant differences were found. Weaning rate adjusted means for B, Bo, and T sired cows were .84, .89, and .85 with no significant differences. Adjusted means for cow weight at palpation in 2004 were 1369, 1196, and 1164 lb. The B-sired cows were significantly heavier than the cows by Bo or T bulls.

Introduction

It has been repeatedly reported that F_1 *Bos taurus-Bos indicus* females are superior to the parental breeds in terms of reproductive and maternal performance (Gregory et al., 1985; Trail et al., 1985; Cundiff et al., 1998). Due to the inability of the F_1 Brahman – *Bos taurus* female to produce a replacement that equals her production capability, interest in breeds of African origin, such as the Tuli and Boran, has increased (Herring et al., 1996). The Tuli is a Sanga breed of cattle developed in what is now Zimbabwe. The Boran is a Zebu breed from East Africa. Comparison of F_1 cows sired by Tuli and Boran bulls to those sired by Brahman bulls is an important step in developing alternative *Bos indicus-Bos taurus* crossbreeding systems. The purpose of the present study was to evaluate and compare F_1 cows sired by Brahman, Boran, and Tuli bulls for traits representing maternal and reproductive performance and cow longevity.

Experimental Procedures

143 F_1 Brahman x Hereford, Brahman x Angus, Tuli x Hereford, Tuli x Angus, Boran x Hereford, and Boran x Angus cows born in 1992 (66) and 1993 (77) at the Texas A&M Research Center (TAES) at McGregor were evaluated. The semen of 9 Tuli, 7 Boran, and 16 Brahman bulls was used to breed mature Angus and Hereford cows by artificial insemination. Boran and Tuli semen was imported from Australia, and semen from Brahman bulls considered to be representative of the breed in the early 1990's was obtained from purebred breeders and commercial breeding services. Herring et al. (1996) reported birth, weaning, and post weaning performance of animals evaluated in the study as well as carcass characteristics of the steers produced from the same matings.

As heifers, females were bred to Angus bulls in 1993 and 1994. In 1994, two-year-old cows born in 1992 were bred to Brangus bulls. The cows were then bred to Brangus bulls in 1995, F_1 Hereford-Brahman bulls in 1996, F_1 Brahman-Angus bulls in 1997, F_1 Angus-Brahman bulls in 1998, 3/8 Nellore-5/8 Angus bulls in 1999, F_1 Nellore-Angus bulls in 2000, 3/8 Nellore-5/8 Angus bulls in 2001 and 2002, and Angus bulls in 2003 and 2004. Although cows have been bred to bulls of different breeds in different years, all females were bred to the same breed of sire each year. Calving occurred from approximately February 15 to May 5 each year. Calves born to these F_1 heifers and cows from 1994 to 2004 were evaluated. Each calf was weighed and tagged for identification within 48 h of birth, and male calves were castrated. Calves were weaned in October or November of each year at approximately seven months of age. At the time of weaning, calves were weighed and assigned a body condition score, and heifers were vaccinated for brucellosis. Cows were palpated for pregnancy diagnosis at weaning, weighed, and assigned body condition scores. Calving rate and weaning rate were evaluated in the F_1 cows as binary (0 or 1) traits using least squares analyses.

In the fall of 2004, at the time of palpation, incisor condition was evaluated with the assignment of mouth scores. Solid mouths had no teeth loose or missing, broken mouths had one or more teeth lose or missing, and smooth mouths had no incisors remaining (or the few remaining were small and badly deteriorated). The mouth scores were analyzed as a binary trait of females remaining in the herd, where, in the first case, the smooth mouths were assigned a value of zero. In the second case, both smooth and broken mouths were assigned a score of zero and solid mouths were assigned a value of one.

The variables considered in this study were analyzed by the mixed model procedure of SAS (1990). Calf's birth weight (n = 1,051) and weaning weight (n = 973) were evaluated using a model that included the effects of sire breed of dam, dam breed of dam, calf's birth year/age of dam, calf's sex, dam's sire within sire breed, and dam within dam's sire within sire breed. In the weaning weight model, weaning age within calf's birth year/age of dam was included as a covariate. Calf crop born (n = 1,170), calf crop weaned (n=1,161), and cow's weight at palpation were evaluated using a model that included sire breed of dam, dam breed of dam, calf birth year/age of dam, dam's sire within sire breed, and dam within dam's sire within sire breed. Models that included lactation status and body condition of the cows were tested to evaluate their effects on these variables, but these variables were not included in the final models. Sire breed of calf was almost completely confounded with calf's birth year, so the latter was used in the analyses. All possible two-way interactions between the main effects were initially tested for significance, and those that were significant were included in the final models. Additional details concerning the analyses were reported Ducoing (2002).

Results and Discussion

No significant differences in birth weight were found among calves out of cows sired by the three breeds. Adjusted means for calves born to Brahman-, Boran-, and Tuli-sired cows were 78.5, 77.8, and 78.3 lb, respectively (Table 1). These values were lower than those obtained by Cundiff et al. (1999). On average, the bull calves were 5.43 lb heavier at birth than the heifers. The effect of calf's birth year/age of dam was significant, with the adjusted mean weight of calves out of two-year-old dams lower than those out of the other age groups.

The effect of sire breed of the cow was significant for weaning weight (Table 1). Calves born to Brahman-sired cows were heavier (512 lb) than those out of cows sired by Boran bulls (484 lb), and those out of Boran-sired cows were heavier than those out of Tuli-sired cows (458 lb). Calf's sex was significant with a difference of 28.4 lb between the adjusted means of the steer and heifer calves. The difference between steers and heifers was 27.8 lb in calves out of Boran-sired cows, and 22.2 lb in calves out of Tuli-sired cows, whereas this difference was 35.2 lb in calves out of Brahman-sired cows. Weights of weaned calf per cow exposed were 428.94 lb, 429.23 lb, and 391.48 lb in Brahman-, Boran-, and Tuli-sired females (Table 2).

Significant differences among the three sire breeds were found for cow's weight at palpation, with the Brahman-sired cows being heavier, on average, than those sired by Boran and Tuli bulls. In the year 2004, adjusted mature weights were 1369 lb, 1196, and 1164 lb for Brahman-, Boran-, and Tuli-sired cows, respectively (Table 2). Cows in the Brahman sire group had the largest adjusted mean weight for every year of evaluation.

Sire breed of the cow did not have a significant effect on calving rate or weaning rate (Table 3). Cundiff et al. (1999) observed similar results for calf crop at weaning.

Least squares means for mouth scores and percentages of cows remaining in the herd in 2004, when the females were 11 and 12, are presented by breed of sire in table 4. Incisor condition was scored as a zero for smooth mouths and one for either broken or solid mouths. The least squares means were much higher for both the Boran (1.0, i.e., none of the Boran crosses were scored as smooth) and the Brahman (0.96) than the Tuli crosses (0.756). When both smooth and broken mouths were scored as zero and only solid mouths were scored as one, the breed rankings were the same, with least squares means of 0.67 (i.e., 67% were scored as having solid mouths), 0.55, and 0.28, again, with the Boran and the Brahman crosses having much higher percentages than the Tuli crosses. Similar results were reported by Riley et al. (2001), when smooth mouths were scored a zero and both solid and broken mouths were scored a one; the least squares means for the *Bos indicus* crosses were 0.92 to 1.01 compared to the least squares means for the Angus crosses of 0.65. When the smooth and broken mouths were scored as zero and solid as one, the least squares means at fourteen years of age for the *Bos indicus* crosses ranged from 0.32 to 0.57 and the means for the Angus crosses was 0.13. The percentage of females remaining in the herd in 2004 (simple means), under the culling procedure that has been practiced, was higher for the Boran crosses (69%) than either the Brahman (51%) or Tuli (50%) crosses (Table 4).

Implications

When Tuli and Boran bulls were crossed with Angus and Hereford females, the resulting crossbred females were more moderate in size than the American Brahman. Reproductive rates were higher in Boran-sired cows than in Brahman-sired cows; however, the Brahman-sired cows weaned heavier calves than the other two sire groups. The Tuli cross cows weaned significantly lighter calves and had shorter productive lives than both the Brahman and Boran-sired cows.

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Table 1. Least squares means for growth traits

Sire breed of cows	Birth weight (lb)	Weaning weight (lb)
Brahman	78.51	512.16
Boran	77.84	484.02
Tuli	78.30	457.98

Table 2. Least squares means for mature F_1 cow palpation weight (lb), simple means for condition score, pounds of calf weaned per cow exposed by sire breed of cow through the fall of 2003 (n = 1,333)

Sire breed of cows	Mature cow weight [a] at palpation (lb)	Cow body condition score [b] at palpation	Pounds of calf weaned per cow exposed
Brahman	1368.96	5.2	428.94
Boran	1195.53	5.5	429.23
Tuli	1163.68	5.2	391.48

[a] Adjusted means in the year 2003, when the cows born in 1992 and 1993 were 10 and 11 years of age, respectively.
[b] Simple means in the year 2003.

Table 3. Least squares means for reproductive traits

Sire breed of cows	Calving rate	Weaning rate
Brahman	.8962	.8368
Boran	.9305	.8868
Tuli	.9037	.8548

Table 4. Least squares means for mouth scores and simple means for cows remaining in the herd through 2004 for F_1 cows

Sire breed	Mouth score [a]	Mouth score [b]	% of original cows remaining in 2004
Boran	1.00	0.67	69
Brahman	0.96	0.55	51
Tuli	0.76	0.28	50

[a] Analyzed as a binary trait, where smooth = 0 and broken or solid = 1.
[b] Analyzed as a binary trait, where smooth or broken = 0 and solid = 1.

EVALUATION OF FOUR COMPONENT TRAITS OF DISPOSITION IN *BOS INDICUS* X *BOS TAURUS* CROSS CATTLE

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Summary

Disposition is important to anyone in the livestock industry because it affects how easily livestock are handled throughout the production process. Furthermore, research suggests a correlation between disposition and average daily gain, dressing percentage and meat tenderness. The purpose of this study was to evaluate disposition in the McGregor genomics population, which comprises 11 Nellore-Angus F_2 embryo transfer families and four half-sib families produced by natural service matings. Disposition was scored at weaning on a 1 to 9 scale for four component traits of behavior: aggressiveness, nervousness, flightiness and gregariousness, and a separate overall score by four evaluators. These traits were highly correlated ($r > 0.79$). Overall disposition scores at weaning were predictive of the disposition of steers in their feeding pens ($r = 0.66$) and of first calf heifers after calving ($r = 0.69$). There was considerable variation amongst disposition scores both within and between families indicating that genes affecting disposition are segregating in these families.

Introduction

In any phase of cattle production, the disposition of an animal is important. Disposition determines how animals will be handled by humans from the time the animal is born, through weaning, on to the breeding herd or finishing in feedlots and finally slaughter. Disposition also influences average daily gain (ADG), dressing percentage, and meat tenderness (Voisinet et al., 1997a,b; Fell et al., 1999; Petherick et al., 2002). The actual genes that control disposition are not known. The purpose of this study was to detect quantitative trait loci (QTL) associated with disposition in the McGregor genomics population. This progress report describes the disposition scoring method and statistical analysis that reveals that genetic variation exists both within and between the full-sibling embryo transfer families and the natural service half-sib families that comprise the McGregor population.

Experimental Procedures

Population Structure

The McGregor research population was developed using *Bos taurus* x *Bos indicus* cross cattle. Disposition scores were available for 147 progeny from 11 F_2 Nellore-Angus families produced through embryo transfer and 65 progeny from four paternal half-sib families produced by natural service matings.

Disposition Scoring

Disposition was scored one month after weaning (at approximately 8 mo of age) by a panel of four evaluators. Calves were grouped in pens of about 15 animals and then released into a 65 ft alleyway in pairs. Two evaluators were at each end of the alley. The animals were left in the alley for two to three minutes, and then one animal was cut back into the pen with the others and the animal remaining in the alley was scored. Animals were scored for four component traits of behavior (aggressiveness, nervousness, flightiness, gregariousness) in addition to overall disposition on a 1 to 9 scale.

Aggressiveness refers to the animal's desire to hit evaluators, where 1 is non-aggressive, and 9 is extremely aggressive. Nervousness refers to the animal's behavior in regard to walking and running, vocalization, and physically shaking, where 1 is totally calm and 9 is extremely nervous. Flightiness refers to an animal's desire to keep away or get away from evaluators, where 1 is totally quiet and 9 is extremely flighty. Gregariousness refers to an animal's desire to get back to the group of individuals from which it came and how it acts in a pair as compared to being separated where 1 is totally willing to be separated from the group and 9 is unwilling to be separated.

Overall disposition was scored as a separate trait (as opposed to being an average of the others), where 1 is completely docile and 9 is crazy. For analysis, disposition scores for each animal were averaged across the four evaluators for each component trait.

Each of the component traits of disposition were scored again in the steer progeny about one week prior to slaughter by a single evaluator. An overall disposition score was also assigned in the pens immediately prior to slaughter. Cow disposition scores will be assigned each year when birth data are recorded on the calves.

Statistical Analysis

Disposition data were studied through analysis of variance using the general linear model procedure of SAS (SAS Inst. Inc, Cary, N.C.). Independent variables included sire, family within sire, sex x family within sire interaction, and sequence within pen within birth year-season combination. The independent effects of birth year-season combination, sex, the regression on birth date within season-year combinations, and the regression on recipient disposition were not significant (P > 0.05) and were excluded from the final model.

Results and Discussion

In the McGregor population, four component traits of disposition as well as overall disposition were scored at weaning, each on a 1 to 9 scale. These traits were scored again in the steer progeny about one week prior to slaughter. An overall disposition score was assigned to recipient dams within 24 hours of the birth of project calves, as well as to steers in the slaughter pens and to first calf heifers from the project families within 24 hours of calving. Simple means for each trait are presented in Table 1.

The four component traits of disposition were highly correlated at weaning (Table 2), though each measures a different part of overall cattle disposition. Likewise, when the steers were assessed in their pens by a single evaluator, flightiness, nervousness, gregariousness and overall disposition score were also highly correlated (r > 0.86). Aggressiveness was not correlated with the other traits at this time, but only one steer was even slightly aggressive. A comparison of overall disposition scores showed that there was no correlation between disposition of the recipient dam and disposition of the progeny (r = 0.01, P = 0.87). For the steer progeny, there was a strong correlation between the scores at weaning and scores taken at McGregor prior to slaughter (r = 0.66, P < 0.0001). The correlation between the weaning scores and overall disposition in the slaughter pens at the Rosenthal Meat Science and Technology Center was only 0.32 (P = 0.0121). It is likely that these three measures of overall disposition of the steers are evaluating different traits. For the heifer progeny, there was a strong correlation between overall disposition at weaning and overall disposition measured after calving (r = 0.69, P = 0.0016).

Since the component traits of disposition were highly correlated, our analysis focused on overall disposition at weaning. Sire, family within sire, and sequence within pen within birth year-season combination accounted for significant variation in overall disposition in the McGregor population. Inclusion of sequence within pen in the model is attempting to account for the effect of animals being in the holding pen longer before being scored and, therefore more agitated. However, some animals were in the pen longer because they were harder to cut out of the group, and in these cases, sequence is actually a characteristic of their disposition.

Calves by sire 437J had worse overall disposition scores at weaning than calves by 297J or 551G, differing by 1.1 and 0.77 units, respectively (Table 3). There was considerable variation among overall disposition scores between and within families (Table 4). Family 81 (sired by 437J) had the worst disposition (6.02), while family 76 had the best overall disposition (2.96). Of note, family 83, which is also by 437J had the second best overall disposition (3.06). Numbers of animals in some families are still small and we expect some re-ranking to occur as families reach their target size (n = 40). These data suggest that genes affecting disposition of animals at weaning are segregating in the McGregor population.

Implications

Variation in scores for aggressiveness, nervousness, flightiness, gregariousness, and overall disposition both within and between families indicates that there are genes affecting disposition segregating in the McGregor population. Using this F_2 Nellore-Angus population, we expect to be able to detect QTL for these component traits of disposition. We also expect that disposition will be related to eating behavior and may affect feed efficiency, and carcass and meat quality in the steers. Identification of QTL, and, ultimately, the genes and underlying causal mutations affecting variation in disposition, will allow us to understand the biology of this complex trait and may facilitate the incorporation of these genes in marker assisted selection programs.

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Table 1. Simple means for component traits of behavior

Category	Trait	N	Mean	Std Dev
Recipient	Overall Disposition	218	2.21	0.86
Weaning scores	Aggressiveness	212	2.83	1.71
	Nervousness	212	4.27	1.77
	Flightiness	212	4.03	1.85
	Gregariousness	212	4.01	1.79
	Overall Disposition	212	3.90	1.83
Steer scores	Aggressiveness	58	1.12	0.59
	Nervousness	58	3.55	1.70
	Flightiness	58	3.53	1.73
	Gregariousness	58	2.93	1.82
	Overall Disposition	58	3.31	1.50
Slaughter pen scores	Overall Disposition	58	2.34	1.09
First calf heifers	Overall disposition	18	1.94	1.20

Table 2. Pearson correlation coefficients and associated significance levels among behavior traits at weaning (n = 212).

	NERV[1]	FLIGHT[1]	GREG[1]	OVERALL
AGRES[1]	0.82359	0.84555	0.79289	0.88967
	<0.0001	<0.0001	<0.0001	<0.0001
NERV		0.96787	0.94508	0.97637
		<0.0001	<0.0001	<0.0001
FLIGHT			0.94260	0.97400
			<0.0001	<0.0001
GREG				0.95519
				<0.0001

[1]NERV = Nervousness; FLIGHT = Flightiness; GREG = Gregariousness; AGRES = Aggressiveness

Table 3. Least squares means and standard deviations for overall disposition score at weaning across sires.

Sire	N	Overall disposition	Std. Dev.
297J	53	3.75[a]	1.67
432H	52	4.30[ac]	1.65
437J	56	4.85[bc]	1.92
551G	51	4.08[a]	1.72

[a-c] Means with no superscripts in common differ ($P < 0.05$)

Table 4. Least squares means and standard deviations for overall disposition at weaning across family within sire combinations.

Sire	Family	N	Overall Disposition	Std. Dev.
297J	70	17	3.85^{adi}	1.83
	71	18	3.30^{ai}	1.74
	95	18	4.10^{adei}	1.42
432H	72	20	4.66^{cdf}	1.56
	73	8	4.30^{adgi}	1.48
	96	24	3.92^{adi}	1.73
437J	74	7	6.00^{bgh}	1.14
	75	11	3.76^{adi}	1.95
	81	25	6.02^{b}	1.58
	83	5	3.06^{ai}	0.91
	97	8	5.43^{befgi}	1.59
551G	76	7	2.96^{i}	1.26
	77	12	4.55^{adhj}	2.24
	80	17	4.38^{adij}	1.33
	98	15	4.42^{adij}	1.85

$^{a\text{-}j}$ Means with no superscripts in common differ ($P < 0.05$)

EVALUATION OF HETEROSIS RETENTION FOR COW PRODUCTIVITY TRAITS IN *BOS INDICUS-BOS TAURUS* CROSSES

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Summary

Heterosis and heterosis retention for cow reproduction and maternal traits are being evaluated in herds of Brahman, Angus, Nellore, Hereford and various crosses involving these breeds. Traits analyzed were calf crop born, calf crop weaned, and pregnancy rate in the cows and birth weight, weaning weight, and survival of their calves. The F_1 Brahman/Angus, as well as the F_1 and F_2 Brahman/Hereford exceeded the parental breed averages for all traits analyzed. The F_2 Brahman/Angus group mean was lower in calf crop born, calf crop weaned, and calf survival than the parental breed average. The estimates for heterosis retention exceeded predictions of the dominance model in Brahman/Hereford crosses, but were below dominance model predictions in Brahman/Angus crosses.

Introduction

A substantial amount of the *Bos indicus*/British F_1 female's productive advantage can be accounted for by heterosis (Franke, 1980). In crosses other than F_1's, if there is any overlap in breed composition of the sire and dam, less heterosis is expressed than is expressed in the F_1's involving the same breeds. In crosses among *Bos taurus* breeds, heterosis expressed in various crosses has been found to be accounted for adequately by the dominance model (i.e., proportional to expected degree of heterozygosity). Since much of the *Bos indicus*/ British F_1 female's productivity is due to heterosis, the amount of heterosis that is retained is of the utmost importance in determining the value of cows resulting from *inter se* mating of crossbred bulls and females (including composites). Some research (e.g., Mackinnon et al., 1989) has indicated that more heterosis is lost in cows produced by the *inter se* mating of *Bos indicus*/*Bos taurus* crosses that would be predicted by the degree of expected heterozygosity. Other research results have been inconclusive or even contradictory.

Experimental Procedures

The breeding herds for this study have been established at McGregor, starting in 1994. The emphasis in the study is on cow productivity. The comparison herds are made up of a minimum of 50 cows each of 14 different groups. The 14 groups include four purebred groups, three F_1 groups, two F_2 groups, two first generation groups of 3/8 *Bos indicus* / 5/8 British breeding, two second generation groups of the same 3/8 *Bos indicus* / 5/8 British breeding, and one four-breed crossbred group. In all 14 groups, all females were produced at McGregor. The four purebred groups are Angus, Brahman, Hereford, and Nellore. An adequate number (>50) of all four of these breeds have now been produced. Results from Brahman/Hereford and Brahman/Angus crosses are reported in this article.

All project-breeding females are exposed to breeding as yearlings to give them the opportunity to calve as two year olds. In the early stages of the study, all of the Brahman and Nellore females were needed to produce purebred replacements. After the minimum number of purebred females was produced these females were bred for purebred and various F_1 combinations. Among the various groups of crossbred females, the main concern has been to make comparisons between first and second generation females of the same breed composition. Therefore, after the evaluation herds were established, the first and second generation females of the same breed composition have been bred to the same bulls in multiple sire breeding pastures. In different years, the crossbred females will be bred to both bulls of their own breed composition and to bulls of a third breed or cross to attempt to separate the effects of heterosis in the calf from maternal heterosis on calf survival.

The females of the fourteen groups will be retained to evaluate lifetime cow productivity. Birth and weaning weight is recorded for all calves and weight and pregnancy status is recorded for the cows in the fall when their calves are weaned.

Cows are culled for severe injuries, poor health, or at least two failures to have or wean a calf. Because of the later puberty in straight *Bos indicus* cattle, the straightbred Brahman and Nellore females are culled after their third failure to have or wean a calf after reaching two years of age. Cows are also culled if udders and/or teats are so large or pendulous that it is apparent that future calves would be unable to nurse without assistance.

The traits of primary emphasis are female reproduction, maternal effects on survival and growth, and longevity. Differences between F_1's and parental purebreds have been used to estimate heterosis. Differences between first and second generation crosses have been evaluated to measure heterosis retention. For F_1 vs. F_2 comparisons, expectations from the dominance model are that the F_2 cows will retain half the heterosis for cow reproduction and for maternal effects.

Results and Discussion

Female Reproductive Characters and Calf Survival

Least squares means and standard errors for calf crop born and calf crop weaned are presented in Table 1. The F_1 Brahman/Angus females expressed heterosis ($P < 0.01$) for calf crop born of 0.095 (calculated as the difference between the value for the F_1 Brahman/Angus and the average of the values for the straight Angus and straight Brahman females). However, the F_2 Brahman/Angus group adjusted mean was below the midparent (average of the straightbred Angus and straightbred Brahman) value ($P < 0.10$). Consequently, the F_2 Brahman/Angus group showed a substantial loss of heterosis ($P < 0.001$) for calf crop born when compared to the F_1 Brahman/Angus group (calculated as the difference between the value for the F_1 and F_2 crosses); the loss was more than the fifty percent of the F_1 value that would have been predicted from the dominance model.

The F_1 Brahman/Hereford females expressed heterosis ($P < 0.01$) for calf crop born of 0.15. The F_2 Brahman/Hereford group showed a small loss ($P > 0.10$) of heterosis for calf crop born when compared to the F_1 Brahman/Hereford; the loss was less than the fifty percent of the F_1 value that would have been predicted from the dominance model.

Least squares means and standard errors for calf survival in Brahman- and/or Hereford-influenced calves are presented by calf breed group in Table 2. Straightbred Brahman calves had the lowest adjusted mean (0.79 ± 0.03) for survival among all of the calf breed groups. Survival in the straightbred Hereford calves was 0.91 ± 0.03, giving a straightbred (midparent) average of 0.85. The F_1 calves by Brahman bulls and out of Hereford cows had a slightly higher ($P > 0.10$) survival rate (0.98) than the reciprocal cross (0.95). The average of the reciprocal F_1 crosses was 0.965, giving a heterosis ($P < 0.10$) estimate of 0.115 for direct effects on calf survival. The adjusted average survival for the F_2 Brahman/Hereford calves was 0.98, giving an estimate of 0.13 for the combination of maternal hybrid vigor in the F_1 cow plus retained heterosis for direct effects on survival in the F_2 calf ($P < 0.001$).

Results for calf survival in Table 2 allow for two comparisons for calves of the same breed composition but out of F_1 vs. F_2 dams. In both cases, survival of calves out of the F_2 dams ($F_{2.5}$ and $BANH_2$) was at least as high as that in calves out of F_1 dams (F_2 and BANH). These results would seem to indicate that most of the heterosis for maternal effects on calf survival was retained in the F_2 Brahman/Hereford cows.

Least squares means, standard errors, and numbers of observations for calf survival are presented by cow breed group in Table 3. Survival in calves out of Brahman/Angus F_1 cows (0.91) was higher ($P > 0.10$) than in the midparent average, giving an estimate of heterosis for maternal effects on calf survival of 0.04. Survival in calves out of Brahman/Angus F_2 cows (0.85) was lower ($P > 0.10$) than in the midparent average, indicating that most of the maternal heterosis for calf survival was lost in the F_2 Brahman/Angus cows.

Survival in calves out of Brahman/Hereford F_1 cows (0.91) was also higher ($P > 0.10$) than in the midparent average, giving an estimate of heterosis for maternal effects on calf survival of 0.035. Survival in calves out of Brahman/Hereford F_2 cows (0.92) was higher ($P > 0.10$) than in those out of F_1 cows, indicating that most of the maternal heterosis for calf survival was retained in the F_2 Brahman/Hereford cows. More details about the results of this study were reported by Key (2004).

Weaning Weight

Least squares means and standard errors for weaning weight in Brahman, Hereford, and Brahman x Hereford crossbred calves are presented by breed group of the calf in Table 2. Adjusted average weaning weight in the F_1 calves out of Brahman cows (495.2 lb) was 45.7 lb heavier ($P < 0.10$) than those out of Hereford cows (449.5 lb). The average of the reciprocal F_1

crosses was 472.4, which compared to the midparent average of 423.1 lb gives a heterosis estimate of 49.3 lb for direct effects on weaning weight. The adjusted average of 480.7 lb in the F_2 calves gives an estimate of 57.6 lb for the combination of heterosis for maternal effects and retained heterosis for direct effects.

Weaning weight comparisons of both the $F_{2.5}$ to the F_2 and the $BANH_2$ to the BANH adjusted averages give estimates of the amount of maternal heterosis that is lost in the F_2 cow. These two estimates (differences of 15.4 lb and 40.7 lb, respectively) give a combined estimate of 28 lb for the maternal heterosis lost in the F_2 cow. If the estimate of 57.6 lb for the combination of heterosis for maternal effects and retained heterosis for direct effects is assumed to be the sum of the maternal heterosis plus one-half of the direct heterosis, this would give an estimate of 33 lb for the heterosis for maternal effect on weaning weight. These estimates of heterosis for weaning weight between Brahman and Hereford (49.3 lb and 33 lb for direct and maternal effects, respectively) are consistent with results from earlier studies. For example, Roberson et al. (1986) reported estimates of 47.5 lb and 28.8 lb for heterosis for direct and maternal effects in Brahman/Hereford crosses.

Simple (unadjusted) means and standard deviations for weaning weight are presented by breed group of the cow in Table 3. Using these unadjusted means give estimates of 29.5 lb and 88.4 lb for maternal heterosis in the Brahman/Angus and Brahman/Hereford F_1 cows, respectively. Comparing the weaning weights from calves out of the F_2 cows to those out of the straightbred parental breeds gives estimates of 2.0 and 42.2 lb for the amount of maternal heterosis retained in the Brahman/Angus and Brahman/Hereford F_2 cows, respectively.

Cow Weight

Least squares means and standard errors for four-year-old cow weight are presented by breed group of the cow in Table 4. This was the oldest age that had weight records across all breed types in the analysis. The F_1 Brahman/Angus females expressed heterosis ($P < 0.10$) for cow weight of 50.4 lb. As with the female reproductive characters, the adjusted cow weight average for the F_2 Brahman/Angus females (1086.8 lb) was less than the average of the straightbred Brahman (1110.3 lb) and Angus (1140.7 lb). The F_1 Brahman/Hereford females expressed heterosis ($P > 0.10$) for cow weight of 72.0 lb

The adjusted average four-year-old weight for the F_2 Brahman/Hereford group (1174.1 lb) was slightly heavier ($P > 0.10$) than that of the F_1 Brahman/Hereford group (1153.5 lb). As was the case for the female reproductive characters, the results from the study indicate that more heterosis for four-year-old cow weight was lost in the F_2 Brahman/Angus group than would be predicted from the dominance model and that less heterosis was lost in the F_2 Brahman/Hereford group than would be predicted from the dominance model.

Implications

The results of this study present additional questions regarding the validity of the dominance model for prediction of heterosis and heterosis retention for reproductive and maternal traits in *Bos indicus* x *Bos taurus* females. The results for the characters evaluated indicate that more heterosis was lost in the Brahman/Angus F_2 cows than would be predicted form the dominance model and that less was lost in the Brahman/Hereford F_2 cows than would be predicted from the dominance model. Cows utilized in the present study will continue to be evaluated for lifetime production for reproductive and maternal traits to obtain additional information regarding heterosis retention in these types of crosses.

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Table 1. Least squares means, standard errors, and numbers of observations for calf crop born and calf crop weaned by cow breed[a] group

Cow Breed Group	Calf crop born	n	Calf crop weaned	n
A	0.93 ± 0.03	176	0.83 ± 0.04	173
B	0.68 ± 0.03	238	0.59 ± 0.03	238
H	0.80 ± 0.03	202	0.72 ± 0.04	201
F_1 BA[b]	0.90 ± 0.03	217	0.82 ± 0.03	217
F_1 BH[c]	0.89 ± 0.02	358	0.82 ± 0.02	357
F_2 BA[d]	0.74 ± 0.03	180	0.64 ± 0.04	179
F_2 BH[e]	0.87 ± 0.03	185	0.81 ± 0.04	184

[a]A – Angus, B – Brahman, H – Hereford
[b]Pairs of letters indicate a crossbred group with sire breed listed first and dam breed listed second.
[c]Includes both BH and HB.
[d]Includes both AB x BA and BA x BA, where first pair of letters designates crossbred sire and second pair of letters designates crossbred dam.
[e]Includes BH x BH, HB x HB, BH x HB, and HB x BH.

Table 2. Least squares means, standard errors, and numbers of observations for calf survival and weaning weight by breed of calf

Breed of Calf	Calf survival	n	Weaning weight (lb)	n
Brahman	0.79 ± 0.03	65	459.1 ± 9.9	52
Hereford	0.91 ± 0.03	97	387.0 ± 10.3	88
F_1 HB[a]	0.95 ± 0.03	71	495.2 ± 10.8	68
F_1 BH	0.98 ± 0.09	8	449.5 ± 25.5	8
F_2 BH[b]	0.98 ± 0.09	110	480.7 ± 7.9	108
$F_{2.5}$ BH[c]	1.06 ± 0.14	4	465.3 ± 27.9	4
BANH[d]	0.89 ± 0.02	198	526.0 ± 6.6	176
$BANH_2$[e]	0.93 ± 0.03	124	485.3 ± 10.6	110

[a]Pairs of letters indicate a crossbred group with sire breed listed first and dam breed listed second.
[b]Includes BH x BH, HB x HB, BH x HB, and HB x BH.
[c]$F_{2.5}$ BH – BH x F_2 BH.
[d]BANH – four breed cross, resulting from breeding F_1 Nellore / Angus bulls to F_1 Brahman / Hereford cows.
[e]$BANH_2$ – four breed cross, resulting from breeding F_1 Nellore / Angus bulls to F_2 Brahman / Hereford cows.

Table 3. Least squares means, standard errors, and numbers of observations for calf survival and unadjusted means, standard deviations, and numbers of observations for calf weaning weight by cow breed[a] group

Cow Breed Group	Calf survival	n	Weaning weight (lb)	n
A	0.88 ± 0.03	144	446.8 (88.0)	131
B	0.86 ± 0.03	144	467.5 (80.1)	127
H	0.89 ± 0.03	145	381.3 (79.6)	131
F_1 BA[b]	0.91 ± 0.03	178	486.6 (81.8)	166
F_1 BH[c]	0.91 ± 0.02	311	512.8 (71.5)	286
F_2 BA[d]	0.85 ± 0.03	114	459.1 (81.0)	93
F_2 BH[e]	0.92 ± 0.03	144	466.6 (70.4)	135

[a]A – Angus, B – Brahman, H – Hereford
[b]Pairs of letters indicate a crossbred group with sire breed listed first and dam breed listed second.
[c]Includes both BH and HB.
[d]Includes both AB x BA and BA x BA, where first pair of letters designates crossbred sire and second pair of letters designates crossbred dam.
[e]Includes BH x BH, HB x HB, BH x HB, and HB x BH.

Table 4. Least squares means, standard errors, and numbers of observations for cow weight at four years of age by breed[a] group

Breed Group	LS Mean ± SE (lb)	n
A	1140.7 ± 31.2	28
B	1110.3 ± 22.2	32
H	1052.7 ± 23.1	40
F_1 BA[b]	1175.9 ± 23.3	47
F_1 BH[c]	1153.5 ± 36.5	51
F_2 BA[d]	1086.8 ± 30.1	30
F_2 BH[e]	1174.1 ± 29.9	30

[a]A – Angus, B – Brahman, H – Hereford
[b]Pairs of letters indicate a crossbred group with sire breed listed first and dam breed listed second.
[c]Includes both BH and HB.
[d]Includes both AB x BA and BA x BA, where first pair of letters designates crossbred sire and second pair of letters designates crossbred dam.
[e]Includes BH x BH, HB x HB, BH x HB, and HB x BH.


Environment

AIR QUALITY: ODOR, DUST AND GASEOUS EMISSIONS FROM CONCENTRATED ANIMAL FEEDING OPERATIONS IN THE SOUTHERN GREAT PLAINS

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Introduction

Concentrated animal feeding operations (CAFO) in the semi-arid Southern Great Plains face air quality challenges, including odor and dust, ammonia (NH_3), gaseous emissions, particulate matter (PM) emissions, and respiratory health of livestock. The scientific basis for selecting cost-effective abatement options and establishing achievable emission factors for odor, odorous gases (odorants), ammonia (NH_3), hydrogen sulfide (H_2S), volatile organic compounds (VOCs), and particulate matter (PM_{10} and $PM_{2.5}$) has not been developed for the CAFO industry especially open-lot livestock feeding systems. To establish a credible scientific basis for addressing these issues, this research and technology-transfer project involves a federal/state partnership of outstanding engineers and scientists from the following institutions/agencies:

- Texas A&M University System (TAMUS)--Texas Agricultural Experiment Station (TAES); West Texas A&M University (WTAMU); and Texas Cooperative Extension (TCE);
- Kansas State University (KSU); and
- USDA-Agricultural Research Service (USDA-ARS)/Bushland

This 5-year field and laboratory research project began in June, 2002. It involves more than 20 faculty members from 5 universities or agencies in the Southern Great Plains states of Texas and Kansas (see Table 1). Together these two states account for more than 40% of the nation's supply of fed beef. Specific research objectives for this project are:

Objective 1. Emissions Measurement: Characterize air quality emissions from open-feedyard surfaces and holding ponds or lagoons using standardized field and laboratory measurement methods for PM (PM_{10} and $PM_{2.5}$), odor, and selected gaseous emissions (NH_3, H_2S, VOCs). Sub-objectives include:

1.1. Develop/demonstrate accurate, standardized measurement methods.
1.2. Quantify emission rates from corral surfaces, runoff holding ponds, and anaerobic lagoons.

Objective 2. Effective Abatement Measures: Develop and evaluate cost-effective abatement measures for open-lot feeding systems for beef and dairy cattle in the Southern Great Plains. Sub-objectives include:

2.1. Quantify interactions among the air contaminants in Objective 1 in relation to surface-manure characteristics, climatic variables, animal movement, and management practices.
2.2. Develop and validate selected cost-effective emissions abatement methods.

Objective 3. Scientific Basis for Emission Factors: Develop a scientific basis for applicable air quality protection policies, including appropriate emission factors for PM_{10}, $PM_{2.5}$, odor, odorous gases, and related ground-level reactive volatile organic compounds (RVOC), ammonia, and hydrogen sulfide, for Southern Great Plains feedyards. Sub-objectives include:

3.1. Refine and validate dispersion models used to predict downwind concentrations from ground-level area sources.
3.2. Develop accurate emission factors for open-lot CAFOs.

Objective 4. Animal Health & Performance: Determine the impact of feedyard air contaminants on animal health and productivity. Sub-objectives include:

4.1. Determine the effects of dust on ruminant animal health and productivity.
4.2. Explore causal pathways by which feedyard dust might contribute to cattle health disorders.

Objective 5. Technology Transfer: Deliver education and technology transfer programs that address characterization and cost-effective abatement of airborne emissions, scientifically sound regulation of open-lot feedyards and dairies, and effects of emissions on livestock health and performance.

Experimental Procedures

Objective 1.

Intensive multi-agency field sampling has been conducted at a 50,000 head commercial beef cattle feedyard (Feedlot C) near Amarillo involving multiple investigators from different agencies on six occasions. Participants represented WTAMU, TAES-Amarillo, BAEN-College Station, and USDA-ARS (Parker, Koziel, Todd, Cole, Parnell, Lacey). A field study involving PM, H_2S and NH_3 monitoring from discrete sources was conducted by BAEN at a combination free-stall and open lot dairy in Central Texas (Parnell, Mukhtar). Data collection and analysis methods appropriate to feedyards and dairies using isolation flux chambers (Koziel, Mukhtar) and micrometeorological/flux gradient approaches (Todd, Cole) were compared, and measurement protocols were refined. Excellent progress was recorded in methods development/refinement and field monitoring research. Techniques for improving concentration measurements for ammonia and PM at dairies and feedyards, respectively, were developed and are being used to refine emission factor estimates. Field measurements of ammonia emissions showed reasonable convergence between two different approaches according to limited field sampling to date. Ranges of values of parameters including feedlot odor, ammonia, hydrogen sulfide and VOCs concentrations and projected emission rates or flux values were identified.

Objective 2.

Weight drop test chambers were used to develop initial simulation of feedlot dust PM_{10} and TSP generation vs. weight/impact (Auvermann/Maghirang, et al.). Abatement treatment evaluations involving chemical amendments (ammonia control) or water application (PM control) proceeded in laboratory scale. Promising results were derived from application of urease inhibitor or humate for ammonia control in laboratory/simulated feedlot conditions; a study was conducted at the WTAMU research feedlot to determine urease performance under field conditions; an apparatus was constructed and a study was initiated to evaluate odor emissions in simulated lagoons; and experimental scale-up to field locations was planned. Water curtain for edge-of-field interception of PM was evaluated further. Certain PI's helped USDA-NRCS develop a state and national sprinkler system standard for PM control that will be used for feedyards under EQIP funding. Laboratory studies of feedlot dust vs. energy inputs and manure properties (depth and moisture content) showed consistent results both at TAES-Amarillo and KSU. Experimental systems for feedlot surface evaporation studies vs. climatic variables were upgraded and preliminary relationships developed.

Objective 3.

Models for converting concentration results from field study protocols to characteristic emission parameters such as flux, emission rate, and emission factors were refined. Emission factor development continued and is being coordinated for all PI's (Parnell). Ammonia losses in isolation flux chambers and tubing were identified experimentally. Gaussian modeling approaches were refined and compared with alternative approaches, with large differences noted between certain modeling approaches. Systematic over-sampling of PM_{10} using Federal Reference Method (FRM) approaches was analyzed and addressed with EPA personnel.

Objective 4.

A prototype instrumented test chamber to determine the effects of animal exposure to feedlot PM was completed (Auvermann, Cole et al.). Feedyard dust exposure/isolation chambers for calves were being constructed and equipped/instrumented. Experiments were designed for calf dust exposure and for lung fluid studies. These studies are targeted for Year 3 (2004-2005).

Literature review was completed showing difference in lung physiology of cattle vs. sheep and goats. Hence, exposure studies to feedlot dust were planned as a graduate student project using calves as experimental animals. Ventilation components for the feedlot dust exposure chambers were received and exposure chambers are complete. They will be installed at WTAMU Nance Ranch, allowing the animal studies to proceed (Brown et al).

Research measures used to evaluate cattle health will focus on lung function and immunity parameters, rather than oxidative stress.

Agglomeration of feedlot dust particles in the lung is being evaluated as an inherent mitigating mechanism of cattle exposed to feedlot PM.

Objective 5.
Technology transfer by PI's included exhibits, radio interviews, conference proceedings papers, news articles, and referred journal articles. Project PI's produced (Jan. 2003 – Aug. 2004) more than 59 manuscripts, published 10 refereed journal articles, and made 45 or more professional presentations. KSU sponsored a Cattle Feeders' Day that featured feedlot dust topics. The PI's also wrote 19 proposals totaling several million dollars. The PI's generated co-funding of $514,000 (Year 2) and a total of $1,330,000 in non-federal external funding since the project began. Project coordination meetings with scientists were held. The project's Industry Advisory Council met with the PI's in September 2003 and August 2004 and provided input into project efforts, design and focus. Annual progress reports were completed (Years 1 & 2) and the Year 3 work plan was prepared and submitted resulting in Year 3 funding award. A 2-day fee-based training short course entitled "Air Quality Emissions and Equipment Short Course" designed for USDA-NRCS technical personnel was conducted in January, 2004 in College Station (Parnell, Shaw & Lacey). A second "management" short course on a similar topic was developed for NRCS and UC-Davis personnel in California.

A research program review was conducted in August 2004 in Amarillo involving external peer reviewers, National Program Leaders/Air Quality for both USDA-CSREES and USDA-ARS, and members of the project's Industry Advisory Committee. Recommendations included a need for greater focus on interactions between odor, odorous gases, ammonia and particulate matter; a standardization of research involving ammonia emissions; measured impacts of BMP's on off-site odor levels; particle size distribution; chemical composition of particulate matter; and timely/accessible information releases of research outcomes including stakeholder workshops.

The project investigators in Year 3 alone have made more than 38 presentations at national or regional meetings of scientific or stakeholder groups. Project investigators wrote more than 50 technical papers in Year 3 to date, including 9 refereed journal articles published or submitted to be published, and 2 M.S. theses completed. Significant co-funding was recruited from within-agencies ($700,000 est.) and from external grants and contracts ($107,130), which together almost matches the grant amount of $835,770 for Year 3.

Summary

This report is meant to give an overview of this broad and diverse air quality research. Questions about specific details of individual components can be directed to Dr. Sweeten or to individual scientists participating in the project.

Literature Cited

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Table 1. Air quality project participants

Project Director:
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David B. Parker, WTAMU, Canyon, TX (Objective 1 Coordinator)
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Feeding and Nutrition

FEED EFFICIENCY IN GROWING AND FINISHING STEERS: I. RELATIONSHIPS BETWEEN FEED EFFICIENCY AND CARCASS ULTRASOUND TRAITS

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[1]Texas Agricultural Experiment Station, College Station
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Summary

The objective of this study was to examine relationships between feed efficiency traits measured in growing steers fed a roughage-based diet and finishing steers fed a grain-based diet. Santa Gertrudis steers (n = 115) were individually fed diets using Calan gate feeders and growth calculated from body weights measured at 14-d intervals. During both growing and finishing phases, four feed efficiency traits were calculated: net feed intake (**NFI**), residual gain efficiency (**RGE**), partial efficiency of growth (**PEG**) and feed conversion ratio (**FCR**). Ultrasound carcass measurements of backfat, ribeye area and intramuscular fat were obtained on day 70 of the growing and finishing phases. Average daily gain was strongly correlated with FCR and RGE, and weakly correlated with PEG, but was not correlated with NFI. Dry matter intake (**DMI**) was not correlated with FCR or RGE. However, DMI was strongly correlated with PEG and NFI during both the growing and finishing phase, such that favorable PEG and NFI phenotypes consumed less feed. All feed efficiency traits were strongly correlated to each other (> ± 0.50) during both the growing and finishing phases. Steers with low NFI consumed 18 and 19% less DMI than steers with high NFI during the growing and finishing phases, respectively, even though ADG were similar. Ultrasound traits were not significantly correlated to either of the feed efficiency traits during the growing phase, but backfat was moderately correlated with PEG and NFI during the finishing phase. Of the feed efficiency traits measured in this study, NFI had the highest correlation between the growing and finishing phases. Although NFI measured during the growing phase was moderately correlated (r = 0.48) with NFI measured during the finishing phase, these results indicate that diet and (or) stage of maturity may influence genetic ranking of cattle for feeding efficiency traits.

Introduction

Feed represents the largest variable cost in producing beef. However, genetic selection remains focused on output traits (e.g., growth and carcass traits) that are moderately heritable and relatively easy to measure. Feed efficiency traits are also moderately heritable, but are more difficult and expensive to measure than growth traits. Past attempts to improve genetic merit for feed efficiency have focused on feed conversion ratio (**FCR**). Selection for improved FCR will not likely reduce feed costs of the integrated beef operation, as FCR is a gross measure of feed efficiency that does not attempt to partition feed intake into growth and maintenance components. In attempts to select cattle for improved efficiency, numerous feed efficiency traits have been evaluated, including net feed intake (**NFI**). Net feed intake attempts to measure variation in feed intake beyond that needed for growth and maintenance, and is moderately heritable and genetically independent of BW and ADG (Arthur et al., 2001b).

Few studies have examined the influence of diet and (or) stage of production on feed efficiency traits. Crews et al. (2003) examined the relationship between NFI in steers measured at two stages of production. They observed a positive genetic correlation (r = 0.55) between NFI measured in growing steers fed a high-roughage diet and finishing steers fed a high-grain diet, indicating that these two measures of NFI were biologically similar. Nkrumah et al. (2004) examined relationships between various measures of efficiency and carcass ultrasound measurements in steers fed a high-grain diet. Their results indicate that NFI and partial efficiency of growth (**PEG**) have the greatest potential to improve efficiency, with minimal responses in growth and carcass traits. Few studies have examined the relationships between various measures of feed efficiency in different production phases, and their relationships with carcass traits. Therefore, the objectives of this study were to examine phenotypic correlations between feed efficiency traits and ultrasound measurements of 12th rib fat thickness (**BF**), longissimus muscle area (**REA**), and percent intramuscular fat (**IMF**) in growing and finishing Santa Gertrudis steers.

Experimental Procedures

One hundred fifteen sire-identified Santa Gertrudis steers from the King Ranch originating from five herds were weaned in early fall (weaning BW = 530 ± 78 lb). Steers were backgrounded at the King Ranch until mid-December (BW = 577 ± 67 lb) before being transported to the King Ranch Feedyard. Steers were fed at the feedyard until mid-January and then transported to the O.D. Butler, Jr. Animal Science Complex in College Station, TX. Upon arrival, steers were assigned to one of 20 pens equipped with Calan-gate feeders, based on sire and BW. Average BW at the start of the study was 642 ± 73 lb. Upon arrival calves were given access to coastal hay and a high-roughage diet. Following a 28-day adaptation period, steers were fed a high-roughage diet for 77-days. The high-roughage diet contained 35% chopped alfalfa hay, 15% alfalfa pellets, 19.5% dry rolled corn, 21.5% cottonseed hulls, 7% molasses, and 2% premix (0.95 Mcal/lb ME; 11.2 % CP DM basis). The high-roughage diet was followed by a 28-day transition period to a high-grain diet, which consisted of 76.5% dry rolled corn, 7.5% cottonseed meal, 5% chopped alfalfa hay, 5% coastal hay, 4% molasses, and 2% premix (1.36 Mcal/lb ME; 10.1% CP DM basis). Anabolic implants were not administered to steers during the study. Individual feed intake and bi-weekly body weights were measured for 77 and 80 days during the growing and finishing phases, respectively. Ultrasound carcass measurements of REA, BF, and IMF were obtained on day 70 of the growing phase and on day 70 of the finishing phase.

Calculations and Statistical Analysis. Linear regression of bi-weekly BW against time was used to derive ADG, initial and final BW, mid-test $BW^{.75}$ (mean of initial and final BW raised to the power of .75) for each steer. Feed conversion ratio was calculated as the ratio of DMI to ADG for each phase. Individual NFI was calculated as actual DMI minus expected DMI to meet growth and maintenance energy requirements. Expected DMI was derived from a phenotypic regression model of actual DMI on ADG and mid-test $BW^{.75}$ for each phase. Partial efficiency of growth was calculated as the ratio of ADG to the difference between actual DMI and expected DMI for maintenance. The expected DMI for maintenance was calculated as 0.077*mid-test BW ÷ NE_m concentrations of the diets. Residual gain efficiency (**RGE**) was calculated as actual ADG minus expected ADG. Expected ADG was derived from a phenotypic regression model of actual ADG on DMI and mid-test $BW^{.75}$. A positive RGE indicates steers are more efficient as they gain more than expected for a given DMI and liveweight. Herd of origin was included as an independent variable in models used to calculate NFI and RGE.

Within each phase, steers were ranked by NFI and separated into low, medium, and high NFI groups based on ± 0.5 standard deviation from the mean NFI of 0.0 ± 1.96 and 0.0 ± 2.2 lb/d for the growing and finishing phases, respectively. Least squares procedures of SAS was used to examine the effects of NFI group on performance, efficiency, and carcass ultrasound data with a model that included the fixed effect of herd of origin. Partial correlation coefficients among traits were determined using PROC CORR of SAS with the partial correlation option used to adjust for fixed effect of herd of origin.

Results and Discussion

Relationships between feed efficiency and growth traits. During the 77-day growing phase, overall ADG, DMI, and NFI were 2.78 (SD = 0.46), 22.2 (SD = 2.87), and 0.00 (SD = 1.96) lb/d, respectively. Phenotypic correlations between growth and efficiency traits for the growing and finishing phases are presented in Table 1. Dry matter intake was correlated with ADG (r = 0.59) during the growing phase. Similar phenotypic correlations have been reported in previous studies in growing steers (Arthur et al., 2001a; Carstens et al., 2002). Average daily gain was not correlated with NFI as expected, but was strongly correlated with FCR (r = -0.66) and RGE (r = 0.81), and weakly correlated with PEG (r = 0.23). Thus selection for favorable NFI and PEG phenotypes would result in minimal growth responses, whereas, selection for favorable FCR and RGE would result in large increases in growth and mature size. Dry matter intake was correlated with PEG (r = -0.58) and NFI (r = 0.68), such that the efficient phenotypes consumed less feed. Nkrumah et al. (2004) and Arthur et al. (2001b) reported similar phenotypic correlations between DMI and PEG and NFI. Net feed intake was strongly correlated with FCR (r = 0.61), RGE (r = -0.48), and PEG (r = -0.91) in growing steers, indicating that all feed efficiency traits examined in this study were strongly related.

Growing steers with low NFI (< 0.5 SD below the mean) consumed 18% less feed than high NFI steers (> 0.5 SD above the mean). Consequently, steers with low NFI had a 19% lower FCR compared to steers with high NFI as ADG was similar for steers with low and high NFI. Steers with low NFI were also more efficient as measured by RGE (0.24 vs -0.15 ± 0.06 lb/d) and PEG (0.32 vs 0.20 ± 0.004 ADG/DMI for growth) compared to steers with high NFI.

During the 80-day finishing phase, overall ADG, DMI, and NFI were 2.26 (SD = 0.53), 20.0 (SD = 3.8), and 0.00 (SD = 2.2) lb/d, respectively. Reasons for the unexpected low performance of steers during the finishing period were not evident. Dry matter intake was correlated with ADG (r = 0.69) during the finishing phase. Dry matter intake was not correlated with FCR or RGE, but was strongly correlated with PEG (r = -0.65) and NFI (r = 0.59). Average daily gain measured during the finishing phase was strongly correlated with FCR (r = -0.63) and RGE (r = 0.73), but not correlated with PEG or NFI. The strong correlations between ADG and FCR and RGE suggests that using either of these feed efficiency traits in selection programs to improve feed efficiency will likely result in increases in growth and mature size (Herd and Bishop, 2000). Net feed intake was strongly correlated to FCR (r = 0.54), RGE (r = -0.59) and PEG (r = -0.79) during the finishing phase. Nkrumah et al. (2004) also reported a strong correlation between PEG and NFI in steers fed a high-grain diet. These results suggest that selection for NFI or PEG will reduce DMI with minimal responses in growth or mature size.

Finishing steers with low NFI (more efficient) consumed 19% less feed and had a 23% lower FCR than finishing steers with high NFI. Steers with low NFI were also more efficient as measured by RGE (0.24 vs. -0.30 ± 0.06) and PEG (0.25 vs. 0.16 ± 0.01) compared to high NFI steers.

Relationships between feed efficiency and carcass traits. Ribeye area and BF measured at the end of the growing phase were positively correlated with DMI, but not with ADG (Table 3). Backfat measured at the end of the growing phase was not correlated with FCR or RGE. Although BF was not significantly correlated with NFI, the correlation (r = 0.14) was similar to the correlations (0.14 to 0.20) reported in previous studies in growing calves (Arthur et al., 2001b; Carstens et al., 2002; Fox et al., 2004). Final IMF was not correlated with feed efficiency traits during the growing phase. However, Fox et al. (2004) found that IMF tended to be positively correlated with NFI in growing bulls, suggesting that IMF may be unfavorably related to NFI. Ribeye area measured at the end of the growing phase was not correlated with either of the feed efficiency traits. The lack of significant correlations between final REA and feed efficiency traits is consistent with previous studies in growing steers (Carstens et al., 2002; Nkrumah et al., 2004) and bulls (Arthur et al., 2001a,b; Fox et al., 2004).

Ribeye area and BF measured at the end of the finishing phase were correlated with ADG (r = 0.33; 0.38) and DMI (r = 0.44; 0.62; respectively). Final REA was weakly correlated to PEG (r = -0.21), which is in contrast to results reported by Nkrumah et al. (2004). Final BF was moderately correlated with NFI (r = 0.30) and PEG (r = -0.46) during the finishing phase. Nkrumah et al. (2004) found similar correlations between BF and NFI and PEG in steers fed a high-grain diet. These results suggests that more efficient cattle as measured by NFI and PEG were leaner, and that phenotypic relationships between NFI and PEG efficiency trait and carcass fat composition are more evident during the finishing phase compared to the growing phase.

Relationships between measures of feed efficiency in the growing and finishing phase. Average daily gain and DMI measured during the growing phase were positively correlated with ADG (r = 0.27) and DMI (r = 0.51) during the finishing phase. Feed conversion ratio (r = 0.22), RGE (r = 0.27), PEG (r = 0.29) were weakly correlated during the growing and finishing phase, whereas, the correlation between NFI (r = 0.48) measured during the growing and finishing phases were moderately correlated. Net feed intake had the highest correlation between growing and finishing phases, suggesting that NFI may be the more appropriate trait to use in evaluating feed efficiency across various production phases. Crews et al. (2003) observed a positive genetic correlation (r = 0.55) between NFI measured in steers fed roughage- and grain-based diets. Although these results indicate that a moderately positive correlation exists between NFI measured when steers are fed roughage- vs grain-based diets, these two feed efficiency traits may not be biologically similar. It is unclear as to whether the lack of a strong correlation between NFI measured during growing vs finishing phases was due to influences of diet and (or) stage of maturity.

Implications

While a number of studies have demonstrated that phenotypic and genetic variation in feed efficiency traits exists in growing cattle, few studies have been conducted to determine if feed efficiency measured in growing calves is comparable with feed efficiency measured in finishing calves. Of the feed efficiency traits examined in this study, NFI was the trait most highly related between growing steers fed a roughage-based diet and finishing steers fed a grain-based diet. However, these results demonstrate that cattle with genetic potential for improved feed utilization on a roughage-based diet may rank differently when feed efficiency is evaluated on a grain-based diet.

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Table 1. Phenotypic correlations[a] between performance traits and measures of efficiency

Trait[b]	DMI	FCR	RGE	PEG	NFI
Growing Phase					
ADG	**0.59**	**-0.66**	**0.81**	**0.23**	-0.002
DMI		0.18†	0.003	**-0.58**	**0.68**
FCR			**-0.95**	**-0.80**	**0.61**
RGE				**0.70**	**-0.48**
PEG					**-0.91**
Finishing Phase					
ADG	**0.69**	**-0.63**	**0.73**	0.03	0.00
DMI		0.07	0.00	**-0.65**	**0.59**
FCR			**-0.94**	**-0.64**	**0.54**
RGE				**0.58**	**-0.59**
PEG					**-0.79**

[a]Correlations in bold are different from zero at $P < 0.05$.
†Correlations are different from zero at $P < 0.10$.
[b]ADG = average daily gain; DMI = dry matter intake; FCR = feed conversion ratio or feed:gain ratio; PEG = partial efficiency of growth; NFI = net feed intake; RGE= residual gain efficiency.

Table 2. Least squares means for growth and feed efficiency traits in steers with low, medium, and high NFI during the growing and finishing phases[a]

Trait	Low NFI	Medium NFI	High NFI	SEM	*P*-value
Growing Phase					
Number of steers/group	35	45	35	----	----
Average daily gain, lb/d	2.81	2.68	2.82	.08	0.33
Dry matter intake, lb/d	20.17[a]	21.75[b]	24.73[c]	0.40	<0.01
Net feed intake, lb/d	-2.20[a]	-0.12[b]	2.32[c]	0.15	<0.01
Residual gain efficiency, lb/d	0.24[a]	-0.06[b]	-0.15[b]	0.06	<0.01
Partial efficiency of growth[b]	0.32[a]	0.24[b]	0.20[c]	0.004	<0.01
Feed conversion ratio, feed/gain	7.26[a]	8.34[b]	8.95[c]	0.17	<0.01
Finishing Phase					
Number of steers/group	40	38	37	----	----
Average daily gain, lb/d	2.33	2.25	2.22	0.10	0.71
Dry matter intake, lb/d	18.44[a]	19.78[a]	22.70[b]	0.60	<0.01
Net feed intake, lb/d	-2.20[a]	-0.11[b]	2.58[c]	0.17	<0.01
Residual gain efficiency, lb/d	0.24[a]	0.02[b]	-0.30[c]	0.06	<0.01
Partial efficiency of growth[b]	0.25[a]	0.20[b]	0.16[c]	0.01	<0.01
Feed conversion ratio, feed/gain	8.09[a]	9.10[b]	10.53[c]	0.32	<0.01

[a]Steers identified as low, medium, and high NFI were < 0.5, ± 0.5, and > 0.5 SD from the mean NFI of 0.00 for the growing and finishing phases.
[b]ADG/DMI for growth.

Table 3. Phenotypic correlations[a] between final carcass ultrasound measurements and performance and efficiency traits in growing and finishing Santa Gertrudis steers

	-Performance Traits-		-----------Feed Efficiency Traits--------			
Trait[b]	ADG	DMI	FCR	RGE	PEG	NFI
Growing Phase						
Rib eye area	0.18†	**0.33**	0.08	-0.04	-0.05	-0.03
Back fat	0.07	**0.21**	0.10	-0.07	-0.14	0.14
IM fat	0.13	0.14	-0.05	0.06	-0.06	0.11
Finishing Phase						
Rib eye area	**0.33**	**0.44**	-0.02	0.06	**-0.21**	0.09
Back fat	**0.38**	**0.62**	0.10	-0.05	**-0.46**	**0.30**
IM fat	0.09	0.09	-0.08	0.04	-0.09	0.07

[a]Correlations in bold are different from zero at $P < 0.05$.

†Correlations are different from zero at $P < 0.10$.

[b]ADG = average daily gain; DMI = dry matter intake; FCR = feed conversion ratio or feed:gain ratio; PEG = partial efficiency of growth; NFI = net feed intake; RGE= residual gain efficiency.

FEED EFFICIENCY IN GROWING AND FINISHING STEERS: II. PHYSIOLOGICAL INDICATORS OF PERFORMANCE AND FEED EFFICIENCY TRAITS

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Summary

Phenotypic correlations between potential indicators of performance and efficiency were examined in growing and finishing Santa Gertrudis steers (n =115). Steers were individually fed a high-roughage diet (growing phase) for 77-days, followed by a high-grain diet (finishing phase) for 80-days. Feed intake was recorded weekly, and body weight was measured bi-weekly. Net feed intake (**NFI**) was calculated as the difference between actual feed intake and feed intake predicted by a linear regression model. Blood samples were collected on day 0 of the growing and finishing phases and analyzed for serum concentrations of insulin-like growth factor-I (**IGF-I**), leptin, cortisol, and insulin. Exit velocity was measured on day 0 of the growing and finishing phases. Growing and finishing steers with low NFI consumed 18 and 19% less feed than high NFI growing and finishing steers, respectively. Serum IGF-I concentrations measured on day 0 of the growing phase were positively correlated with DMI (r = 0.33) and NFI (r = 0.19) measured during the growing phase, but not ADG. However, serum IGF-I measured on day 0 of the finishing phase was not correlated with NFI measured during the finishing phase, but was correlated with DMI (r = 0.18). Growing steers with low NFI tended to have 13% lower serum IGF-I concentrations than high NFI steers. In the finishing phase, day 0 serum insulin concentrations tended ($P < 0.10$) to be correlated with NFI measured during the finishing phase, but not ADG. Serum concentrations of leptin and cortisol were not correlated with NFI in each respective phase. Exit velocity measured on day 0 of the growing phase was negatively correlated ($P < 0.05$) with ADG (r = -0.26) and DMI (r = -0.32) measured during the growing phase. Exit velocity measured on day 0 of the finishing phase was negatively correlated ($P < 0.05$) with DMI (r = -0.21) and FCR (r = -0.23) measured during the finishing phase. Exit velocity in the growing or finishing phases was not correlated with NFI measured in the respective phases. These results suggest that exit velocity can be an indicator of performance, but not NFI. These results also suggest that IGF-I may be a useful physiological indicator of NFI in cattle fed a roughage-based diet and insulin might be an indicator of NFI in cattle fed a grain-based diet.

Introduction

Net feed intake (**NFI**), an alternative feed efficiency trait, will facilitate selection of more efficient cattle with minimal affects on growth or compositional traits. Implementing selection programs to improve NFI is limited due to the difficulty and expense in measuring individual DMI in cattle. Identification of indicator traits predictive of NFI would be useful to reduce costs and improve accuracy of identifying bulls with superior genetics for NFI. Moore et al. (2005) reported that serum IGF-I (**IGF-I**) was genetically correlated with NFI (r_g = 0.41± 0.21) in cattle. Likewise, in growing steers and bulls, serum IGF-I was phenotypically correlated with NFI (r = 0.22; 0.38, respectively), but not with ADG (Brown et al., 2004a). The Australian genetic improvement program is currently using serum IGF-I measurements along with NFI data to generate estimated breeding values for NFI in Angus bulls.

Richardson et al. (2004) found positive correlations between serum leptin (r = 0.31) and insulin (r = 0.43) concentrations and NFI in steers selected for high and low NFI fed a grain-based diet. Recently, Nkrumah et al. (2005) found single nucleotide polymorphisms in the promoter region of the bovine leptin gene that showed associations with serum leptin, ADG, and DMI, but not NFI or FCR.

Richardson et al. (2004) found that steers selected for high NFI tended to have higher serum cortisol concentrations than steers selected for low NFI. Theis et al. (2002) did not observe correlations between serum cortisol concentrations and NFI in growing steers, but observed negative correlations with ADG and DMI. This suggests that serum cortisol is not a potential indicator trait for NFI. Exit velocity (**EV**) has been proposed as an objective measure of temperament (Burrow et al., 1988). Curley et al. (2004) reported positive correlations between EV and serum cortisol concentrations in cows. In growing steers, EV was negatively correlated to ADG and DMI, but not FCR or NFI (Brown et al., 2004b). Results suggest that EV is a predictor of ADG and DMI, but not feed efficiency. Few studies have evaluated potential physiological indicators of performance and feed efficiency traits in the same set of cattle on different diets. Therefore, the objectives were to examine phenotypic correlations between potential physiological indicators and growth and efficiency traits in growing and finishing steers.

Experimental Procedures

The experimental animals and design used in this study were described in a companion paper (Brown et al., 2005). Briefly, 115 sire-identified Santa Gertrudis steers were individually fed a roughage-based diet for 77-days during the growing phase and a grain-based diet for 80-days during the finishing phase. Individual feed intake and bi-weekly body weights were measured and used to calculate FCR and NFI. Blood samples were collected from each steer on day 0 of the growing phase and on day 0 of the transition to the finishing phase. Serum was analyzed for leptin, insulin, IGF-I, and cortisol using radioimmunoassay procedures. Exit velocity was measured as the rate (feet/second) at which a steer exited a squeeze chute and transversed a distance of 6 feet on day 0 of the growing phase and day 0 of the transition to the finishing phase (Brown et al., 2004b).

Calculations and Statistical Analysis. Linear regression of bi-weekly BW against time was used to derive ADG, initial and final BW, mid-test $BW^{.75}$ (mean of initial and final BW raised to the power of .75) for each steer. Feed conversion ratio was calculated as the ratio of DMI to ADG for each phase. Individual NFI was calculated as actual DMI minus expected DMI. Expected DMI was derived from a phenotypic regression model of actual DMI on ADG and mid-test $BW^{.75}$, with herd of origin included as an independent variable.

Within each phase, steers were ranked by NFI and separated into low, medium, and high NFI groups based on ± 0.5 standard deviation from the mean NFI of 0.0 ± 1.96 and 0.0 ± 2.2 lb/d for the growing and finishing phases, respectively. Least squares procedures of SAS were used to examine the effects of NFI group on performance, efficiency, hormone and EV data with a model that included the fixed effect of herd of origin. Partial correlation coefficients among traits were determined using PROC CORR of SAS with the partial correlation option used to adjust for fixed effect of herd of origin.

Results and Discussion

Performance and feed efficiency results measured during the growing and finishing phases are reported in a companion paper (Brown et al., 2005). Briefly, growing steers with low NFI consumed 18% less feed and had a 19% lower FCR than high NFI steers. As expected, ADG did not differ between low and high NFI steers during the growing phase. Finishing steers with low NFI consumed 19% less feed, had a 23% lower FCR, and did not differ in ADG compared to high NFI steers. Average daily gain was strongly correlated with FCR, but was not correlated with NFI during the growing and finishing phases. However, DMI was strongly correlated with NFI during both the growing and finishing phases, such that favorable NFI phenotypes consumed less feed.

Serum IGF-I concentrations on day 0 of the growing phase were positively correlated with growing phase DMI ($r = 0.33$) and NFI ($r = 0.19$; Table1), but not ADG. Positive genetic (Moore et al., 2005) and phenotypic (Brown et al., 2004a) correlations between NFI and serum IGF-I have also been reported in growing steers and bulls fed a roughage-based diet. In this study, growing steers with low NFI tended ($P = 0.16$) to have 13% lower serum IGF-I concentrations than high NFI steers. In contrast, serum IGF-I concentrations on day 0 of the finishing phase were not correlated with NFI, but were correlated with DMI ($r = 0.18$) and ADG ($r = 0.23$). These results indicate that serum IGF-I may be a useful physiological indicator of NFI in growing compared to finishing calves.

Serum leptin concentrations measured on day 0 of the growing phase were not related to ADG, DMI, FCR or NFI measured during the growing phase. Likewise, Brown et al. (2004) found that serum leptin concentrations were not correlated to performance or feed efficiency traits in growing steers and bulls. Serum leptin concentrations measured on day 0 of the finishing phase were positively correlated with DMI ($r = 0.21$) measured during the finishing phase, but were not correlated with ADG, FCR, or NFI. Serum leptin concentrations measured on day 70 of the finishing phase were positively correlated with ADG (r = 0.49), DMI (r = 0.56), and NFI (r = 0.24) during the finishing phase. Richardson et al. (2004) also found serum leptin concentrations measured at the end of the experiment to be positively correlated with NFI in steers fed a high-grain diet, but did not report correlations at the start of the experiment. These results indicate that leptin may not be a useful indicator trait for NFI, as it appears to be more related to carcass fatness than to performance or feed efficiency traits in cattle fed a high-grain diet. Serum leptin concentrations measured on day 70 of the finishing phase were strongly correlated to carcass back fat (r = 0.50) measured after harvesting the steers. Recent reports have found that steers with a single nucleotide polymorphism in the promoter region of the leptin gene (TT genotype) had higher leptin concentrations, higher DMI, and more back fat compared to the CC genotype steers, but did not differ in NFI or FCR (Nkrumah et al., 2005). The use of marker-assisted selection has potential to aid in evaluating performance and efficiency traits in cattle.

Serum insulin concentrations measured on day 0 of the growing phase were not correlated with ADG, DMI, FCR, or NFI measured during the growing phase. Serum insulin concentrations measured on day 0 of the finishing phase tended (P = 0.10) to be correlated with NFI (r = 0.16) during the finishing phase, but not with ADG, DMI, or FCR. Richardson et al. (2004) found a significant correlation between serum insulin concentrations measured at the end of the experiment and NFI in steers fed a grain-based diet, but not ADG, DMI, or FCR. Serum insulin concentrations measured on day 0 of the finishing phase were moderately correlated (r = 0.38) with serum insulin concentrations measured on day 70 of the finishing phase. These results indicate that insulin may be a potential indicator of NFI in cattle fed a grain-based diet.

Serum cortisol concentrations measured on day 0 of the growing phase tended (P = 0.07) to be negatively correlated with ADG (r = -0.18) during the growing phase, but were not correlated with DMI, FCR, or NFI. Likewise, Brown et al. (2004a) reported negative correlations between serum cortisol concentrations and ADG and DMI, but not NFI in growing steers. These results suggest that calves with high cortisol concentrations will have lower DMI and grow at slower rates. During the finishing phase, day 0 serum cortisol concentrations were not correlated with ADG, DMI, FCR, or NFI. Serum cortisol concentrations may be indicative of ADG and DMI, but not feed efficiency traits in growing steers.

Exit velocity measured on day 0 of the growing phase was negatively correlated with ADG (r = -0.26) and DMI (r = -0.32) during the growing phase, but not with FCR or NFI. Exit velocity has been shown to be negatively correlated with ADG and DMI in growing bulls (Brown et al., 2004b), but not correlated with FCR or NFI. Exit velocity measured on day 0 of the finishing phase was negatively correlated with DMI (r = -0.21) and FCR (r = -0.23) during the finishing phase, but not ADG or NFI. Exit velocity has been shown to be related to serum cortisol concentrations and temperament scores in Brahman cows (Curley et al., 2004). Exit velocity measured on day 0 of the growing phase was not correlated to serum cortisol concentrations measured on day 0 of the growing phase. However, EV measured on day 0 of the finishing phase was correlated to serum cortisol concentrations (r = 0.29). These results suggest that EV is an indicator trait for growth, but not NFI.

Implications

Net feed intake has the potential to improve efficiency in beef cattle and to reduce feed costs for the producer.However, measuring individual feed intake in cattle is labor intensive and expensive.Identification of more efficient cattle using physiological indicator traits could aid in identifying cattle early in the testing phase that should be subjected to full NFI evaluations.Serum IGF-I concentrations were correlated with NFI, but not ADG in the growing phase.This suggests that IGF-I might be predictive of NFI in cattle fed a roughage-based diet.Serum insulin concentrations showed a tendency to be correlated with NFI, but not ADG in the finishing phase, suggesting that serum insulin might be indicative of NFI in cattle consuming a grain-based diet.More research is warranted to evaluate the use of serum insulin as an indicator trait for NFI in finishing cattle.

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Table 1. Phenotypic correlations[a] between physiological indicator traits and performance and efficiency traits in growing and finishing Santa Gertrudis steers

Trait[b]	ADG	DMI	FCR	NFI
Growing Phase				
IGF-I	0.16	**0.33**	0.05	**0.19**
Insulin	-0.03	0.003	0.08	-0.04
Leptin	0.11	0.09	-0.10	-0.07
Cortisol	-0.18†	-0.11	0.13	-0.02
Exit velocity	**-0.26**	**-0.32**	0.03	-0.16†
Finishing Phase				
IGF-I	**0.23**	**0.18**	-0.13	-0.13
Insulin	-0.14	-0.01	0.14	0.16†
Leptin	0.06	**0.21**	0.11	0.08
Cortisol	-0.03	-0.17	-0.11	-0.11
Exit velocity	0.03	**-0.21**	**-0.23**	-0.11

[a]Correlations in bold are different from zero at $P < 0.05$.
[b]ADG = average daily gain; DMI = dry matter intake; FCR = feed conversion ratio or feed:gain ratio; NFI = net feed intake
†Correlations are different from zero at $P < 0.10$.

INFLUENCE OF ACETOGENIC VERSUS PROPIOGENIC SUPPLEMENTS ON ADIPOSE TISSUE ACCRETION IN STOCKER STEERS GRAZING RYEGRASS PASTURES

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Summary

Fifty-eight steers were used to evaluate the effects of acetogenic versus propiogenic supplements on subcutaneous (s.c.) and intramuscular (i.m.) adipose tissue accretion during the growing phase. Cattle were allotted to one of three treatments and placed on irrigated ryegrass pastures. Cattle received 1) no supplement (NC), which served as the negative control, or 2) were hand-fed 6 d/wk a pelleted high roughage (acetogenic, HR) supplement or 3) a high starch (propiogenic, HS) supplement. Full BW was measured every 28 d and ultrasound measurements (ribeye area, REA; percent intramuscular fat, IMF; 12th rib fat thickness, BF; ribeye depth, depth) were taken every 56 d. Preliminary statistical analysis of the available data revealed no differences in overall ADG among treatments (1.95, 1.93, and 1.84 lb ± 0.08 for NC, HS, and HR, respectively; P = 0.63). Overall percentage change in BF was greater (P = 0.09) for steers fed HR (35.99) and HS (45.63) than for those fed NC (10.81 ± 7.84). Steers fed HS had numerically greater (P = 0.50) overall percentage change in REA (28.37) than steers fed HR (21.81) and NC (23.96 ± 3.76). Steers fed HS had numerically greater (P = 0.25) percentage change in IMF (0.20) than for steers fed HR (-1.77) and NC (-3.16 ± 1.15). This preliminary analysis may suggest the high starch supplement provided additional propionate needed for increased IMF accretion.

Introduction

Intramuscular (i.m.) fat content is a primary component of the USDA quality grading system, and therefore is a determinant of carcass price, with greater i.m. fat deposition being associated with an increase in price. Subcutaneous (s.c.) fat thickness is a component of the USDA yield grade equation, and typically increases in s.c. fat result in diminished carcass price. Current finishing methods involve feeding cattle for longer periods of time or to a predetermined backfat thickness in an attempt to increase marbling. These methods are generally inefficient and wasteful; consequently, strategies which enhance quality grade without negatively impacting yield grade are desirable, as they may potentially increase carcass value with minimum risk of incurring discounts. Cattle in the finishing phase are often managed in a uniform manner, increasing the logistical difficulty of alternative management strategies. Therefore, growing programs which result in a predisposition toward carcass enhancement may optimize responses.

It is well documented that s.c. and i.m. adipose tissues are metabolically distinct and differ in rates of development and substrates used for synthesis (Hood and Allen, 1978; Smith and Crouse, 1984; Smith et al., 2000). These metabolic differences may allow for the specific manipulation of individual fat depots. Acetate is the preferred substrate for s.c. adipose tissue accretion, while glucose carbon is utilized preferentially for i.m. fat accretion (Smith and Crouse, 1984). Intuitively, an increase in available glucose carbon should result in an increase in lipogenesis in i.m. adipose tissue relative to the s.c. adipose tissue.

Forage-based growing phases are commonly used by beef cattle producers and may reduce overall production costs; however, additional value may be added to the calves by manipulating s.c./i.m. fat characteristics and by sorting and managing groups of animals based on marbling potential. Today's beef market provides an array of end points for products of different specifications. The ability to predict or manipulate product characteristics during the growing phase will benefit producers by allowing them to optimize available forages and production practices to produce a consistent and desirable product that meets market demands.

Experimental Procedures

Fifty-eight spring-born steer calves weaned from the commercial cow herd at Texas Agricultural Research and Extension Center-Uvalde were used for this project. Calves were weaned in two groups on September 29 and October 13 of 2004. Calves were vaccinated against viral and bacterial respiratory pathogens (Titanium 5 + P.H.M. Bac-1, AgriLabs) and clostridial diseases (20/20 Vision 7, Intervet) and were treated with a topical anthelmintic (Cydectin Pour-On, Fort Dodge) at weaning and boostered 2 wk later. Steers were backgrounded 60 to 74 d with ad libitum access to bermudagrass hay and 6 lb/hd/d of a 65% ground milo, 25% peanut hulls, and 10% cottonseed meal diet with 5 lb/ton vitamin premix added. Beginning six days prior to being placed on ryegrass pastures, animals were fed an additional 2 lb/hd/d of a 38% CP cottonseed cake. This allotment was increased daily until refusals occurred. The strategy of adding protein to the diet prior to pasture placement was designed to adapt calves to a high nitrogen diet.

At the conclusion of the backgrounding period, steers were weighed and ultrasound measurements (ribeye area, REA; percent intramuscular fat, IMF; 12th rib fat thickness, BF; ribeye depth, depth) were obtained. Steers were stratified by BW and randomly assigned to one of six management groups. The six management groups were then randomly assigned to one of three treatments. Treatments were 1) no supplement (NC), which served as the negative control; 2) a pelleted high roughage (HR) energy supplement consisting of peanut hulls, soy hulls, and cottonseed hulls at the rate of 3 lb/hd/d, hand-fed 6 d/wk; or 3) a corn-based high starch (HS) energy supplement at the same rate and frequency as HR. A center pivot irrigated ryegrass pasture was subdivided into six 4.8 acre pastures. Treatment groups were randomly assigned to a pasture. Supplemented groups had 10 steers per pasture and NC group had 9 steers per pasture. Stocking rates were lower in the NC pastures to balance available forage per animal with that of the HS and HR supplemented pastures due to anticipated substitution of forage with supplement. Full BW was measured every 28 d, and ADG was calculated for each animal. Blood samples were also collected every 28 d via coccygeal venipuncture to analyze for metabolites. Ultrasound measurements were obtained every 56 d to evaluate changes in REA, IMF, BF, and depth.

Following the growing phase, steers will remain in treatment groups and enter the feedlot at West Texas A&M, Canyon, TX to be finished. Full BW and ultrasound measurements will be obtained at feedlot entry, mid-way though finishing, and at the end of finishing, prior to harvest. Carcass data will be obtained for all calves.

Preliminary data was analyzed as a completely randomized design, one-way treatment structure, using the general linear model (PROC GLM) procedures of SAS (SAS Inst. Inc., Cary, NC) with pasture as experimental unit and treatment as an effect in the model.

Results and Discussion

Statistical analysis was based on preliminary data available to date. Due to lack of sensitivity in the analysis, a $P < 0.1$ was considered statistically significant; $P < 0.2$ was considered a tendency toward statistical difference.

The results for ADG are shown in Table 1. Gain was lower ($P = 0.08$) for steers fed HR than steers fed HS and NC during d 0 to 28 of the pasture phase. There were no differences ($P = 0.63$) in ADG among treatments over the entire growing phase. This response is consistent with experimental objectives and was expected because stocking rates were lowered in the NC pastures to balance available forage per animal and to account for substitution of forage with supplement in the HS and HR supplemented pastures. Mean ADG of all steers was 1.90 lb. Coffey et al. (2002) reported a similar mean ADG (1.84 lb) for calves grazing bermudagrass/dallisgrass pastures overseeded with annual ryegrass during yr 3 of a 3-yr study. Lippke and Holloway (1995) also reported a similar mean ADG (1.76 lb) for backgrounded stocker steers grazing ryegrass pastures.

Results for ultrasound measurements of REA and depth are shown in Table 2. Numerically, HS fed group had a greater percentage increase in REA than steers fed HR and NC over the grazing period, although values were statistically inseparable ($P = 0.50$). This numerical difference is consistent with the tendency for the HS fed steers to have greater percentage change in muscle depth than HR and NC fed steers during d 57-112 ($P = 0.11$). Ultrasound measurements of BF and IMF are shown in Table 3. The NC fed group had a negative proportional change in BF during d 0 to 28, while steers fed HS and HR had an increase in BF during this period ($P = 0.07$). During d 57 to 112, HS fed group had greater ($P = 0.07$) percentage change in BF than steers fed HR and NC. Overall proportional BF change did not differ between steers fed HS and HR and was greater ($P = 0.09$) than in steers fed NC. No statistical differences were observed among treatments for percentage change in IMF during d 0 to 56 or d 57 to 112; however, overall proportional IMF change was numerically greater for HS fed steers than NC fed steers, with steers fed HR intermediate. The 112-d percentage change in IMF was statistically similar to zero for HS fed steers, whereas this measure was statistically negative for HR and NC fed steers. This response is potentially important, especially in light of numerical trends in muscle depth and ribeye area measures. A percent change in IMF of zero indicates that proportional changes in REA and IMF are similar, while a negative change in IMF indicates that muscle accretion is occurring at a greater proportional rate than IMF accretion (Brethour, 2004), resulting in dilution of IMF and a reduction in the percentage of tissue composed of fat (rather than a net loss of fatty tissue). In this experiment, steers fed HS appeared to maintain IMF accretion rate despite a greater increase in REA. In combination, these observations are supportive of our hypothesis that glucogenic supplements may provide greater substrate for i.m. accretion without impacting BW change. However, variability in the response and lack of sensitivity in this preliminary analysis of the data do not provide conclusive evidence of this effect. Results from subsequent phases of this experiment and future analyses may clarify these findings.

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Table 1. Effect of energy supplementation on average daily gain (lb/d) of stocker steers grazing ryegrass pastures

Item	Negative Control	High Roughage	High Starch	SEM[a]	*P*-value
Backgrounding Phase					
d -43 to -15	2.03	1.86	1.70	0.20	0.54
d -15 to 0	1.87[b]	2.25[c]	2.10[c]	0.09	0.13
d -43 to 0	1.98	1.99	1.84	0.16	0.74
Pasture Phase					
d 0 to 28	1.06[d]	0.77[e]	1.09[d]	0.07	0.08
d 29 to 56	1.72	1.85	1.91	0.27	0.88
d 57 to 84	2.42	2.19	2.16	0.40	0.89
d 85 to 112	2.62	2.55	2.58	0.33	0.99
d 0 to 112	1.95	1.84	1.93	0.08	0.63

[a]n=2

[b,c]Values with unlike superscripts have a tendency to differ ($P = 0.13$)

[d,e]Values with unlike superscripts differ ($P = 0.08$)

Table 2. Effects of energy supplementation on percentage change in ribeye area and ribeye depth of stocker calves grazing ryegrass pastures

Item	Negative Control	High Roughage	High Starch	SEM[a]	*P*-value
Ribeye Area, % Change					
d 0 to 56	4.48	7.22	5.68	4.21	0.89
d 57 to 112	18.99	14.69	21.62	6.25	0.73
d 0 to 112	23.96	21.81	28.37	3.76	0.50
Ribeye Depth, % Change					
d 0 to 56	4.94	1.19	0.20	2.49	0.45
d 57 to 112	3.55[b]	2.77[b]	7.12[c]	1.10	0.11
d 0 to 112	8.41	3.77	7.17	3.18	0.60

[a] n=2

[b,c]Values with unlike subscripts have a tendency to differ ($P = 0.11$)

Table 3. Effects of energy supplementation on percentage change in backfat and intramuscular fat of stocker steers grazing ryegrass pastures

Item	Negative Control	High Roughage	High Starch	SEM[a]	*P*-value
Backfat, % Change					
d 0 to 56	-3.18[b]	11.76[c]	12.86[c]	3.28	0.07
d 57 to 112	16.20[b]	22.42[b]	33.72[c]	3.42	0.07
d 0 to 112	10.8[b]	35.99[c]	45.63[c]	7.84	0.09
IMF, % Change					
d 0 to 56	1.67	-0.64	3.01	2.79	0.66
d 57 to 112	-3.77	-0.80	-1.73	1.83	0.56
d 0 to 112	-3.16	-1.77	0.20	1.15	0.25

[a]n=2

[b,c]Values with unlike superscripts differ ($P < 0.10$)

EVALUATION OF FEED EFFICIENCY TRAITS IN GROWING BULLS: I. RELATIONSHIPS WITH GROWTH AND ULTRASOUND CARCASS MEASUREMENTS

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Summary

Angus (n = 214) and Brangus (n = 26) bulls from two performance tests were used to characterize feed efficiency traits and examine phenotypic correlations with performance and ultrasound measurements. Bulls were fed a corn-silage-based diet (ME = 1.26 Mcal/lb) and feed intakes measured using a GrowSafe® feeding system. Four feed efficiency traits were computed based on feed intake and growth traits: net feed intake (**NFI**), residual gain efficiency (**RGE**), partial efficiency of growth (**PEG**) and feed conversion ratio (**FCR**). Growth rate was strongly correlated with RGE (0.74) and FCR (-0.67), weakly correlated with PEG (0.29), but was not correlated with NFI. Feed intake was strongly correlated with NFI (0.58) and PEG (-0.49), such that favorable NFI and PEG phenotypes consumed less feed. All feed efficiency traits were strongly correlated to each other (correlations > ± 0.50). Bulls with low NFI (< 0.50 SD) consumed 15% less feed than bulls with high NFI (> 0.50 SD) even though ADG and BW were similar. Bulls with low NFI also had significantly favorable feed efficiencies as measured by RGE (0.34 vs -0.28 ± 0.05 lb/d), PEG (0.36 vs 0.26 ± 0.01 ADG/DMI for growth) and FCR (5.39 vs 6.44 ± 0.11 DMI/ADG) compared to bulls with high NFI. Final 12th rib fat thickness was weakly correlated with NFI and PEG, but not RGE and FCR. Final ribeye area and intramuscular fat were not correlated with either of the feed efficiency traits. Compared to other feed efficiency traits evaluated in this study, NFI was the least influenced by growth, compositional traits, and initial age and BW of bulls at the start of the test.

Introduction

The cost of feeding cattle is the largest variable expense associated with producing beef. Substantial improvements in profitability could be realized if feed inputs were reduced without compromising output (growth, carcass) traits. Feed conversion ratio has been the traditional trait used to measure feed efficiency, but FCR has been shown to be negatively correlated genetically with growth traits. Selection against FCR would likely increase mature cow size and result in higher feed requirements for the cow herd (Herd and Bishop, 2000). Net feed intake has been suggested as an alternative trait for use in selection programs that seek to improve feed efficiency, due to the fact that NFI is not genetically linked to growth traits. Net feed intake is calculated as actual feed consumed minus an animal's expected feed intake based on its ADG and BW. Thus, favorable NFI phenotypes are negative, as cattle that eat less than expected for their ADG and BW will be more efficient. Several recent studies have demonstrated that NFI is moderately heritable (0.3 to 0.4) and genetically independent of ADG and BW (Arthur et al., 2001b; Schenkel et al., 2004).

A number of studies have reported positive correlations between NFI and carcass fat (Arthur et al., 2001a; Fox et al., 2004; Nkrumah et al., 2004; Schenkel et. al., 2004). While the magnitude of these correlations has been small (range from 0.14 to 0.22), the results suggest that calves with low NFI (more efficient) will be slightly leaner than calves with high NFI (less efficient). In addition to FCR and NFI, a number of other feed efficiency traits have been evaluated in beef cattle, including partial efficiency of growth (Arthur et al., 2001a) and residual gain efficiency (Koch et al., 1963). Few studies have been conducted to fully evaluate these feed efficiency traits in the same set of cattle. Therefore, the objectives of this study were to characterize these feed efficiency traits, and to examine the interrelationships with growth performance and ultrasound measurements of carcass composition and marbling in growing bulls.

Experimental Procedures

Data from two postweaning performance tests conducted at the Beef Development Center in Millican, TX with Angus and Brangus purebred bulls were used in this study. The first test included 99 Angus and 16 Brangus bulls and was initiated in June 2004, whereas, the second test included 115 Angus and 10 Brangus bulls and was initiated in November 2004. Bulls were fitted with

RFID tags and adapted to the test diet and feeding system for 28 d before the start of the tests. The test diet (1.26 Mcal ME/lb DM) consisted of 49% cracked corn, 38.5% corn silage, 5% cottonseed meal, 3% molasses and 4.5% supplement and was fed ad libitum twice daily.

To measure feed intake, bulls were placed into one of two pens each equipped with nine feed bunk units (GrowSafe Systems Ltd., Airdrie, AB). GrowSafe Data Acquisition software was used to record feed intake data for 84 and 91 d during test 1 and 2, respectively. Daily feed intake was computed using GrowSafe Feed Intake Analysis software. Bulls were weighed at 14-d intervals, and ultrasound measurements of 12th rib fat thickness (**BF**), ribeye area (**REA**) and intramuscular fat (**IMF**) obtained at the start and end of each test. Hip height and scrotal circumference were measured at the end of each test.

Growth rates of individual bulls were modeled by linear regression of BW against day on test using the regression procedure of SAS (SAS Inst., Cary, NC). These regression coefficients were used to compute ADG, and initial and final BW. Metabolic body weight (**MBW**) was computed as mid-test BW raised to the 0.75 power. Moisture analyses of feed ingredient samples were used to determine DMI from feed intake data.

Four different feed efficiency measurements were derived from growth and DMI traits for each bull. Feed conversion ratio (**FCR**) was computed as the ratio of daily DMI to ADG. Partial efficiency of growth (**PEG**) was computed as the ratio of ADG to DMI available for growth. Dry matter intake for growth was computed as actual DMI minus expected DMI for maintenance. The expected DMI to meet maintenance requirements was calculated as 0.077*MBW ÷ NEm concentrations of the test diets.

Net feed intake (**NFI**) was computed as the difference between actual DMI and expected DMI to meet growth and maintenance energy requirements. For individual bulls, expected DMI was derived from a phenotypic regression model of actual DMI on ADG and MBW (Arthur et al., 2001a). This model was fitted separately for each test using the Proc GLM procedure of SAS (R^2 = 0.68 and 0.65 for test 1 and 2, respectively). Within test, NFI was calculated as actual DMI minus expected DMI. Residual gain efficiency (**RGE**) was computed as the deviation between actual ADG and expected ADG from MBW and DMI as described by Koch et al. (1963). A separate regression model of ADG on MBW and DMI was fitted for each test (R^2 = 0.47 and 0.43 for test 1 and 2, respectively), and RGE for individual bulls computed as actual ADG minus expected ADG. Bulls with positive RGE are more efficient than bulls with negative RGE as they gain more than expected based on their BW and DMI.

To further characterize NFI, bulls were separated into low, medium and high NFI groups that were < 0.5 SD, ± 0.5 SD, and > 0.5 SD, respectively, from the mean NFI of 0.0 ± 1.37 and 0.0 ± 1.73 lb/d for test 1 and 2, respectively. Least squares procedures (PROC GLM of SAS) were used to examine effects of NFI group on performance, feed efficiency, ultrasound and scrotal circumference traits. The statistical model included the fixed effects of NFI group, breed, test and all significant (*P* > 0.10) interaction terms. The effects of breed on traits examined in this study will not be presented due to limited number of Brangus bulls in the two tests. Phenotypic correlations among traits were determined using PROC CORR of SAS with the partial correlation option used to adjust for fixed effects of breed and test.

Results and Discussion

Summary statistics are presented in Table 1 for the two performance tests. The bulls in test 1 were approximately one month younger, but had similar initial BW compared to bulls in test 2. Numerically, bulls in test 2 had 20% higher ADG and consumed 18% more feed than bulls in test 1. These differences may have been due to divergent environmental conditions (77 vs 50 °F mean temperature during test 1 and 2, respectively) and(or) genetic makeup of bulls between the two tests. The phenotypic SD for feed efficiency traits in Table 1 were similar to those reported in previous studies with growing bulls (Arthur et al., 2001a,b; Fox et al., 2004; Schenkel et al., 2004).

Relationships between feed efficiency and growth traits. Phenotypic correlations among growth and feed efficiency traits are presented in Table 2. Dry matter intake was strongly correlated with ADG and MBW. These correlations are within the range of phenotypic and genetic correlations previously reported in growing calves (Arthur et al., 2001a,b; Schenkel et al., 2004; Fox et al., 2004; Nkrumah et al., 2004). Strong phenotypic correlations (> 0.50) were found among the four feed efficiency traits measured in this study. Net feed intake was strongly correlated with DMI, but not with ADG or MBW, as the use of linear regression to compute this trait forces NFI to be phenotypically independent of its component traits. Bulls with low NFI (< 0.5 SD) consumed 15% less feed than bulls with high NFI (> 0.5 SD) even though there were no differences in ADG and BW between low and high NFI bulls (Table 4). In general, NFI has been shown to be genetically independent of growth and body size (Arthur et al., 2001a,b; Schenkel et al., 2004) in growing bulls.

Net feed intake was strongly correlated (-0.86) with PEG in a favorable direction. Bulls with low NFI had a higher PEG than bulls with high NFI (0.36 vs 0.26 ± 0.01 ADG/DMI for growth). Corresponding phenotypic correlations reported by Arthur et al. (2001b) and Nkrumah et al. (2004) were -0.65 and -0.89 in growing bulls and steers, respectively. Arthur et al. (2001b) reported that the genetic correlation between NFI and PEG was -0.94 suggesting that these two feed efficiency traits are highly related. This is not surprising given that both of these traits attempt to partition variation in feed intake into maintenance and growth components. In this study, PEG was highly correlated with DMI (-0.49), but weakly correlated with ADG (0.29) and MBW (-0.22). Thus, selection responses to PEG will not be as independent of changes in growth and body size compared to NFI. Arthur et al. (2001b) and Nkrumah et al. (2004) reported similar phenotypic correlations between PEG and these production traits.

In contrast to the lack of a correlation between NFI and ADG, and a weak correlation between PEG and ADG, strong phenotypic correlations existed between ADG and FCR (-0.67) and RGE (0.74). Strong genetic correlations between FCR and ADG (> -0.50) have been reported in recent studies (Arthur et al., 2001a,b; Schenkel et al., 2004). The strong correlations between ADG and FCR and RGE suggest that using these traits in selection programs to improve feed efficiency will lead to indirect increases in growth rate and cow mature size, and thus increases in feed requirements for cow maintenance (Herd and Bishop, 2000). However, NFI was strongly correlated with FCR (0.53) and RGE (-0.60), such that bulls with low NFI were more ($P < 0.01$) efficient as measured by RGE (0.34 vs -0.28 ± 0.05 lb/d) and FCR (5.4 vs 6.4 ± 0.11 DMI/ADG) than bulls with high NFI.

Final hip height was correlated with ADG and DMI, but not any of the feed efficiency traits, which is in agreement with Nkrumah et al. (2004). Scrotal circumference was correlated with ADG and DMI (Table 3), which is similar to the results of Schenkel et al. (2004). Final scrotal circumference was not correlated with NFI, PEG or FCR, but was weakly correlated with RGE (0.15). Likewise, other studies with growing bulls have reported that NFI was not correlated with scrotal circumference (Arthur et al., 2001a; Fox et al., 2004; Schenkel et al., 2004).

Relationships between feed efficiency and carcass traits. Initial REA was correlated with DMI but not ADG, while final REA was correlated with both ADG and DMI (Table 3). Initial REA was correlated with NFI, PEG and FCR, and tended ($P < 0.10$) to be correlated with RGE. However, final REA was not correlated with any of the feed efficiency traits. In growing bulls, Arthur et al. (2001a), Fox et al. (2004) and Schenkel et al. (2004) also found that final ultrasound measurements of REA were not genetically correlated with NFI.

Initial and final ultrasound estimates of IMF were not correlated with ADG, DMI or any of the feed efficiency traits measured in this study (Table 3). Schenkel et al. (2004) also found that IMF was not correlated to NFI in growing bulls. However, in Bonsmara bulls, Fox et al. (2004) found that ultrasound estimates of IMF tended to be positively correlated with NFI, suggesting that IMF may be unfavorably related to NFI. Initial BF was not correlated with ADG, DMI or any of the feed efficiency traits (Table 3). Final BF was positively correlated with ADG and DMI, which is in agreement with Schenkel et al. (2004). Final BF was weakly correlated with NFI and PEG, but not with FCR or RGE. The correlation between NFI and final BF in this study (0.16) is within the range of correlations (0.14 to 0.20) reported in recent studies with growing steers and bulls (Arthur et al., 2001a; Carstens et al., 2002; Fox et al., 2004; Nkrumah et al., 2004; Schenkel et. al., 2004). In this study, bulls with low NFI tended ($P < 0.10$) to have less final BF (0.23 vs 0.26 in) compared to bulls with high NFI (Table 4). Likewise, Fox et al. (2004) reported that bulls with low NFI tended ($P < 0.10$) to have less final BF than bulls with high NFI (0.21 vs 0.23 in, respectively). Collectively, these results demonstrate calves with low NFI (more efficient) are slightly leaner compared to calves with high NFI, however, the magnitude of this change in composition of growth is small. Richardson and Herd (2004) have estimated that differences in composition accounted for approximately 5-10% of the variation in NFI.

Effects of initial age and BW on feed efficiency traits. Age of bulls at the start of the test was phenotypically correlated with DMI, RGE, PEG and FCR, but not NFI (Table 3). Likewise, initial BW was correlated with DMI (0.55), RGE (-0.20), PEG (-0.30) and FCR (0.38), but not NFI. These phenotypic correlations suggest that bulls that were younger and lighter at the start of the test were more efficient as measured by RGE, PEG or FCR. In contrast, differences in age and BW at the start of the test were not correlated with NFI. Nkrumah et al. (2004) also found that initial age and BW were correlated with other feed efficiency traits, but not NFI. These results suggest that pretest management practices which influence age and BW of bulls at the start of a performance test will have less influence on NFI than other feed efficiency traits (Schenkel et al., 2004; Herd and Bishop, 2000).

Implications

Recent advances in RFID-based technologies have facilitated the development of feeding systems to more cost-effectively measure feed intake in cattle (GrowSafe Systems Ltd.). Commercialization of this technology will enable seedstock producers to implement selection programs that seek to improve feed efficiency in cattle. The phenotypic correlations reported in this study indicate that, compared to the other feed efficiency traits evaluated in this study, selection against NFI should lead to improvements in feed efficiency with minimal responses in growth and carcass composition traits. Moreover, NFI was the feed efficiency trait least influenced by variation in initial age and BW of bulls, suggesting the NFI might be a more robust feed efficiency trait for use in centralized performance tests for growing bulls.

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Table 1. Summary statistics (mean ± SD) of traits measured during the two postweaning performance tests with Angus and Brangus bulls

Trait	Test 1	Test 2
Age at start of test, d	261.2 ± 25.1	289.6 ± 33.5
Initial BW, lb	812.8 ± 95.7	812.0 ± 73.9
Final BW, lb	1078.9 ± 106.5	1158.7 ± 129.4
ADG, lb/d	3.17 ± .57	3.81 ± .62
DMI, lb/d	18.76 ± 2.43	22.20 ± 2.98
Net feed intake, lb/d	0.00 ± 1.37	0.00 ± 1.76
Residual gain efficiency, lb/d	0.00 ± .42	0.00 ± .49
Partial efficiency of growth[a]	0.32 ± .05	0.29 ± .05
Feed conversion ratio, DMI/ADG	6.05 ± .96	5.91 ± .79
Final back fat, in	0.26 ± .07	0.28 ± .08
Final ribeye area, in^2	11.58 ± 1.42	12.25 ± 1.91
Final intramuscular fat, %	2.16 ± .68	3.22 ± .65
Final hip height, in	49.7 ± 1.83	50.4 ± 1.71
Final scrotal circumference, cm	35.0 ± 2.61	37.2 ± 3.03

[a]ADG/DMI for growth

Table 2. Phenotypic correlations[a] among growth, feed intake and feed efficiency traits in growing bulls

Trait[b]	ADG	DMI	NFI	RGE	PEG	FCR
MBW	**0.34**	**0.68**	-0.01	-0.00	**-0.22**	**0.19**
ADG		**0.64**	-0.01	**0.74**	**0.29**	**-0.67**
DMI			**0.58**	-0.01	**-0.49**	0.10
NFI				**-0.60**	**-0.86**	**0.53**
RGE					**0.82**	**-0.93**
PEG						**-0.83**

[a]Correlations in bold are different from zero at $P < 0.05$.
[b]NFI = net feed intake; RGE = residual gain efficiency; PEG = partial efficiency of growth; FCR = feed conversion ratio; MBW = mid-test metabolic body weight.

Table 3. Phenotypic correlations[a] between feed efficiency traits and ultrasound measurements and scrotal circumference in growing bulls

Trait[b]	ADG	DMI	NFI	RGE	PEG	FCR
Age at start of test	-0.03	**0.22**	-0.02	**-0.17**	**-0.17**	**0.25**
Final hip height	**0.27**	**0.38**	-0.09	0.10	-0.03	0.03
Final scrotal circumference	**0.26**	**0.27**	-0.04	**0.15**	0.03	-0.07
Initial 12th rib fat thickness	-0.06	0.04	-0.08	-0.07	-0.04	0.09
Final 12th rib fat thickness	**0.29**	**0.47**	**0.16**	0.03	**-0.17**	0.03
Initial ribeye area	0.00	**0.25**	**-0.13**	-0.12	**-0.14**	**0.23**
Final ribeye area	**0.32**	**0.49**	0.02	0.07	-0.12	0.05
Initial intramuscular fat	-0.02	0.03	-0.04	-0.01	-0.01	0.04
Final intramuscular fat	0.05	0.12	0.03	-0.02	-0.08	0.05

[a]Correlations in bold are different from zero at $P < 0.05$.
[b]NFI = net feed intake; RGE = residual gain efficiency; PEG = partial efficiency of growth; FCR = feed conversion ratio.

Table 4. Characterization of performance, ultrasound composition, and feeding efficiency traits in growing bulls with low, medium and high net feed intake (NFI)[a]

Trait	Low NFI	Med NFI	High NFI	SE	P-value
Number of bulls	79	88	73		
Growth Traits					
Initial BW, lb	803.3	798.0	794.4	14.3	.86
Final BW, lb	1114.2	1108.5	1102.4	16.7	.83
Daily gain, lb/d	3.55	3.55	3.51	0.08	.92
Final scrotal circumference, cm	36.2	35.6	36.0	0.4	.38
Feed Efficiency Traits					
Dry matter intake, lb/d	18.79^{x}	20.52^{y}	22.12^{z}	0.33	.0001
Net feed intake, lb/d	-1.73^{x}	0.07^{y}	1.82^{z}	0.10	.0001
Residual gain efficiency, lb/d	0.34^{x}	0.02^{y}	-0.28^{z}	0.05	.0001
Partial efficiency of growth[b]	0.36^{x}	0.30^{y}	0.26^{z}	0.01	.0001
Feed conversion ratio, DMI/ADG	5.39^{x}	5.84^{y}	6.44^{z}	0.11	.0001
Initial Ultrasound Traits					
12th rib fat thickness, in	0.12	0.14	0.12	0.01	.52
Ribeye area, in^2	8.34	8.28	7.94	0.18	.12
Intramuscular fat, %	2.52	2.50	2.48	0.09	.92
Final Ultrasound Traits					
12th rib fat thickness, in	0.23	0.26	0.26	0.01	.07
Ribeye area, in^2	11.85	11.85	11.93	0.24	.94
Intramuscular fat, %	2.81	2.86	2.86	0.09	.85

[a]Bulls with low, medium and high NFI were < 0.50, ± 0.50 and > 0.50 SD from the mean NFI, respectively. (NFI SD were 1.76 and 1.73 lb/d for test 1 and 2, respectively).
[b]ADG/DMI for growth.
[xyz]Means with different superscripts in the same row differ ($P < 0.05$).

EVALUATION OF FEED EFFICIENCY TRAITS IN GROWING BULLS: II. RELATIONSHIPS WITH FEEDING BEHAVIOR TRAITS

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Summary

Angus (n = 214) and Brangus (n = 26) bulls from two performance tests were used to examine the phenotypic correlations between feeding behavior and feed efficiency traits. Bulls were adapted to a corn silage based diet (ME = 1.26 Mcal/lb) for 28 d prior to the performance tests. Individual feeding behavior traits (28-d pre-test and test periods) and feed intake (test period only) were measured using a GrowSafe® feeding system. Four feed efficiency traits were computed from growth and feed intake data: net feed intake (**NFI**), residual gain efficiency (**RGE**), partial efficiency of growth (**PEG**), and feed conversion ratio (**FCR**). Meal frequency and duration of bunk attendance during the test period were not correlated with ADG. Moreover, meal frequency was not correlated with dry matter intake (**DMI**), but bunk attendance duration was weakly correlated with DMI (0.14). However, eating rate was moderately correlated with both ADG (0.31) and DMI (0.46), demonstrating that eating rate is more related to ADG and DMI than meal frequency or bunk attendance. Duration of bunk attendance was correlated with NFI (0.43) and PEG (-0.22), such that favorable phenotypes spent less time at the bunk. Bunk attendance during the test was not correlated with RGE or FCR. Meal frequency was weakly correlated with NFI (0.19), but not the other feed efficiency traits. Bulls with low NFI spent significantly less time at the feed bunk and ate fewer meals than bulls with high NFI. Bunk attendance and meal frequency measured during the 28-d pre-test period were strongly correlated with the same traits measured during the performance test. Pre-test bunk attendance and meal frequency were correlated with NFI, but pre-test bunk attendance was also correlated with ADG and DMI. These results suggest that feeding behavior traits may be indicator traits of NFI that could be used for early identification of bulls with favorable phenotypes for NFI.

Introduction

Considerable genetic variation is known to exist in the efficiency with which cattle utilize feed resources, thus providing opportunities to improve the efficiency of beef production systems through selection. However, the traditional measure of feed efficiency, feed conversion ratio (**FCR**), is inversely related to growth and mature size, such that selection for improved FCR will increase cow size and feed input requirements for the cow herd. Net feed intake (**NFI**) is an alternative feed efficiency trait that can facilitate selection of cattle that consume fewer feed inputs with minimal corresponding affects on growth traits or cow mature size (Arthur et al., 2001; Schenkel et al., 2004). However, the expense of measuring feed intake in cattle has been a major obstacle to implementation of breeding programs to improve genetic merit for NFI. One method of reducing the expense of measuring this trait is the use of indicator traits. Indicator traits could be used to identify bulls with favorable NFI phenotypes early in the testing period, thereby reducing the number of bulls that would need to complete the full NFI evaluation protocol.

Recent advances in RFID-based technologies have led to the development of feeding systems (GrowSafe Systems Ltd.) that are capable of measuring feed intake and feeding behavior traits in commercial bull test facilities. Feeding behavior traits were found to be related to feed intake, growth and FCR in calves (Schwartzkopf-Genswein et al., 2002, 2004; Streeter et al., 1999). Richardson and Herd (2004) reported that steer progeny from parents selected for low NFI (one generation) tended to spend less time eating early in the testing period than steers from high NFI parents. Thus, feeding behavior traits, which are less expensive to measure than feed intake, may have potential to be used as indicator traits of NFI. Moreover, Streeter et al. (1999) suggested that feeding behavior traits may be useful in segmenting feeder calves into expected performance outcome groups. The objectives of this study were to examine the relationships between feeding behavior and feed efficiency traits in growing bulls, and to determine if feeding behavior traits measured during the pre-test adaptation period were related to feeding efficiency traits measured during the performance test.

Experimental Procedures

Angus (n = 214) and Brangus (n = 26) bulls from two performance tests conducted at the Beef Development Center in Millican, TX were used in this study. The bulls and test protocols are more fully described in a companion paper (Lancaster et al., 2005). Briefly, for each performance test, bulls were fitted with RFID tags and adapted to a corn-silage based diet for 28 days. To measure feed intake and feeding behavior, bulls were placed into one of two pens each equipped with nine feed bunk units (GrowSafe Systems Ltd., Airdrie, AB). GrowSafe Data Acquisition software was used to record feed intake and feeding behavior data for 84 and 91 d during test 1 and 2, respectively. Feeding behavior traits were also measured during the 28-d pre-test adaptation periods. Daily feed intake and feeding behavior traits were computed using GrowSafe Feed Intake Analysis software, and dry matter intake (**DMI**) determined from moisture analysis of feed ingredient samples. Four feed efficiency traits were computed based on feed intake and growth traits: NFI, residual gain efficiency (**RGE**), partial efficiency of growth (**PEG**) and FCR as described by Lancaster et al. (2005).

The GrowSafe feeding system can identify and record bunk attendance of multiple animals in the same pen simultaneously. The reader panel records the presence of each RFID tag every 6 seconds for as long as the RFID tags are within the read range of the antennas that are imbedded in the feed bunks. Meal frequency was defined as the number of independent visits to the feed bunk each day that are separated by at least a 5-minute absence (i.e. a return to the feed bunk within five minutes of the previous departure was considered to be the same meal). Duration of bunk attendance was computed as the sum of time intervals corresponding to each meal during the day. Eating rate was computed as daily DMI divided by duration of bunk attendance.

To examine the relationships between feeding behavior and feed efficiency traits partial correlation coefficients were determined using PROC CORR of SAS with the partial correlation option used to adjust for fixed effects of breed and test. To further evaluate NFI, bulls were separated into low, medium and high NFI groups that were < 0.5 SD, ± 0.5 SD, and > 0.5 SD, respectively, from the mean NFI of 0.0 ± 1.37 and 0.0 ± 1.76 lb/d for test 1 and 2, respectively. Least squares procedures (PROC GLM of SAS) were used to examine effects of NFI group on feeding behavior traits. The statistical model included the fixed effects of NFI group, breed, test and all significant ($P < 0.10$) interaction terms.

Results and Discussion

Summary statistics of feed efficiency traits measured during the performance tests, and feeding behavior traits measured during the 28-d pre-test and performance-test periods are presented in Table 1. The bulls spent less time at the feed bunk during the first compared to the second performance test. This may have been related to differences in environmental conditions between the two tests; average temperatures were 77 and 50 °F for test 1 and 2, respectively. Streeter et al. (1999) found that bunk attendance of growing calves decreased 8.5 min/day for each 10 °F increase in ambient temperature. The durations of bunk attendance measured in the two performance tests were within the range of those reported for calves fed high-grain diets during a 54-d study (131 min/d; Schwartzkopf-Genswein et al., 2002) and during a 153-d study (105 min/d; Schwartzkopf-Genswein et al., 2004). For the first test, the duration of bunk attendance during the pre-test period was similar to bunk attendance during the performance-test period, whereas, in the second test bunk attendance during the pre-test period was slightly longer than during the performance-test period. Meal frequencies were similar during the pre-test and performance-test periods in both tests, but were substantially lower then meal frequencies of 9 to 17 visits per day reported by Schwartzkopf-Genswein et al. (2002, 2004).

Feeding behavior traits during the performance test. Phenotypic correlations among growth, feed efficiency and feeding behavior traits are presented in Table 2. Duration of bunk attendance during the test was not correlated with ADG, but was weakly correlated with DMI (0.14). Likewise, Cammack et al. (2005) found that bunk attendance was not correlated with ADG (0.09) or DMI (0.09) in growing rams. In contrast, Schwartzkopf-Genswein et al. (2002) found that bunk attendance was weakly correlated with ADG (0.14), and moderately correlated with DMI (0.38). Meal frequency during the test was not correlated with ADG or DMI. Schwartzkopf-Genswein et al. (2002) also found that meal frequency was not correlated to either ADG or DMI. However, positive correlations between meal frequency and DMI (0.14) and ADG (0.22) were found in growing lambs (Cammack et al., 2005). Eating rate during the test was moderately correlated with both ADG (0.31) and DMI (0.46), suggesting that eating rate was more related to ADG and DMI than bunk attendance or meal frequency. As DMI is strongly correlated with ADG (0.64; Lancaster et al., 2005), these results imply that faster gaining bulls consume more feed per day and consume feed at a faster rate.

Duration of bunk attendance during the test was moderately correlated phenotypically with NFI (0.43), and weakly correlated with PEG (-0.22), such that favorable phenotypes spent less time at the feed bunk. Bunk attendance was not correlated phenotypically with RGE or FCR. Cammack et al. (2005) reported positive phenotypic (0.10) and genetic (0.22) correlations between bunk attendance and NFI in growing rams. Bulls with low NFI spent less ($P < 0.05$) time at the feed bunk during the test than bulls with high NFI (110.9 vs 131.3 ± 2.9 min/d, respectively; Figure 1). Meal frequency during the test was not correlated with RGE, PEG or FCR, but was weakly correlated with NFI (0.19). Bulls with low NFI consumed fewer ($P < 0.05$) meals per day (4.8 vs 5.1 ± .08 visits/d) than bulls with high NFI. In growing ram lambs, Cammack et al. (2005) found small, but positive phenotypic (0.10) and genetic (0.20) correlations between meal frequency and NFI. Eating rate during the test was not correlated with any of the feed efficiency traits measured in this study. The energetic costs of eating, ruminating and activity associated with the observed differences in bunk attendance and meal frequency likely contributed to a small, but significant portion of the difference in feed energy consumed by low vs high NFI bulls.

Pre-test feeding behavior traits. As bunk attendance and meal frequency measured during the test were more strongly related to NFI than ADG or DMI, these feeding behavior traits may be considered as potential indicator traits of NFI. Duration of bunk attendance and meal frequency during the pre-test period were strongly correlated with bunk attendance (0.68) and meal frequency (0.63) during the performance test.

Pre-test bunk attendance and meal frequency were also positively correlated with NFI (Table 2), suggesting that these feeding behavior traits may be predictive of NFI phenotypes. However, pre-test bunk attendance was also correlated with ADG (0.24) and DMI (0.31) during the test. Pre-test bunk attendance was correlated to PEG, but not RGE or FCR. As with meal frequency measured during the test, pre-test meal frequency was not significantly correlated with ADG or DMI.

Implications

Bunk attendance and meal frequency measured during the performance test were related to NFI, but not ADG suggesting that these feeding behavior traits may be useful as indicator traits for NFI. Bulls identified as having low NFI in this study spent less time at the feed bunk and consumed fewer meals per day than bulls with high NFI, indicating that the energetic costs associated with feeding activity may account for some of the biological variation in NFI. Given the potential value of NFI to improve feed efficiency of beef production systems, additional research is warranted to further evaluate the use of feeding behavior measurements as indicator traits of NFI.

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Table 1. Summary statistics (mean ± SD) for feeding behavior traits measured before and during the two postweaning performance tests with Angus and Brangus bulls

Trait	Test 1	Test 2
Feed efficiency and growth traits		
Daily gain, lb/d	3.17 ± .57	3.81 ± .62
DMI, lb/d	18.76 ± 2.43	22.20 ± 2.98
Net feed intake, lb/d	0.00 ± 1.37	0.00 ± 1.76
Residual gain efficiency, lb/d	0.00 ± .42	0.00 ± .49
Partial efficiency of growth[a]	0.32 ± .05	0.29 ± .05
Feed conversion ratio, DMI/ADG	6.05 ± .96	5.91 ± .79
Pre-test feeding behavior measurements		
Bunk attendance, minutes/day	108.1 ± 26.6	137.4 ± 25.9
Meal frequency, visits/day	5.30 ± .88	5.60 ± .84
Performance-test feeding behavior measurements		
Bunk attendance, minutes/day	109.4 ± 24.1	121.9 ± 20.9
Meal frequency, visits/day	5.03 ± .66	4.91 ± .55
Eating rate, g DMI/minute	80.8 ± 17.1	84.9 ± 17.9

[a]ADG/DMI for growth.

Table 2. Phenotypic correlations[a] between feeding behavior measurements and growth, feed intake and feed efficiency traits in growing bulls

Trait	ADG	DMI	NFI	RGE	PEG	FCR
Pre-test feeding behavior measurements						
Bunk attendance	**0.24**	**0.31**	**0.36**	-0.02	**-0.22**	-0.02
Meal frequency	0.11	0.12	**0.25**	-0.02	**-0.13**	-0.02
Performance-test feeding behavior measurements						
Bunk attendance	0.08	**0.14**	**0.43**	-0.12	**-0.22**	0.00
Meal frequency	0.06	0.00	**0.19**	0.01	-0.04	-0.08
Eating rate	**0.31**	**0.46**	-0.04	0.10	-0.09	0.05

[a]Correlations in bold are significantly different from zero, $P < 0.05$.

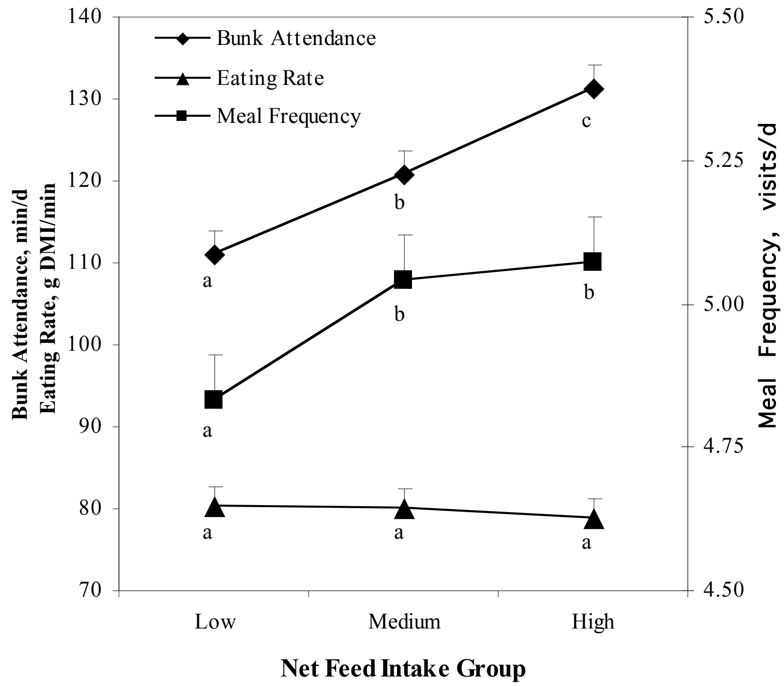

Figure 1. Feeding behavior measurements during the test in bulls with low, medium and high net feed intake. [abc]Means without a common superscript differ at $P < 0.05$.

RATE OF GAIN AND EFFICIENCY OF GROWTH IN STEER CALVES THAT HAVE BEEN IMPLANTED AND LIMIT-FED INDIVIDUALLY OR IN GROUPS

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Summary

Two trials were conducted to compare weight gain and feed efficiency of calves in response to implants during an 85-day limit feeding growing program. Four implant treatments were evaluated: Nonimplanted controls, Synovex-S®, Finaplix-S® and Revalor-S®. Calves were fed to gain 2.2 lb per day. Implants affected weight gain in group-fed steers but not in individually-fed steers ($P < 0.05$). Revalor-S® produced a greater average daily gain than Finaplix-S® or non-implanted control. Average daily gain for the steers receiving Revalor-S® also tended ($P = 0.085$) to be greater than that of Synovex-S®. Feed to gain ratio was inversely proportional to rate of weight gain in all treatment groups but this difference was not statistically significant. These data seem to indicate that the superior gains for Revalor-S® in group-fed cattle may have been due to an increase in feed consumption rather than increased efficiency of growth.

Introduction

Growing programs utilizing limited intake of high concentrate diets have become more common over the past ten years. Confinement growing programs have typically utilized roughage based diets with some added grains. These programs allow for free choice feed consumption of high roughage diets. In contrast, limit feeding programs utilize high grain, energy dense diets. Limit feeding has been shown to increase efficiency of gain both in comparison to full feeding and to high roughage diets (Wertz et al., 2001; Schoonmaker et al., 2003). Very little is known about the effect of implants when cattle are limit fed. Estrogenic implants increase weight gain and feed efficiency by increasing feed intake (Gerken et al., 1995; Hardt et al., 1995). Trenbolone acetate (TBA) has neutral to negative effects on feed intake (Johnson et al., 1996) but weight gain and efficiency of growth are improved (Guiroy et al., 2002; Kerth et al., 2003).

Experimental Procedures

Management of Cattle. Four implant treatments were evaluated: Nonimplanted controls, estrogen implant (Synovex-S®), trenbolone acetate implant (Finaplix-S®), and trenbolone acetate + estrogen combination implant (Revalor-S®). All cattle in both trials were managed under limit feeding conditions during an 85-day growing period. Average daily feed intake was formulated to produce 2.2 lb daily weight gain (NRC, 1996). Composition of the diet fed in both trials is shown in Table 1. Daily feed amount in both trials was based upon the average projected feeding weight for the 85-day trial period (calculated for the average of a pen in Trial 1 and for each individual steer in Trial 2).

Trial 1. Sixty-four steer calves of known breed type and age (335 ± 23 days) were allocated to the four implant treatments described previously. Breed types included Brangus x Braford, Hereford x Brahman and Simmental x Angus crosses. Cattle were blocked by breed type and then sorted into four feeding groups of 16 head based on weight. Within each group, four head were randomly assigned to each implant treatment. Steers in this trial were fed in groups and therefore no measure of feed efficiency was available. Final weight and weight gain were the only measures of performance obtained in Trial 1. Cattle were weighed at 28 day intervals during the trial.

Trial 2. Sixty Brangus steer calves of known age (346 ± 15 days) were allocated to the four implant treatments. The cattle were sorted into 15 groups of four head based on weight. Within each group, one steer was randomly assigned to each implant treatment. Each of the 15 groups was confined in a partially covered pen with a concrete floor that contained four Calan® gates to facilitate individual feeding. Steers were adapted to the diet and trained to use the Calan gates during the two-week period immediately prior to beginning the study. Weight gain, daily feed intake and feed efficiency were determined for each steer. Cattle were fed once daily and weighed at 28-day intervals during the trial. Refused feed was removed from feeders and weighed back each time the steers were weighed.

Statistical Analyses. Data were analyzed using SAS statistical software (SAS, 1999). In Trial 1, growth data were subjected to an analysis of variance with each steer being an experimental unit and implants as treatments. The model was composed of breed type, pen and treatment. Least squares means were separated using preplanned orthogonal contrasts when model treatment P-value < 0.10. A probability of P < 0.05 was accepted as significant for determination of treatment effect. In Trial 2, growth data, feed intake and feed efficiency were analyzed by the GLM procedure of ANOVA with each steer being treated as an experimental unit and implants as treatments. The model was composed of pen and treatment.

Results and Discussion

Data for initial weight, final weight and average daily gain for steers limit fed in groups are given in Table 2. By design, there was no difference in initial weight at the beginning of the trial. Average daily gain for all treatment groups was similar to the target gain of 2.2 lb per head per day. An implant treatment effect was detected (P < 0.05). Preplanned orthogonal contrasts indicated that the combination of estrogen and androgen (Revalor-S®) produced a greater average daily gain than androgen-only or non-implanted control. Average daily gain for the steers receiving the combination implant also tended (P = 0.085) to be greater than that of estrogen-only.

Data for initial weight, final weight, average daily gain, total feed intake and feed to gain ratio for steers that were limit fed individually are shown in Table 3. Under these conditions, where difference in feed bunk behavior was eliminated, no treatment effect was detected for either rate or efficiency of weight gain. In Trial 2, feed to gain ratio was inversely proportional to rate of gain for all treatment groups, but large within treatment variation precluded detection of a significant difference among treatments.

The observation that the combination implant (Revalor-S®) produced a greater average daily gain than androgen-only or non-implanted control is in agreement with the review article on implants reported by Guiroy et al. (2002). They summarized the results of 13 investigations involving almost 14,000 head of cattle. The observation in the present study that the combination implant tended to produce greater gains than the estrogen-only implant disagreed with the findings of Gerken et al. (1995). Gerken and coworkers imposed the same implant treatments as in the present study. However, they had a novel experimental model in that they used genetically identical cloned steers. In the Gerken study, all three implant treatments produced increased gains as compared to non-implanted controls, but no difference was detected among the implant treatments. The intent of the authors in the present study was to investigate the effect of implants on rate and efficiency of gain under limit feeding conditions. It should be noted, however, that in Trial 1, steers were group-fed in pens containing steers of all treatment groups and intake of individual steers could not be controlled. Total feed for a pen was estimated to produce an average of 2.2 lb per head per day but timid steers may have consumed less feed than steers with more aggressive feeding behavior. Thus, efficiency of gain could not be measured for steers in Trial 1.

Johnson et al. (1996) reported an improvement in feed efficiency as well as increased protein accretion for implanted steers, but steers were fed free choice in their study. With individual steer feed intake controlled, no improvement in feed efficiency was observed in Trial 2 of the present study. These data seem to indicate that the superior weight gain for cattle receiving the combination implant in Trial 1 may have been due to an increase in feed consumption rather than increased efficiency of growth. Steers implanted with Revalor-S® may have been stimulated to have a greater appetite and hence a more aggressive feeding behavior. Under individual feeding conditions where they could only consume the feed that was allotted to each steer, appetite was not a factor and no treatment effect was observed for average daily gain or for feed efficiency.

Implications

These data indicate that choice of implant treatment may not impact rate of gain or efficiency of growth in limit feeding programs. It remains to be seen, however, what carryover effects imposing different implant treatments during the growing phase may have on growth and feed efficiency during the finishing phase. It also needs to be determined whether carcass quality and yield of retail cuts may be affected by different implant strategies during a limit feeding growth period.

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Table 1. Composition and Proximate Analysis of Finishing Diet[a]

Ingredient	
Cracked corn	47.00
Ground milo	23.00
Cottonseed meal	11.00
Cottonseed hulls	12.00
Molasses	3.50
Limestone	1.30
Potassium chloride	0.25
Trace minerals[b]	0.35
R1500 supplement[c]	1.60
Total	100.00
Proximate Analysis	
DM %	89.7
CP %	13.4
NEm (Mcal/kg)	1.85
NEg (Mcal/kg)	1.22
ADF %	13.3
Ca %	0.55
P %	0.37

[a]As fed basis.
[b]Composition of trace mineralized salt: NaCl, 98%; Zn, 0.35%; Mn, 0.28%; Fe, 0.175%; Cu, 0.035%; I, 0.007%; Co, 0.007%.
[c]R-1500 contains 1.65 g monensin sodium (Rumensin™) per kg.

Table 2. Growth performance of limit-fed steers fed in groups[a] (Trial 1)

	Implant Treatment[c]						
Dependent variable	CON	EST	AND	COMB	DF	SE	Model Treatment *P* - value
Initial wt, lb	524.7	519.9	523.6	521.8	28	14.1	0.9352
Final wt, lb	681.3	702.2	695.4	741.4	28	26.6	0.0803
Average daily gain, lb	1.85	2.16	2.02	2.57	28	0.26	0.0389

	P - values	
Contrasts evaluated[b]	Final wt	Average daily gain
Control vs. estrogenic implant	0.2488	0.2455
Control vs. androgenic implant	0.5019	0.4832
Control vs. combination implant	0.0066	0.0063
Androgenic vs. estrogenic implant	0.6190	0.6344
Androgenic vs. combination implant	0.0303	0.0315
Combination vs. estrogenic implant	0.0862	0.0853

[a]Steers were fed a daily allotment of feed estimated to produce 2.2 lb of gain per head per day.
[b]Least squares means were compared using preplanned orthogonal contrasts.
[c]CON = Non-implanted control; EST = Synovex-S® (estrogen); AND = Finaplix-S® (trenbolone acetate); COMB = Revalor-S® (estrogen + trenbolone acetate).

Table 3. Growth rate and efficiency of growth of limit-fed steers fed individually[a] (Trial 2)

	Implant Treatment[b]						
Dependent variable	CON	EST	AND	COMB	DF	SE	Model Treatment *P*-value
Initial wt, lb	555.1	555.1	557.7	560.6	55	18.22	0.9961
Final wt, lb	736.1	761.6	759.4	770.2	55	23.14	0.7577
Average daily gain, lb	2.13	2.42	2.38	2.46	55	0.15	0.3728
Total feed intake, lb	1227	1216	1217	1213	55	28.3	0.9870
Feed to gain ratio	7.3	7.2	6.4	5.9	55	0.82	0.5774

[a]Steers were fed a daily allotment of feed estimated to produce 2.2 lbof gain per head per day.
[b]CON = Non-implanted control; EST = Synovex-S® (estrogen); AND = Finaplix-S® (trenbolone acetate); COMB = Revalor-S® (estrogen + trenbolone acetate).

ALTERNATION OF IONOPHORES IN FEEDLOT DIETS DOES NOT IMPROVE RATE OR EFFICIENCY OF GROWTH OR CARCASS TRAITS OF BULLOCKS

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Summary

Five hundred seven bull calves were fed for 126 days with either Bovatec® daily or Bovatec® and Rumensin® fed on alternating days. The objectives of the study were to determine whether alternating ionophores affected rate or efficiency of growth, volatile fatty acid production, acetate to propionate ratio or carcass traits. No differences were detected ($P < 0.05$) in average daily gain, feed to gain ratio, cost of gain, total volatile fatty acid production, acetate to propionate ratio, maturity score, ribeye area, kidney, pelvic and heart fat or carcass weight. Fat thickness, marbling and quality grade were slightly higher and USDA sex class was lower ($P < 0.05$) for Bovatec® than for alternating ionophores. While small differences were observed for certain carcass traits, it was concluded that alternating ionophores in feedlot diets fed to young bullocks makes little difference in beef production traits of economic importance and is probably not cost effective.

Introduction

Rumensin® and Bovatec® are commonly fed to improve rate and efficiency of gain (Downs et al., 2000; Steele et al., 2004). The primary mode of action has been attributed to changes in the rumen microbial population and a shift in proportions of volatile fatty acids (Bergen and Bates, 1984; McGuffey et al., 2001). Propionic acid is increased relative to acetic acid and methane production is reduced (Tedeschi et al., 2003). Omar (2004) reported, however, that reduction of methane may only persist for two weeks. It has also been reported that ionophores decrease maintenance requirements and increase efficiency of energy utilization (Schelling, 1984). If the rumen microflora are able to adapt to ionophores, the beneficial effects might be reduced. In response to this concern, some researchers have postulated that alternating ionophores in feedlot diets could improve and extend the desirable effects of ionophores (Duff et al., 1995; Pordomingo et al., 1999).

Experimental Procedures

Cattle Management. Five hundred seven Angus crossbred bull calves were assembled at a commercial feedlot in North-central Utah and sorted by frame size into 8 pens. All bullocks were fed a high energy diet free choice once daily. Approximately one-half of the bullocks received 25 grams of Bovatec® (lasalocid) per ton of feed while the other treatment consisted of feeding 25 grams per ton of Bovatec® or Rumensin® (monensin) on alternating days. Cattle were harvested when the average fat thickness of a pen of bullocks was estimated by visual appraisal to be 0.25 inch. Bullocks were weighed individually at the initiation of the trial, at 28-day intervals and as cattle were selected for harvest. Total feed consumed by each pen of cattle was recorded and efficiency of gain was determined for each pen.

Volatile Fatty Acids. A representative sample of each treatment group was selected for volatile fatty acid analysis. A total of sixty-nine rumen fluid samples were collected at the packing plant on several different days when cattle were harvested. Rumen fluid was collected and transported to the laboratory for further analysis. Rumen fluid was prepared for analysis by screening through four layers of cheesecloth. A 5 ml aliquot of strained rumen fluid was placed in a centrifuge tube with 1 ml of 25% (w/w) metaphosphoric acid and allowed to stand for 30 minutes. Tubes were subsequently centrifuged at 19,000 g for 20 minutes. Supernatant was decanted and volatile fatty acids were measured by gas chromatography. Total volatile fatty acids, percentages of acetic, propionic, isobutyric, butyric, isovaleric, and valeric acid, and acetic to propionic acid ratio were determined.

Statistical Analyses. Data were analyzed using SAS statistical sofware (SAS, 1999). All data were subjected to an analysis of variance within a randomized block design where ionophore treatment was the main effect and pens were blocks. Frame size was not included in the model because frame size and pen were completely confounded. Therefore, variation attributable to frame size was accounted for by variation within pens. Treatment by pen (frame size) interaction was included in the first analysis of variation and was included in the final model when $P < 0.05$ for the interaction. Duncan's New Multiple Range Test was employed to separate means when the model probability was less than 0.10. A probability of $P < 0.05$ was accepted as significant for determination of treatment effect on each growth, volatile fatty acid or carcass trait of interest.

Results and Discussion

Least squares means for growth rate, feed efficiency and cost of gain are given in Table 1. No treatment effect was detected for rate, efficiency or cost of gain. Rate of gain and efficiency of growth were determined for both treatment groups, and the cost of gain was sufficiently low to make feeding these cattle profitable given the cost of feeder cattle and market price for finished beef at the time the study was conducted.

Least squares means for relative percentages of volatile fatty acids and the ratio of acetate to propionate are shown in Table 2. No differences between treatment groups were observed for the relative percentages of any of the volatile fatty acids studied or in the ratio of acetate to propionate. Apparently, alternation of Rumensin® and Bovatec® did not cause a shift in the rumen microflora as compared to that of cattle fed Bovatec® continuously.

Least squares means for certain carcass traits are compared in Table 3. Cattle from both treatment groups were similar for carcass weight, ribeye area, kidney, pelvic and heart fat percentage, and USDA yield grade. Statistically different ($P < 0.05$), but small treatment effects were observed for fat thickness, USDA marbling score, USDA quality grade and USDA sex class. Bullocks fed Bovatec® continuously were fatter than cattle in the alternating ionophore treatment. It seems counterintuitive that the bullocks that were fatter also had higher masculinity scores when one considers that there was no difference in growth rate.

The observation that daily alternation of ionophores did not impact feed efficiency or rate of gain is in agreement with Downs et al. (2000) and Portomingo et al. (1999). Tedeschi et al. (2003), however, reported that feed intake decreased 4% in cattle fed ionophores with a concurrent increase in feed efficiency. The inclusion of ionophores in feedlot cattle diets may increase in the future because of environmental concerns, regardless of potential gains in efficiency of gain or economic benefits. Methane gas is a known contributor to the greenhouse effect and could possibly exacerbate global warming (EPA, 2004). Ionophores have been demonstrated to reduce methane production by up to 25% in feedlot cattle (Tedeschi et al., 2003) and may therefore become of increasing importance as environmental regulations become more restrictive.

Duff et al. (1995) reported increased dry matter digestibility of a concentrate diet in vitro after 12 and 24 hours of incubation with ionophores as compared to non-ionophore treated controls. They also saw a shift in volatile fatty acid production with an increase in acetate to propionate ratio. No shift in relative percentage of the volatile fatty acids or acetate to propionate ratio was observed in the present study. However, no untreated control was included; rather, continuous feeding of one ionophore was compared to alternating two different ionophores.

Smith and Crouse (1984) reported on the effects of acetate, glucose and other substrates preferentially utilized by various adipose tissue depots in cattle. While the present study did not detect a shift in volatile fatty acids, alternating ionophores did have an effect on adiposity (relative fatness) of bullocks. Interfasicular (marbling) and subcutaneous (trim) fat were increased in cattle continuously receiving Bovatec® as compared to cattle fed a daily alternation of ionophores. This finding is in contrast with the observations of Downs et al. (2000) wherein they saw no change in adiposity but they did observe an increase in ribeye area attributable to ionophore treatment. Ionophores have been reported to increase the efficiency of protein utilization as compared to untreated controls (Bergen and Bates, 1984; Schelling, 1984) but no differences in carcass muscularity or efficiency of growth were noted in the present study.

Implications

These data indicate that daily alternation of ionophores in feedlot diets of bullocks does not improve rate of gain, efficiency of growth, volatile fatty acid production or carcass traits of economic importance. The additional expense and effort required to implement such a practice in commercial cattle feedlots is not justified economically nor in terms of animal performance.

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Table 1. Growth rate, feed efficiency and cost of gain

	Ionophore Treatment[a]	
Dependent variable	LasLas	LasMon
Initial weight, lb	683.0[c]	688.1[c]
Final weight, lb	1027.0[c]	1029.6[c]
Average daily gain, lb	3.34[c]	3.48[c]
Average daily intake, lb	21.34[c]	22.00[c]
Feed to gain ratio[b]	6.38[c]	6.33[c]
Cost of gain, $ per cwt	44.09[c]	43.18[c]

[a]LasLas = 25 grams Bovatec ® per ton of feed fed daily; LasMon = 25 grams of Bovatec® or Rumensin® per ton of feed fed on alternate days.

[b]Dry matter basis.

[c]Least squares means for a given trait with a common superscript are not different (P > 0.05).

Table 2. Least squares means for percentages of volatile fatty acids and acetic to propionic acid ratio[a]

	Ionophore Treatment[b]	
Dependent variable	LasLas	LasMon
Acetic acid	0.56[c]	0.57[c]
Propionic acid	0.32[c]	0.31[c]
Isobutyric	0.02[c]	0.03[c]
Butyric	0.06[c]	0.05[c]
Isovaleric	0.02[c]	0.02[c]
Valeric	0.01[c]	0.01[c]
Acetate to propionate ratio	1.75[c]	1.84[c]

[a]n = 69.

[b] LasLas = 25 grams Bovatec ® per ton of feed fed daily; LasMon = 25 grams of Bovatec® or Rumensin® per ton of feed fed on alternate days.

[c]Least squares means for a given trait with a common superscript are not different (P > 0.05).

Table 3. Least squares means for certain carcass traits

Dependent variable	Ionophore Treatment[a] LasLas	LasMon
Carcass weight, lb	618.0[e]	617.5[e]
Fat thickness, inch	0.24[f]	0.22[e]
Ribeye area, $inch^2$	12.58[e]	12.51[e]
Kidney, pelvic, heart fat, %	1.87[e]	1.85[e]
USDA yield grade	1.66[e]	1.64[e]
Marbling score[b]	2.87[f]	2.69[e]
USDA quality grade[c]	3.05[f]	2.94[e]
USDA sex class[d]	3.27[e]	3.42[f]

[a]LasLas = 25 grams Bovatec ® per ton of feed fed daily; LasMon = 25 grams of Bovatec® or Rumensin® per ton of feed fed on alternate days.
[b]2.00 = Traces^{00}.
[c]2 = USDA Standard; 3 = USDA Select.
[d]3 = "steer." A higher number denotes more masculinity.
[e,f]Least squares means for a given trait with a common superscript are not different (P > 0.05).

DIETARY ENERGY SOURCE IMPACTS INSULIN SENSITIVITY IN FINISHING STEERS

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Summary

The objectives of this study were to evaluate the effects of different energy sources in steer finishing diets on metabolism and insulin sensitivity of subcutaneous and intramuscular adipose tissues. Angus (n = 8) and 7/8 Wagyu (n = 8) steers were assigned to either a grain-based (**CORN**) or a hay-based (**HAY**) diet. At slaughter, subcutaneous (**SQ**) and intramuscular (**IM**) adipose samples were collected and cultured with ^{14}C-acetate to quantify fatty acid (**FA**) synthesis, or ^{14}C-glucose to assess glucose oxidation and conversion to lactate in the presence of 0 or 500 ng/ml insulin. Study results suggest that feeding HAY limited both glucose supply and tissue capacity to increase glucose utilization in response to insulin without altering acetate synthesis to FA. Because SQ consistently utilized more acetate and oxidized more glucose than IM, these results suggest that HAY diets may alter IM metabolism with less impact on SQ.

Introduction

Beef carcass value is influenced by the quantity and distribution of adipose tissue. Increasing intramuscular adipose tissue increases carcass quality grade, and thus value, while increasing subcutaneous adipose tissue reduces carcass value due to increased waste. Production systems impact the distribution and quantity of carcass fat. Production systems utilizing high proportions of roughage typically result in lower value carcasses than those using high concentrate strategies (Schaake et al., 1993) and those that increase subcutaneous fat deposition excessively increase production costs while decreasing carcass value (Wertz et al., 2001). Elucidation of the metabolic control of caloric partitioning between subcutaneous and intramuscular adipocytes could lead to development of production solutions that enhance production efficiency and market value. Previous studies have demonstrated substrate preference differences among these fat depots (Smith and Crouse, 1984). Other studies have shown dietary impacts on whole body insulin sensitivity and energy partitioning (Waterman et al., 2003).

Experimental Procedures

Eight Wagyu (174 lb) crossbred (7/8 Wagyu or higher) and 8 Angus (210 lb) steers were purchased as calves at weaning. Four steers of each breed type were assigned to receive a high-energy, corn-based diet containing 48% ground corn, 20% ground milo, 15% cottonseed hulls, 7.5% molasses, 0.96% limestone, 0.56% trace mineral salt, and 0.08% vitamin premix (**CORN**) fed *ad libitum* for 16 mo. Feeding this diet resulted in an average gain of .85 lb/d. The remaining 4 steers of each breed type were offered coastal bermuda grass hay (9.5% crude protein) *ad libitum*, supplemented daily with non-protein nitrogen, and an amount of the corn-based diet to gain 0.72 lb/d (**HAY**) for 20 mo. Targeted final body weights were 650 lb for steers fed for either 16 mo on corn or 20 mo on the hay-based diet. Although diet and time-on-feed were confounded in the production portion of the trial, steers were fed to constant BW endpoints. Therefore, it is arguable that retained energy was similar between treatments.

Steers in each group were slaughtered on two consecutive days at the Rosenthal Meat Science and Technology Center, Texas A&M University. A section of longissimus dorsi muscle (**LM**) between the 5th and 8th thoracic ribs was removed immediately following hide removal (approximately 20 min postmortem). The LM section and associated subcutaneous (**SQ**) and intramuscular (**IM**) adipose tissue were immediately transported to the laboratory. Within 20 min, SQ and IM tissue samples were dissected from the LM section.

Lipogenesis from acetate procedures were followed according to Page et al. (1997). Glucose metabolism was conducted as described by Espinal et al. (1983). Briefly, 50-100 mg of adipose tissue was incubated in either a 10 m*M* sodium acetate, 10 m*M* glucose, 5x Krebs-Henseleit and 20 m*M* HEPES buffer (pH 7.40), and 1 µCi [U-^{14}C] acetate or a 10 m*M* glucose, 5x KHB and 20 m*M* HEPES buffer and 1 µCi [U-^{14}C] glucose for 2 hr at 37°C. Bovine insulin

(0 or 500 ng/mL) was also added to those flasks receiving glucose. Measurement of [1-^{14}C] acetate incorporation into fatty acids was conducted as described by Page et al. (1997). Determination [1-^{14}C] glucose carbon into CO_2 was preformed according to Smith (1983), and the remaining glucose carbon recovery in the form of lactate was followed according to the method of Smith and Freeland (1981). Glucose, G-6-P, and F-6-P were measured using assay systems described by Bergmeyer (1974), with modifications as conducted by Rhoades et al. (2005).

Data were analyzed as a split plot. Diet, breed, and their interaction served as main plot effects, and were tested using steer nested within breed × diet as the error term. Tissue type, insulin addition (when appropriate), tissue × insulin, diet × insulin, diet × tissue, and diet × insulin × tissue were sub-plot effects, and were tested with residual mean square as the error term. Means were separated using Fisher's LSD. All analyses were performed using the General Linear Models procedures of SAS v.9 (SAS Institute, Cary, NC, USA).

Results and Discussion

Breed type (Table 1) had no affect on the conversion of glucose to CO_2 ($P = 0.19$), or lactate ($P = 0.58$) nor did breed have an affect on acetate incorporation into fatty acids ($P = 0.96$). Breed did not interact ($P > 0.18$) with other effects tested. In a companion study, breeds were similar in marbling, although Wagyu were numerically greater, and Angus had greater subcutaneous fat thickness (data not shown).

Tissue glucose concentrations (pooled across tissue type) were 28% greater ($P < 0.01$) in steers fed CORN (1.52 µmol/g) vs. HAY fed steers (1.19 µmol/g). The concentration of glucose was 264% greater ($P < 0.01$) in IM tissue (2.13 µmol/g) when compared to SQ adipose tissue (0.58 µmol/g), but no interaction between tissue type and diet was observed for glucose concentration ($P = 0.44$). These results demonstrate that there was an increased supply of glucose carbon in steers fed a higher concentrate diet. This effect is expected due to the higher production of propionate from starch fermentation associated with such diets (Orskov et al. 1991), and the preferential use of propionate as a glucogenic substrate by ruminants (Danfaer et al., 1995). Additionally, available glucose from either diet was preferentially accumulated in IM depots relative to SQ. This effect is consistent with observations by Smith and Crouse (1984), in which IM adipocyte preferentially utilized glucose as an anabolic substrate.

Glucose-6-P (0.04 vs. 0.05 ± 0.01 µmol/g for CORN and HAY) and Fructose-6-P (0.06 vs. 0.08 ± 0.02 µmol/g for CORN and HAY) were similar among diets ($P > 0.46$). There was a tendency ($P = 0.07$) for increased concentrations of Fructose-6-P in SQ tissue (0.09 µmol/g) vs. IM (0.05 µmol/g; SE = 0.02), however, the low overall concentrations of these intermediates makes this separation unimportant. Due to the lack of accumulation of glycolytic intermediates, it is unlikely that the increased levels of glucose in both the CORN diet and IM adipose tissue is due to an accumulation as a result of decreased pathway flux. This accumulation is more likely the result of enhanced substrate supply (diet effect) or increased uptake by IM.

Diet did not affect ($P = 0.42$) acetate incorporation into fatty acids, and there were no diet by tissue interactions for this response ($P = 0.71$). Acetate incorporation rates (nmol·10^5 cells^{-1}·h^{-1}) were 16.46 and 17.80 (SE = 5.99) for CORN and HAY, respectively, pooled across SQ and IM. These rates of acetate incorporation are consistent with values discussed by Smith (1983).

Diet by insulin interactions existed (Table 2) for measures of glucose utilization ($P < 0.05$). When steers were fed HAY, CO_2 production was similar in the presence or absence of insulin; i.e., the addition of insulin did not increase glucose oxidation. Similarly, lactate synthesis from glucose was not affected by insulin addition when steers were fed a HAY diet. Conversely, the addition of insulin when steers were fed CORN resulted in a 103% increase in glucose conversion to CO_2 and a 50% increase in lactate synthesis from glucose. This data provides substantial evidence that dietary energy source alters insulin sensitivity, as adipose tissues became insulin resistant when cattle consumed a forage-based diet. A mechanism for this effect is suggested by Tardif et al., (2001) who demonstrated that accumulation of ketones interrupted insulin signal transduction and reduced GLUT-4 migration to cell surfaces. This reduction in insulin sensitive glucose transporter presentation reduces insulin-stimulated glucose uptake, and thus would limit apparent rates of glucose metabolism. Ketone bodies may accumulate under acetate loading, particularly when glucose is limiting (Herdt et al., 1981), and thus, the higher acetate loads anticipated and the reduced glucose concentration demonstrated with HAY vs. CORN diets may have affected this response. Schoonmaker et al. (2003) found greater levels of insulin in steers fed a high-concentrate diet compared to steers fed a high-forage diet during the growing phase. This observation coupled with our results suggests that adipose tissues in steers fed high concentrate diets would not only be exposed to greater circulating insulin but would also be more sensitive to its effects on glucose uptake.

Neither diet by tissue ($P > 0.71$) nor tissue by insulin ($P > 0.59$) interactions were observed for measured responses ($P > 0.71$). The lack of differential tissue responses to insulin may be due to the level of insulin that was added to the media during the incubation period (McCann and Reimers, 1985). These authors demonstrated that even when insulin sensitivity was altered in heifers, the maximum response to insulin was unaffected.

Subcutaneous fat had a 37% greater ($P = 0.04$) rate of glucose conversion to CO_2, pooled across diets and insulin levels (Table 3). Lactate production was similar ($P = 0.99$) among adipose depots. It is noteworthy, that SQ utilized acetate at a 290% greater ($P = 0.04$) rate for fatty acid synthesis than IM tissue. These data are consistent with previous findings that SQ adipose tissue utilizes more glucose for oxidative metabolism, and uses acetate as its primary substrate for fatty acid synthesis (Smith and Crouse, 1984). These results may provide an alternative explanation for observed tissue differences in glucose concentration. Reduced concentration of glucose in SQ tissue may be due to increased oxidative metabolism of glucose carbon, alone or in conjunction with increased glucose uptake by IM cells.

Overall, these results suggest that feeding HAY limited both glucose supply and tissue capacity to increase glucose utilization in response to insulin without altering acetate synthesis to FA. Because SQ consistently utilized more acetate and oxidized more glucose than IM, these results suggest that HAY diets may alter IM metabolism with less impact on SQ. These results support the hypothesis that high concentrate diets enhance glucose metabolism and increase insulin effects in adipose tissues. Smith and Crouse (1984) established the preferential use of glucose as a substrate in IM fatty acid synthesis, while SQ fat primarily utilizes acetate as substrate. High-concentrate feedstuffs produce a greater proportion of propionic acid than do forage diets (Orskov et al., 1991), and propionate is a preferred glucogenic substrate. Our results support this premise, as CORN fed steers had greater concentrations of glucose in adipose tissues. Conversely, a roughage-based diet provides greater concentrations of acetate. In this study, acetate was much more effectively utilized for fat synthesis by SQ adipose tissue. Acetate load may also inhibit insulin action. In this study, adipose tissues in HAY-fed steers were insensitive to insulin, while insulin had profound effects on adipose from CORN fed steers. These differences could lead to a divergent partitioning of energetic substrate in steers fed different diets, where CORN feeding enhances glucose availability and uptake, and apparently fatty acid synthesis in IM adipose (increased glucose supply, reduced oxidation, similar lactate capture), while HAY feeding reduced glucose availability without altering acetate incorporation in fatty acids. Because SQ used acetate more effectively than IM, this condition would promote SQ deposition over IM.

Reports exist that are consistent with this hypothesis. Propionate is insulinogenic in ruminants (Sano et al., 1995). Choat et al. (2003) reported increased intramuscular fat deposition in steers fed a concentrate diet that generated 39.3% greater propionate. Schaake et al. (1993) found that feeding grain or high-concentrate diets increased intramuscular fat content relative to forage feeding. These findings, especially in light of our observation about diet effects on insulin sensitivity, correspond with increased accretion of intramuscular lipid from glucose (Smith and Crouse, 1984). Although data reported here cannot confirm these hypotheses, further research is certainly warranted in this area.

Implications

The results of this experiment demonstrate diet-mediated differences in insulin sensitivity of adipose tissues in steers. Diet also altered substrate supply. Apparent differences in SQ vs. IM metabolism, and their interaction with diet, provide foundation for a hypothesis regarding diet-mediated regulation of differential adipose tissue metabolism. Validation of these hypotheses could generate nutritional strategies that alter the rate and site of adipose deposition.

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Table 1. Least squares means for rates of conversion of [U-^{14}C] glucose to CO_2 and lactate (nmol·10^5 cells^{-1}·h^{-1}), and incorporation of [U-^{14}C] acetate (nmol·10^5 cells^{-1}·h^{-1}) into fatty acids of Wagyu and Angus steers.

Item	Wagyu	Angus	SE	*P* > F
CO_2	10.68	14.58	1.98	0.19
Lactate	564.21	681.78	146.95	0.58
Acetate	16.93	17.33	5.99	0.96

Table 2. Least squares means for rates of conversion of [U-^{14}C] glucose to CO_2 and lactate (nmol·10^5 cells^{-1}·h^{-1}) in adipose tissue from steers fed hay- or corn-based diets incubated with 0 or 500 ng/ml insulin

	Diet					
Item	Hay		Corn			
Insulin	0	500	0	500	SE	*P*
CO_2	8.7^b	10.2^b	10.4^b	21.2^a	1.8	.02
Lactate	278^c	228^c	794^b	1192^a	113	.05

[a,b,c]Least squares means without common superscript differ (P < 0.05).

Table 3. Least squares means for rates of conversion of [U-^{14}C] glucose to CO_2 and lactate (nmol·10^5 cells^{-1}·h^{-1}), and incorporation of [U-^{14}C] acetate into fatty acids (nmol·10^5 cells^{-1}·h^{-1}) of SQ and IM adipose tissue from steers

Item	SQ	IM	SE	*P* > F
CO_2	14.59	10.67	1.29	0.04
Lactate	623.20	622.79	79.55	0.99
Acetate	27.26	6.99	5.54	0.04

EVALUATION OF NET FEED INTAKE AND RELATIONSHIPS WITH CARCASS COMPOSITION ESTIMATES IN FINISHING STEERS ADMINISTERED DIFFERENT ANTHELMINTIC TREATMENTS

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Summary

The objective of this study was to examine phenotypic relationships between net feed intake (**NFI**) and estimates of carcass composition in finishing steers. Red Angus steers (n = 119; BW 652.6 ± 75.0 lb) were assigned to one of three anthelmintic treatments and individually fed a high-grain diet (ME = 1.24 Mcal/lb) using Calan gate feeders. Feed intake and 28-d BW were measured for 138 d and 12th rib fat thickness (**BF**), KPH, marbling score, and ribeye area (**REA**) were obtained at harvest. Anthelmintic treatment did not affect any of the traits in this study. Net feed intake (**NFIp**) was calculated as the difference between actual intake and expected intake from linear regression of DMI on ADG and mid-test BW$^{0.75}$ (**MBW**; base model). NFIp was correlated with DMI (0.64), but not with ADG and MBW. Steers with low NFIp (< 0.50 SD) consumed 19% less DMI than steers with high NFIp (> 0.50 SD), even though ADG and BW were similar. NFIp was significantly correlated with BF, KPH and marbling score, but not with REA. Thus, a second NFI trait was calculated as the difference between actual DMI and expected DMI from linear regression of DMI on ADG, MBW and appropriate carcass traits (**NFIc**). Inclusion of KPH and BF in the adjusted model (R^2 = 0.66; RMSE = 0.81) used to calculate NFIc accounted for more variation in DMI compared to the base model (R^2 = 0.59; RMSE = 0.88) used to calculate NFIp. NFIp and NFIc were strongly correlated with each other (Spearman rank correlation = 0.87) and with other feed efficiency traits measured in this study. As expected, NFIc was not correlated with the component carcass traits (KHP, BF) used to compute expected DMI, and was not significantly correlated with marbling score. Results suggest that inclusion of carcass fat traits along with ADG and MBW to compute NFI may be warranted to minimize potential unfavorable responses when NFI is incorporated into selection programs to improve feed efficiency in beef cattle.

Introduction

Feed costs constitute the single largest expense in beef production, yet current genetic selection in beef cattle is predominantly focused on growth performance and carcass traits. Feed conversion ratio (**FCR**) is a simple calculation that measures gross feed efficiency, but fails to consider feed requirements for maintenance and growth. Furthermore, selecting for improved FCR will lead to an increase in growth rate and mature cow size, thus, increasing feed requirements for maintenance (Herd and Bishop, 2000). An alternative measure of feed efficiency is net feed intake (**NFI**), also referred to as residual feed intake. Net feed intake is calculated as the difference between actual feed intake and expected feed intake based on body size and growth rate, and is a moderately heritable trait (Arthur et al. 2001; Schenkel et al., 2004)

Although genetically independent of performance traits, NFI has been reported to be positively correlated to ultrasound estimates of backfat thickness in growing bulls (Schenkel et al., 2004) and carcass composition traits in finishing steers (Jensen et al., 1992; Basarab et al., 2003). These studies indicate that cattle with low NFI tend to be leaner than cattle with high NFI. Few studies have examined the relationships between NFI and carcass quality traits. McDonagh et al. (2001) examined carcass quality traits in steers produced from a single generation of divergent selection for low and high NFI. In this study, selection for NFI had no effect on marbling scores or longissimus dorsi muscle shear force. However, steers from the low NFI parents had higher levels of calpistatin activity compared to steers from the high NFI parents, suggesting that selection for low NFI may be unfavorably associated with tenderness. The objective of this study was to evaluate feed efficiency traits in steers fed a high-grain diet, and to examine correlations between feed efficiency traits and carcass cooler traits at harvest.

Experimental Procedures

Data from an experiment designed to examine the effects of anthelmintic treatments on growth performance, feed efficiency, and carcass traits in finishing Red Angus steers (n = 119; BW 652.6 ± 75.0 lb) were used in this study. Steers were blocked by body weight (**BW**) and randomly assigned to one of three anthelmintic treatments in pens equipped with Calan gate feeders (4 steers/pen) at the McGregor research center. Steers were adapted to the experimental diet and trained to eat from Calan gate feeders for 28 d, and individual feed intake measured for 138 d. The experimental diet (ME = 1.24 Mcal/lb) consisted of 47.5% cracked corn, 20% ground milo, 15% cottonseed hulls, 7.5% molasses, 7% cottonseed meal, and 3% vitamin/mineral supplement. At harvest, 12th rib fat thickness (**BF**), kidney, heart, and pelvic fat (**KPH**), marbling score, and ribeye area (**REA**) were measured.

Linear regression of 28-d BW on days of test was used to derive ADG, initial BW, final BW and mid-test BW$^{0.75}$ (**MBW**). Partial efficiency of growth (**PEG**) was computed as the ratio of ADG to DMI for growth. Dry matter intake for growth was computed as actual DMI minus expected DMI for maintenance. The expected DMI to meet maintenance requirements was calculated as 0.077*MBW ÷ NEm concentrations of the test diets. Feed conversion ratio (**FCR**) was calculated as the ratio of DMI to ADG.

Net feed intake was calculated as the difference between actual dry matter intake (**DMI**) and expected DMI derived from a linear regression model of DMI on ADG and MBW (Arthur et al., 2001). Inclusion of anthelmintic treatment as a fixed effect in the model had minimal effect on the coefficient of determination (R^2), and so was not included in the base model (DMI = a + b_1MBW + b_2ADG + residual) used to calculate NFIp. To evaluate the importance of carcass traits in the prediction of DMI, stepwise regression analysis was conducted using PROC REG of SAS (SAS Inst., Cary, NC) to determine the order in which carcass traits should be added to the base model. Using the order derived from stepwise regression analysis, carcass traits were progressively included in linear models, and the change in R^2 used to evaluate the relative importance of their inclusion. Based on these results, an additional NFI trait was computed (NFIc), where KPH and BF were included in an adjusted model (DMI = a + b_1MBW + b_2ADG + b_3KPH + b_4BF + residual) to compute expected DMI that also accounted for variation in carcass traits. Net feed intake adjusted for carcass traits (NFIc) was computed as the difference between actual DMI and expected DMI derived from the adjusted model.

To further characterize NFIp, steers were separated into low, medium and high NFIp groups that were < 0.5 SD, ± 0.5 SD and > 0.5 SD from the mean NFI of 0.00 ± 1.92 lb/d, respectively. Least squares procedures (PROC GLM of SAS) were used to examine the effects of NFIp group on growth performance, feed efficiency and carcass traits. Spearman's rank correlation coefficient was used to compare animal rank between NFIp and NFIc, and phenotypic correlations among traits were determined using PROC CORR of SAS.

Results and Discussion

There was no effect (P > 0.25) of anthelmintic treatment on BW, ADG, feed intake and efficiency, or any carcass cooler traits, and inclusion of anthelmintic treatment in the base linear regression model did not account for additional variation in DMI beyond that assigned to ADG and BW. During the 138-d study, overall ADG, DMI and NFIp were 2.89 (SD = 0.56), 22.75 (SD = 3.02) and 0.0 (SD = 1.92) lb/d, respectively. Overall BF, KPH, REA and marbling score at harvest were 0.51 inch (SD = 0.15), 2.10% (SD = 0.52), 11.18 inch^2 (SD = 0.85) and 4.38 (SD = 0.82), respectively.

Average daily gain was strongly correlated with FCR and moderately correlated with PEG, but as expected was not correlated with NFIp (Table 1). Initial BW was moderately correlated with both PEG and FCR, such that favorable PEG and FCR phenotypes were steers that weighed less at the start of the study. Initial BW was not correlated with NFIp, and final BW was not correlated with any of the feed efficiency traits. Feed intake was significantly correlated with NFIp and PEG, but not FCR. Steers with low NFI (< 0.5 SD) consumed 19% less feed than steers with high NFI (> 0.5 SD), even though BW and ADG were similar (Table 3). Steers with low NFI were also more efficient as measured by PEG (0.25 vs 0.18 ± .01 ADG/DMI for growth) and FCR (7.42 vs 8.89 ± .26 DMI/ADG) compared to steers with high NFI, demonstrating that these feed efficiency traits were favorably correlated.

Phenotypic correlations between feed efficiency and carcass composition traits are presented in

Table 2. Feed conversion ratio was not correlated with any of the carcass traits. Partial efficiency of growth was negatively correlated with BF and KPH, but was not correlated with REA or marbling score. Net feed intake from the base model was positively correlated ($P < 0.05$) with BF, KPH and marbling score, but was not correlated with REA. The phenotypic correlation between NFIp and BF in this study with finishing steers (0.27) is slightly higher than the correlations (range 0.14 to 0.22) previously reported in steers and bulls that were fed roughage-based diets (Arthur et al., 2001; Carstens et al., 2002; Fox et al., 2004; Nkrumah et al., 2004; Schenkel et al., 2004). Jensen et al. (1992) reported a similar phenotypic correlation (0.22) between NFIp and dissectable carcass fat composition in dairy bulls fed a concentrate-based diet. A number of studies have found that NFIp was not correlated with ultrasound estimates of marbling fat in growing cattle (Arthur et al., 2001; Carstens et al., 2002; Nkrumah et al., 2004; Schenkel et al., 2004). However, Fox et al. (2004) and Basarab et al. (2003) reported that NFIp tended to be positively correlated with marbling fat. The lack of a correlation between NFIp and REA in this study is consistent with results from previous studies in growing (Carstens et al., 2002; Fox et al., 2004; Nkrumah et al., 2004; Schenkel et al., 2004) and finishing cattle (Basarab et al., 2003). In this study, steers with low NFIp had significantly less BF, KPH and marbling scores, but similar REA compared to steers with high NFIp (Table 3).

The significant correlations between NFIp and carcass measurements obtained at harvest, suggest that NFIp should be adjusted for estimates of carcass fatness. Inclusion of KPH and BF in an adjusted model used to calculate NFIc accounted for more of the variation in DMI (adjusted model $R^2 = 0.66$; RMSE = 0.81) compared to the base model used to calculate NFIp ($R^2 = 0.59$; RMSE = 0.88). Ribeye area and marbling score did not account for additional variation in DMI, so these carcass traits were excluded from the final linear regression model used to calculate NFIc. Arthur et al. (2003) and Basarab et al. (2003) also found that including ultrasound estimates of carcass fat composition in linear regression models to compute NFI accounted for more variation in DMI than base models that only included ADG and MBW. In these studies, the R^2 of adjusted models increased by 2 to 4 (Arthur et al., 2003) and 2 to 3 percentage units (Basarab et al., 2003) compared to base models. The larger increase in R^2 between the compositional and base models in the current study (7 percentage unit increase) compared to the studies cited above may be related to differences in final fat composition of the cattle. Average BF of steers in the current study was 0.51 inches compared to only 0.28 and 0.39 inches for calves in the studies of Arthur et al. (2003) and Basarab et al. (2003), respectively.

The Spearman rank correlation between NFIp and NFIc was 0.87, indicating that NFIp and NFIc are highly correlated to each other. Both NFI traits were also similarly correlated to PEG and FCR. As expected, NFIc was not correlated with the component carcass traits (KHP, BF) used to compute expected DMI, and was not significantly correlated with marbling score. These results suggest that inclusion of estimates of carcass fatness in models to compute NFI may be warranted to minimize potentially unfavorable responses when NFI is incorporated into selection programs to improve feed efficiency in beef cattle.

Implications

Identifying a feed efficiency trait that facilitates reductions in feed inputs without impacting growth or other value-determining traits (e.g., carcass quality grade) has considerable potential to improve profitability of beef production systems. Net feed intake facilitates selection for improved feed efficiency independent of changes in growth and mature body size. If NFI were also adjusted for variation in carcass fat traits, the potential for unfavorable responses (e.g., body composition, marbling fat) to the use of NFI in selection programs would be minimized.

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Table 1. Phenotypic correlations[a] between feed efficiency traits[b] and growth traits in growing steers

Trait	NFIp	NFIc	PEG	FCR
Initial BW	-0.00	-0.00	**-0.46**	**0.48**
Final BW	-0.00	-0.00	-0.08	-0.13
Average daily gain	0.00	-0.00	**0.42**	**-0.75**
Feed intake	**0.64**	**0.58**	**-0.46**	0.07
Partial efficiency of growth	**-0.77**	**-0.70**	—	**-0.86**
Feed conversion ratio	**0.46**	**0.43**	**-0.86**	—

[a]Correlations in bold are significantly different from zero at $P < 0.05$.

[b]NFI_P = Net feed intake calculated from the base model; NFI_C = Net feed intake calculated from the compositional model; PEG = partial efficiency of growth; FCR = feed conversion ratio.

Table 2. Phenotypic correlations[a] between feed efficiency traits[b] and carcass cooler measurements in growing steers

Trait	NFIp	NFIc	PEG	FCR
Hot carcass weight	0.04	0.03	-0.13	-0.09
Ribeye area	-0.11	-0.11	0.04	-0.15
12[th] rib back fat	**0.27**	0.00	**-0.21**	0.06
KPH fat	**0.32**	0.00	**-0.18**	-0.06
Marbling score	**0.20**	0.13	-0.09	-0.09

[a]Correlations in bold are significantly different from zero at $P < 0.05$.
[b]NFI_P = Net feed intake calculated from the base model; NFI_C = Net feed intake calculated from the compositional model; PEG = partial efficiency of growth; FCR = feed conversion ratio.

Table 3. Characterization of growth and feed efficiency traits and carcass measurements at harvest in steers with low, medium, and high net feed intakes (NFI)[a]

Trait	Low NFI	Medium NFI	High NFI	SE	*P* - value
Number of steers	36	55	28		
Growth Traits					
Initial BW, lb	780	784	770	17	0.82
Final BW, lb	1169	1188	1168	21	0.65
Average daily gain, lb/day	2.82	2.93	2.89	0.11	0.66
Feed Efficiency Traits					
Feed intake, lb DM/day	20.4^x	23.1^y	25.1^z	0.5	0.001
Base model NFI, lb/day	-2.15^x	0.11^y	2.55^z	0.16	0.001
Adjusted model NFI, lb/day	-1.71^x	0.01^y	2.18^z	0.20	0.001
Partial efficiency of growth[b]	0.25^x	0.21^y	0.18^z	0.01	0.001
Feed conversion ratio, DMI/ADG	7.42^x	8.13^y	8.89^z	0.26	0.001
Carcass Traits					
Hot carcass weight, lb	676	700	684	13	0.25
12th rib back fat, in	0.46^x	0.52^y	0.56^y	0.03	0.02
REA, in^2	11.2	11.3	11.0	0.2	0.32
KPH fat, %	1.83^x	2.19^y	2.29^y	0.09	0.001
Yield grade	3.12^x	3.42^y	3.58^y	0.10	0.002
Marbling score[c]	4.11^x	4.41^{xy}	4.66^y	0.15	0.02

[a]NFI calculated from the base model; low, medium and high NFI steers were < 0.5 SD, ± 0.5 SD, and > 0.5 SD from the mean NFI of 0.0 ± 1.92 lb/d.
[b]ADG/DMI for growth.
[c]4.00 = $Small^{00}$, 5.00 = $Modest^{00}$.
[x,y,z]Least squares means within a row with different superscripts differ at $P < 0.05$.

EFFECT OF NUTRITIONAL MANAGEMENT ON INTRAMUSCULAR AND SUBCUTANEOUS ADIPOSE TISSUE DEPOSITION OF GROWING BEEF STEERS

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Summary

Forty-eight steers (BW = 654.0 ± 37.0 lb) were fed in four different feeding systems to evaluate the effect of nutritional management on intramuscular and subcutaneous fat deposition during the growing phase. Four dietary treatments were assigned: AL-LS - a low energy diet fed ad lib for a rate of gain of approximately 2.2 lb/day; AL-HS - a high energy diet fed *ad lib* for a rate of gain of approximately 3.5 lb/day; LF-HS - a limit fed high concentrate diet with the same amount of energy provided by AL-LS; and AL-IS - a diet with approximately the midpoint daily energy intake between AL-LS and AL-HS, fed *ad lib*. Ultrasound measurements of i.m. and s.c. fat were recorded on d 0, d 27 and d 56. On d 56 all animals were placed on the same high-concentrate diet for the finishing phase.

Introduction

Nutrition management of beef steers prior to entering the feedlot may impact carcass characteristics. Diet composition influences VFA profile, which can be related to differences in composition of gain (Berger and Faulkner, 2001). Starch based diets lead to propionate production, and the presence of this glucogenic precursor results in elevated blood insulin levels (Johnson et al., 1982). This increase in insulin concentration can lead to an increase in the uptake and utilization of glucose for accretion of intramuscular fat, which can potentially increase marbling scores of steer fed high-concentrate diets during the growing phase (Schoonmaker et al., 2003). The present study evaluated the influence of source and amount of energy on intramuscular and subcutaneous fat deposition of growing animals.

Experimental Procedures

A 56 d growing trial was conducted at the Texas Agricultural Experiment Station/USDA-ARS Conservation and Production Laboratory, Bushland, TX. Care, handling, and sampling of steers were approved by the Cooperative, Research, Education, and Extension Triangle Animal Care and Use Committee (FASS, 1999).

Forty eight crossbred steers (BW = 654.0 ± 37.0 lb) were purchased from a commercial order buyer and utilized for a summer grazing trial during the summer/fall of 2004 at the Bush Research Farm, Bushland, TX. In the winter of 2004/2005 these steers were transported to the Texas Agricultural Experiment Station/USDA-ARS Experimental Feedlot in Bushland and trained to consume their daily feed from individual feeders (American Calan, Northwood, NH) for a 2-wk period while fed a high roughage diet. Steers were then weighed, implanted with Synovex-S (20 mg of estradiol benzoate and 200 mg of progesterone; Fort Dodge Animal Health, Overland Park, KS), and assigned to each of six pens and four different dietary treatments in a completely randomized block design.

The four dietary treatments assigned were: 1) a low starch diet fed ad lib for a rate of gain of approximately 2.2 lb/day (AL-LS); 2) a high starch diet fed ad lid for a rate of gain of approximately 3.5 lb/day (AL-HS); 3) - a limit fed high starch diet designed to provide the same amount of metabolizable energy as provided by treatment 1 (LF-HS); and 4) a diet with approximately the midpoint daily energy intake between treatments 1 and 2, fed ad lib (AL-IS).

Steers were individually fed once daily at 0800. Feed refusals were collected and weighed at 7-d intervals. Samples of diet ingredients and total mixed diets were collected and analyzed by a commercial laboratory (Dairy One Forage Lab, Ithaca, NY).

Ultrasound measurements were recorded on d 0, d 27 and d 56. Ultrasound measurement of i.m. and s.c. fat were obtained using a real-time linear array ultrasound instrument (SSD-500V; Aloka Co., Wallingford, CT). Ultrasound measurements were taken caudal to the last rib and at approximately 3 in. of distance from the centerline of the steers' back.

Performance and ultrasound data were analyzed using the general linear model (PROC GLM) procedures of SAS (SAS Inst. Inc., Cary, NC). Data were analyzed by analysis of variance as a randomized complete block design with each animal as the experimental unit. All the models included effect of block and treatment.

Results and Discussion

Diets compositions are presented on Table 1. During d 0 to d 27, the amount of energy and protein fed in AL-LS and AL-IS were not similar to the formulated values. The reason for these differences in diet composition is likely due to a higher CP concentration in the wheat middlings than expected. From d 27 to d 56, the amount of wheat middlings fed was reduced to reflect this discrepancy.

Overall performance and ultrasound data are presented on Table 2. Results from periods d 0 - d 27 and d 27 - d 56 were similar for ADG. Steers fed diets from AL-HS and AL-IS during the growing phase had higher ($P < 0.0001$) ADG than AL-LS and LF-HS. Possibly due to the higher CP than the expected formulated values, animals on AL-LS and AL-IS gained more than anticipated.

Higher energy levels from diets containing higher amounts of grain resulted on a higher amount of i.m. fat deposition ($P = 0.009$; Table 2). The differences from d 0 to d 56 on marbling scores were 0.18, 0.83, 0.45, and 0.82 for AL-LS, Al-HS, LF-HS, and AL-IS, respectively. In addition, lower energy levels resulted on lower accretion of s.c. fat ($P = 0.0025$). The difference on s.c. fat was 0.57, 2.07, 1.25, and 2.24 for AL-LS, AL-HS, LF-HS, and AL-IS.

The increased marbling score at d 56 may be a consequence of elevated propionate production, and consequently higher serum insulin concentrations for those steers fed higher concentrate levels. Of particular interest is the greater increase in marbling in steers fed LF-HS compared to AL-LS, despite a lower rate of gain. This effect is supportive of a repartitioning of dietary energy. Steers fed starch as a glucogenic precursor are likely to have a higher de novo production of glucose. Smith and Crouse (1984) demonstrated that glucose provides 50 to 75% of the acetyl units for intramuscular fat deposition, providing only 1 to 10% of the acetyl units for subcutaneous fat deposition. Schoonmaker et al. (2003) observed that insulin concentration was increased in steers fed a high-concentrate diet compared with steers fed a high-forage diet in the growing phase. This may suggest that there was an increased uptake of glucose by peripheral tissues, which would support the results from the present study.

Implications

Data from this growing trial have shown increased marbling rate during early growth of beef steers. This data support the concept that corn-based diets promote provision and utilization of glucose for accretion of intramuscular fat relative to forage-based diets.

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Table 1. Composition of growing diets

	Treatment (diets from d0-d27)			
	AL-LS	AL-HS	LF-HS	AL-IS
Ingredient (DM basis)				
Corn Grain, Steam Flaked	0.00	79.2	79.2	38.00
Cottonseed, Hulls	36.00	7.00	7.00	30.00
Fat/Steep/Molasses blend	3.00	3.00	3.00	3.00
TAES Supplement 99	11.00	10.00	10.00	10.00
Wheat, Middlings	50.00	0.00	0.00	19.00
Chemical composition				
CP,%	26.95	12.85	12.85	17.30
NEm, mcal/lb	0.84	0.92	0.92	0.84
NEg, mcal/lb	0.55	0.63	0.63	0.56
Ca, %	2.11	0.79	0.79	1.19
P, %	0.87	0.30	0.30	0.47

	Treatment (diets from d27-d56)			
	AL-LS	AL-HS	LF-HS	AL-IS
Ingredient (DM basis)				
Corn Grain, Steam Flaked	0.00	79.2	79.2	38.00
Cottonseed, Hulls	61.00	7.00	7.00	40.00
Fat/Steep/Molasses blend	3.00	3.00	3.00	3.00
TAES Supplement 99	11.00	10.00	10.00	10.00
Wheat, Middlings	25.00	0.00	0.00	9.00
Chemical composition				
CP,%	22.40	12.45	12.45	13.07
NEm, mcal/lb	0.79	0.93	0.93	0.83
NEg, mcal/lb	0.51	0.63	0.63	0.54
Ca, %	1.37	0.66	0.66	0.72
P, %	0.87	0.39	0.39	0.38

Table 2. Effect of source of energy and amount on performance and fat deposition of beef steers

	Treatment					
	TRT1	AL-HS	LF-HS	AL-IS	SEM	P
d0 - d27						
ADG, lb	3.78	4.38	2.01	4.90	0.32	<.0001
Intake, lb	19.76	18.66	12.85	21.99	0.42	<.0001
Feed Efficiency	5.46	4.59	9.10	4.51	0.93	0.0029
Marbling (d27)	3.35	3.64	3.45	3.56	0.16	0.6245
Back fat (d27)	1.07	1.59	1.20	1.51	0.18	0.1700
Marbling (difference d0/d27)	0.25	0.43	0.36	0.44	0.10	0.6179
Back fat (difference d0/d27)	0.17	0.64	0.29	0.37	0.23	0.5143
d27 - d56						
ADG, lb	3.75	4.77	2.98	4.93	0.25	<.0001
Intake, lb	24.69	26.39	15.83	29.11	0.92	<.0001
Feed Efficiency	7.09	5.73	5.57	5.92	0.44	0.0936
Marbling (d56)	3.27	4.04	3.54	3.95	0.20	0.0296
Back fat (d56)	1.48	3.02	2.16	3.38	0.28	<.0001
Marbling (difference d0/d56)	0.18	0.83	0.45	0.82	0.15	0.009
Back fat (difference d0/d56)	0.57	2.07	1.25	2.24	0.32	0.0025
Marbling (difference d27/56)	-0.08	0.40	0.10	0.39	0.13	0.0256
Back fat (difference d27/56)	0.41	1.44	0.97	1.88	0.27	0.004


Food Safety

INNOVATIVE APPLICATION OF ANTIMICROBIAL COMPOUNDS DURING HIDE REMOVAL AS A MEANS TO REDUCE CARCASS CONTAMINATION BY PATHOGENIC MICROORGANISMS

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Summary

Food safety is an important issue for beef harvest operations. There are multiple interventions that are available for treating carcasses. This project was designed to evaluate interventions that could reduce bacterial counts on the hide prior to opening to minimize carcass contamination. In Trial I, fresh beef hides (n = 12) were cut into sections and assigned to serve as either shaved or non-shaved samples. Sections were inoculated with a bovine fecal slurry, and sampled with a sterile sponge following a water wash. Treatments (distilled water, isopropyl alcohol, 3% hydrogen peroxide, 2% L-Lactic acid, 10% Povidone-iodine, and 1% cetylpyridinium chloride) then were applied before sections were again sampled to determine APCs coliform, and *E. coli* counts. Among shaved samples, 1% CPC and hydrogen peroxide produced among the greatest reductions for APCs, and 1% CPC, 2% L-lactic acid, and hydrogen peroxide produced among the greatest reductions for coliforms. In Trial II, beef carcasses with hides on were sampled initially and shaved, and then antimicrobials (2% L-lactic acid, 3% hydrogen peroxide, and 1% CPC) were applied before sampling again for APC, coliform, and *E. coli* counts. For APCs, 1% CPC produced the greatest reduction on the hide surface. Selective application of these antimicrobials to shaved hide opening sites can reduce bacterial counts on hide surfaces, and therefore potentially reduce final carcass counts in these areas by decreasing the bacterial load before opening.

Introduction

Hides are considered an important source of pathogenic organisms during slaughter because of fecal contamination experienced during holding (Castillo et al., 1998). Prevalence levels of *Salmonella* on the hides of cattle have been determined to be as high as 15.4% pre-slaughter (Bacon et al., 2002). Bacteria present on hides can eventually be transferred to underlying "sterile" carcass tissue during the hide removal process. Contamination can occur when manure on the hide surface that has not been washed away before slaughter is carried onto the underlying carcass tissue (Delazari et al., 1998). Because errors in slaughter and dressing have been implicated as the primary vehicles for contamination of beef carcasses (Bacon et al., 2000), many processors have incorporated hide washes into their systems to reduce levels of microbial contamination in the final product; however, these systems often increase the solubilization and migration of pathogenic bacteria on hide surfaces. Selective application of antimicrobial compounds to hide opening areas targets the specific site on the hide that is of most concern to potentially minimize pathogen transfer from the hide to carcass tissues during harvest without increasing solubilization.

Experimental Procedures

Trial I

Fresh beef hides (n = 12; 4 per rep) were cut into 900-cm^2 sections with a minimum of 12 sections removed from each. Half of these sections were blown dry and shaved using Oster ClipMaster® clippers (Sunbeam Products, Inc., Boca Raton, FL) and the other half remained unshaved. The following day, hide sections were stretched over plastic clipboards and inoculated over a 400-cm^2 area with a bovine fecal slurry (10g bovine feces and 10 mL 0.1% sterile peptone water, Difco Laboratories, Detroit, MI) containing approximately 10^6 CFU/g. Inoculum was allowed a 20 min attachment period before gross fecal material was washed off using a handheld, compressed-air sprayer standardized to deliver approximately 1 L of distilled water over 90 sec.

After washing, hides sections were sampled with a pre-moistened (25 mL sterile 0.1% peptone water), sterile sponge (BioPro Sampling System, International BioProducts, Inc., Muncie, IN) to determine initial counts on hide surfaces. Following pre-treatment sampling, sections were subjected to one of seven antimicrobial treatments (control; distilled water; isopropyl alcohol; 3% hydrogen peroxide (Aaron Industries, Inc., Clinton, SC); 2% L-Lactic acid (Purac®, Rotra International, Wood Dale, IL); 10% Povidone-iodine (Vetadine, Vedco, Inc., St. Joseph, MO); and 1% cetylpyridinium chloride (Zeeland Chemicals, Zeeland, MI)) using saturated (50 mL), sterile sponges (Enviro-Sponge™; International BioProducts, Inc., Muncie, IN). Following treatment, hide sections were sampled again as described previously with a pre-moistened, sterile sponge to determine post-treatment counts. Sponge samples were then hand-massaged inside their plastic bags for 1 min and plated for enumeration of Coliform, *E. coli*, and APC.

Trial II

Beef carcasses (n = 18) with hides attached were selected from a small commercial processor. After exsanguination, approximately 100-cm^2 of the hide in the brisket area was sampled with a pre-moistened, sterile sponge as described previously to determine initial counts on hide surfaces. Following sampling, hides were shaved in approximately a 400-cm^2 area in the brisket region of the carcass. Cattle were then assigned to receive one of three antimicrobial treatments (2% L-lactic acid, 10% Povidone-iodine, and 1% CPC), and treatments were applied using saturated (50 mL), sterile sponges. After application of the designated treatment, hides were sampled again as described above to determine post-treatment counts. Following hide removal, 100-cm^2 of the carcass surface in the brisket area was sampled using a pre-moistened, sterile sponge as described previously. Sponge samples were placed in an insulated shipping container with refrigerant to keep them cool for transport to the food microbiology laboratory at Texas A&M University (College Station, TX). The next day, sponge samples were hand-massaged inside their plastic bags for 1 min, and then plated for enumeration of Coliform, *E. coli*, and APC. Data were analyzed using PROC GLM of SAS (SAS Institute, Cary, NC). Least-squares means were generated for each main effect and separated using the PDIFF option when appropriate.

Results and Discussion

Trial I

Least-squares means for the interaction of shaving × antimicrobial agent on APC reduction for hide sections inoculated with 10^6 CFU/g fresh bovine feces are reported in Table 1. Within non-shaved samples, 1% CPC and hydrogen peroxide produced among the greatest reductions, and within shaved samples, 1% CPC, 2% L-lactic acid, and hydrogen peroxide produced among the greatest reductions. Least-squares means for the interaction of shaving × antimicrobial agent on coliform reduction for hide sections inoculated with 10^6 CFU/g fresh bovine feces are reported in Table 2. Within non-shaved samples, 1% CPC produced the greatest reduction at 5.3 $\log_{10}$ CFU/100 cm^2, followed by 2% L-lactic acid, iodine, hydrogen peroxide. Within shaved samples, 1% CPC, 2% L-lactic acid, and hydrogen peroxide produced among the greatest reductions with 4.5, 4.1, and 3.9 $\log_{10}$ CFU/100 cm^2 reported, respectively.

Least-squares means for the treatment effects of shaving and antimicrobial agents on *E. coli* reduction on hide sections inoculated with 10^6 CFU/g fresh bovine feces are reported in Table 3. Non-shaved samples had a mean reduction of 2.0 $\log_{10}$ CFU/100 cm^2, and shaved samples had a mean reduction of 2.8 $\log_{10}$ CFU/100 cm^2. Within the antimicrobials tested, 1% CPC produced the greatest reduction, followed by 2% L-lactic acid and hydrogen peroxide.

Across all treatments, shaving appeared more advantageous than not shaving when applying antimicrobial agents to reduce bacterial counts on the hide surface. After completion of Trial I, shaving together with 1% CPC, 2% L-lactic acid, and hydrogen peroxide were determined to be the three most effective shaving/antimicrobial combinations, and were selected for further evaluation in Trial II.

Trial II

The average initial hide counts before treatment application were 8.1 $\log_{10}$ CFU/100 cm^2 for APC, 4.2 $\log_{10}$ CFU/100 cm^2 for coliforms, and 4.5 $\log_{10}$ CFU/100 cm^2 for *E. coli*. Least-squares means for APCs, coliform, and *E. coli* counts and log reductions on brisket areas of hides before and after treatment are reported in Table 4. For APCs, 1% CPC produced the greatest reduction on the hide with 3.9 $\log_{10}$ CFU/100 cm^2 reported. For coliforms and *E. coli*, there were no ($P > 0.05$) differences among treatments for hide reductions. Though few differences existed between antimicrobial treatments, all three resulted in approximately a 3 $\log_{10}$CFU/100 cm^2 reduction when applied to shaved hide surfaces in the brisket region of the carcass.

Implications

By shaving and applying an antimicrobial agent directly to the hide opening area in the brisket region, we were able to reduce bacterial counts on hide surfaces. This method targets a specific area on the hide that is very susceptible to fecal contamination, yet very critical when opening up the hide for removal. Selective application of these antimicrobials to shaved hide opening sites can reduce bacterial counts on hide surfaces, and therefore potentially reduce final carcass counts in these areas by decreasing the bacterial load before opening. Further research should be conducted to determine effectiveness along additional areas of the hide surface, and to evaluate the practicality of this process outside of a research setting.

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Table 1. Least-squares means for the interaction of shaving × antimicrobial agent on APC reduction

	$\log_{10}$CFU/100 cm^2 reduction[a]	
Antimicrobial	Non-shaved	Shaved
Water	0.9c	0.6c
Alcohol	0.5c	1.8bc
1% CPC	4.1a	4.6a
Iodine	1.3c	1.8bc
2% L-lactic acid	2.7b	4.1a
Hydrogen peroxide	4.5bc	4.4a
SEM	0.48	0.48

LS means lacking common letters (a-c) differ ($P < 0.05$).

[a]Log reduction = ($\log_{10}$CFU/100 cm^2 reduction on untreated hide area) – ($\log_{10}$CFU/100 cm^2 reduction on treated hide area).

Table 2. Least-squares means for the interaction of shaving × antimicrobial agent on coliform reduction

	$\log_{10}$CFU/100 cm^2 reduction[a]	
Antimicrobial	Non-shaved	Shaved
Water	-0.9d	0.5d
Alcohol	0.2d	1.8c
1% CPC	5.3a	4.5ab
Iodine	2.4c	2.5c
2% L-lactic acid	2.8c	4.1b
Hydrogen peroxide	2.2c	3.9bc
SEM	0.43	0.43

LS means lacking common letters (a-d) differ ($P < 0.05$).
[a]Log reduction = ($\log_{10}$CFU/100 cm^2 reduction on untreated hide area) – ($\log_{10}$CFU/100 cm^2 reduction on treated hide area).

Table 3. Least-squares means for treatment effects of shaving and antimicrobial agents on *E. coli* reduction

Treatment effects	$\log_{10}$CFU/100 cm^2 reduction[a]
Shaving	
Non-shaved	2.0b
Shaved	2.8a
SEM	0.17
Antimicrobial	
Water	0.2d
Alcohol	0.9d
1% CPC	4.5a
Iodine	2.4c
2% L-lactic acid	3.3b
Hydrogen peroxide	2.9bc
SEM	0.30

LS means within treatments lacking common letters (a-d) differ ($P < 0.05$).
[a]Log reduction = ($\log_{10}$CFU/100 cm^2 reduction on untreated hide area) – ($\log_{10}$CFU/100 cm^2 reduction on treated hide area).

Table 4. Least-squares means for APCs, coliform, and *E. coli* counts and log reductions on brisket area of shaved hides before and after treatment with 1% CPC, 2% L-lactic acid, or hydrogen peroxide

		$\log_{10}$CFU/100 cm^2		
Indicator organism	Treatment	Before	After	Reduction[a]
APC	1% CPC	8.2a	4.4c	3.8a
	2% L-lactic acid	7.5b	5.2b	2.3b
	Hydrogen peroxide	8.7a	6.5a	2.2b
	SEM	0.22	0.21	0.28
Coliform	1% CPC	4.6b	1.3b	3.3a
	2% L-lactic acid	3.7c	1.1c	2.6a
	Hydrogen peroxide	5.2a	2.6a	2.6a
	SEM	0.20	0.27	0.29
E. coli	1% CPC	4.3b	1.3a	3.0a
	2% L-lactic acid	3.2c	1.1b	2.1a
	Hydrogen peroxide	5.1a	2.1a	3.0a
	SEM	0.24	0.29	0.33

LS means lacking common letters (a-c) differ ($P < 0.05$).

[a]Log reduction = ($\log_{10}$CFU/100 cm^2 reduction on untreated hide area) – ($\log_{10}$CFU/100 cm^2 reduction on treated hide area).

RELATIONSHIP BETWEEN STRESS RESPONSIVENESS, ANIMAL TEMPERAMENT, AND FECAL SHEDDING OF *ESCHERICHIA COLI* O157:H7 IN FEEDLOT CATTLE

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Summary

A study was conducted to determine if a relationship exists between temperament, stress response and the shedding of *Escherichia coli* O157:H7. Cattle (n = 150) were evaluated for disposition and stress response by measuring exit velocities, chute and pen scores, and serum cortisol levels at four different times during the feeding period. A temperament index was created to classify cattle as Excitable, Intermediate, or Calm. The presence of *E coli* O157:H7 was determined by rectal swabs on live cattle and swabs of colons collected at the processing facility. Variables for pre-shipment temperament index, exit velocity, pen score, arrival exit velocity and mid-point exit velocity, and cortisol levels were all affected by temperament group classification. The percentage of cattle shedding *E. coli* O157:H7 at arrival was approximately equal between temperament groups. Calm cattle tended to have a greater percentage test positive for *E. coli* O157:H7 when sampling times were pooled together. Based on these results, it appears that fecal shedding occurs in Calm cattle at later points in the feeding period. However, due to a relatively low incidence of *E coli* O157:H7, a small occurrence of positive samples could drastically change these distributions.

Introduction

Evidence suggests that reducing the presence of *Escherichia coli* O157:H7 on live animals entering a harvest facility should reduce the contamination of carcasses (Elder et al., 2000). Even with cattle that have been exposed to *E. coli* O157:H7, not all will shed the microorganism (Sargeant et al., 2000). Curley et al. (2004) indicated strong relationships between animal temperament and stress responsiveness. Stress response may affect the colonization and shedding of pathogens. Stress has been linked to reduced immune capacity, and the stress hormone epinephrine has been linked to the expression of bacterial genes essential for colonization (Sperandio et al., 2003). Because some animals do not shed *E. coli* O157:H7, despite being exposed to the pathogen, this might be due to variation in stress response among individuals. Research on human subjects suggests that individuals respond neurogically to stressful situations differently (Rosenkranz et al., 2003). We hypothesized that animals exhibiting a large stress response to common management practices will be more susceptible to colonization of the colon by *E. coli* O157:H7 and will, therefore, exhibit increased shedding of this organism compared to animals displaying a lesser stress response.

Experimental Procedures

Cattle (n = 150) were selected to evaluate the relationship between animal temperament and stress responsiveness to the fecal shedding of *E. coli* O157:H7. With the exception of data and sample collection, the cattle were managed identically to standard practices of the feedlot. The disposition of the animals was evaluated by measuring exit velocity prior to shipping the cattle, upon arrival at the feedlot, and at approximately 70d on feed. Exit velocity (Burrow et al., 1998) was determined by the rate at which an animal exited the working chute and traveled a fixed distance of 6.00 ft. During the pre-shipment data collection, each animal was evaluated visually and assigned a chute score (Grandin, 1993). Chute scores consisted of a scale from 1 to 5, with 1 = calm, no movement, and 5 = rearing, twisting, and struggling violently. Pen scores were assigned based on an individual animal's response to being approached (Hammond et al., 1996). Pen scores ranged from 1 to 5 with 1 = not excited by humans, and 5 = excited, runs over everything in its path. A temperament index {(exit velocity + pen score)/ 2} was created to classify cattle as Excitable, Intermediate, and Calm. Temperament groups were segmented based on mean standard deviation values of the temperament index. Index values greater than one standard deviation higher than the mean were classified as Excitable, whereas more than one standard deviation below identified Calm cattle. Temperament index values within one standard deviation either side of the mean incorporated Intermediate cattle.

Blood samples were collected via tail venipuncture and serum concentrations of cortisol were determined by method of Carroll et al., (1996). Fecal swabs were obtained upon arrival at the feedlot, at approximately 70d on feed, and before transport to the harvesting facility by inserting a cotton swab into the animal's anus, contacting the sides of the rectum. The swabs were placed in Cary Blair transport medium and placed on ice packs for transport to the laboratory.

At the harvesting facility, sections of the distal colon were removed and transported to the laboratory. There, colons were opened longitudinally, and a 25-cm^2 area was swabbed. The rectal and colon swabs were each placed in a tube containing 10 ml of m-EC broth supplemented with 20mg/L novobiocin and incubated for a minimum of 16 h at 42°C. An indirect enzyme linked immunosorbent assay (ELISA) using monoclonal antibodies specific for O157 lipopolysaccharide and H7 flagellar antigen was used as a screening test to identify positive samples. Positive samples from the ELISA screening test were subjected to immunomagnetic separation. Briefly, 1 ml of the pre-enriched sample was added to a tube containing 20 µl of anti-O157:H7 beads and agitated for 10 min at room temperature. The beads were washed three times with physiological buffered saline with 0.05% Tween-20. Then 25 µl of the bead-bacteria mixture was streaked onto CT-SMAC plates containing 0.05 mg/ml cefixime and 2.5 mg/L tellurite. The remaining 25 µl bead-bacteria mixture was streaked onto CHROMagar plates supplemented with 2.5 mg/L potassium tellurite. The plates were incubated for a minimum of 16 h at 37°C. Following incubation, typical O157:H7 colonies were selected and transferred to Tryptic Soy Agar slants and blood agar plates. Typical colonies then were subjected to a Gram stain, catalase test, oxidase test, and latex agglutination. Isolates that were presumptive for *E. coli* O157:H7 were confirmed biochemically using a Vitek system.

Temperament data were analyzed using the PROC MIXED procedure of SAS (SAS Institute, Cary, NC), whereas the Chi-square option in the PROC FREQ procedure of SAS was used to analyze fecal shedding of *E. coli*.

Results and Discussion

As expected, variables of pre-shipment temperament index, exit velocity, and pen score, as well as arrival and mid-point exit velocity differed (P < 0.05) greatly between temperament groups (Table 1). Pre-shipment chute scores for Excitable cattle differed (P < 0.05) from the other two groups. Contrary to what was expected, pre-shipment, arrival, and final cortisol levels differed (P <0.05) only for Excitable cattle compared to both Calm and Intermediate groups. Conversely, mid-point cortisol levels differed (P <0.05) between all classifications.

Frequency diagrams for fecal shedding of *E. coli* O157:H7 are shown in Figure 1. Chi-square analysis showed that the percentage of cattle shedding the pathogen at arrival was approximately equal between temperament groups. At the mid-point cattle with Intermediate temperament index values tended (P = 0.12) to have a greater proportion of animals shedding than those from either extreme. When sampled before shipment to the processing facility, a higher proportion (P = 0.02) of cattle displaying Calm temperaments shed *E. coli* O157:H7 than the other groups. Results for postmortem colon samples had a similar trend. However, the disparity in the results of these two sets of tests is troubling, particularly because swabbing the excised colon was expected to be more sensitive than the fecal swab. When the results from all four sampling times were pooled, the Calm cattle tended (P = 0.15) to have a greater percentage test positive for *E. coli*. However, this trend in the pooled frequency distribution is largely dictated by the final sampling time. Based on these results, it appears that Excitable cattle are not more likely to shed *E. coli* O157:H7. In fact, it seems that Calm cattle are more susceptible. However, it is important to note that a relatively small number of the sample tested positive for *E. coli* O157:H7 (82 of 600 tests). Therefore, a relatively small number of positive samples could potentially cause drastic changes in these distribution.

Implications

Variables used for estimating animal temperament appear consistent throughout the trial for groups of Excitable, Intermediate, and Calm cattle. Based on these results, it appears that fecal shedding occurs in Calm cattle at later points in the feeding period. However, due to a relatively low incidence of *E. coli* O157:H7, data must be interpreted with care because of potential bias attributable to a very small occurrence of the pathogen.

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Table 1. Least-squares means for temperament indicating traits of yearling-fed cattle segmented into groups according to temperament traits measured before shipment to the feeding facility

Trait	Temperament classification Calm	Intermediate	Excitable	RMSE	*P* >F
n	25	93	32		
Pre-shipment temperament index[a]	1.63c	2.85b	4.31a	0.22	<0.001
Pre-shipment exit velocity (m/s)	1.35c	2.27b	3.60a	0.40	<0.001
Pre-shipment pen score[b]	1.11c	2.40b	3.58a	0.53	<0.001
Pre-shipment chute score[c]	1.25b	1.52b	1.93a	0.51	<0.01
Pre-shipment cortisol (ng/mL)	10.10b	10.87b	15.20a	28.16	<0.001
Arrival exit velocity	1.50c	2.16b	2.99a	0.65	<0.001
Arrival cortisol (ng/mL)	10.60b	11.74b	16.83a	55.62	<0.01
Mid-point exit velocity	1.49c	1.99b	2.76a	0.52	<0.001
Mid-point cortisol (ng/mL)	10.23c	13.21b	16.38a	37.54	<0.001
Final cortisol (ng/mL)	11.93b	12.89b	16.43a	40.21	0.01

[a]Temperament index = (exit velocity + pen score)/2

[b]1 = not excited by humans; 2 = stands in corner if humans stay away; 3 = runs along fences, head up, stops before hitting gates and fences , avoids humans; 4 = stays in back of the group, head high and very aware of humans; 5 = excited, runs over anything in its path (Hammond et al., 1996)

[c]1 = calm, no movement; 2 = slightly restless; 3 = squirming, occasionally shaking the chute; 4 = continuous, vigorous movement and shaking of the chute; 5 = rearing, twisting and struggling violently (Grandin, 1993)

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$)

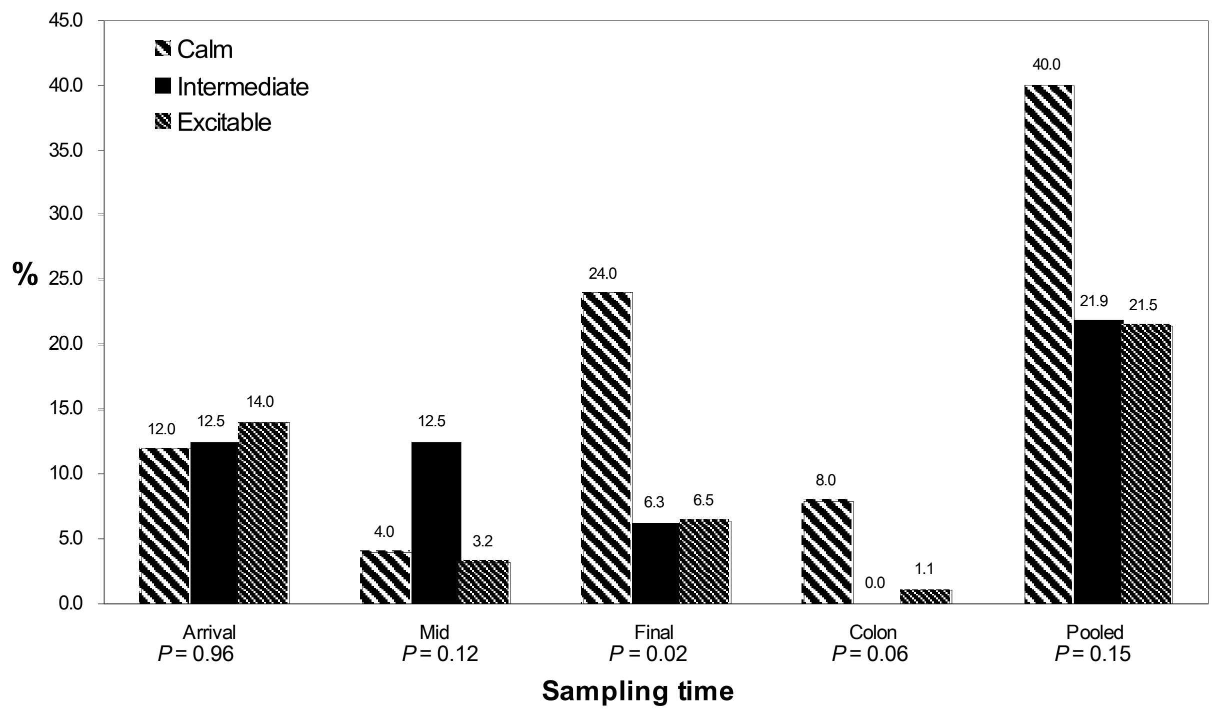

Figure 1. Fecal shedding of *Escherichia coli* O157:H7 at three different sampling times in feedlot cattle segmented into temperament groups before shipment to the feeding facility. P-values are for chi-square tests.

Health

DETECTION AND CONTROL OF BOVINE PARATUBERCULOSIS IN BEEF HERDS IN TEXAS

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Summary

Johne's Disease is a chronic digestive disease of cattle and other ruminant caused by *Mycobacterium avium* subsp. *paratubeculosis* (MAP). The disease causes body weight loss and chronic intermittent diarrhea. With the objective of evaluating diagnostic techniques, we conducted a cohort study (n = 849) in three beef cow/calf operations using a commercial ELISA and Fecal Culture (FC) in parallel and serial testing, during 2002, 2003 and 2004. Test results were evaluated using statistical analysis (Chi square), and Bayesian distribution. Under the situations evaluated the ELISA test showed a sensitivity of 0.083, specificity 0.920, positive predictive value 0.509, negative predictive value 0.500, positive likelihood ratio 1.033, negative likelihood ratio 0.997, diagnostic odds ratio 1.036, and kappa (agreement beyond chance) of 0.003. Bayesian estimations indicated a low positive predictive value of the ELISA test (0.035), with a high negative predictive value (0.999).

Introduction

Johne's Disease is a chronic digestive disease of cattle and other ruminants caused by *Mycobacterium avium* subsp. *paratubeculosis* (MAP). This disease is characterized by a decrease in milk production, loss of body condition, and intermittent diarrhea (Johnson-Ifearulundu et al., 2000). MAP infects young cattle and the infection progresses slowly, with clinical signs most commonly appearing in cows 3 to 6 years of age. Johne's diseases and its sub-clinical form (known as paratuberculosis), (Whitlock and Buergelt, 1996) are widely distributed in beef herds in Texas (3% of 4,579 tested herds)(Roussel et al 2005). These diseases do not have treatment, and although a vaccine is currently available, its efficacy is questionable (Whittington and Seargeant, 2001). MAP has also being implicated affecting humans (Hermon-Taylor et al., 2000).

Paratuberculosis is, apart from an individual disease, more importantly, a herd problem. Early detection of infected herds can lead to early intervention, thereby minimizing economic damage caused by the infection. The purpose of this investigation was to determine the prevalence of exposed cattle to MAP, and prevalence of fecal positive cattle in three commercial cow/calf operations in Texas.

Experimental Procedures

Three herds A (n = 39), B (n = 690) and C (n = 120) of purebred Brahman, Santa Gertrudis and commercial stock Brahman herds were selected for this investigation. The herds were located in central and southeast Texas. The experiments were conducted during 2002, 2003 and 2004. Risk analysis was conducted for each herd owner and revealed the presence of Johne's disease in the herds, with previous history of Johne's disease cases present. All the breeding cows were included in the experiments. Blood and fecal samples were taken from each cow, yearly. Blood samples were collected and serum samples were analyzed against Johne's disease with ELISA using a commercial kit (HerdCheck, *Mycobacterium paratuberculosis*, antibody test Kit, IDEXX laboratories). This test is an enzyme immunoassay for the detection of MAP-specific antibodies in serum and plasma of cattle. Individual fecal samples were collected and analyzed by fecal culture using liquid media (Bactrec System) and solid media (Herrold's yolk media) using a serial and parallel testing schemes. Test sensitivity and specificity were calculated using regression modeling and Chi square. Bayesian estimations were calculated based on derivatives of the Bayes's formula.

Results and Discussion

The number of positive cases of bovine paratuberculosis based on ELISA found during 2002 were 5.12% (herd A), and 2.60% (herd B). During 2003 ELISA cases were 10.25% (herd A), 5.94% (herd B) and 39.21% (herd C). During 2004, ELISA cases were 10.25% (herd A), 8.26% (herd B) and 38.11% (herd C) (Table 1). No animals were detected by fecal culture for herd A, two positive cases by fecal culture were detected in herd B in 2004, four cases in herd C during 2003 and none in 2004. Under the situations evaluated, the ELISA test showed a sensitivity of

0.083, specificity 0.920, positive predictive value 0.509, negative predictive value 0.500, positive likelihood ratio 1.033, negative likelihood ratio 0.997, diagnostic odds ratio 1.036, and kappa (agreement beyond chance) of 0.003. Bayesian estimations indicated a low positive predictive value of the ELISA test (0.035), with a high negative predictive value (0.999).

Our results are indicative of three possible scenarios: a) Brahman and Brahman crossed cattle can have immune response against MAP detectable by ELISA, before bacterial elimination, b) available diagnostic methods for fecal culture are unable to detect low levels of MAP elimination or c) non-specific immune response is detected by ELISA, creating numbers of false-positives cases in the absence of MAP elimination. On the other hand, fecal positive cases showed high ELISA test results, 75% of the time, when serial testing was conducted.

Implications

Although widely known, Johne's Disease and bovine paratuberculosis are diseases poorly understood, with lengthy development and limited test accuracy. Under these circumstances, veterinarians, animal health officials and beef producers face interpretation of test results for Johne's disease difficult (Kennedy and Benedictus, 2001). Variation in test results reduces test confidence, thus making decisions based on test results hard. Our experience indicates that the use of ELISA for Johne's disease tested only once to detect MAP eliminating individuals will result as a poor decision. Consecutive testing, however, can provide better results. Although not very reliable to identify positive cases, ELISA testing could be used to monitor individuals in absence of the disease or exposure. ELISA testing could be also used (with 99.9% of accuracy) when purchasing new animals to be introduced once a herd reaches MAP-free status or during disease management control programs.

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Table 1. Prevalence of bovine paratuberculosis in the experimental herds (by year)

Year	Herd	ELISA + (%)	Fecal culture (cases)
2002	A	5.12	0
2003	A	10.25	0
2004	A	10.25	0
2002	B	2.60	0
2003	B	5.94	0
2004	B	8.26	2
2003	C	39.21	4
2004	C	38.11	0

Marketing and Economics

ELECTRONIC ANIMAL IDENTIFICATION FOR PRODUCTION AND FINANCIAL RISK MANAGEMENT

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Summary

Increased record keeping will be required to meet animal tracking, food safety and trace-back requirements, and possibly, country of origin labeling information for the beef industry. Cattle marketability may eventually hinge on recordkeeping requirements over and above current standard operating procedures for the majority of operations in Texas. A primary goal of this project is to make producers better able to use new products that can assist them in implementing an effective animal identification plan for production and economic management. This project introduces producers to electronic identification tools and demonstrates their use with readily available computer software. As a result of this project, producers have gained experience with individual electronic animal identification systems to meet tracking requirements and improve management decision-making.

Introduction

Livestock producers face a new level of market and price risk due to animal diseases that could wreak havoc on the market. This new risk is price risk in that events cause price swings, as evidenced by inconclusive BSE tests. Another risk component is market access and, potentially, large price discounts based on the lack of animal specific information.

Animal identification, as currently discussed, is an animal tracking mechanism primarily to allow the containment of diseases. Potentially, it has the ability to facilitate a traceability system further through the meat supply chain. These systems will lead to a more differentiated market where animals with more identification information will command premiums over those animals without information. The lack of information may even preclude producers from access to some markets. More sophisticated animal identification systems will enable producers to track production and management data and, most important, turn this data into decision making information.

Experimental Procedures

A primary objective of this project is to make Texas cattle producers aware of the products and/or strategies that can assist them in developing and implementing an effective production and economic risk management plan for their operation from the dual use of animal identification data. We demonstrate how individual cow data can be obtained by electronic identification, and then track that data through a record-keeping system, showing how that data can be processed into information for management decision purposes. We then demonstrate how this data can be used in decision support aids related to heifer retention, cow investment, stocking rate, and leasing decisions.

This project was demonstrated at Texas Cooperative Extension cattle clinics around the state. The presentations were part of larger programs put on by county livestock committees. Most of the presentations were part of a larger program where officials from the Texas Animal health Commission discussed premises identification and the broader animal identification process.

Electronic animal identification (EID) tags were distributed to the clinic participants. In this case eartags were used. Two different brands were demonstrated. The key is that as long as the tags are ISO compliant they are compatible with ISO compliant EID readers. Rubber ears with EIDs attached were also distributed to the audience to illustrate the current preferred and recommended location for the tags.

The EIDs were read using a wand-type reader. This reader was attached to a laptop computer. When the reader "read" the tag the 15 digit electronic ID number appeared on a large screen for the audience to see that the reader did, in fact, read the number.

One commercially available software package was used to demonstrate the technology. The EID number was read by the wand and fed into the computer software package, which was projected onto a large screen. The tag, or calf, was now identified for future record keeping. Information on the animal (calf or cow) was entered into the software and was stored by EID number, among other various identifiers. A large amount of information could be recorded for the producer's future use such as approximate date of birth, vaccination routine, weight at various times, dam, and sire, etc. Various report writing routines were demonstrated for producers for record keeping information.

Results and Discussion

At this time, four programs of this type have been presented in different regions of the state. More than 400 producers have participated in the programs. For many producers it was the first opportunity to observe the EIDs in person. The use of the tags has generated a lot of discussion particularly focusing on the longevity of the tags. At this point, little is known about the loss rate of tags in range cattle conditions. Reports have been of very low to no losses in feedlot conditions. In addition, little is known about the useable life on the tags. For instance, there is not a lot of information on breakage or loss of electronic signal. Reports are that there is ongoing research in this area.

Issues about replacement of electronic identification tags and their linkage to a tracking system was the source of many questions. At this time, it is unclear that a procedure is in place to replace lost or damaged tags during the production process other than the expectation that there will be some failure or loss rate and a procedure developed replacement.

Part of the importance of this project has been to demonstrate the costs of animal identification to producers. We purchased the equipment at retail prices as part of this project. The EID tags cost $2.25 for each tag. The wand type reader was $500. The software was $395 for the deluxe, top end version (other scaled down versions exist). Obviously per head costs would decline as the cost of the reader and software was spread over more head. If a producer already tagged their calves at their normal working time then the labor costs involved would not change. Office labor time involved in implementing the system depends in large part on the amount of detail a producer desires. The funding for this project was obtained in a commodity research partnership with the Risk Management Agency of the United States Department of Agriculture.

Another important result of this project was demonstrating what works and what does not. Produces were able to see on the screen that the wand reader worked with real cattle and they could see the EID number projected on the screen. It was demonstrated that one type of reader was able to read eartags from several companies.

The software was easy to use with icons to aid the user. Customized reports listing cattle sold, inventory numbers, and vaccination records tied to the EID number were easy to develop. For demonstration purposes under a time constraint only one software package was used. There are other packages and systems available.

The beef cattle industry is moving towards individual cattle identification to provide trace-back capability for food safety issues, cattle age verification, and a potential voluntary country of origin labeling (COOL) program. There are a number of areas where the commercial cow-calf producer can use individual animal identification data in addition to the reasons listed above to make their cow-calf operations more cost effective. Some of these areas are:

- Provide precise inventories by category of animal.
- Cow herd reconciliation for financial reporting purpose.
- Identify cows that are to be culled for reasons related to the weight and/or quality of the calf.
- Use the dam's historical production data to select replacement heifers after they have met other heifer selection criteria.
- Verify and record calf age and origin.
- In case of herd downsizing in response to drought, individual animal performance data is very valuable to determine which cows to save.
- Record sale information and when animals left the operation.

Implications

The key to increasing individual producer profit from animal identification, irrespective of what the system is mandating, is to make the investment and effort to get more out of the data for monitoring and managing cattle. Merely meeting identification requirements is not going to generate decision-making profitable information. Now there is an opportunity for industry participants to reap the benefits and to offset the mandate's increase in cost to cattle producers.

ECONOMIC IMPACT OF COUNTRY-OF-ORIGIN LABELING IN THE U.S. BEEF INDUSTRY

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Summary

Financial and production data were collected and used from U.S. retail chain stores and distributors, meat packers and processors, cattle feedlots, and cattle backgrounding yards and stockers to estimate the beef industry costs of country-of-origin labeling (COOL) implementation. These estimates were calculated from the survey data to determine the magnitude of increases in the demand for retail beef, wholesale beef, fed cattle, and feeder cattle necessary to offset the increase in costs of implementing mandatory COOL regulations. The survey results indicated a total cost of COOL of $1.875 billion to the beef industry. The model results suggest that a modest increase in beef demand at all levels of the marketing channel would offset the cost of COOL.

Introduction

One of the most contentious issues in the 2002 farm bill was mandatory country-of-origin labeling (COOL) for beef, lamb, pork, fish, and other agricultural commodities. A primary concern about the COOL program is the incremental costs incurred by retail chain stores and distributors, meat packers and processors, and others in the supply chain. Since the release of the mandatory COOL program, a number of individuals and organizations have published estimates of the additional costs associated with the implementation of the mandatory COOL program. This research provides a cost assessment of implementing COOL regulations for the beef industry. Using these costs, an estimate is made of the increases in the demand for retail beef, wholesale beef, fed cattle, and feeder cattle needed to offset the increase in costs of implementing mandatory COOL.

Experimental Procedures

Past estimates of the costs to the beef industry of COOL range from $200 million to $5.9 billion dollars (see Hanselka (2004) for details). Interestingly, in arriving at these cost figures, none of the studies formally surveyed industry participants. In order to gain a comprehensive look at the economic impact of COOL on each sector of the beef industry, surveys were developed in such a way as to collect actual company cost estimates and production data that would result from the implementation and compliance of COOL. Because of the differences in cost structure, production practices, and marketing strategies that exist among the various sectors of the beef supply chain, the actual additional company costs resulting from the implementation of COOL included both incremental and capital costs associated with identification, segregation, preservation, management, operational, labeling, labor, and other compliance and enforcement costs. As for the production practices, the survey included questions pertaining to identification and distribution measures and changes that could occur as a result of the implementation of COOL.

Aside from estimating the incremental and capital costs accruing to each market level of the beef industry, we also seek to determine the changes in market demand, price and overall economic welfare effects of COOL on all participants of the beef industry. Similar to the cost estimates, several studies have been conducted examining the market, social welfare, and revenue effects of COOL on the beef, pork, and poultry industries. Unlike previous studies, this research determined the magnitude of increases in the demand for retail beef, wholesale beef, fed cattle, and feeder cattle needed to offset or negate the induced costs of COOL such that producers and consumers would be no worse off from an economic welfare standpoint. In order to accomplish this feat, a linked Excel spreadsheet was developed comprised of economic parameters (e.g. estimates of elasticities of supply and demand) and industry data associated with the beef industry. Changes in demand and prices needed to offset the estimated incremental costs of COOL so as to leave the quantity moved through the supply chain unchanged as well as the welfare of those engaged in the beef marketing channel unchanged were calculated. By holding quantity constant, the size of the industry remains unchanged.

Results and Discussion

Based on the survey results, the estimated retail chain store and distributor level costs for the beef supply chain are approximately $.08 per pound of beef sold to reconfigure their meat departments to maintain product identity, to maintain required record-keeping at individual stores, and to place COOL labels on every beef item in the meat case. Meat packers and processors costs, to reconfigure their slaughter and fabrication departments to maintain segregation and identity of cattle into boxed beef, were estimated to be $16.99 per head. Costs for the cattle feedlot segment were estimated at $12.94 per head for feeding segregation, data storage, and costs associated with tracking cattle. Finally, it was estimated that the marginal costs of implementing COOL for cow-calf operators, cattle backgrounders, and cattle stockers was roughly $3.89 per head for identifying the movement of cattle and starting the passport transactions up to delivery of the animal to finishing. It is important to note that the cost estimates at any level of the marketing channel varied noticeably with each individual firm or company. This finding is due in part to the specific management and production practices the firm/company has in place and whether or not that particular firm/company handles only foreign beef products or cattle, only domestic beef products or cattle, or a combination of foreign and domestic beef products.

The aforementioned costs were applied to actual beef industry numbers in 2003, determining the total costs incurred at each level of the supply chain in the beef industry. Using consumption figures of 18.892 billion pounds of beef in 2003 and assuming 52 percent was sold at retail, total incremental costs of the mandatory COOL program accruing to retail chain stores and distributors amounted to $818 million dollars. As for meat packers and processors, given that 35.494 million head of cattle were slaughtered in 2003, total additional costs added to the meat packing sector amounted to $603 million dollars. For cattle feedlots, based on 27.567 million head of fed cattle marketed in 2003, total costs to the cattle feeding sector was $356 million dollars. Finally, given the fact that 24.930 million head of calves were placed in feedlots in 2003, total incremental costs to the cow-calf producer, cattle backgrounding, and cattle stocker segments of the beef industry amounted to $97 million dollars. For the beef industry as a whole then, the estimated additional annual costs to satisfy COOL requirements totaled $1.875 billion dollars, using 2003 numbers. All told, our cost estimates are comparable to those reported in the literature, falling at the upper end of the spectrum.

Based on industry estimates of elasticities of supply and demand, incremental costs associated with COOL, and data from 2003, our results indicate that an increase of 1.2 percent in beef demand for heavy choice cuts is necessary for the economic gains and losses in the retail sector to be zero. In other words, a 1.2 percent increase in demand would be enough to offset the increase in costs due to COOL. Furthermore, our results reveal that increases of 0.78 percent in beef demand for heavy choice carcasses and 0.71 percent in beef demand for heavy select carcasses are necessary for the producers and consumers in the wholesale production sector to be no worse off economically. Finally, for fed cattle and feeder cattle markets, our results indicate that increases of 0.56 percent and 0.24 percent in demand for fed and feeder cattle, respectively, are necessary to leave economic welfare effects unchanged.

Under these conditions, retail beef prices would increase by 2.44 percent, whereas retail select beef prices increase by 2.72 percent. Similar to the retail market, wholesale beef prices would increase about 1.9 percent under the COOL program. Fed cattle prices would increase by 1.40 percent and feeder cattle prices would increase by 0.62 percent under this mandatory legislation.

Where there is no change in demand arising from the implementation of COOL and only increases in costs, the results reveal economic losses of $827 million at the retail level, $596 million at the wholesale level, $331 million at the fed cattle level, and $95 million at the farm level (feeder cattle). Thus, with no rightward shifts in consumer demand, the beef industry stands to lose $1.85 billion.

With this information, the decision as to whether or not COOL is feasible, ultimately depends on two key factors: (1) the level of marketing and production costs accruing at all marketing levels of the industry; and (2) the increase in demand at the various marketing levels needed to offset the induced costs of COOL. In order to offset increased costs to the industry as a result of COOL and to allow the same amount of beef to be sold before the implementation of COOL, rather moderate shifts in demand at each level of the marketing channel are necessary. Given that the magnitudes of these demand shifts are indeed modest, it is possible that COOL may not be problematic from an economic standpoint. Over the last 6 years beef demand has increased, so a one percent increase in demand is not out of the question.

Implications

This research provides information on the costs and benefits of COOL to better inform producers, policy makers, and other industry participants. While the costs of COOL were large for the beef industry, the increase in demand, necessary to offset them, was not overly large.

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Meat Science

FATTY ACID COMPOSITION OF PLASMA AND SUBCUTANEOUS ADIPOSE TISSUE OF ANGUS AND WAGYU STEERS FED TO JAPANESE AND U.S. CARCASS ENDPOINTS

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Summary

We predicted that the lipid composition of subcutaneous adipose from Angus and Japanese Wagyu steers would not differ unless the steers were fed to a Japanese live weight. Eight steers of each breed type were assigned to a high-energy, corn-based diet. Another 8 steers of each breed type were a hay-based diet. Targeted final body weights were 1,200 lb (U.S. endpoint) and 1,400 lb (Japanese endpoint). Omega-6 and omega-3 fatty acids were higher in plasma of hay-fed steers than in corn-fed steers. Oleic acid was greater in fat from Wagyu steers than in Angus steers. Oleic acid in fat was decreased, and omega-3 fatty acids were increased slightly, by the hay diet. Melting points of lipids from the ribeye decreased with time, and were least in corn-fed steers (P = 0.05). Ribeye cholesterol increased with time. In conclusion, composition of carcass fat is profoundly influenced by diet and slaughter endpoint.

Introduction

Fatty acids in meat, especially monounsaturated fatty acids (MUFA), have been shown to influence beef palatability (Dryden and Marchello, 1970; Westerling and Hedrick, 1979) and fat softness (Perry et al., 1998). Fatty acid composition of subcutaneous fat is affected by breed, sex, age, and nutrition (Clemens et al., 1973; Yoshimura and Namikawa, 1983; Eichhorn et al., 1986; Huerta-Leidenz et al., 1993; Zembayashi, 1993; Mandell et al., 1998). Japanese Black (Wagyu) steers have been known to produce carcasses that have adipose tissues with higher percentages of MUFA than Holstein, Japanese Brown, Charolais, or Angus steers (Sturdivant et al., 1992; May et al., 1993; Zembayashi et al. 1995; Oka et al., 2002). The longer finishing period of Wagyu cattle compared to other breed types (Lunt et al., 1993) may contribute to the higher concentration of adipose tissue MUFA. Therefore, this study was designed to document the interaction between diet and slaughter endpoint on composition of fat from Angus and cross bred Wagyu steers.

Experimental Procedures

Animals and Diets

Sixteen Wagyu crossbred (7/8 Wagyu or higher) and 16 Angus steers were purchased as calves at weaning (approximately 8 months of age). Coastal bermuda grass hay containing 9.5% crude protein was fed free choice for 8 d after the steers were transported to the Texas A&M University Research Center, McGregor. Eight steers of each breed type were assigned to a high-energy, corn-based diet containing 48% ground corn, 20% ground milo, 15% cottonseed hulls, 7.5% molasses, 0.96% limestone, 0.56% trace mineral salt, and 0.08% vitamin premix (Table 1). The diet was designed to achieve an average gain of 3 lb per day, and was fed free choice for 8 or 16 months after weaning (n = 4 per breed and time on feed). The remaining 8 steers of each breed type were offered coastal bermuda grass hay free choice, supplemented with non-protein nitrogen in a cooked molasses carrier, and fed daily an amount of the corn-based diet estimated to achieve a targeted rate of gain of 2 lb per day. The hay-fed steers were fed for 12 or 20 months after weaning (n = 4 per breed and time on feed). The average initial weights for Wagyu and Angus steers were 382 lb and 462 lb, respectively. Targeted final body weights were 1,200 lb for steers fed for either 8 months on corn or 12 months on the hay-based diet (U.S. endpoint), and were 1,400 lb for steers fed for either 16 months on corn or 20 months on the hay-based diet (Japanese endpoint). Diet and time-on-feed were totally confounded in the trial but diet effect was not of particular interest; rather, different diets were utilized to produce similar carcass weights within breed at different ages and days-on-feed. Moreover, the corn-based diet was formulated to be similar to diets typically fed to Angus steers in the U.S., whereas the hay-based diet was intended to be more like diets Wagyu cattle might be fed in Japan.

The steers in each diet/endpoint group were slaughtered on two consecutive days. One Angus steer from the 8-month, corn-fed group escaped the holding pen before slaughter, and had to be removed from the investigation. Details about carcass traits of these cattle are presented by Lunt et al. (2005) in this issue.

Sample Collection
Immediately following removal of the hide, a section of the ribeye and overlying fat was removed from the carcass. Samples of fat were snap-frozen in liquid nitrogen and stored at –94 °C. Blood samples were collected at slaughter, and plasma were prepared and stored at –20°C until analyzed for fatty acid composition.

Lipid Analyses
Total lipid was extracted by a modification of the method of Folch et al. (1957). Fatty acid methyl esters were prepared as described by Morrison and Smith (1964) and analyzed using a Varian gas chromatograph. Individual FAME was quantified as a percentage of total FAME analyzed. Cholesterol concentration of the ribeye was analyzed by published methods (Rule et al., 1997; Rule et al., 2002) using gas chromatography. Melting points of the subcutaneous fat lipids were measured as described previously (Smith et al., 1998).

Results and Discussion

Plasma Fatty Acid Composition
Wagyu steers had lower plasma concentrations of palmitic acid, a saturated fatty acid (SFA), than Angus steers, but higher concentrations of palmitoleic acid, a monounsaturated fatty acid (MUFA). There was diet x endpoint interaction for SFA and MUFA; steers fed the corn diet to the Japanese endpoint had higher plasma MUFA and lower plasma SFA, then steers fed hay to the Japanese endpoint. Omega-6, but not omega-3 fatty acids were elevated in the plasma of hay-fed steers.

Fatty Acid Composition of Subcutaneous Fat
Subcutaneous fat from hay-fed steers contained more omega-3 and omega-6 fatty acids that fat from corn-fed steers. However, the concentration of omega-3 fatty acids was extremely low even in fat from hay-fed steers. In contrast, the concentration of MUFA was markedly reduced in fat from hay-fed steers, such that it was not as healthful as that from corn-fed steers.

In general, fatty acid composition in beef cattle is mainly affected by age and time on feed (Waldman et al., 1968; Leat, 1975; Huerta et al., 1996; Rule et al., 1997). In fat from Angus steers fed extended periods, the percentage of oleic acid reaches 45% of total fatty acids (May et al., 1993). We have demonstrated that MUFA increase with age in feedlot cattle (Huerta-Leidenz et al., 1996), and it is likely that the lower MUFA in the U.S. endpoint steers in the current study was due to the more youthful maturity of these cattle. Additionally, these data indicate that the differences in MUFA between Wagyu and other breed types is not expressed until the cattle reach greater maturity. Tanaka (1985) reported a higher percentage of oleic acid fat from Japanese Black steers as compared to Japanese Shorthorn or Holstein steers. The higher MUFA:SFA ratios may be more genetically determined than environmentally influenced. Wagyu steers have higher percentages of MUFA in their fat depots than Holstein or Angus steers (Yoshimura and Namikawa, 1983; May et al., 1993; Zembayashi et al., 1995). Sturdivant et al. (1992) postulated that elevated stearoyl-CoA desaturase activity could be responsible for the elevated MUFA observed in Wagyu cattle adipose tissue.

Melting Points and Cholesterol Concentrations
Fat from steers raised to the Japanese endpoint was softer than that from U.S. endpoint steers (Table 3). The concentration of cholesterol in the total ribeye was higher in the older, Japanese endpoint steers.

Variation in fatty acid composition, affects firmness of fat, which in turn affects the economics of meat processing and consumer acceptance of meat (Perry et al., 1998). Melting point of subcutaneous fat is significantly affected by sire breed, environment, and age. Subcutaneous fat from Brahman-sired steers had a lower melting point than from the *Bos taurus* steers (Perry et al., 1998). Multivariate analysis that included melting point in the model instead of sire breed showed that fatty acid composition was related to melting point and environment. Cholesterol content of bovine muscle and adipose tissue has proven resistant to nutritional (Christie, 1981; Eichhorn et al., 1986) and breed effects (Eichhorn et al., 1986; Wheeler et al., 1987). However, it is not known whether sire breed, maturity, and nutritional background interact to affect cholesterol in beef.

Implications

Contrary to popular belief, fat from corn-fed steers actually contained a more healthful fatty acid composition than fat from hay-fed steers. Hay feeding caused incremental increases in omega-3 fatty acids that were not nutritionally significant. Although feeding cattle to the Japanese endpoint resulted in softer fat, it also increased the cholesterol content of the meat.

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Table 1. Percentage of total fatty acids in plasma of Wagyu and Angus steers fed to U.S. and Japanese endpoints.

	Months on feed/diet													
	U.S. endpoint				Japanese endpoint									
	8 mo/corn		12 mo/hay		16 mo/corn		20 mo/hay			*P* - values				
Item	Angu	Wagy	Angu	Wagy	Angu	Wagy	Angu	Wagy	SE	Bree	Die	Endpoi	DxE	BxDxE
Myristic	0.10	0.20	0.96	0.50	0.80	0.57	0.00	0.00	0.5	0.43	0.7	0.59	0.01	0.29
Myristoleic	0.20	0.30	0.50	0.28	0.59	0.87	0.00	0.00	0.3	0.78	0.0	0.73	0.01	0.93
Palmitic	12.6	10.7	15.8	14.6	16.6	13.1	11.5	11.2	2.2	0.04	0.9	0.70	0.01	0.44
Palmitoleic	1.13	1.20	1.18	0.25	1.27	0.50	0.17	0.55	0.4	0.04	0.0	0.04	0.82	0.01
Stearic	17.3	18.5	22.2	21.9	17.1	18.6	20.4	20.4	1.5	0.30	0.0	0.15	0.16	0.98
Oleic	12.4	12.3	14.2	12.4	15.5	14.6	10.7	10.3	2.9	0.44	0.1	0.95	0.02	0.62
Omega-6	34.7	42.3	44.6	48.9	43.5	49.1	50.4	51.6	7.0	0.08	0.0	0.03	0.50	0.91
Omega-3	0.37	0.35	0.48	0.88	0.00	0.22	0.28	0.14	0.5	0.54	0.2	0.07	0.56	0.31
Saturates	30.0	29.4	38.9	37.0	34.6	32.2	31.9	31.7	3.8	0.35	0.0	0.38	0.01	0.54
Monounsaturat	13.8	13.8	15.8	13.0	17.4	16.0	10.9	10.8	2.9	0.32	0.0	0.75	0.01	0.33
Polyunsaturates	35.1	42.7	45.1	49.8	43.5	49.3	50.7	51.7	7.1	0.08	0.0	0.04	0.47	0.86

[a]Diet x endpoint interaction. Breed x diet interactions all $P > 0.21$. Breed x endpoint interactions all $P > 0.42$.
[b]Breed x diet x endpoint interaction.

Table 2. Percentage of total fatty acids in subcutaneous fat of Wagyu and Angus steers fed to U.S. and Japanese endpoints.

	Months on feed/diet													
	U.S. endpoint				Japanese endpoint									
	8 mo/corn		12 mo/hay		16 mo/corn		20 mo/hay			*P* - values				
Item	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	SE	Bree	Die	Endpoi	DxE	BxDxE
Myristic	3.66	2.85	3.45	2.87	3.21	3.27	3.74	2.60	0.6	0.01	0.7	0.98	0.96	0.12
Myristoleic	1.08	1.28	0.82	1.00	2.27	2.18	2.12	1.60	0.5	0.76	0.1	0.01	0.81	0.61
Palmitic	27.6	26.1	28.5	26.3	25.9	25.7	26.8	24.4	1.6	0.01	0.7	0.03	0.54	0.55
Palmitoleic	2.95	4.02	2.31	2.44	6.54	6.55	5.87	4.98	1.3	0.88	0.0	0.01	0.99	0.98
Stearic	16.2	14.2	20.4	19.3	7.25	4.17	9.11	8.32	4.5	0.55	0.0	0.01	0.35	0.82
Trans-vaccenic	2.00	1.55	2.44	2.43	0.92	1.11	1.38	1.41	0.5	0.75	0.0	0.01	0.45	0.41
Oleic	37.5	39.3	32.1	35.4	41.7	42.8	39.9	44.4	3.1	0.03	0.0	0.01	0.05	0.67
Omega-6	2.58	2.49	1.56	2.07	2.41	2.71	1.72	1.90	0.3	0.05	0.0	0.91	0.92	0.11
Omega-3	0.00	0.09	0.23	0.30	0.05	0.19	0.14	0.18	0.1	0.05	0.0	0.71	0.03	0.68
*c*9,*t*11 CLA	0.29	0.42	0.38	0.39	0.51	0.31	0.48	0.59	0.1	0.86	0.1	0.08	0.39	0.07
*t*10,*c*12 CLA	0.04	0.24	0.12	0.25	0.29	0.26	0.24	0.42	0.1	0.02	0.3	0.01	0.91	0.16
Saturates	47.9	43.7	52.8	48.8	36.9	36.8	40.3	35.9	4.9	0.09	0.0	0.01	0.29	0.53
Monounsaturat	43.6	46.2	37.7	40.3	51.5	52.7	49.2	52.3	4.1	0.12	0.0	0.01	0.14	0.76
Polyunsaturates	2.91	3.24	2.29	3.00	3.27	3.46	2.58	3.09	0.4	0.01	0.0	0.16	0.77	0.92

[a]Diet x endpoint interaction. Breed x diet interactions all $P > 0.25$. Breed x endpoint interactions all $P > 0.21$.
[b]Breed x diet x endpoint interaction.

Table 3. Melting points of subcutaneous adipose tissues and cholesterol content in the ribeye of Angus and Wagyu steers fed to U.S. and Japanese endpoints.

	Melting point	Cholesterol
Endpoint/diet	°F	mg per 4 oz
U.S. Endpoint		
8 mo/corn		
Angus	100.2	72.1
Wagyu	95.5	70.8
12 mo/hay		
Angus	109.0	71.5
Wagyu	102.0	68.3
Japanese Endpoint		
16 mo/corn		
Angus	82.0	78.4
Wagyu	82.2	83.9
20 mo/hay		
Angus	88.3	78.9
Wagyu	80.1	89.2
SE	8.91	9.75
P - value		
Breed	0.14	0.43
Diet	0.15	0.85
Endpoint	0.01	0.01
Breed x diet	0.41	0.84
Diet x endpoint	0.39	0.53
Endpoint x breed	0.79	0.16
Breed x diet x endpoint	0.64	0.64

EXIT VELOCITY EFFECTS ON GROWTH, CARCASS CHARACTERISTICS, AND TENDERNESS IN HALF-BLOOD BONSMARA STEERS

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Summary

This study examined chute exit velocity (EV) measured at weaning and upon entry to the feedlot as an indication of temperament in response to stress. The objective was to examine the relationship between EV and growth, carcass characteristics and beef tenderness in half-blood Bonsmara steers. The steers were grazed on ryegrass pasture and then finished in a commercial feedlot. The cattle were harvested as they reached 0.3 in of backfat. Exit velocity at weaning was the most useful indicator of performance in the feedlot, carcass characteristics and Warner-Bratzler shear force (WBS). The relationship of EV and feedlot performance, carcass characteristics, and WBS was independent of previous stocker nutritional management.

Introduction

Studies have shown steers expressing flighty behaviors in response to handling stress will have lower average daily gains (ADG), higher feed to gain ratios, lower USDA Quality and Yield grades and higher WBS values (Brown et al., 2004, Vann et al., 2004). Development of tools that can identify cattle likely to meet production expectations or to help manage cattle would be a step in reaching the goal of producing a more acceptable product. Exit velocity may be a method of classifying and sorting cattle. Producers could select breeds or types of animals which may be better suited to handle the stressors inherent in a production system.

The Bonsmara breed (*Bos taurus Africanus*) has been imported into the United States, and was selected for productivity and adaptation to subtropical conditions. They have also been shown to produce tender carcasses. The breed has shown promise since being introduced into US production systems.

The objective for this study was to examine the relationships between escape velocity at weaning and entering the feedlot on live animal growth, carcass characteristics and beef tenderness in half-blood Bonsmara steers.

Experimental Procedures

Bonsmara X Beefmaster (BM) steers (n = 139) from Dos Amigos Ranch near Roswell, NM were used to evaluate EV at weaning and upon entering the feedlot. The relationships of EV with growth, carcass characteristics, and WBS were studied. At weaning, steers were evaluated for EV and live animal weight (BW). Exit velocity is an adopted procedure described by Burrow et al. (1988). Exit velocity was measured electronically as the rate (ft/sec) at which animals passed between two sets of timers placed 6 ft apart and 3 ft in front of a squeeze chute. Twenty-two weaned Bonsmara cross (1/4 Angus ¼ Tuli, Brahman or Senepol ½ Bonsmara) (BONX) steers from the Harris Ranch (Cline, TX) were also used in this study. Sixty-two BM steers and 22 BONX steers were randomly assigned to Uvalde (semi-arid) and 77 BM steers assigned to Overton (humid), TX for winter grazing (Table 1). Prior to the initiation of grazing, Uvalde steers were fed hay *ad libitum* and 2 lb/head/d of a 20% protein range cube. Steers in Uvalde were allowed to graze irrigated 'TAM 90' annual ryegrass pasture. Steers assigned to Overton remained in a dry lot and were allowed *ad libitum* Coastal bermudagrass hay and 2 lb/hd/d of a 4:1 (corn:SBM) ration until initiation of a winter pasture ('Maton rye' + 'TAM 90' ryegrass) experiment. The experiment at Overton used a 2 x 2 x 2 factorial arrangement to examine the effects of stocking rate, stocking method, and stocking strategy on grazing performance. Upon completion of the winter grazing, all steers entered the Liveoak Feedlot (Batesville, TX) on May 13, 2002. One week after entering the feedlot, EV and BW were measured during routine feedlot processing (defined as EV and BW entering the feedlot). Exit velocity was determined as described earlier. Approximately 50 d after entering the feedlot, an estimate of subcutaneous fat was taken using ultrasound. Animals were harvested in five groups on 23, 68, 90, 126, and 153 d on feed as steers were targeted to be harvested at 0.3 in subcutaneous fat thickness based on visual and ultrasound measurements. The BW was recorded prior to leaving the feedlot to calculate average daily gain (ADG). Average daily gain was calculated by subtracting the weight taken when the cattle left the feedlot minus the weight taken during processing (when the cattle entered the feedlot), divided by the number of days on feed. Animals were harvested at Sam Kane Packing Plant in Corpus Christi, TX as each group reached approximately 0.3 in of backfat. At approximately 36 h post-harvest, hot carcass weight (HCW), 12th rib fat thickness (BF), estimated percentage of kidney, pelvic and heart fat (KPH), ribeye area (REA), and marbling score were determined as defined by USDA (1989). The USDA Yield and Quality grades were calculated according to USDA (1989) using these factors. A 1-in steak was removed from the 13th rib for WBS determination at 14 d post-harvest. For WBS, steaks were removed from the -112°F freezer and allowed to thaw at 35°F for 48 h. The steaks were cooked on Faberware Open-Hearth broilers (Faberware Co., Bronx, NY) to an internal temperature of 158°F (monitored by copper constantan thermocouples and a recording potentiometer). When the desired internal temperature was reached, steaks were removed and cooled at room temperature (68°F) before testing. Six, 0.5-in diameter cores were removed parallel to the longitudinal orientation of the muscle fibers. Each core was sheared using an Instron Universal Testing Instrument (Instron, Canton, MA) equipped with Warner-Bratzler shearing device. The average force (lbs) required to segment the six cores was reported as the WBS for each steak.

Statistical Analysis

The purpose of this research was to determine relationships between EV and growth, carcass characteristics and WBS (Table 2). Stocker treatments have been shown to impact growth and carcass characteristics of steers fed high concentrate diets (Miller et al., 1987), and therefore might be expected to impact the relationship between EV and these variables. As steers in our study were fed from 23 to 153 days to a projected fat constant endpoint of 0.3 in during finishing, nutritional and management practices for steers prior to entering the finishing phase would be expected to impact ADG and HCW. While understanding the effect of stocker treatments on live animal growth and carcass characteristics is important, cattle often vary in nutritional management and stocker treatments prior to entering the finishing phase of beef production. As a result, variation in stocker management of steers in this study provided a backdrop not dissimilar to industry situations in which cattle enter a feedlot from a variety of stocker programs. Therefore, in order to determine the impact of stocker treatment on the relationships between EV and variables of interest, statistical procedures were performed that both disregarded stocker treatment and corrected for the variation introduced by stocker treatment. This was accomplished by performing two analyses: (1) the first analysis ignored the effect of stocker treatment on these relationships, and (2) the second included stocker treatment in the model so that the correlations were corrected for the effects of stocker treatment.

(1) Simple correlation coefficients were determined by PROC CORR procedure of SAS (Version 6.12, Cary, NC, 1998) with a predetermined significance level of $P \leq 0.05$ (Table 3). (2) For carcass characteristics that were affected by stocker treatment, least squares means were calculated and differences between means were determined through t tests (Table 1). Partial regression coefficients were calculated using the manova function of GLM where the effect of stocker treatment was defined as a fixed effect (Table 4). Correlation coefficients were calculated through this procedure allowing for correction for the variation introduced by the stocker treatments. Exit velocity data were converted to discrete variables defined as exit velocity groups of slow, medium and fast based on < 0.5 SD, $\pm$ 0.5SD, and > 0.5 SD, respectively, from the mean. Weaning EV categories were analyzed by Analysis of Variance as previously described using stocker treatment as a block and the EV category as a main effect. Least squares means were calculated and if, differences in EV category were reported ($P < 0.05$) then least squares means were separated with t tests.

Results and Discussion

When the effect of stocker treatment was ignored, EV taken at weaning was correlated ($P < 0.05$) with ADG (r = -0.25), Yield Grade (r = 0.29), and WBS (r = 0.23). As exit velocity increased when cattle left the chute at weaning, Yield Grade increased as well as WBS, and ADG decreased. When the steers were measured for exit velocity upon entering the feedlot, no correlations were found with feedlot performance, carcass traits or WBS (Voisinet et al., 1997). Stocker treatments affected feedlot ADG and HCW measurements (Table 1). When stocker treatment was used as a fixed effect, ADG (r = -0.28) and WBS (r = 0.29) were still correlated ($P < 0.05$) with EV measured at weaning, but EV measured at entry into the feedlot was not related to these variables (Table 4). These correlations are illustrated in Table 5 when EV is expressed as a discrete variable. A tendency exists for cattle exhibiting slow EV to have lower WBS and higher ADG than cattle exhibiting fast EV. These results indicate that stocker treatments had little impact on the relationship of EV and growth, carcass characteristics, and WBS. Also, EV measured at weaning had much higher relationships with these variables than EV measured upon entry into the feedlot.

Implications

Exit velocity at weaning was more related to feedlot ADG and WBS than EV measured upon entry into the feedlot. This implies that cattle can be conditioned to stressors such as routine handling, but when confronted with unfamiliar stressors associated with slaughter, they retain the responses observed at weaning, and these responses apparently impact meat tenderness. It appears that as cattle are either fed in production systems that incorporate more exposure to humans or as they get older, EV is not as good of a predictor of ADG, carcass characteristics and tenderness. These relationships are not impacted by stocker treatments,

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Table 1. Effects of grazing treatment on average daily gain in the feedlot (p = 0.051) and hot carcass weight (p = 0.024) due to stocking treatment.

Stocking treatment[a]			Average daily gain, lbs/d		Hot Carcass weight, lbs	
Method[b]	Strategy[c]	Level[d]	LSMean	SE	LSMean	SE
Continuous	Fixed	Low	2.49[e]	0.222	666.2[e]	21.10
Continuous	Variable	Low	2.92[efg]	0.210	667.3[ef]	25.85
Rotational	Fixed	Low	2.78[efg]	0.235	643.3[ef]	19.54
Rotational	Variable	Low	2.76[ef]	0.210	620.6[e]	23.12
Continuous	Fixed	Medium	2.98[efg]	0.184	663.6[ef]	19.54
Continuous	Variable	Medium	3.21[fg]	0.235	674.2[ef]	23.12
Rotational	Fixed	Medium	3.23[fg]	0.251	696.5[f]	25.85
Rotational	Variable	Medium	3.40[g]	0.235	665.0[ef]	23.12
Continuous	Fixed	Medium	3.17[fg]	0.075	620.9[e]	7.62

[a]The first 8 treatments were stocking treatments applied at the Texas Agricultural Research and Extension Center in Overton, TX and last treatment was the stocking treatment at the Texas Agricultural Research and Extension Center in Uvalde, TX.
[b]Continuous: steers were continual access to grass on the same pasture during the stocking treatment; Rotational: 8-paddock rotation with an approximate 2-day residence and 14-day rest.
[c]Fixed: the stocking rate was not changed the entire grazing period; Variable: stocking rate at initiation (both 0.9 and 1.7 hd/ac) were fixed until March 4, 2003, and then both low and medium stocking rates, respectively, were increased to approximately 3 hd/ac for the duration of the grazing period.
[d]Low: approximately 0.9 steer/ac at initiation of grazing; Medium: approximately 1.7 steers/ac at initiation of grazing.
[efg]Least squares means with different superscripts within a column differ, $P < 0.05$.

Table 2. Exit velocity characteristics, average daily gain, carcass characteristics and Warner-Bratzler shear force descriptive statistics.

	Experiment 1		
Variable	N	Mean	SD
Weaning exit velocity, ft/sec	138	11.58	1.709
In feedlot exit velocity, ft/sec	156	9.55	1.041
Average daily gain, lb/d	152	3.07	0.68
Hot carcass weight,	88	639.7	54.86
Backfat, in	88	0.28	0.10
Quality grade[a]	88	692.56	31.14
Yield grade	88	2.16	0.40
Warner-Bratzler shear force, lbs	146	5.95	1.40

[a]600 = Select.

Table 3. Simple correlations coefficients for average daily gain, carcass characteristics and Warner-Bratzler shear force and exit velocity measurements.

	Experiment 1	
Trait	Weaning Exit Velocity	In Feedlot Exit Velocity
Average daily gain, lb/d	-0.25[a]	0.05
Hot carcass weight, lb	-0.17	-0.08
Backfat, in	0.02	-0.03
Quality grade[c]	0.03	-0.02
Yield grade	0.29[a]	-0.03
Warner-Bratzler shear force, lb	0.23[a]	0.02

[a]$P < 0.05$

Table 4. Partial correlations coefficients for average daily gain, carcass characteristics and Warner-Bratzler shear force and exit velocity measurements adjusted for the effect of prefinishing background treatment.

	Experiment 1	
Trait	Weaning Exit Velocity	In Feedlot Exit Velocity
Average daily gain, lb/d	-0.28[a]	0.06
Hot carcass weight, lb	-0.22	-0.22
Backfat, in	-0.07	-0.03
Quality grade[c]	-0.19	0.09
Yield grade	0.20	-0.05
Warner-Bratzler shear force, lb	0.29[a]	0.13

[a]$P < 0.05$

Table 5. Least squares means, standard errors and p-values for average daily gain, carcass characteristics and Warner-Bratzler shear force as effected by exit velocity groups at weaning and entering the feedlot for Experiment 1.

	Weaning exit velocity group					In feedlot exit velocity group				
Variable	Slow	Medium	Fast	P-value	RMSE[d]	Slow	Medium	Fast	P-value	RMSE[d]
Average daily gain, lb/d	3.24	2.98	2.86	0.058	0.654	2.97	2.96	3.06	0.75	0.668
Hot carcass weight, lb	683.3	653.6	651.8	0.11	51.47	661.5[a]	667.2[a]	628.0[b]	0.05	50.30
Backfat, in	0.34[b]	0.26[a]	0.31[b]	0.002	0.084	0.28	0.31	0.27	0.35	0.096
Quality grade[c]	692.7	681.2	690.5	0.39	30.15	680.2	691.6	684.9	0.31	29.75
Yield grade	2.20[ab]	2.06[a]	2.38[b]	0.015	0.354	2.16	2.22	2.09	0.54	0.392
Warner-Bratzler shear force, lb	5.62	6.17	6.30	0.108	1.372	6.24	5.93	6.16	0.54	1.991

[ab]Least squares means with different superscripts within a row and velocity group differ, $P < 0.05$.
[c]USDA Beef Quality Grade for Experiment 1: 600 = Select.
[d]RMSE: Root Mean Square Error from analysis of variance table.

IMPACT OF CASTRATION AND ZERANOL IMPLANTS ON BULLOCKS: I. BEHAVIOR, GROWTH AND CARCASS TRAITS

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Summary

The effects of Ralgro® implants on behavior, feedlot performance and carcass traits were studied using 95 bullocks and 98 steer calves. The bullocks were heavier at slaughter, had less backfat, larger loin eye area, more desirable USDA yield grades, a higher percentage of lean cuts and less bone and fat trim than steers. Steers had more marbling, higher USDA quality grade and reached market condition 5 days earlier than the bullocks. Castration had a much greater effect on carcass cutout than did implants. Implant treatment affected percentage of blade and top sirloin, and castration increased yield of every primal and subprimal cut studied except for lean trim and sirloin tip. Implantation made bulls and steers more docile. Libido measurements were also lower for the implanted bulls as compared to non-implanted bulls. These data confirm that castration and implants have significant effects on behavior, growth and carcass characteristics of young cattle.

Introduction

Consumer concerns over fat and cholesterol have increased interest in lean beef production. Reviews by Field (1971) and Seideman et al. (1982) documented advantages for feeding bullocks such as increased rate of gain, greater feed efficiently and leaner carcasses. However, resistance to the production of bulls persists, primarily due to management problems (Mies, 1982; Oltjen, 1982), slaughter and dressing difficulties, and lower quality grades (Binger, 1982). Baker and Arthaud (1972) and Greathouse et al. (1983) found inconsistent responses to implants. Ralgro® implantation shortly after birth reduces masculinity and decreases behavior problems (Greathouse et al., 1983; Baker and Gonyou, 1984). Greathouse et al. (1983), and McKenzie (1984) also reported that young bulls implanted shortly after birth had improved performance, behavior and carcass characteristics when compared to non-implanted bulls. However, post-weaning implantation of young bulls has been shown to have minimal affect on performance and carcass characteristics (Price et al., 1983).

Experimental Procedures

Cattle Management. One hundred ninety-three Hereford, Hereford x Angus and Charolais crossbred calves from two ranches in central Utah were blocked by breed and weight before being assigned to one of four treatments: 1) control steers, 2) Ralgro®-implanted steers, 3) control bulls and 4) Ralgro®-implanted bulls. Ralgro® treated groups received 36 mg of zeranol according to label at branding. After weaning, calves were adjusted to the feedlot for four weeks and divided into two equal replications per group based on weight and estimate of breed (Table 1). Pen order was staggered so as not to have two bull pens together and pens were rotated at 28-day intervals at weighing but the original group order was maintained (Table 2). Treatment groups that were implanted at the time of branding were reimplanted at the beginning of the feeding trial and 56 days later. Hip height measurements and individual scrotal measurements were taken on day 28 and 140 of the trial.

Behavioral Observations. Each pen was observed once weekly for 30 minutes to assess sexual, antagonistic, eating and resting behaviors. Observations began at 1:00 p.m. when no cattle were being fed and human activity was at a minimum in the vicinity of the cattle.

Libido Test. A libido test was conducted prior to harvest for both the bulls and steers. Four yearling heifers were restrained in stanchions. After the heifers were restrained, the pen of animals to be tested was moved to a pen adjacent to the heifers. Cattle were given 15 minutes to adjust to their surroundings. Two bulls or steers were placed in the pen with the heifers and observed for 10 minutes by two observers. Each observer watched one animal and recorded the number of mounts without an erection, services, flehmens and masturbations.

Carcass Data. Bulls and steers were slaughtered at 12 to 15 months of age when an estimated USDA yield grade of 2.0 was attained for the average of a pen. Cattle were shipped 35 miles to the Deseret Meat Packing plant in Spanish Fork, Utah. Bulls were transported in compartments which contained only individuals of the same lot. All cattle were harvested approximately 2-3 hours after arrival at the plant. Testicles from the bulls were removed and individually weighed. USDA quality and yield grade were assessed by trained personnel of Brigham Young University and Texas A&M University after 24 hours of chilling. The chilled right half of each carcass was individually weighed and used as the denominator in calculating primal and sub-primal cut percentages. All primal and sub-primal cuts were made using International Meat Purchasing Specifications (IMPS).

Statistical Analysis. Statistical analyses of the data were accomplished using the Rummage II system of the Statistical Department of Brigham Young University, using 1984 version. Analysis of variance and Pearson's simple correlation test were utilized. Factors included in the analysis of variance were: treatment, sex, and pen. Treatment by sex interaction was also included in the model.

Results and Discussion

Live Animal Performance and Behavior. Means for feedlot performance of implanted and control bulls and steers are given in Table 3. By design, there was no difference in branding weight at the beginning of the test. Although not significant, ($P > 0.05$) the implanted bulls and steers were heavier than non-implanted controls at weaning. Non-implanted steers had significantly ($P < 0.05$) lower off test weights than the other three groups. Feedlot average daily gain was higher for bulls than for steers and for implanted animals as compared to controls ($P < 0.05$). Control steers were less efficient converters of feed to gain. Implanted bulls converted 5.6:1 as compared to 6.1:1 for control bulls. Feed conversion for the implanted steers was 5.8:1 as compared to 6.2:1 for the control steers ($P < 0.05$). During the 19 weeks of this study each treatment and pen was observed for 30 minutes once weekly for sexual, antagonistic, eating and resting behaviors. No significant sex or treatment difference was found for the time spent eating, drinking, resting or standing. However, control bulls were much more responsive to out of pen disturbances. Each pen of cattle was observed for the behavior traits listed in Table 4. Control bulls were significantly more aggressive ($P < 0.05$) than implanted steers for mounting, bunting and fighting (Table 5). Control bulls were significantly different from implanted bulls ($P < 0.05$) in attempts to breed, in the number of actual services as well as in total mounts and services. Differences were not noted for all other traits observed.

Several studies have found it economical to implant calves during the suckling phase (Thomas and Armitage, 1970a,b; Cooper and Kirk, 1982; Mies, 1982). Mader et al. (1985) reported no differences in response to zeranol implanting during suckling between bulls and steers. Response to implanting suckling calves has been quite variable. Ralston (1978) found that zeranol had a non-significant response between implanted and non-implanted bull calves, but it had a positive response between the implanted and non-implanted steer calves. The age at which young bulls are implanted has a significant effect on their sexual development (Ralston, 1978). Staigmiller et al. (1985) and Bagley et. al. (1989) showed that if Ralgro® was administered to young suckling calves there was a reduction of testicular growth and secondary sex characteristics, while weanling bull calves had no reduction in testicular growth or change in sex characteristics. In contrast to our findings, Gregory and Ford (1983) found that implanting yearling bulls had no effect on testicle size or aggressive behavior.

Numerous studies have shown that intact males grow faster and are more efficient than steers (Prescott and Lamming et al., 1964; Ellis et al., 1974). Reviews by Field (1971) and Seideman et al., 1982 showed that bulls had a higher average daily gain and were more efficient than were steers. Newland and Turner (1989) reported implants increase feed conversion by 2%. Feedlot data in this study generally agree with those of Corah et al. (1979), and Mies (1982) who reported no significant response to implants for bullocks. McKenzie (1984) found that implanting young bulls with Ralgro® early in life (less than 6 months of age) reduced aggressive behavior. In contrast, implanting yearling bulls once or twice did not reduce aggressive behavior (Gregory and Ford, 1983). Price and Makarechian (1982) found Ralgro® implanted bulls after 6 months to be more docile when compared to control bulls. In the present study, control bulls were found to be significantly different from implanted bulls ($P < 0.05$) in attempts to breed, in the number of actual services as well as in total mounts and services. For all other traits observed, differences were not observed.

Carcass Characteristics. Carcass weight and traits used to determine USDA quality and yield grade are shown in Table 6. Bull carcasses were heavier than those from steers. The carcasses from the control steers were significantly ($P < 0.05$) lighter than those for all other treatments. The yield of hot carcass was higher for the bulls than the steers. When comparing hot carcass yield within treatment, the implanted bulls and steers tended to be higher than their control or non-implanted counterparts. The carcasses of bulls were significantly ($P < 0.05$) leaner than their contemporary steer carcasses as observed from loin eye area, fat thickness, percent KPH fat and USDA yield grade. When comparing implanted and non-implanted bulls, the control bull carcasses were slightly leaner for the above traits, followed by the implanted bull carcasses, implanted steers and control steers. However, when marbling and final USDA quality grades were evaluated, the steer carcasses, both implanted and control, graded significantly higher ($P < 0.05$) than the bulls. When loineye area was evaluated on a 100 lb of carcass weight basis, implantation decreased loineye area because loin eye does not increase proportionally as carcass weight increases (Table 6). Implanted bulls had more subcutaneous fat than control bulls. Marbling for the steer treatments was Small minus and Small plus, respectively. Loin eye area, fat thickness at the 12th rib and USDA yield grade were in favor of the bull carcasses when compared to steer carcasses with the control bull carcasses having a slight advantage over implanted bulls. Cut out percentage for the bull carcasses exceeded that of steer carcasses 81.5% to 80.1%, respectively, as shown in Table 7. Significant differences ($P<.05$) for certain primals and sub-primals between bull and steer carcasses existed. The arm chuck, blade chuck, and bottom round made up a larger percentage of the carcass in bulls than in steers. Percentage of lean trim, kidney-pelvic fat and bone and fat trim waste were significantly higher for the steers than bulls. The content of lean trim was not standardized to a specific amount or percent of lean. The weight of lean trim from the steer carcasses was higher due to increased amount of fat since the steer carcasses were fatter. The percent KPH fat in Table 6 was an estimated figure, whereas the KPH fat percent listed in Table 7 was calculated from the actual carcass weight. Percent KPH for the bull carcasses was 26% less than steer carcasses and 12% less total bone and fat waste. Table 8 shows there was a significant sex difference between bulls and steers for the weight of most primal and sub-primal cuts. Implantation did not significantly modify the weights and percentages of primal and subprimal cuts listed in Table 8.

Field (1971) reviewed fifteen studies and reported average dressing percentages for bullocks versus steers of 59.7% and 59.6% respectively. Allen (1982) summarized a composite of research trials and reported that bulls produce heavier carcasses. The carcasses of bulls in the present study were significantly ($P < 0.05$) leaner than their contemporary steer carcasses as observed from loin eye area, fat thickness, percent KPH fat and USDA yield grade. When comparing implanted and non-implanted bulls, the control bull carcasses were slightly leaner for the above traits, followed by the implanted bull carcasses, implanted steers and control steers. Cooper and Kirk (1983) reported Friesian bulls implanted from near birth to slaughter had greater lean meat yields and larger ribeye areas, thus heavier *longissimus* weights. In the present study, implanted bulls had more subcutaneous fat than the control bulls. This agrees with Greathouse et al. (1983) and McKenzie (1983), who showed that Ralgro® implants increase fat deposition in bulls. Carcass cutout data in the present study confirm work done by Bailey et al. (1985). Fortin et al. (1985) also reported bulls had a smaller percentage of round when compared to steers.

Implications

These data confirm that castration and implants have significant effects on behavior, growth and carcass characteristics of young bulls. It remains to be seen whether management, behavioral and carcass tenderness challenges may be offset by increases in leanness and efficiency of growth.

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Table 1. Experimental design

	Bulls		Steers	
	Implant	Control	Implant	Control
Replication 1	23	23	23	24
Replication 2	27	22	24	26
Total	50	45	48	50

Table 2. Pen assignments

Pen 1	Pen 2	Pen 3	Pen 4
Implant Bulls Rep. 1	Implant Steers Rep. 1	Control Bulls Rep. 1	Control Steers Rep. 1

Pen 5	Pen 6	Pen 7	Pen 8
Implant Bulls Rep. 2	Implant Steers Rep. 2	Control Bulls Rep. 2	Control Steers Rep. 2

Initial pen assignments. Cattle were rotated to the next highest pen each 28 days.

Table 3. Means for feedlot performance of Ralgro® implanted and control bulls and steers (lb)

	Bulls		Steers			Bull	Imp	Trt
Item	Imp	Con	Imp	Con		vs	vs	x
					SD[a]	Steer	Con	Sex
Number	50	45	48	50				
Branding Wt.	185	178	185	178	12.30	NS	NS	NS
Day 0 Feedlot Wt.	594	581	572	548	22.40	*	NS	NS
Pre-test Gain	409	403	387	370	19.69	NS	*	NS
Pre-test ADG.	1.91	1.87	1.80	1.74	0.79	NS	*	NS
Final Wt.	1142	1118	1124	1030	31.99	*	*	NS
Feedlot Gain	548	537	552	482	24.40	*	*	NS
Feedlot Daily Intake[b]	17.4	18.3	16.9	16.9				
Feedlot ADG	3.10	3.01	3.01	2.71	0.15	*	*	NS
Feed Conversion[b]	5.6	6.1	5.8	6.2				

a) Pooled standard deviation of the observation
b) Calculated on a group basis without statistical measurement or analysis
* Differences between bulls vs. steers; implanted animals vs. control animals or the treatment x sex interaction are significant at the $P < 0.05$ level.

Table 4. Means for pen observations of behavioral traits

	Bulls		Steers	
Item[d]	Implant	Control	Implant	Control
Total Mounts	$.81^{b}$	3.79^{a}	$.55^{b}$	1.18^{b}
Total Bunts	5.17^{c}	13.91^{a}	3.72^{c}	8.04^{b}
Total Fights	2.58^{b}	8.85^{a}	$.94^{c}$	3.53^{b}
Flehmens	1.81^{b}	3.82^{a}	$.04^{c}$	$.02^{c}$
Masturbations	$.04^{b}$	$.47^{a}$	0^{b}	0^{b}

a,b,c) Figures in the same row with different superscripts differ significantly ($P < .05$).

d) Average per head per 30-minute observation.

Table 5. Means of libido test behaviors

	Bull		Steer	
Item[d]	Implant	Control	Implant	Control
Mounts W/O an Erection	1.99^{a}	4.09^{a}	1.4^{a}	1.25^{a}
Attempts to Breed	1.47^{b}	$.62^{a}$	$.75^{b}$	2.32^{b}
Actual Services	2.04^{b}	6.19^{a}	0^{c}	0^{c}
Total Mounts and Services	5.49^{b}	10.89^{a}	2.15^{c}	3.57^{bc}
Flehmens	$.16^{a}$	$.58^{a}$	$.00^{a}$	$.00^{a}$
Time With Heifer (min)	6.81^{ac}	8.46^{a}	5.85^{bc}	7.49^{ac}
Fighting time (min)	$.46^{ab}$	$.60^{a}$	$.07^{bc}$	0

a,b,c) Figures in the same row with different superscripts differ significantly ($P < 0.05$).

d) Average per head per 10-minute observation.

Table 6. Means of carcass characteristics for implanted and control bulls and steers

Item	Bulls Imp	Bulls Con	Steers Imp	Steers Con	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	50	45	48	50				
Hot Car Wt, lb	713	693	684	627	14.26	*	*	*
Hot Car Yield %	62.4	61.7	61.6	60.9	0.10	*	NS	NS
Loin eye area (LEA), in^2	13.4	14.3	12.2	11.6	0.02	*	NS	*
LEA/100lb Carcass Wt	1.88	2.06	1.78	1.85	0.01	*	*	NS
Backfat, inch	0.35	0.29	0.42	0.52	0.02	NS	NS	NS
Backfat/100lb carcass Wt	0.05	0.04	0.06	0.08	0.00	*	NS	NS
Percent Kidney, Pelvic & Heart Fat	2.4	2.4	3.1	3.4	0.06	*	NS	NS
Yield Grade	2.4	1.9	2.9	2.9	0.52	*	*	NS
Marbling[b]	12.2	12.2	14.3	15.7	0.70	*	NS	NS
Carcass Maturity[c]	1.8	1.9	1.4	1.2	0.03	*	NS	NS
Quality Grade[d]	5.9	5.8	7.1	7.6	0.15	*	NS	NS

a) Pooled standard deviation of the observation
b) 11.0 = slight, 14.0 = small, 17.0 = modest
c) 1.0 = A-, 1.5 = A(-), 2.0 = A.
d) 5.0 = Select, 6.0 = Select+, 7.0 = Choice-, 8.0 = Choice (o).
* Differences between bulls vs steers; implanted animals vs control animals or the treatment x sex interaction are significant at the P < .05 level.

Table 7. Means for percent carcass cutout of implanted and control bulls and steers

Item	Bulls Imp	Bulls Con	Steers Imp	Steers Con	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	50	45	48	50				
% Cut out Yield	81.1	81.9	79.7	80.5	.02	*	NS	NS
% Arm Chuck	8.3	8.7	8.2	8.4	.006	*	*	NS
% Blade Chuck	15.2	14.9	13.2	12.8	.012	*	NS	NS
% Rib	6.0	6.1	6.1	6.1	.005	NS	NS	NS
% Tenderloin	1.5	1.5	1.4	1.5	.001	*	NS	NS
% Shortloin	3.0	3.0	3.1	3.0	.002	NS	NS	NS
% Sirloin	3.2	3.2	3.1	3.2	.002	NS	NS	NS
% Top Round	5.3	5.3	5.1	5.1	.005	NS	NS	NS
% Bottom Round	5.7	5.8	5.3	5.3	.004	*	NS	NS
% Sirloin Tip	2.7	2.6	2.6	2.7	.003	*	NS	NS
% Lean Trim[b]	30.2	30.8	31.8	32.5	.019	*	NS	NS
% Kidney Knob[c]	2.4	2.4	3.1	3.4	.005	*	NS	NS
% Bone, Fat, Waste	16.3	16.6	18.4	18.9	.021	*	NS	NS

a) Pooled standard deviation of the observation
b) Total weight of edible lean and trim (lb) from right side.
c) Measured weight of indicated cut or portion per right side carcass cold weight.
* Differences between bulls vs steers; implanted animals vs control animals or the treatment x sex interaction are significant at the P < 0.05 level.

Table 8. Least square means for primal, sub-primal cut weight (lb) and percentage for implanted and control bulls and steers

Item	Bulls Implant	Bulls Control	Steers Implant	Steers Control	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	50	45	48	50				
Blade	52.16	51.68	44.04	39.60	0.16	*	*	*
Arm chuck	28.69	29.57	27.54	25.81	0.07	*	NS	*
Rib wt.	20.59	20.86	20.20	18.50	0.07	*	NS	*
Loin eye	29.48	31.46	26.84	25.74	0.22	*	NS	*
Off feed wt	1131	1131	1113	1049	24,64	*	*	*
Kidney Knob	8.58	8.58	10.78	10.87	0.66	*	NS	NS
Fat trim	56.10	56.78	61.60	58.08	2.20	*	NS	NS
Lean trim	103.40	104.5	105.38	101.42	2.20	NS	NS	*
Outside round	19.58	19.62	17.64	16.39	0.57	*	NS	NS
Inside round	18.08	17.64	16.87	15.91	0.60	*	NS	NS
Sirloin tip	9.17	8.89	8.71	8.38	0.82	NS	NS	NS
Sirloin	10.54	10.47	10.21	9.28	0.44	*	NS	NS
Tenderloin	5.24	5.17	4.75	4.64	0.22	*	NS	NS
Top Sirloin	11.15	11.09	10.45	9.99	0.20	*	*	NS
Strip Loin	28.82	31.46	27.94	27.06	0.66	*	NS	NS
Round %[b]	13.6	13.5	13.0	13.2	0.10	*	NS	NS
Chuck/Loin %[c]	37.2	37.7	35.1	35.1	0.10	*	NS	*
Chuck %[d]	23.4	23.7	21.4	21.3	0.10	*	NS	*

a) Pooled standard deviation of the observation
b) Top and bottom rounds added together.
c) Sum of chucks and loins divided by right side weight.
d) Sum of arm and blade chuck divided by right side weight.
* Differences between bulls vs steers; implanted animals vs control animals or the treatment x sex interaction are significant at the $P < 0.05$ level.

IMPACT OF CASTRATION AND ZERANOL IMPLANTS ON BULLOCKS: II. ORGANOLEPTIC AND INSTRUMENT ASSESSMENT OF TENDERNESS

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Summary

The effects of Ralgro® and castration on tenderness were studied using the 193 young beef cattle described in the companion paper. Sensory panel evaluations showed that steaks from control and implanted steer carcasses had higher scores for tenderness, juiciness, flavor and overall palatability than those from control and implanted bulls. Implanting did not influence juiciness or flavor within the bull or steer groups, but control bulls and steers were significantly ($P < .005$) more tender and more palatable overall than were implanted bulls and steers. There was considerable variation among the instruments used to mechanically assess tenderness. Behavior and palatability characteristics of implanted and control bulls and steers were also studied. Within group of implanted bulls and steers, those that were least aggressive tended to be more tender than their more aggressive counterparts.

Introduction

Lamm et al. (1980), Ford and Gregory (1983), and Vanderwert et al. (1984) found no difference in sensory traits between bulls and steers. In contrast, Cross (1982) and Riley et al. (1983a, b) reported steaks from masculine carcasses were not as tender as steaks from fatter, less masculine carcasses, and that fat thickness was more important in predicting palatability than was masculinity. The causes of tenderness problems in young bulls have not been fully documented, but they appear to be related to the state of muscle contraction, or amount and strength of connective tissue and could be affected by the amount of cold shortening the leaner carcasses exhibit (Carmichael and Lawrie, 1967; Cross et al., 1984b; Dutson, 1974; Marsh, 1977). The objectives of this study were to examine the effect of implants and castration on meat tenderness and the comparison of three mechanical means of assessing beef tenderness.

Experimental Procedures

Carcass Handling. Carcasses were chilled for 24 hours before each side was ribbed. Quality grade, yield grade and Armour Tenderometer® readings were obtained shortly after ribbing. A five rib section from the small end of the rib was removed and shipped to the Brigham Young University Meats Laboratory. Meat was frozen for approximately 3 months until organoleptic tests could be performed.

Palatability Measures. Steaks from the posterior end of the rib were cut one inch thick. The first two steaks or 11th and 12th ribs were used in sensory panel evaluations. The 10th rib was removed for Warner-Bratzler shear determinations, and the 9th rib for Krammer Shear press evaluations. The Instron Press, as described by Field et al. (1984), was also used to measure tenderness.

Sensory Evaluation. Eight steaks (two from each treatment group) were thawed for 16 hours and placed in one of three electric ovens and broiled to medium degree of doneness. After 3 minutes they were weighed and served to a trained taste panel in both hedonic scale (best to least preferred) and triangle testing (panelists are asked to identify the sample that is different from the other two).

Warner-Bratzler Shear. Steaks were cooked to the same internal temperature as those of the sensory panel. Steaks were cooled for 15 minutes before three, ¾ inch cores were obtained parallel to the muscle fibers. Three cores per steak were sheared once through the center and averaged.

Krammer Shear Press. Steaks cooked the same as previously and cooled for 15 minutes prior to evaluation. Muscle patterns were positioned in the same direction each time.

Instron Press. Steaks were measured at three different stages: raw, medium and medium well. One inch thick, raw steaks were pressed onto tapered needles mounted 2 mm apart around the perimeter of a Plexiglas ring 73 mm in diameter. A 1.27 mm diameter steel ball mounted on the head of an Instron moving at a constant rate of 10 cm/min penetrated the steak. Peak break force of the steaks was measured as described by Field et al. (1984).

Heat-Labile Collagen Analysis. Two samples from each steak and treatment were thawed for 16 hours and pulverized in dry ice for 45 seconds using a Waring Blender. Analysis of collagen was done according to the method of Hill (1966).

Statistical Analysis. Statistical analysis for the data was made using the Rummage II system of the Statistical Department of Brigham Young University, using 1984 version. Analysis of variance, and Pearson's simple correlation tests were utilized. Factors included in the analysis of variance were: treatment, sex, and pen. Treatment by sex interaction was also included in the model.

Results and Discussion

Sensory tenderness, juiciness, flavor and overall palatability scores are shown in Table 1. Steaks from the steer carcasses--both control and implanted--had higher scores for tenderness, juiciness, flavor and overall palatability when compared to those from the bull carcasses. Implanting did not influence flavor or juiciness scores within the bull or steer groups. The control steers were found to be significantly more tender in this study than all treatments and sexes ($P < 0.05$). Although not significant, the sensory mean values for juiciness were higher for the steaks from the control carcasses. Table 2 shows means for behavior and palatability characteristics of Ralgro® implanted and control bulls and steers. Values for the seven more aggressive and the seven least aggressive animals for which we had complete behavior and palatability data are listed for the four groups. The most aggressive animals were more than twice as active as the less aggressive animals for behavioral attributes. Scores for libido showed the implanted bulls and steers to be less aggressive. The libido scores for control steers were about equal to the implanted bulls. Tenderness values for cooked steaks showed that implanting made the least aggressive animal more acceptable. Implanting also improved tenderness for the most aggressive animals. However, the control steers were the most acceptable. Juiciness and flavor were lower for the less aggressive bulls than in other treatment groups. The least aggressive control bulls were the lowest in acceptability to the trained sensory panel for juiciness and flavor. The Armour tenderometer readings made on the intact carcass were lowest for the most aggressive implanted bulls and control steers, while the Warner-Bratzler Shear values indicated that the least aggressive implanted bulls and steers to be more tender and the most aggressive bulls and steers in the control group were more tender. The Krammer Shear showed the least aggressive animals to be the most tender except for the control steers, which showed the most aggressive steers to be more tender.

Table 3 lists simple correlations between aggressive behavior and the various palatability traits studied. All correlations except four explained less than nine percent of variation existing in a particular trait, which could be attributed to behavior. The highest correlations were found between the aggressive behavior of the non-implanted steers and the Krammer shear press ($r = -45$). However, it is noted that most of the simple correlations between measures of tenderness and juiciness and behavior for the bulls were positively related whereas those same correlations for the steers generally showed inverse relationships. Simple correlations between libido and measurements of meat palatability are listed in Table 4. Libido was associated with variation in palatability as measured by the taste panel and by objective measures of tenderness. With the exception of the implanted steers, libido was related to overall palatability. Although significant correlations were present, no consistent trend was found for steaks from the implanted versus the non-implanted animals. As expected, simple correlations between libido and the various measures for meat palatability were higher for bulls than steers. Since most correlations showed a negative sign, as libido increased there was a tendency for tenderness to decrease. Treatment means for the various mechanical measurements of tenderness generally favored the steers (Table 5). There was variation among the various instruments for measuring tenderness. The Armour tenderometer ranked meat from the implanted steers significantly tougher than meat from the bulls. However, the Warner-Bratzler shear, the Krammer Shear press and Instron values ranked steaks from steers significantly more tender than those from bulls. Differences in shear and press values between implanted and control groups were not significant ($P > 0.05$).

Table 6 compares means for raw rib steaks cooked to medium and medium well. The Least

Significant Difference test was used to make all possible pairwise comparisons. The pairwise comparison for treatment vs sex was not significant, but the other combinations of treatment, sex, with meat raw or cooked were significant at $P < 0.05$. This was done to test the between sample variability relative to the within sample variability. Differences between means of meat samples were large making the raw, treatment, and sex variables significant. Table 7 shows collagen properties of *longissimus* muscle from Ralgro® implanted and control bulls and steers. The residue or insoluble collagen was higher in the implanted bulls, when compared to the other treatment groups. Supernatant or soluble collagen was higher in the implanted bulls and steers. The total collagen was higher in the bulls, while the percent soluble collagen was higher in the steers.

The finding in the present study that steers were always more tender than bulls is different from Greathouse (1983) who found flavor intensity greater in the implanted bulls. Cross (1982) reported that bulls were less juicy and flavorful than steers. Cross (1984a) and Unruh et al. (1986) found that bulls and steers were similar in tenderness at 12 mo; at 15 mo bulls were more tender than steers, but by 18 mo steers were more tender than bulls. Barham et al. (2003) reported that control cattle were significantly more tender than control cattle. Both trained and untrained taste panels could distinguish between implant and control for flavor, juiciness and tenderness while consumers could not. In contrast, Morgan et al. (1993) reported sensory panelists were unable to detect differences in tenderness or other sensory traits between bulls and steers. Tenderness is due to the contractile state of the myofibrillar proteins, and the properties and conditions of the stromal proteins (Cross et al., 1973; Dutson, 1974; Marsh, 1977). Tanzer (1973) and Marsh (1977) reported that collagen is important in meat tenderness because of its abundance in muscle. Cross et al. (1973) suggested that the concentration and percent of heat-liable collagen was related to tenderness. Bailey (1972) reported that collagen was responsible for the age-related changes in tenderness since metabolic turnover time for contractile elements of actin and myosin was about 12 d and therefore in older animals actin and myosin is not old. However, collagen has a very long turnover time. The amount of heat-liable collagen in bovine skeletal muscle decreases during maturation and this is responsible for the age associated toughening of beef. Bailey (1985) showed collagen types IV and V are synthesized first in the embryo then types I and III later. There is no direct relationship between collagen content and toughness, but a difference can be explained by the nature and extent of cross-links with increasing age. Collagen fibers are initially stabilized by intramolecular and intermolecular cross-links. Therefore it is the quality rather than the quantity of collagen that determines the texture.

Implications

Implanting young bulls and steers with Ralgro® from branding through to slaughter may improve performance and behavior. Implants have minimal effects on carcass characteristics and palatability characteristics when compared to non-implanted animals. However, within the groups of implanted bulls and steers those animals that were least aggressive tended to be more tender than their more aggressive counterparts.

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Table 1. Means for sensory evaluation

Item	Bulls Imp	Bulls Con	Steers Imp	Steers Con	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	14	14	14	14				
Tenderness[b]	64.2	66.4	70.4	74.8	14.24	*	*	*
Juiciness[b]	64.6	65.0	67.2	69.9	12.51	*	NS	NS
Flavor[b]	67.6	66.6	69.1	69.9	9.98	*	NS	NS
Overall[b]	64.7	66.6	69.4	72.3	11.94	*	*	NS

a) Pooled standard deviation of the observation.
b) Higher values are more acceptable.
* Differences between bulls vs. steers; implanted animals vs. control animals or the treatment x sex interaction are significant at the $P < 0.05$ level.

Table 2. Means for behavior and palatability characteristics

	Bulls		Steers	
Item	Implant	Control	Implant	Control
Behavior[a]				
7 Most Aggressive	17.6	39.7	6.9	18.4
7 Least Aggressive	4.6	16.6	2.6	6.9
Libido[b]				
7 Most Aggressive	8.7	10.6	1.0	2.7
7 Least Aggressive	5.4	12.6	3.9	2.4
Tenderness[c]				
7 Most Aggressive	64.3	69.3	66.2	72.7
7 Least Aggressive	66.3	60.9	74.4	72.2
Juiciness[c]				
7 Most Aggressive	67.1	70.8	65.1	67.9
7 Least Aggressive	65.5	61.1	71.9	69.1
Flavor[c]				
7 Most Aggressive	68.0	66.9	68.4	67.2
7 Least Aggressive	65.8	66.3	69.4	69.5
Overall Palatability[c]				
7 Most Aggressive	66.4	68.7	66.3	70.0
7 Least Aggressive	67.1	62.7	74.9	70.9
Armour Tenderometer[d]				
7 Most Aggressive	12.9	15.5	12.9	12.3
7 Least Aggressive	13.9	14.4	12.9	12.5
Warner-Bratzler Shear[d]				
7 Most Aggressive	28.6	21.6	23.6	21.7
7 Least Aggressive	23.8	23.6	21.9	21.8
Krammer Shear[d]				
7 Most Aggressive	55.0	48.1	47.7	40.3
7 Least Aggressive	47.4	44.1	40.6	45.4

a) Averages for mounts, bunts, fights per animal during Observation of 30 minutes per week for the total 19 week the animals were on feed.
b) Averages of total flehmens, mounts, attempts and services per animal during observation of 10 min. Observations were made on one occasion 2 weeks before slaughter.
c) Organoleptic results of a 12 member trained panel on a 100 point scale; the higher the number the more appealing to the panelists.
d) Objective measures to evaluate tenderness. Measured in lbs. of pressure to shear through sample. The lower the score the more tender the sample was.

Table 3. Correlations between behavior and palatability[a] (N=14)

	Bull		Steer	
Item	Implant	Control	Implant	Control
Tenderness	.07	.00	-.06	.04
Juiciness	.11	.35	-.16	-.04
Flavor	.06	.18	.15	-.19
Overall Palatability	.06	.02	-.18	-.00
Armour	-.28	.36	.26	-.03
WBS	-.26	-.22	-.03	-.07
KSP	.18	.33	-.09	-.45

[a]Correlations greater than .47 are significant at the $P < 0.05$ level.

Table 4. Correlations between libido and palatability[a] (N=14)

	Bull		Steer	
Item	Implant	Control	Implant	Control
Tenderness	-.48	-.42	-.06	-.36
Juiciness	-.41	-.02	.08	-.52
Flavor	-.49	-.09	-.13	-.36
Overall Pal.	-.54	-.33	.17	-.48
Armour	-.05	-.27	-.06	.32
WBS	.16	.25	-.04	.12
KSP	.12	.61	-.22	.14

[a]Correlations greater than .47 are significant at the P < 0.05 level.

Table 5. Means for mechanical measurements of tenderness[a]

Item	Bulls Imp	Bulls Con	Steers Imp	Steers Con	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	14	14	14	14				
Armour Tndr	13.1	12.7	14.3	12.2	1.88	*	NS	*
Warner-Bratzler	23.7	23.5	22.4	21.0	.84	*	NS	NS
Krammer Shear	47.8	47.3	43.1	41.1	2.15	*	NS	NS
Instron Press	33.9	32.8	28.8	27.4	2.17	*	NS	NS

[a]Pooled standard deviation of the observation.
*Differences between bulls vs steers; implanted animals vs control animals or the treatment x sex interaction are significant at the P < 0.05 level.

Table 6. Instron values (lb) for one-inch thick rib steaks

	Bull		Steer	
Steaks	Implant	Control	Implant	Control
Number	5	5	5	5
Raw	10.6	8.4	10.9	8.9
Cooked to 68 C	14.5	15.3	15.5	13.9
Cooked to 77 C	17.3	14.2	19.2	14.2

Table 7. Heat-labile collagen properties of m. *longissimus*

Item	Bulls Imp	Bulls Con	Steers Imp	Steers Con	SD[a]	Bull vs Steer	Imp vs Con	Trt x Sex
Number	5	5	5	5				
Residue Collagen mg/g	.72	.59	.37	.40	.22	*	*	NS
Supernatant Collagen mg/g	.13	.11	.13	.11	.00	*	*	NS
Total Collagen Resid. + Super.	.85	.70	.50	.51	.26	*	*	NS
Sol. Collagen/Total %	15.29	15.71	26.00	21.57	.00	*	*	NS

a) Pooled standard deviation of the observation.
* Differences between bulls vs. steers; implanted animals vs. control animals or the treatment x sex interaction are significant at the P < 0.05 level.

HEALTH STATUS EFFECTS ON CARCASS QUALITY AND BEEF TENDERNESS OF FEEDLOT STEERS

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Summary

A study was conducted to evaluate the effects of illness present during the feeding period and its influence on carcass and meat quality. Angus-sired steers (n = 48) were placed on feed at a commercial feedlot. Steers that required treatment for disease during the feeding period were designated as the Treated group and those without treatment were designated as the Non-treated group. The steers were slaughtered and subjected to high-voltage electrical stimulation. At 48 h postmortem, carcass yield and quality grade data and CIE L^*, a^*, and b^* values were collected. Steaks were taken from each carcass and used to measure sarcomere length, 72-h calpastatin activity and Warner-Bratzler shear force. Various characteristics were different between the Treated and Non-treated groups suggesting that illness during the feeding period had an influence on various carcass components.

Introduction

Profitability of feedlot cattle is dependent upon production efficiency and carcass quality. Illness during the feeding period will reduce growth performance, lowering overall value. In addition to costs for treating affected animals and reduced efficiency, additional losses may be incurred due to reduced carcass value. Evidence from the Ranch to Rail program (McNeill, 2001) sponsored by the Texas Cooperative Extension Service suggests that cattle that have encountered sickness while on feed tended to obtain a greater loss in value and produced fewer carcasses grading U.S. Choice.

Gardner et al. (1999) reported that steers treated for Undifferentiated Bovine Respiratory Disease (UBRD) had lower carcass weights and higher percentages of carcasses grading U.S. Standard. Furthermore, the animals possessing lung lesions had smaller daily gains, lighter carcass weights, lower marbling scores, and higher Warner-Bratzler shear force values than those that did not have lung lesions. This investigation was conducted to further investigate the effects of health status during the feeding period.

Experimental Procedures

Angus-sired steers (n = 48) were weaned and backgrounded for 40 d before being placed in the feedlot for this trial. The steers were from a common herd and possessed similar genetics and were handled identically to all other cattle at the facility. The cattle were marketed at the end-point determined by the feedlot manager (200 d on feed). During this time, records were maintained for treatments received by the animals. Each animal requiring treatment was subsequently classified in the Treated group (n = 10). All remaining animals were classified as Non-treated (n = 38). Due to a limited population size, no distinction was made for multiple treatments.

Cattle were processed at a commercial abattoir, and carcasses were subjected to high-voltage electrical stimulation. Carcasses were chilled for 48 h in a 32 °C cooler with intermittent spray chill for 8 h. Forty-eight h postmortem, carcasses were ribbed at the 12th-13th rib interface and allowed to bloom for at least 15 min before carcass quality and yield grade characteristics (USDA, 1996) were determined. At this time, CIE L^*, a^*, and b^* values were measured. Following grading, carcasses were fabricated and the strip loin was removed from the left side of each carcass.

At 72 h postmortem, the strip loins were sliced into 1.0 in. steaks, which were assigned to laboratory analyses. Calpastatin activity was determined at 72 h postmortem by the protocol of Koohmaraie et al. (1995). Sarcomere length was measured by the method of Cross et al. (1981). Additional steaks were randomly assigned to be aged for 14 d and used for Warner-Bratzler shear force determination using the method of McKenna et al. (2004). Treated and Non-treated cattle were compared using analysis of variance with the PROC MIXED procedure of SAS (SAS Institute, Cary, NC).

Results and Discussion

The calf-fed steers used in this trial had beginning and final body weights of 640.2 ± 74.8 and 1276.0 ± 134.2 lbs., respectively. Initial weight did not differ between the groups. However, the final weight tended (P = 0.06) to be greater in the cattle that remained healthy throughout the feeding period compared to those that required treatment (1295.8 versus 1205.6 lbs., respectively). Average daily gain was not affected by health status.

The least squares means for the carcass characteristics of cattle treated for illness during the feeding period and those not requiring treatment are presented in Table 1. Those cattle that did not get sick during the feeding period and were not treated for illness had greater (P = 0.05) dressing percentages and heavier carcass weights than those that were treated. Additionally, the carcasses of the cattle that got sick had less subcutaneous fat as indicated by adjusted fat thickness. Longissimus muscle area tended (P = 0.10) to be larger in cattle that did not require treatment during feeding. The finding that healthy cattle had more fat and tended to be more muscular indicates that the cattle requiring treatment were less advanced in their development, conceivably because of gains lost due to illness. Marbling score did not differ with regard to health status. However, the quality grade of the carcasses from cattle treated for illness tended (P = 0.10) to be lower than the grades of healthy cattle. The mean quality grade of cattle that had been sick was the equivalent of U.S. Select while the mean quality grade of carcasses from healthy cattle was equivalent to U.S. Choice.

The least squares means for color values, sarcomere length, 72-h calpastatin activity and Warner-Bratzler shear force values of the treated and non-treated steers are presented in Table 2. Muscle L^*, a^*, and b^* values were not different between health status groups. Additionally, sarcomere length, 72-h calpastatin activity, and Warner-Bratzler shear force were unaffected by previous illness in these cattle. This suggests that the differences in growth that affected carcass characteristics did not affect the tenderness of the meat from these animals.

Implications

It is evident that there were some differences in carcass characteristics between the Treated and Non-treated groups. Cattle identified as having required treatment during feeding produced carcasses that were lighter when compared to those free of illness. Carcasses of non-treated cattle were fatter and tended to have larger longissimus muscle areas and higher quality grades. Furthermore, the tenderness attributes did not differ between the treated and non-treated steers. These results further demonstrate that illness during the feeding period can have an effect on carcass characteristics, more specifically the reduction of carcass weight and overall quality grade in feedlot cattle.

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Table 1. Means for carcass characteristics for steers treated and non-treated for illness during the feeding period

Trait	Treated	Non-treated	*P* > F
Dressing percentage	58.7 ± 0.6	60.1 ± 0.3	0.04
Hot carcass weight, lbs.	708.2 ± 27.7	780.8 ± 13.4	0.02
Adjusted fat thickness, in	0.6 ± 0.0	0.7 ± 0.0	0.01
Longissimus muscle area, in^2	30.7 ± 1.2	33.0 ± 0.6	0.09
Estimated kidney, pelvic, and heart fat, %	2.0 ± 0.1	2.2 ± 0.1	0.11
Yield Grade	3.2 ± 0.2	3.5 ± 0.1	0.11
Marbling score[a]	390.0 ± 29.3	438.9 ± 14.1	0.13
Quality Grade[b]	676.7 ± 14.1	702.9 ± 6.8	0.10

[a]300 = Slight^{00}; 400 = Small^{00}; 500 = Modest^{00}
[b]600 = Select^{00}; 700 = Choice^{00}

Table 2. Means for tenderness and histochemical traits for steers treated and non-treated for illness during the feeding period

Trait	Treated	Non-treated	*P* > F
L^*	48.2 ± 0.8	48.4 ± 0.4	0.77
a^*	30.8 ± 0.4	30.6 ± 0.2	0.71
b^*	22.7 ± 0.5	22.3 ± 0.2	0.48
Sarcomere length, µm	1.78 ± 0.01	1.79 ± 0.02	0.59
72-h Calpastatin activity	1.07 ± 0.19	1.08 ± 0.09	0.96
Warner Bratzler Shear-14 Day, lbs	6.2 ± 0.4	6.2 ± 0.2	0.91

INFLUENCE OF ANIMAL TEMPERAMENT ON THE TENDERNESS OF BEEF *M. LONGISSIMUS LUMBORUM* STEAKS

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Summary

Yearling fed steers (n = 81; Trial 1) and calf-fed steers (n = 48; Trial 2) were fed for 120 and 200 d, respectively, to evaluate the influence of animal temperament on carcass quality and meat tenderness. Temperament-indicating data were collected before shipment to the feedlot, on arrival at the feedlot, and at 70-d on feed. Cattle were sorted into temperament groups for data analysis. Carcass grade characteristics and Warner-Bratzler shear force were determined postmortem. Carcass grade was not affected by temperament in either trial. Warner-Bratzler shear force was higher in Excitable cattle in Trial 1, but did not differ in Trial 2. Warner-Bratzler shear force values were relatively low in both trials. It is not clear what mechanism mediated the differences in tenderness, but the large difference in time on feed may have contributed to the difference in the relationship between tenderness and temperament classification observed between the trials.

Introduction

Previous research has indicated strong relationships between animal temperament and stress responsiveness (Curley et al., 2004). Cattle with more excitable temperaments also had more extensive responses to a CRH challenge. Elevated stress responsiveness has been linked to decreased animal growth and efficiency, as well as reduced immune function.

Voisinet et al. (1997) reported that a greater percentage of excitable cattle displayed borderline dark cutting lean compared to less temperamental animals. Those investigators also found that steaks from the carcasses of excitable cattle had higher Warner-Bratzler shear force values than those from the carcasses of calmer animals. Additionally, a low-to-moderate relationship has been observed between these measures of temperament and Warner-Bratzler shear force (Vann et al., 2004). We hypothesize that animals exhibiting excitable temperament characteristics during common management practices may produce carcasses that possess less merit and consequently, meat that is less tender than animals that exhibit a lesser response.

Experimental Procedures

Two trials were conducted under typical industry conditions to test the stated hypotheses. Trial 1 consisted of Bonsmara-sired (n = 32) and Angus-sired (n = 49) yearling steers that had been grown on grass prior to entering the feed yard. Forty-eight Angus-sired steers were backgrounded for 40 d post-weaning and then fed for Trial 2. With the exception of data and sample collection as described, these steers were managed identically to other cattle in the feed yard.

In both trials, temperament-indicating traits were measured on the farm before transport to the feed yard, upon arrival at the feed yard, and after approximately 70 d on feed. At each time, exit velocity was measured as the rate at which cattle left the working chute (Burrow et al., 1988). As the animals moved through the facilities during the pre-shipment data collection, chute score (scale of 1 to 5; 1 = calm, no movement; 5 = rearing, twisting, and struggling violently; Grandin, 1993) and pen score (scale of 1 to 5; 1 = not excited by human presence; 5 = excited by human presence, runs over anything in its path; Hammond et al., 1996) were assigned subjectively to each animal. Each time the animals were handled, serum samples were collected via tail venipuncture and subsequently assayed for cortisol concentrations as an indicator of hypothalamic-pituitary-adrenal axis status (Carroll et al., 1996).

The cattle were fed to an endpoint determined by the feedlot manager and slaughtered using standard procedures. Days on feed were 120 (Trial 1) and 200 (Trial 2). Carcasses were subjected to high-voltage electrical stimulation immediately before evisceration. Carcasses were chilled for 48 h in a 0°C cooler with spray chill for 8 h. Muscle pH and temperature decline were monitored during chilling in the caudal portion of the *M. longissimus lumborum*. Due to equipment failure, pH readings were not taken after 12 h on the carcasses in Trial 2. Forty-eight h postmortem, carcasses carcass quality and yield grade characteristics were determined. At this time, CIE L^*, a^*, and b^* values were measured. Following grading, the carcasses were fabricated, and the strip loin was removed from the left side of each carcass.

At 72 h postmortem, the strip loins were sliced into 1-in. steaks, which were assigned to laboratory analyses. Calpastatin activity was determined at 72 h postmortem by the protocol of Koohmaraie, et al. (1995). Sarcomere length was measured by the method of Cross, et al. (1981). Additional steaks were assigned to be aged for 3, 7, 14, or 21 d and used for Warner-Bratzler shear force determination using the method of McKenna et al. (2004).

Cattle were segmented into temperament groups based on a temperament index value calculated as the sum of the pre-shipment exit velocity (in meters per second) and pen score divided by 2. Cattle with temperament index values more than 1 standard deviation higher or lower than the mean of their contemporary group were included in the Excitable and Calm groups, respectively. The Intermediate group consisted of animals with temperament index values within 1 standard deviation of the mean. Temperament groups were compared using analysis of variance with the PROC MIXED procedure of SAS (SAS Institute, Cary, NC).

Results and Discussion

These cattle were segmented into temperament categories based on exit velocity and pen scores taken before the cattle were transported to the feedlot. Because of this classification, all temperament-indicating variables differed ($P < 0.05$) between the classifications (Table 1). These differences were maintained in subsequent exit velocity measurements, although the magnitude of the differences diminished somewhat as the animals grew larger. This is likely due to a combination of the larger cattle having more difficulty moving through the facility and adaptation with increasing experience to being handled. Serum cortisol was higher ($P < 0.05$) in the Excitable cattle than the other groups at the pre-shipment sampling. Though no differences were observed in later samplings, the Excitable cattle had numerically higher means for cortisol concentration at each sampling.

The muscle pH and temperature decline for these carcasses during chilling are presented in Figure 1. The pH decline was extremely rapid and had reached a minimum value by 7 h postmortem, which was lower than the values typically seen in muscle. During the next 40 h, the pH increased to a point normally observed in postmortem muscle. This initial drop in pH early postmortem is much more rapid and pronounced than generally observed during chilling. Additionally, it is not clear why the pH increased later during chilling. Neither pH nor muscle temperature differed between temperament groups during chilling (Table 2).

None of the carcass yield or quality grade characteristics differed between temperament groups (data not shown). The temperament group × aging interaction was not significant for Warner-Bratzler shear force in this trial. However, aging resulted in considerable improvements in tenderness (data not shown). Steaks from cattle in the Excitable group produced Warner-Bratzler shear force values that were higher ($P < 0.05$) than the Calm or Intermediate groups, which did not differ. Despite this tenderness difference, sarcomere length, calpastatin activity, and color values were not affected.

The cattle in Trial 2 were segmented into temperament categories in the same manner as Trial 1, and differences in temperament measurements taken before shipment to the feedlot were similar to those in Trial 1 (Table 3). Similarly, the differences between the temperament groups diminished as the animals aged, though this trend was more pronounced than in Trial 1. Serum cortisol concentrations did not differ between groups; however, the means for excitable cattle were consistently higher numerically than those for the intermediate and calm groups.

Figure 2 presents the pH and temperature decline curves for the *M. longissimus lumborum* in these carcasses. These curves indicate that these carcasses mirrored the rapid pH and temperature declines observed in Trial 1. However, it is unknown if the buffering phenomenon observed in Trial 2 occurred in this trial because these readings were not taken due to equipment failure. Once again, neither pH nor temperature during chilling was affected by temperament.

Carcass characteristics were not affected by temperament grouping in these steers (data not shown). Once again, aging improved the tenderness of steaks in this trial (data not shown).

In contrast to Trial 1, temperament group did not affect Warner-Bratzler shear force. Perhaps the effects of temperament group on tenderness were related to time on feed, as these cattle were fed much longer than the cattle in Trial 1 (200 versus 120 d). It should be noted that the Warner-Bratzler shear force values for all temperament groups in both trials were very tender. This may be due, in part, to electrical stimulation, which has been consistently reported to improve tenderness. As observed in Trial 1, temperament had no effect on color values, sarcomere length, and calpastatin activity.

Implications

Measures of animal temperament appeared to rank animals consistently, and differences observed between temperament groups before shipment to the feedlot remained throughout the feeding period. Temperament affected tenderness in the yearling-fed cattle, but not in the calf-fed cattle. Based on these data, it is not clear what mechanism mediates these tenderness differences, but it appears that time on feed may play a role.

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Table 1. Least-squares means for temperament indicating traits of yearling-fed steers segmented into groups according to temperament traits measured before shipment to the feeding facility (Trial 1)

Trait	Temperament classification Calm	 Intermediate	 Excitable	RMSE	*P* > F
n	15	50	16		
Pre-shipment temperament index[a]	1.75[c]	2.98[b]	4.20[a]	0.31	<0.001
Pre-shipment exit velocity (ft/s)	4.79[c]	8.81[b]	11.45[a]	1.22	<0.001
Pre-shipment pen score	1.07[c]	2.56[b]	3.47[a]	0.65	<0.001
Pre-shipment chute score	0.68[c]	1.12b	1.50[a]	0.50	0.01
Pre-shipment cortisol (ng/mL)	11.92[b]	12.02[b]	16.13[a]	26.86	0.02
Arrival exit velocity (ft/s)	4.29[c]	6.77[b]	9.54[a]	2.44	<0.001
Arrival cortisol (ng/mL)	10.48	12.46	13.20	52.64	0.55
Mid-point exit velocity (ft/s)	4.06[c]	6.14[b]	9.08[a]	2.112	<0.001
Mid-point cortisol (ng/mL)	8.82	12.10	13.50	37.34	0.09
Final cortisol (ng/mL)	9.85	10.90	11.69	32.96	0.67

[a]Temperament index = (exit velocity + pen score)/2.
[a,b,c]Least-squares means within a row with different superscripts differ ($P < 0.05$).

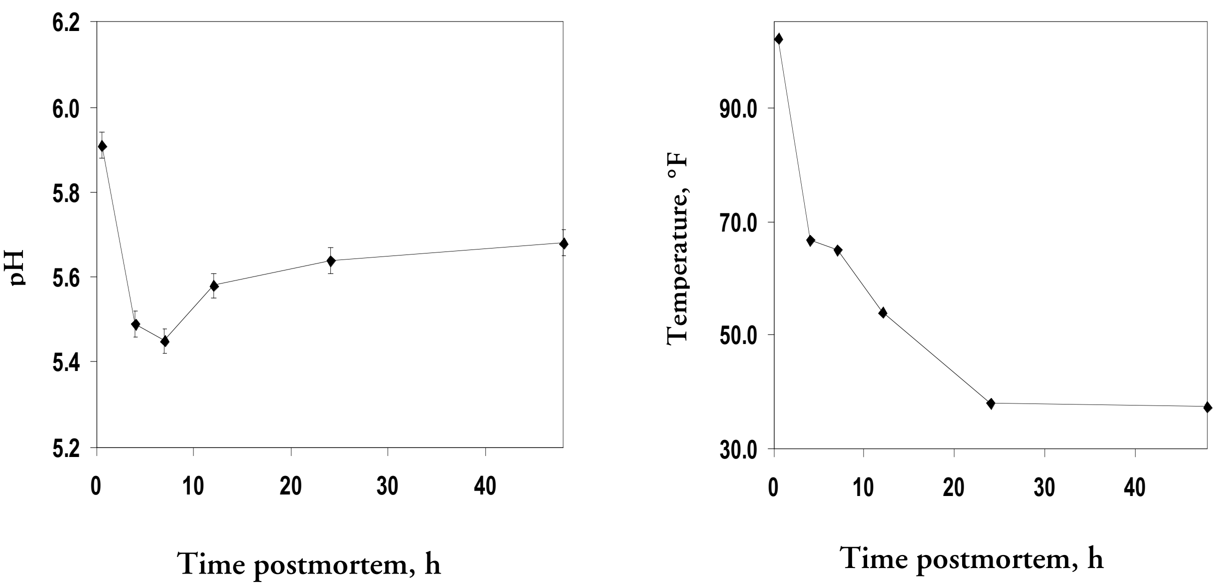

Figure 1. Muscle pH and temperature decline of the *M. longissimus lumborum* of beef carcasses during the chilling process (Trial 1)

Table 2. Least-squares means for carcass traits of yearling-fed steers segmented into groups according to temperament traits measured before shipment to the feeding facility (Trial 1)

	Temperament classification				
Trait	Calm	Intermediate	Excitable	RMSE	P > F
pH	5.62	5.66	5.60	0.04	0.10
Temperature (°F)	63.32	63.55	63.82	0.19	0.43
$L*$	42.49	43.23	43.74	6.13	0.38
$a*$	31.81	31.75	31.74	1.24	0.98
$b*$	23.30	23.48	23.24	1.99	0.81
Sarcomere length (µm)	1.86	1.84	1.82	0.001	0.37
Calpastatin activity	1.01	0.99	0.94	0.25	0.92
Warner-Bratzler shear force (lb)	6.33[b]	6.53[b]	7.35[a]	0.53	0.01

[a,b]Least-squares means within a row with different superscripts differ (P < 0.05)

Table 3. Least-squares means for temperament indicating traits of calf-fed steers segmented into groups according to temperament traits measured before shipment to the feeding facility (Trial 2)

	Temperament classification				
Trait	Calm	Intermediate	Excitable	RMSE	P > F
n	7	33	9		
Pre-shipment temperament index[a]	1.33c	2.48b	4.02a	0.22	<0.001
Pre-shipment exit velocity (ft/s)	4.06[c]	8.22[b]	13.70[a]	0.42	<0.001
Pre-shipment pen score	1.43[c]	2.48[b]	3.89[a]	0.67	<0.001
Pre-shipment chute score	1.57	1.54	2.22	0.64	0.08
Pre-shipment cortisol (ng/mL)	7.24	9.77	10.57	20.18	0.31
Arrival exit velocity (ft/s)	6.93[c]	8.38[b]	10.33[a]	0.62	0.04
Arrival cortisol (ng/mL)	9.75	10.95	13.94	39.25	0.35
Mid-point exit velocity (ft/s)	7.62	8.05	9.47	0.41	0.15
Mid-point cortisol (ng/mL)	13.31	15.17	19.25	37.32	0.13
Final cortisol (ng/mL)	15.68	16.10	18.31	45.47	0.65

[a]Temperament index = (exit velocity + pen score)/2.

[a,b,c]Least-squares means within a row with different superscripts differ (P < 0.05).

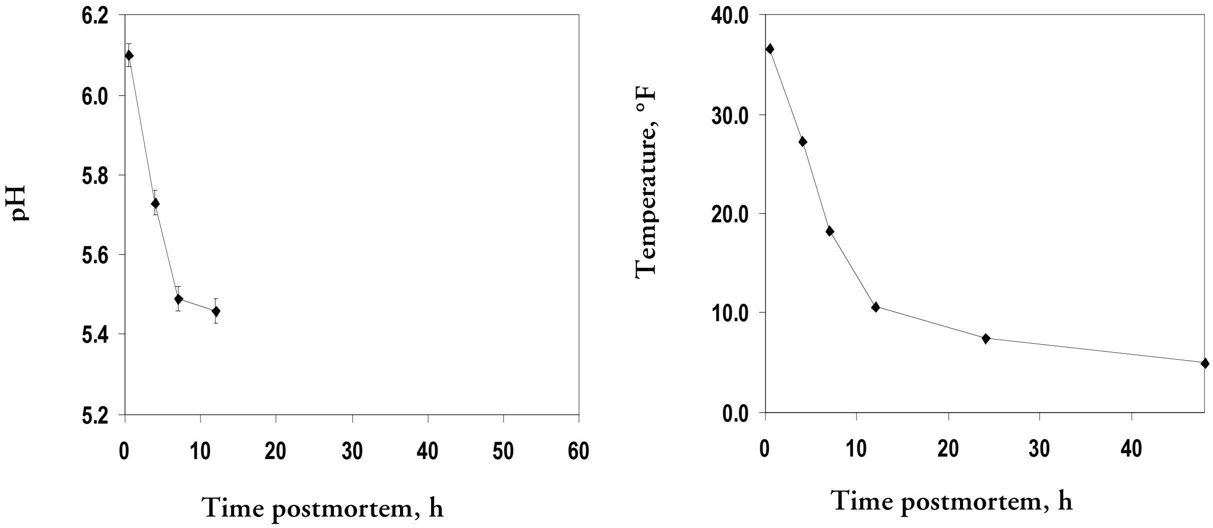

Figure 2. Muscle pH and temperature decline of the *M. longissimus lumborum* of beef carcasses during the chilling process (Trial 2)

Table 4. Least-squares means for carcass traits of calf-fed steers segmented into groups according to temperament traits measured before shipment to the feeding facility (Trial 2)

	Temperament classification				
Trait	Calm	Intermediate	Excitable	RMSE	*P* > F
pH	5.73	5.70	5.65	0.03	0.25
Temperature (°F)	60.94	60.80	60.93	32.32	0.74
*L**	48.04	48.75	47.34	5.55	0.27
*a**	31.25	30.38	31.07	1.65	0.15
*b**	22.87	22.18	22.68	2.30	0.44
Sarcomere length (μm)	1.79	1.79	1.77	0.003	0.65
Calpastatin activity	0.86	1.15	0.97	0.32	0.41
Warner-Bratzler shear force (lb)	6.40	6.69	6.29	0.31	0.62

Least-squares means within a row with different letters (a-c) differ ($P < 0.05$).

PRODUCTION CHARACTERISTICS AND CARCASS QUALITY OF ANGUS AND WAGYU STEERS FED TO U.S. AND JAPANESE ENDPOINTS

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Summary

We predicted that USDA quality grades of Angus and Wagyu steers would not differ unless the steers were fed to a typical Japanese endpoint (1,400 lb). Additionally, we postulated that Wagyu steers would perform better on higher roughage diets than Angus steers. Sixteen Angus and 16 Wagyu weaned steers were assigned to a corn-based diet for 8 or 16 months or hay-based diet for 12 or 20 months. USDA yield grades were greater for Angus steers than for Wagyu steers ($P \leq 0.01$). USDA quality grades were not different between breed types ($P \geq 0.30$), but steers fed to the Japanese endpoint had higher quality grades than those fed to the U.S. endpoint. Ribeye intramuscular lipid increased to over 20% in the Wagyu steers, but to only 14.7% in the Angus steers. Wagyu cattle must be raised to heavy weights before they differ from Angus cattle in intramuscular lipid concentration.

Introduction

Although Wagyu steers produce carcasses with higher quality grades than Angus steers when fed to a typical Japanese endpoint (1,400 lb), it is less clear whether Japanese cattle will produce higher quality carcasses if fed to a typical U.S. endpoint (1,200 lb). Japanese Black cattle fed in Japan typically are fed diets low in concentrate and high in fiber, but the concentration of intramuscular lipid in the ribeye increases throughout their extended feeding periods (Zembayashi et al., 1995). It is not known if Angus steers can deposit intramuscular lipid throughout extended feeding. Therefore, we compared Angus and Wagyu cattle fed a corn-based finishing diet or a hay-based diet to U.S. and Japanese weight endpoints. We predicted that Angus steers would produce carcasses of equal quality to Wagyu steers when fed to the U.S. endpoint, but that Wagyu steers would produce greater quality carcasses if fed to the Japanese endpoint.

Experimental Procedures

Animals and Diets

Sixteen Wagyu crossbred (7/8 Wagyu or higher) and 16 Angus steers were purchased as calves at weaning (approximately 8 months of age). Coastal bermuda grass hay containing 9.5% crude protein was fed free choice for 8 d after the steers were transported to the Texas A&M University Research Center, McGregor. Eight steers of each breed type were assigned to a high-energy, corn-based diet containing 48% ground corn, 20% ground milo, 15% cottonseed hulls, 7.5% molasses, 0.96% limestone, 0.56% trace mineral salt, and 0.08% vitamin premix (Table 1). The diet was designed to achieve an average gain of 3 lb per day, and was fed free choice for 8 or 16 months after weaning (n = 4 per breed and time on feed). The remaining 8 steers of each breed type were offered coastal bermuda grass hay free choice, supplemented with non-protein nitrogen in a cooked molasses carrier, and fed daily an amount of the corn-based diet estimated to achieve a targeted rate of gain of 2 lb per day. The hay-fed steers were fed for 12 or 20 months after weaning (n = 4 per breed and time on feed). The average initial weights for Wagyu and Angus steers were 382 lb and 462 lb, respectively. Targeted final body weights were 1,200 lb for steers fed for either 8 months on corn or 12 months on the hay-based diet (U.S. endpoint), and were 1,400 lb for steers fed for either 16 months on corn or 20 months on the hay-based diet (Japanese endpoint). Diet and time-on-feed were totally confounded in the trial but diet effect was not of particular interest; rather, different diets were utilized to produce similar carcass weights within breed at different ages and days-on-feed. Moreover, the corn-based diet was formulated to be similar to diets typically fed to Angus steers in the U.S., whereas the hay-based diet was intended to be more like diets Wagyu cattle might be fed in Japan.

After being fed for their respective time periods, the steers in each group were slaughtered on two consecutive days. One Angus steer from the 8-mo, corn-fed group escaped the holding pen before slaughter, and had to be removed from the investigation.

Carcass Characteristics

Carcasses were chilled at 4°C for 48 h and quality and yield grade factors were evaluated by trained personnel (USDA, 1997). USDA quality grade factors include overall maturity score and marbling score, whereas USDA yield grade was calculated based on adjusted fat thickness, longissimus muscle cross-sectional (ribeye) area, carcass weight and percentage of kidney, pelvic and heart fat.

Fats and Moistures

A 4-oz portion of the longissimus muscle, completely trimmed of subcutaneous adipose tissue, was homogenized in a Virtis homogenizer (The Virtis Company, Inc., Gardiner, N.Y., USA). Fat and moisture content were determined by standard methods (AOAC, 1990).

Results and Discussion

Initial body weight was greater ($P = 0.01$) for weaned Angus steers than for weaned Wagyu steers (Table 2). This laboratory previously documented that Wagyu calves have lower weaning weights than Angus calves (Smith et al., 1992). Final body weight and carcass weights were also significantly greater for Angus steers than for Wagyu steers across diets and all times-on-feed ($P \leq 0.002$). The corn-based diet was formulated to provide the same average daily gain of 3 lb per day (approximately 700 lb over the 8-month period) for both breed types. This targeted gain was nearly achieved by the Angus steers in the U.S. endpoint group, as they gained an average of 695 lb over the duration of the feeding trial, but the corn-fed Wagyu steers had lower rates of gain, accumulating only 570 lb over the same period. The hay diet was designed to provide similar live weights at slaughter as the corn diet, i.e., 700 lb of gain over a 12-month period. Hay-fed Angus steers approached this objective, gaining an average of 704 lb, whereas hay-fed Wagyu steers gained 670 lb, so that, even on the hay diet, the Angus steers had greater rates of gain.

A similar breed effect was observed in the Japanese endpoint group of cattle. Cattle of both breed types in both diet treatment groups were anticipated to achieve a total gain of 1,200 lb. Neither breed achieved the targeted gain. Angus steers were heavier than Wagyu after either 16 monthes on the corn-based diet or 20 months on the hay-based diet. However, the difference in average final weight between the breeds was only 35 lb in the long-fed groups as opposed to a difference of 90 lb in the first endpoint comparison. This observation supports the hypothesis that Wagyu cattle would perform better on a hay-based diet than on a higher concentrate corn-based diet. In a previous study, Lunt et al. (1993) demonstrated that Angus steers fed a moderately high-roughage diet had greater rates of gain than Wagyu steers fed the same diet. Although a tendency for a breed effect on average daily gain was noted ($P < 0.06$), almost all of the difference was observed in the first 8 mo the cattle were on feed.

The goal of the study was to slaughter the cattle at the same physiological maturity at each slaughter interval. Over all time periods, no breed effect was apparent. Angus steers, however, tended to mature at a more rapid rate than the Wagyu steers ($P < 0.08$; Table 3). There were, of course, diet and endpoint effects on maturity scores ($P < 0.001$). The hay-fed steers were by design 4 months older than the corn-fed steers in both endpoint groups, and there was a significant breed x diet interaction for skeletal maturity ($P < 0.03$). All maturity values were within "A" maturity, the most youthful classification in the U.S. grading system.

Wagyu cattle are characterized by a greater ability to accumulate marbling than other breed types within the ribeye (Lunt et al., 1993; Oka et al., 2002; Zembayashi et al., 1995). Previously, these comparisons were made in steers fed to typical Japanese market endpoints, with steers fed in excess of 500 days (to B maturity). In the A maturity steers of the current study, marbling scores and USDA quality grades were not different between breed types ($P \geq 0.30$; Table 3). It should be noted, however, that most of the carcasses in the 16-month and 20-month groups were up into the USDA prime grade. At this high level of marbling, under the USDA grading system it is difficult to discern differences between such highly marbled carcasses.

Chemically extractable intramuscular lipid may be a more appropriate measure of differences in marbling scores in cattle raised to the Japanese endpoint. Although no overall breed effect was observed, the interactions between breed and diet and breed and endpoint were significant ($P < 0.01$); the Wagyu carcasses in the Japanese endpoint group contained more than 20% lipid, as compared to 12% for the Angus at the same endpoint. Intramuscular lipid increased in Angus steers until 16 mo on feed and did not increase thereafter. In contrast, lipid continued to increase in the Wagyu cattle until the end of the study. In a previous investigation (Zembayashi et al., 1995), we demonstrated that intramuscular lipid in the ribeye of Japanese Black (Wagyu) cattle increased indefinitely with age (up to 900 days of age), whereas in Charolais X Japanese Black/Holstein crossbred cattle, the accumulation of intramuscular lipid ceased after approximately 500 days of age. In another study, we fed 126 Angus steers to 1,500 lb live weight (Cameron et al., 1993). In that investigation, we observed marbling scores that were similar to those achieved by the Angus steers in the present study but we were not able to reach the level of marbling like those of the Wagyu steers in this study or in any of our previous investigations where we have fed Angus and Wagyu cattle (Cameron et al., 1993; Lunt et al., 1993;).

The USDA yield grade is calculated based on carcass weight, ribeye area, adjusted fat thickness at the 12th thoracic rib, and percentage kidney, pelvic, and heart fat (USDA, 1997). There was sufficiently greater fat thickness in the Angus steers ($P = 0.001$) to cause a significant difference in yield grade ($P = 0.01$; Table 3). Not surprisingly, time-on-feed also had a significant effect on ribeye area, fat thickness, and USDA yield grade ($P < 0.01$). The higher yield grade of the Angus steers indicates the greater carcass fatness of this breed type, compared to Wagyu steers (Zembayashi, 1994; Mir et al., 2002).

Implications

Our previous results, combined with the data of the present study, indicate that differences in marbling between Wagyu cattle and British or Continental breed types may not become evident until the cattle are fed to a greater physiological maturity. We further conclude that Wagyu cattle should be fed a high roughage diet for a relatively lengthy feeding period in order to reach their genetic potential to deposit maximum levels of marbling.

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Table 1. Ingredients and chemical composition of the high-corn diet at each time on feed interval

	Diets at each time on feed interval			
Item	1 mo	2 mo	3 mo	4 mo to end
Ground milo	20.00	20.00	20.00	20.00
Ground corn	21.80	40.55	47.55	48.05
Cottonseed meal	10.00	8.00	6.50	6.00
Cottonseed hulls	35.00	20.00	15.00	15.00
Molasses	10.00	8.00	7.50	7.50
Limestone	0.96	0.96	0.96	0.96
Trace mineralized salt[a]	0.56	0.56	0.56	0.56
Dicalcium phosphate	0.23	0.23	0.23	0.23
Potassium chloride	0.16	0.16	0.16	0.16
Zinc oxide	0.01	0.01	0.01	0.01
Ammonium sulphate	0.00	0.25	0.25	0.25
Vitamin premix[a]	0.08	0.08	0.08	0.08
R-1500[a]	1.20	1.20	1.20	1.20
Total percentage	100.00	100.00	100.00	100.00
Nutritional composition[b]				
Dry matter, %	88.80	89.08	89.13	89.13
Crude protein, %	11.41	11.58	11.34	11.16
NEm (Mcal/kg)	1.48	1.72	1.81	1.81
NEg (Mcal/kg)	0.88	1.11	1.19	1.19
Acid detergent fiber, %	27.04	17.50	14.19	14.12
Calcium, %	0.58	0.54	0.52	0.52
Phosphorous, %	0.34	0.36	0.36	0.36

[a]Trace mineralized salt: NaCl, 98%; Zn, 0.35%; Mn. 0.28%; Fe, 0.175%; Cu, 0.035%; I, 0.007%; Co, 0.0007%. Vitamin premix: vitamin A, 2,200,000 IU/kg; vitamin D, 1,100,000 IU/kg; vitamin E, 2,200 IU/kg. R-1500: 1.65 g monensin sodium (Rumensin) per kg.

[b]Percentage of dry matter. Calculated values based on NRC (1996).

Table 2. Production characteristics from Angus and Wagyu steers fed corn or hay-based diets for 8, 12, 16, or 20 months

	Months on feed/diet											
	8 mo/corn		12 mo/hay		16 mo/corn		20 mo/hay			*P* - values		
Item	Angu	Wagy	Angu	Wagy	Angu	Wagy	Angus	Wagy	SE	Bree	Die	Endpoi
Initial body weight, lb	459	372	456	385	481	383	452	385	15	0.02	0.89	0.81
Final body weight, lb	1,155	940	1,162	1,054	1,458	1,261	1,458	1,327	16.8	0.01	0.32	0.01
Cumulative ADG, lb	1.29	1.05	0.89	0.83	0.90	0.81	0.75	0.70	0.56	0.06	0.01	0.05

Table 3. Carcass characteristics and longissimus proximate composition for Angus and Wagyu steers fed corn or hay-based diets for 8, 12, 16, or 20 mo

	Months on feed/diet													
	U.S. endpoint				Japanese endpoint									
	8 mo/corn		12 mo/hay		16 mo/corn		20 mo/hay			*P* - values				
Item	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	Angus	Wagyu	SE	Breed	Diet	Endpoint	BxD[w]	BxE[x]
HCW, lb	711	555	676	623	897	786	887	777	83	0.01	0.89	0.01	0.40	0.91
Skeletal maturity[a]	133.3	140.0	165.0	140.0	167.5	172.5	185.0	185.0	11.3	0.42	0.01	0.01	0.03	0.16
Lean maturity[a]	160.0	147.5	160.0	150.0	170.0	160.0	170.0	177.5	12.4	0.17	0.27	0.01	0.27	0.27
Overall maturity[a]	146.6	142.5	162.5	146.2	168.7	165.0	178.7	181.2	8.3	0.08	0.01	0.01	0.63	0.12
Marbling score[b]	673.3	612.5	580.0	572.5	802.5	897.5	672.5	762.5	135.3	0.55	0.05	0.01	0.80	0.20
Quality grade[c]	483.3	462.5	443.7	468.7	531.2	562.5	487.3	518.7	44.4	0.30	0.07	0.01	0.48	0.37
No. animals grading Prime	2/3	0/4	0/4	1/4	3/4	4/4	1/4	3/4						
Adjusted fat thickness, inches	0.56	0.37	0.51	0.41	0.99	0.60	0.75	0.51	0.18	0.01	0.19	0.01	0.35	0.20
Ribeye area, inches^2	12.5	10.6	11.1	10.6	11.8	13.5	13.2	12.8	8.8	0.75	0.90	0.01	0.59	0.10
KPH, %	3.00	2.88	2.63	3.13	2.75	3.00	2.50	3.25	0.51	0.07	0.86	0.86	0.14	0.40
Yield grade	3.33	2.75	3.33	3.08	5.17	3.27	4.04	3.29	0.56	0.01	0.32	0.01	0.07	0.03
Lipid, %	9.3	6.1	8.3	7.8	14.7	14.1	12.0	20.4	3.84	0.47	0.44	0.01	0.01	0.01
Moisture, %	67.7	70.6	68.7	68.1	62.9	62.1	67.2	59.6	3.35	0.24	0.01	0.04	0.01	0.01

[a]A = 100; B = 200; C = 300; D = 400; E = 500.
[b]Practically Devoid = 100; Traces = 200; Slight = 300; Small = 400; Modest = 500; Moderate = 600; Slightly Abundant = 700; Moderately Abundant = 800; Abundant = 900.
[c]Standard = 200; Select = 300; Choice = 400; Prime = 500.
[w]Breed x diet interaction.
[x]Breed x endpoint interaction. There were no significant breed x diet x endpoint interactions.

SURVEY OF CARCASS TRAITS FROM SHOW STEERS COLLECTED DURING THE CARCASS CONTEST OF THE HOUSTON LIVESTOCK SHOW AND RODEO FROM 1990-2005

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Summary

Sixteen years of carcass data from the top two placing steers in each breed/weight class at the Houston Livestock Show and Rodeo Junior Market Steer Show were analyzed. This study found that carcass weight has increased in recent times with Continental cattle having the heaviest carcasses. Adjusted fat thickness of the top placing steers was shown to be higher after 1996, and English cattle possessed the greatest amount of subcutaneous fat with Continental cattle being the leanest. Ribeye area was shown to increase during each year group, and cattle of Continental background had the largest average ribeyes, while English steers had the smallest. Kidney, pelvic, and heart fat percentage did not differ between breed groups and was only significantly different during the 1996-2000 period, which corresponded to the same period at which external fat thickness was the highest. USDA yield grade decreased numerically, which may be attributed to increasing ribeye size, as carcass weight and fat thickness increased, and kidney, pelvic, and heart fat percentage remained relatively constant. As suggested by ribeye area and fat thickness data, calculated yield grade was shown to be the lowest (most desirable) in Continental cattle, with American cattle being intermediate, and English cattle possessing the highest numerical yield grade. Finally, marbling score was shown to increase during the past sixteen years, with intramuscular fat increasing during each of the year groups. English breed group cattle possessed the greatest amount of marbling, with Continental steers being intermediate and American influenced cattle having the least amount of marbling. These data are reported for use in the carcass contest competition, as well as an educational tool for exhibitors, parents, extension agents, educators, and breeders alike.

Introduction

The Texas junior livestock show program involves several thousand FFA and 4-H students across Texas, USA each year. One of the largest shows in the state (and country) is the Houston Livestock Show and Rodeo. One very popular portion of the show is the Junior Market Steer Show in which exhibitors show market steers divided into 16 breed divisions that are further segmented by weight within each breed. A carcass contest is held after the live steer exposition that includes the animals that placed either first or second in their respective breed/weight class. A similar analysis was performed and data were reported by Hammack and Griffin (1997), in which data were analyzed from steers from the same event from 1977-1996. Carcass data are obtained from animals as both a competition of carcass merit as well as an educational tool for students, educators, show managers, exhibitors' parents, and breeders alike.

Because of the extensive number of factors and the need to narrow the scope to be reported, the information presented herein encompasses hot carcass weight, adjusted fat thickness, ribeye area, percentage kidney, pelvic and heart fat, yield grade and marbling score. As part of this analysis, breeds were grouped, analyzed, and reported as: American (Brahman, Brangus, Santa Gertrudis, Simbrah, and American Crossbreeds), Continental (Charolais, Chianina, Limousin, Maine-Anjou, and Simmental), and English (Angus, Hereford, Polled Hereford, Red Angus, Shorthorn). Finally, data included in this report were collected from the years 1990 through 2005, but for more defined results, we analyzed the factors as segmented into three different year groups: 1990-1995, 1996-2000, and 2001-2005.

Experimental Procedures

Steers (n = 1,519) qualified for competition in the carcass contest by placing first or second in the market steer show at the Houston Livestock Show and Rodeo. Steers were transported to a commercial slaughter facility at Eddy Packing Company, Yoakum, Texas, or Sam Kane Beef Processors, Corpus Christi, Texas, where they were harvested using standard industry practices. Carcasses were chilled for a minimum of 24 hours and then were ribbed between the 12th and 13th ribs by plant employees. Trained personnel from Texas A&M University collected the following factors: adjusted fat thickness, ribeye area, percentage kidney, pelvic, and heart fat, marbling score, skeletal and lean maturity, as well as any quality defects such as dark cutting, echymosis, bruising, etc. Hot carcass weight was obtained from in-plant records.

Statistical analysis

Data were analyzed using Analysis of Variance procedures with the JMP, 2004 program (SAS Institute, Cary, NC). Tests included cattle group (American, Continental, and English) and year group (1990-1995, 1996-2000, and 2001-2005). Least squares means were separated using Tukey's methods.

Results and Discussion

Hot carcass weight

Carcass weight between breed group differed ($P < 0.05$) with the Continental group being heavier (820 lb) than American (782 lb) and English cattle (772 lb) (Figure 1). However, American cattle and English cattle did not tend to differ, with the exception of the third period (2001-2005), where English cattle had heavier average carcass weights. Carcass weights, regardless of breed type, from the 2001-2005 year group, were heavier ($P < 0.05$) than each of the other two-year groups (Figure 2), with 2004 producing the heaviest carcass weights numerically. However, in a similar study, Hammack and Griffin (1997) found that carcass weight had shown some fluctuations since 1977, but had plateaued by 1996.

Adjusted fat thickness

Adjusted fat thickness measurements differed ($P < 0.05$) between each of the three breed groups (Figure 3). The English group had the highest (0.50 in) and Continental the lowest (0.42 in), with American cattle being intermediate at 0.46 in of adjusted subcutaneous fat thickness. No difference in average adjusted fat thickness was observed between the 1996-2000 and the 2001-2005 year groups (Figure 4); yet these years proved to have cattle with a higher ($P < 0.05$) amount of external fat than the 1990-1995 year group (0.48 in and 0.46 in versus 0.43 in).

Ribeye area

The Continental group had larger ($P < 0.05$) ribeye areas than the American group (15.11 in^2 and 14.10 in^2, respectively) and the English group had the smallest ($P < 0.05$) average ribeye size at 13.44 in^2 (Figure 5). Additionally, ribeye area increased ($P < 0.05$) considerably from 1990 to 2005, with this value increasing each year group (Figure 6). Likewise, Continental cattle in the 1996-2000 and 2001-2005 year groups had the largest ribeye areas (15.0 in^2 and 15.4 in^2, respectively), whereas the English group from the 1990 to 1995 year group had with the smallest ribeyes (12.9 in^2). Part of these results could be attributed to the increase in hot carcass weight between periods; however, with the year groups of 1990-1995 and 1996-2000 containing steers with statistically similar carcass weights, it can be deduced that there was an upward trend in muscling.

Kidney, pelvic, and heart fat percentage

No difference ($P > 0.05$) was observed between breed groups for kidney, pelvic, and heart fat percentage. Steers from the 1996-2000 year group had the highest ($P < 0.05$) kidney, pelvic, and heart fat percentages, which was also the year group with the greatest adjusted fat thickness.

Yield grade

USDA yield grade differed ($P < 0.05$) between all three-breed groups (Figure 7), and some differences were observed between year groups (Figure 8). The English group had the highest numerical yield grades (2.84) and, conversely, the Continental group had the lowest (most desirable) yield grade (2.31), with cattle from the American group being intermediate (2.55). The 1990-1995 and the 1996-2000 year groups proved to have cattle that did not differ in terms of yield grade, but both had higher ($P < 0.05$) yield grades than the 2001-2005 year group. As stated earlier, this improvement in USDA yield grade can be attributed to increasing ribeye size, because carcass weights and fat thicknesses increased, which would each raise yield grades (with all factors kept constant) and kidney, pelvic, and heart fat percentages remaining relatively steady.

Marbling score

When simply considering marbling score, the English group exhibited the greatest ($P < 0.05$) amount of intramuscular fat (Slight^{95}), with cattle in the Continental group being intermediate (Slight^{81}) and the American group possessing the lowest average marbling scores (Slight^{57}) (Figure 9). Moreover, average marbling score increased ($P < 0.05$) over the past 16 years. Data indicated that during each year group cattle possessed a greater amount of marbling (Figure 10). The 1990-1995 year group had cattle with the least amount of marbling and oppositely the 2001-2005 year group had steers possessing the most intramuscular fat.

Implications

This carcass information from steer shows provides feedback and an educational tool to participants about the individual animals they exhibited and to understand trends of competitive market steers and the effects of theses changes on carcass merit. In addition, teachers, extension agents, producers, breed associations, and other interested parties may use this information for various educational, promotional and selection/breeding decisions. The data shows that there are differences between years, year groups, breeds, as well as between cattle breed groups. This study showed that there has been an increase in carcass weight and ribeye area, as well as a slight raise in fat thickness and marbling score. These findings support the discoveries of the industry wide review conducted for 1995 and 2000 Beef Quality Audits (Boleman et al., 1998 and McKenna, et al., 2002).

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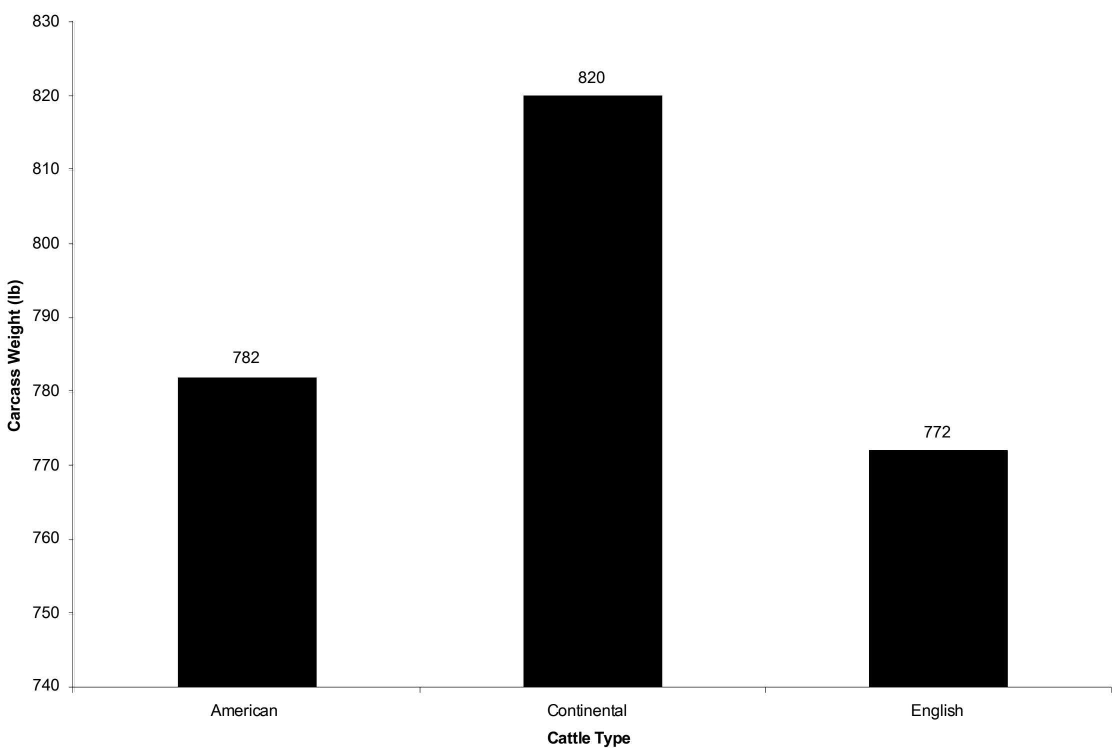

Figure 1. Comparison of average hot carcass weight (lb) of steers from the American, Continental, and English groups.

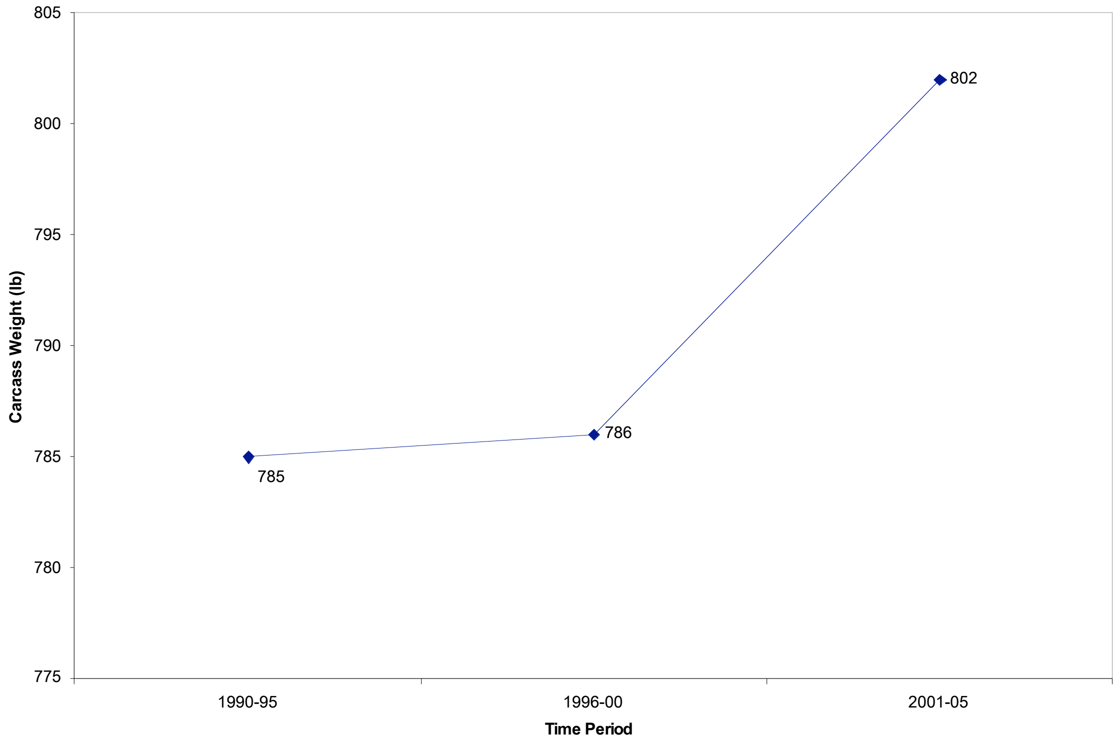

Figure 2. Changes in average hot carcass weight (lb) of steers from three-year groups.

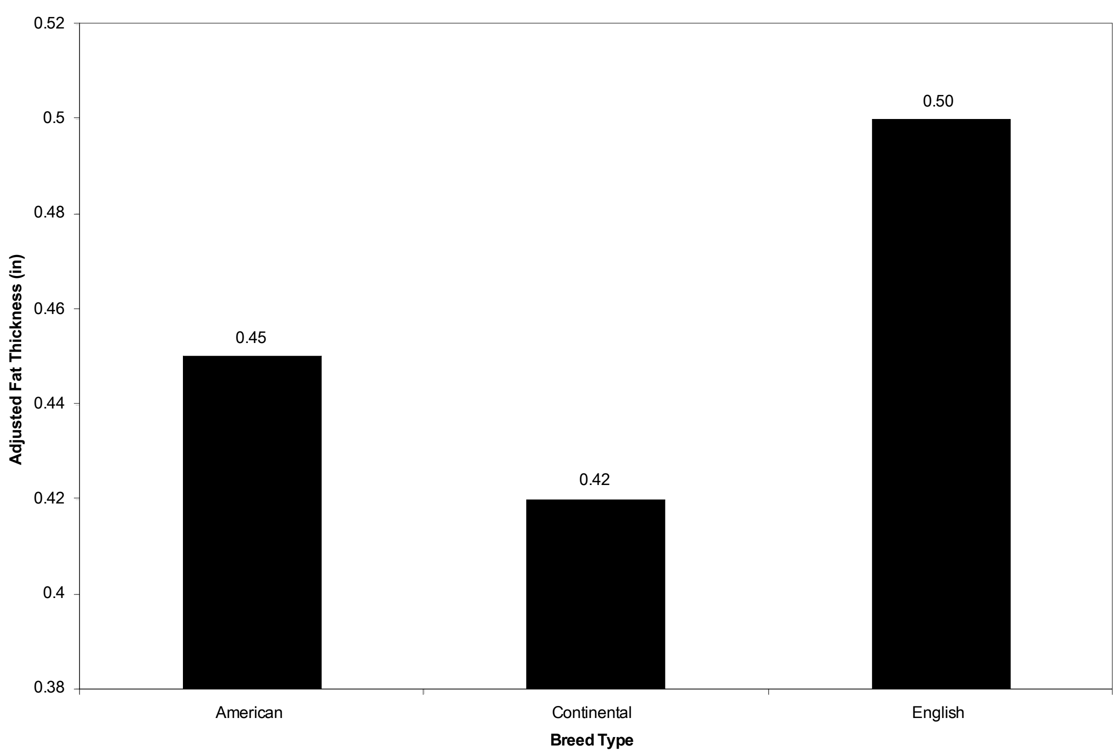

Figure 3. Comparison of average adjusted fat thickness (in) of steers from the American, Continental, and English groups.

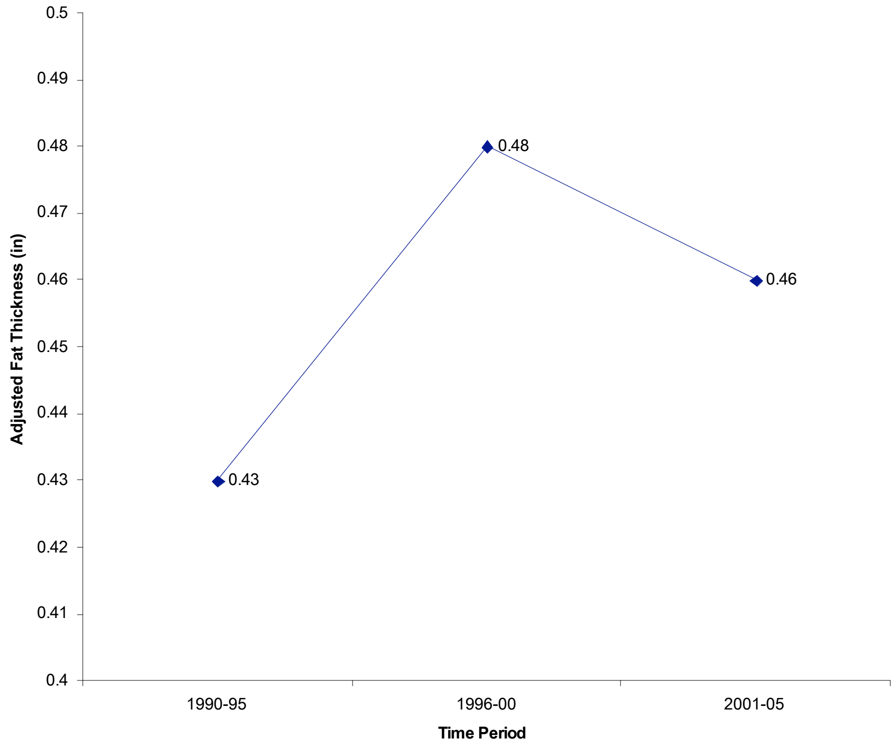

Figure 4. Changes in average adjusted fat thickness (in) of steers from three-year groups.

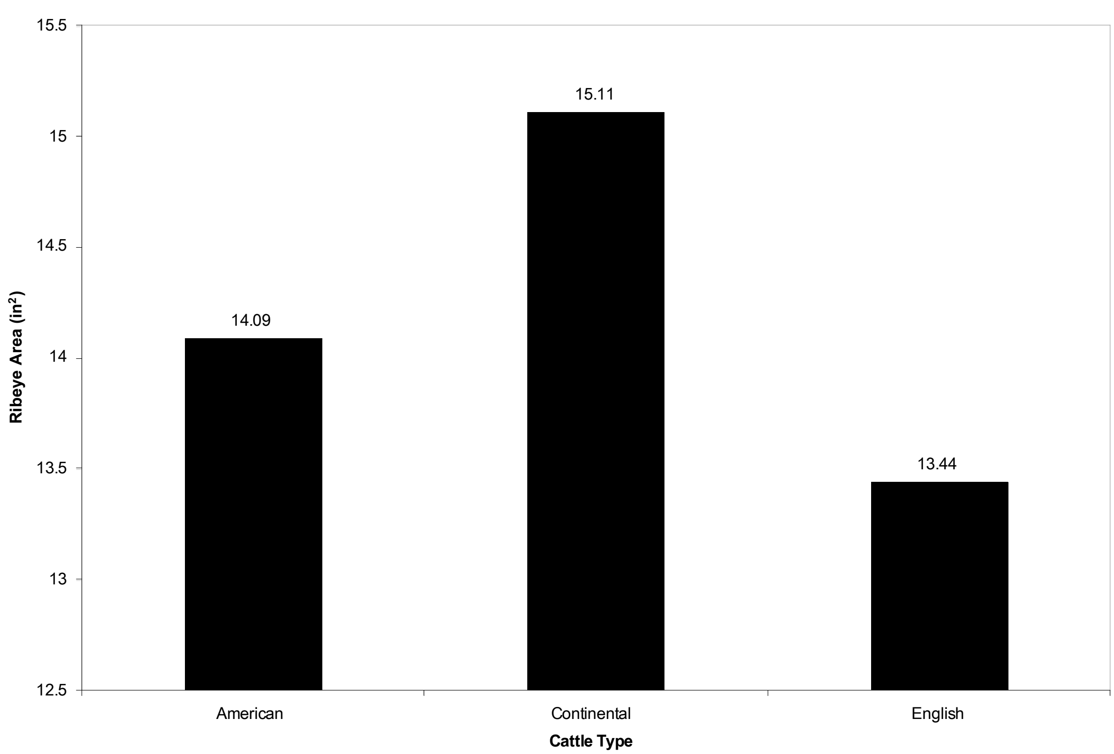

Figure 5. Comparison of average ribeye area (in^2) of steers from the American, Continental, and English groups.

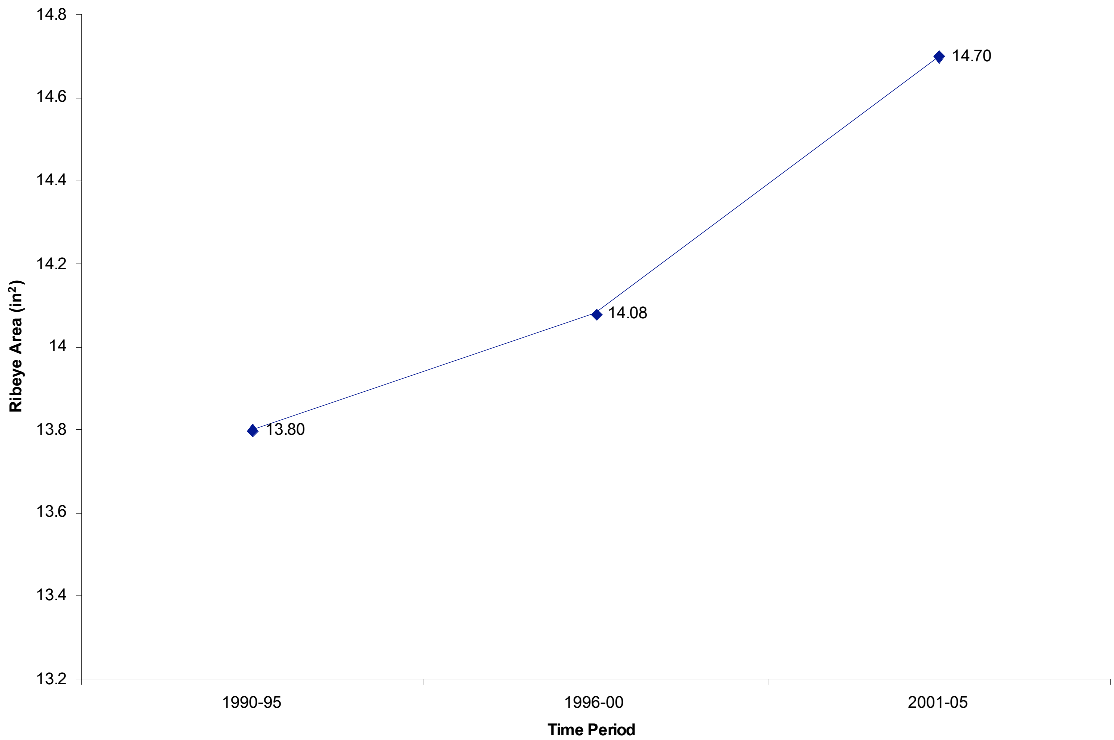

Figure 6. Changes in average ribeye area (in^2) of steers from three-year groups.

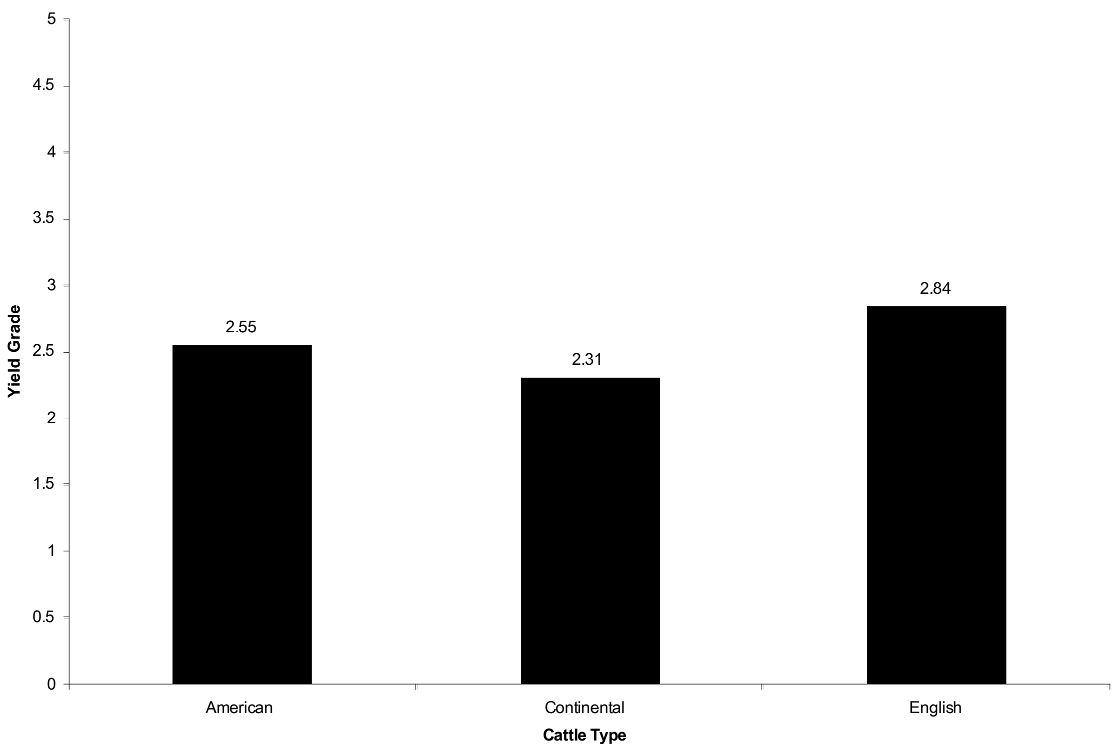

Figure 7. Comparison of average USDA yield grade of steers of from the American, Continental, and English groups.

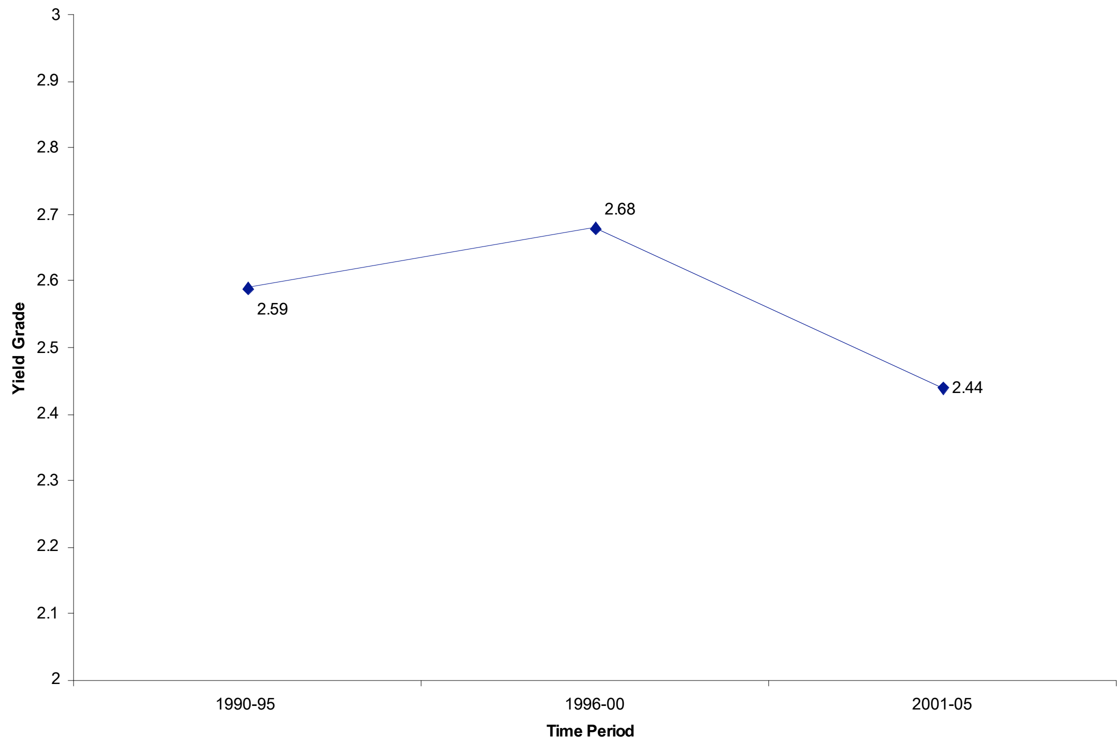

Figure 8. Changes in average USDA yield grade of steers from three-year groups.

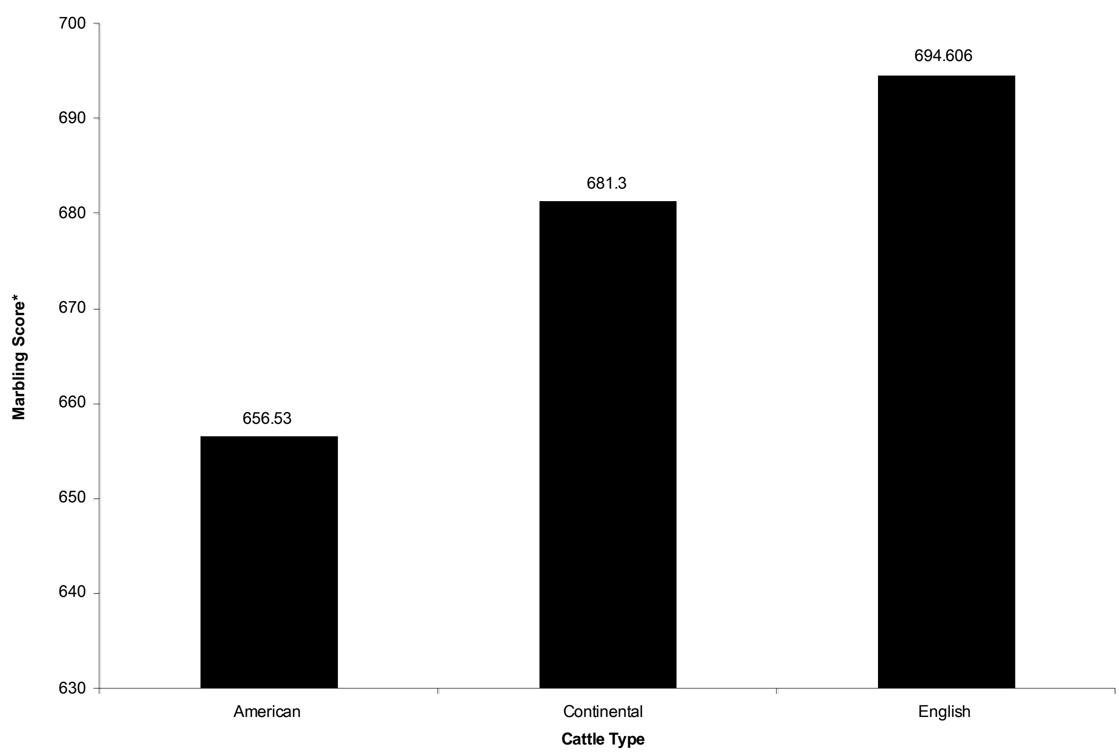

Figure 9. Comparison of average marbling score* from the American, Continental, and English groups.
*Marbling score: 600=Slight^{00}; 700=Small^{00}

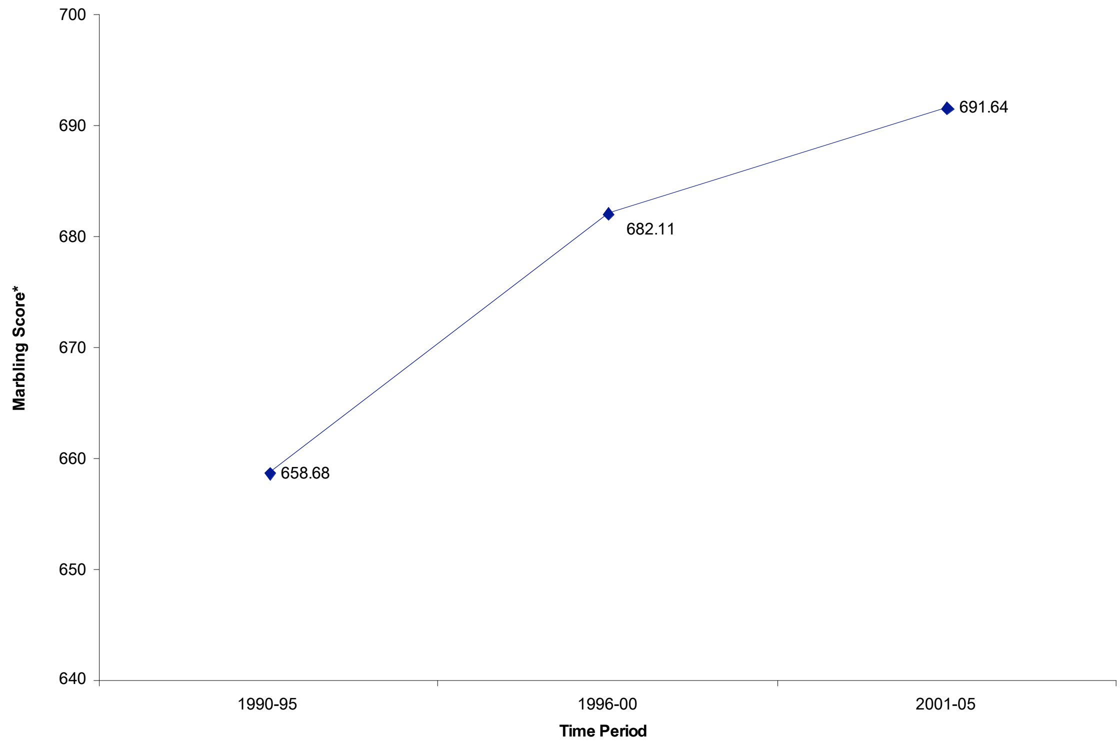

Figure 10. Changes in average marbling score* of steers from three-year groups.
*Marbling score: 600=Slight^{00}; 700=Small^{00}

IN-HOME CONSUMER EVALUATIONS OF INDIVIDUAL MUSCLES FROM BEEF ROUNDS SUBJECTED TO TENDERIZATION TREATMENTS

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Summary

An in-home evaluation of beef value cuts from the round was conducted to determine ways to improve palatability attributes for steaks prepared by consumers. Four beef round muscles were either blade tenderized, enhanced with a salt and phosphate solution, or served as a control. Consumers cooked these steaks as they normally would and were asked to document the cooking method and degree of doneness, as well as the palatability ratings for each steak.

Enhancing round muscles with a salt and phosphate solution improved most palatability traits compared to those that were blade tenderized or were not treated. This process may enable marketers to provide products that will be more favorably received by consumers. For the most part, cooking method and degree of doneness had little influence on consumer palatability ratings. Where differences occurred, they were muscle specific, which may allow limited recommendations for certain muscles with respect to the most appropriate cooking method and degree of doneness.

Introduction

The beef industry is moving towards merchandising individual muscles, and has been focused on identifying and improving underutilized muscles. Kolle et al. (2004) investigated the effects various tenderization treatments on individual muscles from beef rounds and found that responses to tenderization systems were largely muscle dependent, with the *M. semimembranosus*, *M. adductor*, *M. rectus femoris*, and *M. vastus lateralis* showing promising improvements in tenderness. Although most research has suggested that tenderness is the most important determinant of beef palatability, consumer controlled factors such as degree of doneness and cooking method can have a great impact on consumer satisfaction (Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999). One of the limitations of objective measures of meat tenderness is that many factors that can influence tenderness and palatability, such as cooking method and degree of doneness, are controlled (Kolle et al., 2004). An in-home study was conducted to give insight into consumer's ability to pick up both positive and negative effects of tenderization treatments, and subsequent tenderization recommendations can be made to retailers and processors so that muscles from beef rounds are tenderized in a manner that maximizes palatability.

Experimental Procedures

USDA Select, beef inside rounds (IMPS#169A) (n = 67) and knuckles (IMPS# 167A) (n = 66) were purchased from a local processing facility and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. Subprimals were assigned randomly to one of three treatments (control, blade tenderization, or injection with salt and phosphate solution). Inside rounds were separated into *M. semimembranosus* and *M. adductor,* and knuckles were separated into *M. rectus femoris* and *M. vastus lateralis*. Muscles were trimmed, defatted, and treated. The blade tenderization treatment consisted of a double pass through a 286 blade (13 rows of 22 blades) TEND-R-RITE Blade tenderizer (TR-2, Bettcher Industries, Inc., Birmingham, OH). The injection/enhancement treatment consisted of a water solution containing 5.0% sodium chloride and 2.95% sodium tripolyphosphate (Brifisol ® 512, BK Giulini Corp., Simi Valley, CA). The solution (pH 7.61 ± 0.23 at 16.1° ± 1.07°C) was injected into the muscles at a 15% level using a single pass through a commercial injection machine (Inject Star BI 72, Inject Star, Inc., Brookfield, CT). Final concentrations of sodium chloride and sodium tripolyphosphate in the muscles were estimated to be 0.71% and 0.42%, respectively. After processing, muscles were cut into 2.54 cm steaks, individually vacuum-packaged, and frozen. Three steaks were cut from each muscle perpendicular to the muscle fiber orientation starting from the most cranial aspect of each muscle and moving towards the most caudal aspect (or proximal and distal when appropriate). Steaks were stored a -10º C until delivery to consumers.

Beef consumers (n = 395) were solicited through direct contact by Texas A&M University personnel (261 consumers completed the study). Participants were given a box of steaks and asked to prepare those steaks as they normally would if they had purchased them from the supermarket. Preparers were asked to identify the cooking method (outdoor or indoor grill, pan-broil, pan-fry, stir-fry, broil, oven roasted, uncovered, braise and simmer, or stew) used by referring to the definitions provided in the included directions. The approximate degree of doneness was determined by consumers using the National Cattlemen's Beef Association beef steak color guide provided for them in the box. The consumers were asked to evaluate steaks for overall-like, tenderness, juiciness, flavor intensity, and flavor desirability using a 10-point scale (10 = extreme like, extremely tender, extremely juicy, extremely intense, and extremely desirable; 1 = extreme dislike, extremely tough, extremely dry, extremely bland, and extremely undesirable). This study was approved by the Institutional Review Board at Texas A&M University, and informed consent was obtained from all participants.

Data were analyzed for each muscle individually using the PROC GLM procedures of SAS (SAS Institute, Cary, NC). Initial models tested the main effects of tenderization treatment and cooking method and their interaction. Cooking methods were pooled into four categories including: grill, oven, skillet, and moist cookery. Within cooking methods displaying sufficient numbers of steaks cooked to various degrees of doneness (grilling and skillet methods), the effects of degree of doneness and tenderization treatment were tested. A predetermined α of 0.05 was used for all determinations of statistical significance.

Results and Discussion

Tenderization Treatments

Least squares means for consumer evaluations of steaks are reported in Table 1. *M. semimembranosus* steaks from the salt/phosphate treatment received the highest ($P < 0.05$) ratings for all traits compared to those from the control and blade tenderized treatments. For the *M. rectus femoris*, consumers gave steaks from the salt/phosphate treatment higher ($P < 0.05$) palatability ratings compared to the control steaks, and higher ($P < 0.05$) tenderness and juiciness ratings than steaks from the blade tenderized treatment. For the *M. vastus lateralis* steaks, those that were from the salt/phosphate treatment received higher ($P < 0.05$) palatability ratings for all traits compared to the steaks from the blade tenderization treatment and the controls. In general, the salt/phosphate treatment resulted in improved palatability compared to the blade tenderized treatment and to the controls. In most cases, blade tenderizing did not improve palatability compared to controls.

Cooking methods

When looking at the various cooking methods (Table 2), *M. adductor* steaks cooked in the skillet and using a grilling method received higher ($P < 0.05$) consumer ratings for juiciness than steaks cooked in an oven or using moist cookery. For flavor intensity and desirability, steaks cooked in a skillet, on the grill, and in the oven were ranked higher ($P < 0.05$) than those cooked using moist cookery. This might suggest that cooking with moist heat cookery may reduce the flavor attributes of the *M. adductor* steak to an unacceptable level for consumers. For *M. rectus femoris* steaks, tenderness ratings were higher ($P < 0.05$) for those steaks cooked using moist cookery and in a skillet than those cooked in an oven or on a grill. For *M. vastus lateralis*, the steaks cooked with moist cookery were given higher ratings ($P < 0.05$) for tenderness, whereas, those cooked on a skillet, in the oven, or on a grill, were given similar and lower ratings. The increase in tenderness of the *M. vastus lateralis* steaks cooked using moist heat also created higher ($P < 0.05$) ratings for overall like suggesting that the role that moist heat cookery played in increasing tenderness, increased the overall palatability of the steak for consumers. In general, cooking methods did not provide substantial increases in consumer palatability attributes. For the knuckle steaks (*M. rectus femoris and M. vastus lateralis*), moist heat cookery did create an increase in tenderness ratings from consumers over the dry heat methods (grill and oven).

Degree of Doneness

M. semimembranosus steaks cooked on a grill (Table 3) to medium rare and below received the highest ($P < 0.05$) ratings for juiciness, flavor intensity, and desirability. The method of cookery clearly influenced consumer palatability ratings for *M. rectus femoris* steaks cooked on a grill. Lower degrees of doneness (medium rare and below and medium) received higher ($P < 0.05$) tenderness ratings than steaks cooked to well done. Juiciness ratings increased as the degree of doneness decreased, with steaks cooked to medium rare or below receiving higher ($P < 0.05$) ratings than those cooked to medium well. In addition, those steaks cooked to medium well produced higher ($P < 0.05$) juiciness ratings than those cooked to well done. Steaks cooked at medium rare and below received the highest ($P < 0.05$) ratings for flavor intensity. Flavor desirability and overall like ratings received similar ratings as those steaks cooked to medium rare and below. In general, lower degrees of doneness produced higher palatability ratings. This, combined with other findings, suggest that a dry heat cookery method like grilling may be acceptable for the *M. rectus femoris* if cooked to lower degrees of doneness.

In Table 4 least squares means for consumer evaluations of steaks cooked using moist cookery are presented. For the attribute of overall like, consumers rated those *M. semimembranosus* steaks cooked medium rare and below the lowest ($P < 0.05$).

Consumers that prepared *M. semimembranosus* steaks in an oven (Table 5) ranked steaks cooked to medium rare and below higher ($P < 0.05$) than those cooked to medium well and well done for overall like. For M. *rectus femoris* steaks cooked in an oven to medium rare and below, higher ratings ($P < 0.05$) were given for juiciness than for all other attributes. For *M. Vastus lateralis* steaks cooked in an oven, ratings for juiciness and overall like were higher ($P < 0.05$) for steaks cooked to medium rare and below than those cooked to medium well and lowest ($P < 0.05$) for those cooked well done. For flavor intensity, those cooked to medium rare and below and medium were rated higher ($P < 0.05$) than those cooked well done. Ratings for overall like patterned those for juiciness signifying that juiciness plays an important role in the overall palatability of a round steak when cooked using a dry heat method.

M. adductor steaks cooked in a skillet (Table 6) to a well done degree of doneness received lower ($P < 0.05$) ratings for juiciness than those cooked to medium rare and below and those cooked to medium well. For *M. Vastus lateralis* steaks cooked in a skillet, juiciness ratings were higher ($P < 0.05$) for those steaks cooked to medium rare and below than for those cooked to medium well and well done.

Implications

Injecting round muscles with a salt and phosphate solution improved most palatability traits compared to those that were blade tenderized or were not treated. For the most part, cooking method and degree of doneness had little influence on consumer palatability ratings. Where differences occurred, they were muscle specific, which may allow limited recommendations for certain muscles with respect to the most appropriate cooking method and degree of doneness.

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Table 1. Least-squares means (SEM) for consumer evaluations of beef steaks treated with blade tenderization or salt/phosphate injection

		Treatment			
Muscle	Attribute	Control	Blade	Inject	*P* > F
M. adductor	Tenderness	5.7 ± 0.2	6.2 ± 0.2	6.3 ± 0.2	0.06
	Juiciness	5.4 ± 0.2	5.7 ± 0.2	6.0 ± 0.2	0.13
	Flavor Intensity	5.9 ± 0.2	6.2 ± 0.2	6.3 ± 0.2	0.15
	Flavor Desirability	6.0 ± 0.2	6.3 ± 0.2	6.3 ± 0.2	0.35
	Overall Like	6.3 ± 0.2	6.8 ± 0.2	6.8 ± 0.2	0.10
M. semimembranosus	Tenderness	6.0 ± 0.2b	6.1 ± 0.2b	6.6 ± 0.2a	0.04
	Juiciness	5.5 ± 0.2b	5.3 ± 0.2b	6.2 ± 0.2a	<0.01
	Flavor Intensity	5.9 ± 0.2b	6.0 ± 0.2b	6.5 ± 0.2a	0.05
	Flavor Desirability	6.0 ± 0.2b	6.0 ± 0.2b	6.7 ± 0.2a	0.01
	Overall Like	6.4 ± 0.2b	6.5 ± 0.2b	7.1 ± 0.2a	0.02
M. rectus femoris	Tenderness	6.3 ± 0.2b	6.7 ± 0.2b	7.2 ± 0.2a	<0.01
	Juiciness	5.9 ± 0.2b	6.1 ± 0.2b	6.9 ± 0.2a	<0.01
	Flavor Intensity	6.3 ± 0.2b	6.5 ± 0.2ab	7.0 ± 0.2a	0.02
	Flavor Desirability	6.2 ± 0.2b	6.5 ± 0.2ab	6.9 ± 0.2a	0.02
	Overall Like	6.5 ± 0.2b	6.9 ± 0.2ab	7.3 ± 0.2a	<0.01
M. vastus lateralis	Tenderness	5.4 ± 0.2b	5.7 ± 0.2b	6.5 ± 0.2a	<0.01
	Juiciness	5.3 ± 0.2b	5.6 ± 0.2b	6.2 ± 0.2a	0.01
	Flavor Intensity	5.5 ± 0.2b	5.8 ± 0.2b	6.6 ± 0.2a	<0.01
	Flavor Desirability	5.6 ± 0.2b	6.0 ± 0.2b	6.7 ± 0.2a	<0.01
	Overall Like	5.8 ± 0.2b	6.1 ± 0.2b	6.9 ± 0.2a	<0.01

Means within the same row lacking common letters (a,b) differ ($P < 0.05$).

Table 2. Least-squares means (SEM) for consumer evaluations of beef steaks cooked with grilling, oven moist, cookery methods, or in a skillet

Muscle	Attribute	Cooking Method				
		Grill	Oven	Moist	Skillet	*P* > F
M. adductor	Tenderness	6.1 ± 0.2	6.1 ± 0.3	5.7 ± 0.4	6.5 ± 0.2	0.17
	Juiciness	6.0 ± 0.2ab	5.4 ± 0.3b	5.3 ± 0.4b	6.2 ± 0.2a	0.05
	Flavor Intensity	6.4 ± 0.1a	6.2 ± 0.3ab	5.4 ± 0.4b	6.6 ± 0.2a	0.02
	Flavor Desirability	6.3 ± 0.1a	6.4 ± 0.3a	5.4 ± 0.4b	6.7 ± 0.2a	0.02
	Overall Like	6.4 ± 0.1	6.8 ± 0.3	6.4 ± 0.4	6.9 ± 0.2	0.21
M. semimembranosus	Tenderness	5.9 ± 0.1	6.3 ± 0.4	6.6 ± 0.4	6.0 ± 0.2	0.33
	Juiciness	5.8 ± 0.2	5.4 ± 0.4	5.8 ± 0.4	5.6 ± 0.2	0.72
	Flavor Intensity	6.1 ± 0.1	6.1 ± 0.3	6.4 ± 0.4	6.1 ± 0.2	0.90
	Flavor Desirability	6.1 ± 0.1	6.2 ± 0.4	6.4 ± 0.4	6.2 ± 0.2	0.91
	Overall Like	6.5 ± 0.2	6.8 ± 0.3	7.0 ± 0.3	6.4 ± 0.2	0.38
M. rectus femoris	Tenderness	6.4 ± 0.2b	6.3 ± 0.4b	7.2 ± 0.3a	6.9 ± 0.2a	0.03
	Juiciness	6.3 ± 0.2	5.9 ± 0.4	6.6 ± 0.3	6.6 ± 0.2	0.26
	Flavor Intensity	6.4 ± 0.2	6.3 ± 0.4	6.8 ± 0.3	6.9 ± 0.2	0.29
	Flavor Desirability	6.4 ± 0.2	6.2 ± 0.4	6.7 ± 0.3	6.8 ± 0.2	0.21
	Overall Like	6.7 ± 0.1	6.6 ± 0.3	7.2 ± 0.3	7.1 ± 0.2	0.21
M. vastus lateralis	Tenderness	5.6 ± 0.2b	5.1 ± 0.3b	7.1 ± 0.3a	5.6 ± 0.2b	<0.01
	Juiciness	5.7 ± 0.2	5.3 ± 0.4	6.1 ± 0.3	5.7 ± 0.2	0.40
	Flavor Intensity	6.1 ± 0.2	5.4 ± 0.3	6.2 ± 0.3	6.1 ± 0.2	0.26
	Flavor Desirability	5.9 ± 0.2	5.7 ± 0.3	6.6 ± 0.3	6.2 ± 0.2	0.21
	Overall Like	6.1 ± 0.2b	5.7 ± 0.3b	7.1 ± 0.3a	6.1 ± 0.2b	0.01

Means within the same row lacking common letters (a,b) differ (*P* < 0.05).

Table 3. Least-squares means (SEM) for consumer evaluations of beef steaks cooked on a grill

Muscle	Attribute	Degree of Doneness				$P > F$
		Med Rare and Rare	Medium	Medium Well	**Well Done**	
M. adductor	Tenderness	5.8 ± 0.4	5.7 ± 0.3	6.4 ± 0.3	6.4 ± 0.3	0.22
	Juiciness	5.9 ± 0.4	5.7 ± 0.3	6.2 ± 0.3	6.1 ± 0.4	0.67
	Flavor Intensity	6.5 ± 0.4	6.2 ± 0.2	6.7 ± 0.2	6.3 ± 0.3	0.36
	Flavor Desirability	6.4 ± 0.4	6.0 ± 0.3	6.6 ± 0.3	6.1 ± 0.3	0.36
	Overall Like	6.1 ± 0.4	6.1 ± 0.2	6.7 ± 0.2	6.8 ± 0.3	0.22
M. semimembranosus	Tenderness	6.8 ± 0.4	5.8 ± 0.2	5.6 ± 0.3	6.0 ± 0.3	0.09
	Juiciness	7.0 ± 0.4a	5.9 ± 0.3	5.7 ± 0.3b	5.1 ± 0.4b	<0.01
	Flavor Intensity	7.3 ± 0.4a	6.0 ± 0.2b	5.7 ±0.2b	5.8 ± 0.3b	<0.01
	Flavor Desirability	7.4 ± 0.4a	6.0 ± 0.2b	5.8 ± 0.3b	5.9 ± 0.3b	0.01
	Overall Like	7.1 ± 0.4	6.4 ± 0.2	6.4 ± 0.2	6.4 ± 0.3	0.38
M. rectus femoris	Tenderness	6.9 ± 0.3a	6.6 ± 0.3a	6.2 ± 0.3ab	5.5 ± 0.4b	0.04
	Juiciness	7.2 ± 0.3a	6.5 ± 0.3ab	6.0 ± 0.3b	4.3 ± 0.4c	<0.01
	Flavor Intensity	7.4 ± 0.3a	6.4 ± 0.3b	6.0 ± 0.3b	5.7 ± 0.4b	<0.01
	Flavor Desirability	7.2 ± 0.3a	6.5 ± 0.3ab	5.9 ± 0.3b	5.4 ± 0.4b	0.01
	Overall Like	7.2 ± 0.3a	6.9 ± 0.2ab	6.3 ± 0.3b	6.1 ± 0.4b	0.05
M. vastus lateralis	Tenderness	5.5 ± 0.3	5.8 ± 0.3	5.1 ± 0.3	6.7 ± 0.5	0.07
	Juiciness	6.1 ± 0.4	5.9 ± 0.3	5.2 ± 0.3	5.2 ± 0.5	0.18
	Flavor Intensity	6.1 ± 0.3	6.1 ± 0.3	5.7 ± 0.3	7.0 ± 0.5	0.22
	Flavor Desirability	5.9 ± 0.4	6.1 ± 0.3	5.4 ± 0.3	7.0 ± 0.5	0.10
	Overall Like	6.1 ± 0.3	6.2 ± 0.3	5.6 ± 0.3	6.9 ± 0.5	0.20

Means within the same row lacking common letters (a-c) differ ($P < 0.05$).

Table 4. Least-squares means (SEM) for consumer evaluations of beef steaks cooked using moist cookery

Muscle	Attribute	Degree of Doneness				$P > F$
		Med Rare and Rare	Medium	Medium Well	Well Done	
M. adductor	Tenderness	-	4.7 ± 1.2	4.9 ± 0.8	6.1 ± 0.5	0.32
	Juiciness	-	4.7 ± 1.1	4.9 ± 0.7	5.4 ± 0.5	0.76
	Flavor Intensity	-	5.0 ± 1.0	5.4 ± 0.7	5.3 ± 0.4	0.95
	Flavor Desirability	-	5.0 ± 1.1	4.3 ± 0.8	5.8 ± 0.5	0.24
	Overall Like	-	5.3 ± 1.0	6.7 ± 0.6	6.4 ± 0.4	0.52
M. semimembranosus	Tenderness	1.1 ± 2.0	7.8 ± 1.2	6.3 ± 0.9	6.8 ± 0.4	0.06
	Juiciness	2.5 ± 2.4	7.3 ± 1.4	5.6 ± 1.1	5.8 ± 0.5	0.41
	Flavor Intensity	3.1 ± 2.1	6.5 ± 1.2	5.7 ± 1.0	6.6 ± 0.4	0.34
	Flavor Desirability	2.0 ± 2.0	6.7 ± 1.2	6.0 ± 1.0	6.7 ± 0.4	0.17
	Overall Like	2.0 ± 2.0b	8.7 ± 1.2a	6.1 ± 0.9a	7.1 ± 0.4a	0.05
M. rectus femoris	Tenderness	7.0 ± 2.1	6.9 ± 1.0	7.3 ± 0.5	7.4 ± 0.4	0.98
	Juiciness	5.1 ± 2.4	5.4 ± 1.1	6.8 ± 0.6	6.9 ± 0.5	0.54
	Flavor Intensity	4.5 ± 2.4	5.5 ± 1.1	7.6 ± 0.6	6.8 ± 0.4	0.29
	Flavor Desirability	3.7 ± 2.3	5.2 ± 1.1	7.5 ± 0.6	6.9 ± 0.4	0.17
	Overall Like	5.9 ± 2.0	6.1 ± 0.9	7.1 ± 0.5	7.7 ± 0.4	0.33
M. vastus lateralis	Tenderness	7.8 ± 1.6	6.2 ± 0.8	6.9 ± 0.6	7.4 ± 0.5	0.63
	Juiciness	8.4 ± 1.7	5.2 ± 0.9	6.3 ± 0.6	5.8 ± 0.5	0.39
	Flavor Intensity	8.4 ± 1.3	4.7 ± 0.7	6.6 ± 0.5	6.1 ± 0.4	0.06
	Flavor Desirability	8.3 ± 1.5	4.9 ± 0.8	6.8 ± 0.5	6.7 ± 0.5	0.15
	Overall Like	8.3 ± 1.4	6.4 ± 0.7	7.2 ± 0.5	7.1 ± 0.4	0.57

Means within the same row lacking common letters (a,b) differ ($P < 0.05$).

Table 5. Least-squares means (SEM) for consumer evaluations of beef steaks cooked in an oven

Muscle	Attribute	Degree of Doneness				P > F
		Med Rare and Rare	Medium	Medium Well	Well Done	
M. adductor	Tenderness	5.3 ± 1.1	6.4 ± 0.7	5.9 ± 0.7	6.3 ± 0.6	0.79
	Juiciness	6.0 ± 1.3	6.1 ± 0.8	5.7 ± 0.8	4.4 ± 0.7	0.36
	Flavor Intensity	6.0 ± 1.2	6.5 ± 0.7	6.8 ± 0.8	5.5 ± 0.6	0.57
	Flavor Desirability	6.6 ± 1.2	6.8 ± 0.7	6.7 ± 0.8	6.0 ± 0.6	0.83
	Overall Like	6.5 ± 1.0	7.0 ± 0.6	6.6 ± 0.7	7.1 ± 0.5	0.92
M. semimembranosus	Tenderness	5.2 ± 0.9	7.0 ± 0.8	5.4 ± 1.0	6.5 ± 0.6	0.37
	Juiciness	5.2 ± 1.0	6.8 ± 0.8	4.4 ± 1.1	5.1± 0.7	0.31
	Flavor Intensity	5.6 ± 1.0	7.2 ± 0.8	5.0 ± 1.0	6.1 ± 0.6	0.35
	Flavor Desirability	5.1 ± 0.9	7.0 ± 0.8	5.2 ± 1.0	6.5 ± 0.6	0.31
	Overall Like	5.8 ± 0.6a	6.9 ± 0.6ab	5.6 ± 0.7b	7.7 ± 0.4b	0.04
M. rectus femoris	Tenderness	7.4 ± 0.8	6.7 ± 0.5	6.3 ± 0.5	5.4 ± 0.6	0.21
	Juiciness	7.9 ± 0.7a	6.1 ± 0.4b	5.3 ± 0.5b	5.2 ± 0.5b	0.03
	Flavor Intensity	7.4 ± 0.8	6.7 ± 0.5	5.9 ± 0.5	5.9 ± 0.6	0.32
	Flavor Desirability	7.6 ± 0.8	6.4 ± 0.5	6.0 ± 0.5	5.3 ± 0.6	0.13
	Overall Like	8.2 ± 0.8	6.6 ± 0.4	6.4 ± 0.5	6.0 ± 0.6	0.17
M. vastus lateralis	Tenderness	6.1 ± 0.6	5.6 ± 0.5	4.6 ± 0.5	3.8 ± 0.7	0.06
	Juiciness	6.7 ± 0.5a	5.6 ± 0.5ab	5.1 ± 0.5b	3.3 ± 0.6c	<0.01
	Flavor Intensity	6.3 ± 0.6a	6.1 ± 0.5a	5.0 ± 0.5ab	4.0 ± 0.6b	0.02
	Flavor Desirability	7.2 ± 0.6a	6.2 ± 0.5ab	5.0 ± 0.5b	4.4 ± 0.6b	0.01
	Overall Like	6.7 ± 0.6a	6.1 ± 0.5ab	5.1 ± 0.5b	4.1 ± 0.6c	0.02

Means within the same row lacking common letters (a-c) differ (P < 0.05).

Table 6. Least-squares means (SEM) for consumer evaluations of beef steaks cooked in a skillet

Muscle	Attribute	Degree of Doneness				P > F
		Med Rare and Rare	Medium	Medium Well	Well Done	
M. adductor	Tenderness	6.8 ± 0.6	6.7 ± 0.3	6.8 ± 0.3	6.1 ± 0.3	0.47
	Juiciness	7.3 ± 0.6a	6.3 ± 0.3ab	6.6 ± 0.3a	5.6 ± 0.3b	0.03
	Flavor Intensity	7.3 ± 0.6	6.6 ± 0.4	7.0 ± 0.4	6.1 ± 0.3	0.19
	Flavor Desirability	7.3 ± 0.6	6.5 ± 0.3	7.1 ± 0.3	6.4 ± 0.3	0.43
	Overall Like	7.5 ± 0.6	6.9 ± 0.3	7.3 ± 0.3	6.5 ± 0.3	0.29
M. semimembranosus	Tenderness	5.2 ± 0.5	6.0 ± 0.4	6.5 ± 0.4	5.9 ± 0.4	0.32
	Juiciness	5.6 ± 0.5	5.9 ± 0.4	5.7 ± 0.4	5.4 ± 0.4	0.74
	Flavor Intensity	6.3 ± 0.5	6.2 ± 0.3	6.2 ± 0.4	5.9 ± 0.4	0.94
	Flavor Desirability	5.9 ± 0.5	6.2 ± 0.4	6.1 ± 0.4	6.3 ± 0.4	0.94
	Overall Like	5.4 ± 0.5	6.3 ± 0.4	6.8 ± 0.4	6.5 ± 0.4	0.24
M. rectus femoris	Tenderness	6.7 ± 0.5	7.3 ± 0.3	6.7 ± 0.3	6.9 ± 0.4	0.57
	Juiciness	7.5 ± 0.5	6.6 ± 0.3	6.4 ± 0.3	6.0 ± 0.4	0.11
	Flavor Intensity	7.5 ± 0.5	6.8 ± 0.3	6.9 ± 0.3	6.5 ± 0.4	0.53
	Flavor Desirability	7.1 ± 0.5	6.9 ± 0.4	6.7 ± 0.3	6.7 ± 0.4	0.91
	Overall Like	7.6 ± 0.5	7.1 ± 0.3	6.8 ± 0.3	7.0 ± 0.4	0.52
M. vastus lateralis	Tenderness	5.9 ± 0.5	5.7 ± 0.4	5.7 ± 0.3	4.8 ± 0.4	0.24
	Juiciness	6.7 ± 0.5a	5.9 ± 0.4ab	5.4 ± 0.4b	4.9 ± 0.4b	0.04
	Flavor Intensity	6.8 ± 0.4	6.1 ± 0.4	6.3 ± 0.3	5.4 ± 0.4	0.10
	Flavor Desirability	6.7 ± 0.5	6.1 ± 0.4	6.3 ± 0.4	5.7 ± 0.4	0.46
	Overall Like	6.5 ± 0.5	6.1 ± 0.4	6.4 ± 0.4	5.4 ± 0.4	0.28

Means within the same row lacking common letters (a,b) differ ($P < 0.05$).

AN ALTERNATIVE METHOD OF CARCASS FABRICATION TO OPTIMIZE BEEF VALUE

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Summary

Innovations in beef carcass fabrication to improve subprimal yield and overall carcass value were evaluated. Alternating sides from thirty beef carcasses were assigned to either an innovative or conventional style of fabrication. The innovative method resulted in greater ($P < 0.001$) total subprimal yield and less ($P < 0.001$) lean trimmings from the forequarter; however, hindquarter total subprimal yield and lean trimmings were not affected ($P > 0.05$) by fabrication style. Value was greater for the innovative forequarter ($P < 0.001$) and hindquarter ($P < 0.01$), and total value was increased by more than US $14 per beef carcass compared to the conventional style. Selected subprimals were evaluated in retail cutting tests. In general, the innovative retail subprimals had yields equal to or greater than the conventional subprimals. Innovative carcass fabrication may allow for greater utilization of wholesale cuts to improve carcass value and to offer greater retail merchandizing opportunities.

Introduction

Traditionally, the beef industry has changed little to manipulate the fabrication of beef carcasses into more efficiently used primals and subprimals. In the past, most of the breaking points had been done out of tradition rather than optimization of the muscles. Cuts even as major as the separation of the chuck and round from the rib and loin should be questioned since multiple muscles and muscle groups are bisected. With current retail trends moving towards merchandising single muscles and/or muscle groups, there is a growing need to better utilize beef carcasses.

With this trend in mind, the Beef Value Cuts Program (NCBA, 2001) and the Muscle Profiling and Bovine Myology studies (Jones et al., 2001) began. The goal of these studies was to increase utilization of individual muscles instead of marketing beef in the traditional multi-muscle cuts. Using these concepts, we used an innovative fabrication method to improve yields and value of beef carcasses.

Experimental Procedures

Carcass selection

Beef carcasses (n = 30) were selected from a commercial packing facility and transported to the Texas A&M University for subsequent fabrication. Carcasses were selected by trained evaluators to obtain an equal mix of USDA (1997) Choice and Select, yield grade 2 and 3 carcasses. Comparisons were made by fabricating one side of each carcass in a conventional manner, whereas the opposite side was fabricated by an innovative method.

Conventional style

Carcasses were fabricated into boneless and semi-boneless, closely-trimmed subprimal cuts by Texas A&M personnel. Carcasses were fabricated to produce cuts (Table 1) following the Institutional Meat Purchase Specifications (IMPS) described by NAMP (2003) and USDA (1996). Additionally, special trim items including cap and wedge meat, chuck tender, pectoral muscle and flank muscle were removed intact from each carcass. Finally, lean trimmings (approximately 80% lean determined visually), fat, and bone were obtained from each carcass. Further details of fabrication can be found in Pfeiffer (2004).

Innovative style

Complete innovative fabrication details can be found in Pfeiffer (2004). Innovative techniques differing from conventional methods are explained below.

The innovative fabrication style begins with the forequarter hanging on the rail. Beginning at the twelfth rib and progressing cranially, external muscles were removed, leaving the *M. Serratus ventralis* exposed. The shoulder clod and the *m. Serratus ventralis* were removed. The thoracic limb was hung by the foreshank and a subprimal similar to shoulder clod was removed. Innovative brisket fabrication included removal of the *Mm. Pectoralis profundus*. The deckle and hard fat, along the ventral edge, were trimmed flush with the lean surface.

The rib/chuck separation was made by a saw cut between the fourth and fifth ribs, instead of the conventional fifth/sixth rib separation. The back ribs were removed. All bones and connective tissue were removed in fabrication of the chuck roll. The remaining neck, plate, foreshank, and rib portions were separated into lean trimmings, excess fat, and bone components.

The innovative hindquarter fabrication style begins with the hindquarter hanging on the rail. The *M. Tensor fasciae latae* was removed and trimmed practically free of fat to create the tri-tip. The bottom sirloin flap was removed and trimmed practically free of fat. Starting at the patella, the entire *M. Quadriceps femoris* was removed through the natural seam and trimmed of any bone and fat. The entire *M. Gluteobiceps* was removed, as suggested by Reuter et al. (2002a). The top (inside) round was removed through the natural seam. The tenderloin was fabricated from the full loin. The sirloin/short loin separation was made by a saw cut immediately anterior to the hip bone. In preparation of the strip loin, the body of the vertebrae and all other bones were removed from the shell short loin. The hindshank was separated into lean trimmings, excess fat, and bone components.

Carcass value

Data collected during carcass fabrication were used in determination of value differences that may have occurred between cutting styles. Subprimal and component prices used in the analysis were obtained from the United States Department of Agriculture, Agricultural Marketing Service (USDA, 2001; 2002; 2003). Subprimal and component prices were averaged over the three-year period to minimize any seasonal or annual price biases.

For comparative purposes, the innovative brisket, shoulder clod, chuck roll, ribeye roll, back ribs, blade meat, 2-piece top sirloin butt, round tip, and outside round flat from this study were priced identical to their conventional counterparts. The *M. Serratus ventralis* was priced using the reported prices for blade meat.

Statistical analysis

Subprimal percentages and values were analyzed using the MIXED procedure of SAS (Version 9, SAS Institute, Inc., Cary, NC). Models included cutting style and quality grade as main effects, and carcass number was included as a randomized effect. Least squares means were generated, and when an alpha-level of $P < 0.05$ was found, they were separated using the PDIFF option.

Results and Discussion

Carcass fabrication

Forequarter wholesale cuts and carcass component percentages were analyzed by cutting style and reported in Table 2. The innovative brisket comprised a greater ($P < 0.001$) percentage of the beef forequarter than the conventional brisket. Inclusion of the pectoral meat with the conventional brisket still resulted in a lighter combined subprimal weight than the innovative brisket.

The conventional shoulder clod was higher ($P < 0.001$) yielding than the innovative shoulder clod. This was expected due to the portions of the *M. trapezius* and *M. latissimus dorsi* that remained on the conventional shoulder clod, but were removed from the innovative shoulder clod and were included as a portion of the blade meat.

Reuter et al. (2002b) concluded that a rib/chuck separation between the fourth and fifth rib could result in merchandizing four additional ribeye steaks per carcass without decreasing tenderness or consumer acceptance of these steaks. Based on their conclusions, the innovative rib/chuck separation was made between the fourth and fifth ribs instead of the conventional fifth/sixth rib separation. Consequently, the innovative ribeye represented a greater ($P < 0.001$) percentage of the forequarter, and the innovative chuck roll was a lesser ($P < 0.001$) percentage.

It was a priority to remove the three extrinsic muscles of the forelimb (*M. rhomboideus, M. trapezius,* and *M. latissimus dorsi*) in their entirety. Conventionally, these muscles are portioned throughout several subprimals and are primarily merchandized as lean trimmings. The innovative fabrication style optimized the merchandizing potential of these individual muscles by removing them as whole muscles. Blade meat fabricated from the innovative side was heavier (8.4 vs. 3.6 lb), comprising a greater ($P < 0.001$) forequarter percentage than the conventional blade meat. The chuck tender, inside skirt, and outside skirt were not affected ($P > 0.05$) by fabrication style. The combined forequarter subprimal yield of the innovative fabrication style was greater ($P < 0.001$) than the combined yield of the conventional cuts, and less ($P < 0.001$) lean trimmings were generated by the innovative fabrication style.

Hindquarter wholesale cuts and carcass component percentages were analyzed by cutting style and reported in Table 3. The tenderloin fabricated from the innovative side was heavier ($P < 0.001$) than the conventional tenderloin because it contained the most posterior portion of the *M. iliopsoas*, which is typically excluded from the tenderloin by the conventional round/loin break.

The top sirloin cap (coulotte) was separated at a point immediately anterior to its caudal origin at the lateral tuberosity of the tuber ischiadicum, which is the point of separation recommended by Reuter et al. (2002a). Their study showed that the *M. gluteobiceps* was most tender at the origin (sirloin section) and was tougher 2.8 to 3.9 in posterior to the conventional round/loin break. In addition, the authors explained that the conventional round/loin separation bisected the most tender portion of the *M. gluteobiceps*. In our study, the innovative top sirloin cap (coulotte) was higher ($P < 0.001$) yielding than the conventional cut, which was a direct result of how the *M. gluteobiceps* was fabricated. This cutting style may provide the beef industry with an opportunity to better utilize the proximal portion of the *M. gluteobiceps*.

The innovative bottom sirloin tri-tip was higher ($P < 0.001$) yielding than its conventional counterpart, because this style included removal of the *M. tensor fasciae latae*, including the distal tip of the muscle that is normally excluded by the round/loin separation. The round tip (*M. quadriceps femoris*) of the innovative style comprised a greater ($P < 0.001$) percentage of the hindquarter due to the inclusion of the bottom sirloin ball tip in the innovative round tip.

Due to the separation that created a larger top sirloin cap (coulotte) from the innovative side, the bottom round flat was lower ($P < 0.001$) yielding in comparison to the conventional bottom round flat. The flank steak, strip loin, special trim flank muscle, center-cut top sirloin, top round, lean trim, bone, and fat were not affected ($P > 0.05$) by cutting style.

Carcass value

Forequarter value comparisons were made between cutting styles and reported in Table 4. Value differences parallel weight and yield differences between cutting styles. Due to the weight differential created by fabricating the whole *M. pectoralis profundus*, the innovative brisket was more ($P < 0.001$) valuable than the conventional brisket, whereas the innovative chuck roll generated less ($P < 0.001$) value due to extreme weight differences. The conventional shoulder clod was more ($P < 0.001$) valuable than the innovative shoulder clod, though by excluding the *M. trapezius* and *M. latissimus dorsi,* the innovative shoulder clod should realistically command a higher market price. The innovative ribeye roll was more ($P < 0.001$) valuable, though in a market setting, this cut may not realize the same unit price as the conventional ribeye roll. Overall, total subprimal, saleable yield, and forequarter values were higher ($P < 0.001$) for the innovative style.

Hindquarter value comparisons were made between cutting style and reported in Table 5. The increased weight of the innovative tenderloin, 2-piece top sirloin butt, and bottom sirloin tri-tip resulted in greater ($P < 0.001$) value, as did the innovative bottom sirloin flap ($P < 0.005$). As was found for the forequarter, total subprimal, saleable yield, and hindquarter values were greater ($P < 0.05$) for the innovative style.

Our focus was to optimize beef carcass value through exploring innovative fabrication styles. Although labor requirements were not measured, in this demonstration, innovative fabrication increased subprimal yield and beef carcass value of approximately U.S. $14. In general, innovative subprimals produced similar steak/roast and saleable yields as compared to conventional subprimals.

Implications

As the industry changes with consumer demands, traditional cutting methods will begin to fade away. In their place, new and innovative styles will begin to form as muscles are merchandized individually, creating a more valuable and consistent retail cut for the industry and consumer.

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Table 1. USDA (1996) Institutional Meat Purchase Specifications (IMPS) descriptions subprimals generated in conventional fabrication

IMPS #	Subprimal
112A	Beef Rib, Ribeye, Lip-On[a]
114	Beef Chuck, Shoulder Clod
116	Beef Chuck, Chuck Roll
120	Beef Brisket, Deckle-Off, Boneless
121C	Beef Plate, Outside Skirt (IM)[b]
121D	Beef Plate, Inside Skirt (IM)[b]
124	Beef Rib, Back Ribs
130	Beef Chuck, Short Ribs
167A	Beef Round, Tip (Knuckle), Peeled
168	Beef Round, Top (Inside), Untrimmed
171B	Beef Round, Outside Round (Flat)
171C	Beef Round, Eye of Round (IM)[b]
180A	Beef Loin, Strip Loin, Boneless (1 × 0)[c]
184	Beef Loin, Top Sirloin Butt, Boneless
185A	Beef Loin, Bottom Sirloin Butt, Flap, Boneless (IM)[b]
185B	Beef Loin, Bottom Sirloin Butt, Ball Tip, Boneless
185C	Beef Loin, Bottom Sirloin Butt, Tri-Tip, Boneless (IM)[b]
189A	Beef Loin, Tenderloin, Full, Side Muscle On, Defatted
193	Beef Flank, Flank Steak (IM)[b]

[a] Lip = *M. serratus dorsalis, M. longissimus costarum* and related intermuscular fat lateral to the *M. longissimus thoracis* (USDA, 1996).

[b] IM = Individual muscle.

[c] (1 × 0) = The flank side shall be lateral to, but not more than 2.54 cm from, the *M. longissimus lumborum* at the rib end to a point on the sirloin end immediately lateral to the *M. longissimus lumborum* (USDA, 1996).

Table 2. Least squares means for forequarter subprimal and component percentages stratified by conventional (CONV) and innovative (INNOV) cutting styles

Subprimal	CONV	INNOV	SEM[a]	*P* > F
	------------------	% ------------------		
Brisket	5.77	8.41	0.12	<0.001
Shoulder clod	9.70	8.60	0.08	<0.001
Chuck tender	1.57	1.57	0.02	0.81
Pectoral meat	1.16	-	0.04	-
Chuck roll	8.01	3.02	0.10	<0.001
M. Serratus ventralis	-	4.69	0.09	-
Chuck short rib	1.65	-	0.04	-
Inside skirt	1.22	1.25	0.03	0.29
Outside skirt	0.68	0.68	0.02	1.00
Ribeye roll	5.53	6.19	0.08	<0.001
Back ribs	1.75	1.96	0.03	<0.001
Blade meat	1.85	4.19	0.09	<0.001
Subprimal total	38.86	40.55	0.29	<0.001
Lean trimmings (85% lean)	27.23	26.12	0.35	<0.001
Fat	15.75	15.39	0.47	0.27
Bone	18.16	17.94	0.23	0.27

[a]SEM is the standard error of the least-squares mean.

Table 3. Least squares means for hindquarter subprimal and component percentages stratified by conventional (CONV) and innovative (INNOV) cutting styles

Subprimal	CONV	INNOV	SEM[a]	$P > F$
	----------------	% ----------------		
Flank Steak	1.08	1.06	0.02	0.34
Tenderloin	3.30	3.46	0.04	<0.001
Bottom sirloin flap	1.94	2.06	0.04	0.01
Strip loin	6.19	6.10	0.09	0.34
Flank muscle	1.24	1.17	0.05	0.15
Center-cut top sirloin	4.73	4.64	0.08	0.30
Top sirloin cap	0.96	1.43	0.03	<0.001
Bottom sirloin ball tip	1.15	-	0.07	-
Bottom sirloin tri-tip	2.28	2.63	0.05	<0.001
Round tip	5.67	6.68	0.09	<0.001
Top round	11.75	11.83	0.12	0.46
Eye of round	3.31	3.24	0.05	<0.01
Bottom round flat	7.70	6.94	0.09	<0.001
Subprimal total	50.32	50.10	0.34	0.38
Lean trimmings (85% lean)	10.72	10.76	0.17	0.86
Fat	24.27	24.53	0.43	0.42
Bone	14.68	14.62	0.19	0.73

[a]SEM is the standard error of the least-squares mean.

Table 4. Least squares means for forequarter subprimal and component values (U.S. $) stratified by conventional (CONV) and innovative (INNOV) cutting styles

Subprimal	CONV	INNOV	SEM[a]	$P > F$
	----------------	U.S. $ ----------------		
Brisket	10.97	15.97	0.25	<0.001
Shoulder clod	24.48	21.70	0.34	<0.001
Chuck tender	4.23	4.24	0.07	0.71
Pectoral meat	3.74	-	0.13	-
Chuck roll	22.13	8.34	0.37	<0.001
M. Serratus ventralis	-	14.36	0.33	-
Chuck short rib	5.45	-	0.15	-
Inside skirt	5.28	5.39	0.14	0.25
Outside skirt	2.93	2.93	0.09	0.99
Ribeye roll	46.64	52.27	0.71	<0.001
Back ribs	4.32	4.85	0.08	<0.001
Blade meat	5.55	12.88	0.34	<0.001
Lean trimmings (85% lean)	57.14	54.84	1.03	<0.001
Fat	3.46	3.38	0.10	0.28
Bone	1.82	1.80	0.03	0.37
Subprimal total value	135.72	142.94	1.68	<0.001
Forequarter total value	198.13	202.96	2.38	<0.001

[a]SEM is the standard error of the least-squares mean.

Table 5. Least-squares means for hindquarter subprimal and component values (U.S. $) stratified by conventional (CONV) and innovative (INNOV) cutting styles

Subprimal	CONV	INNOV	SEM	*P* > F
	----------------	U.S. $	----------------	
Flank Steak	6.02	5.88	0.16	0.37
Tenderloin	42.77	44.93	0.66	<0.001
Bottom sirloin flap	8.20	8.70	0.21	0.005
Strip loin	43.80	43.27	0.71	0.39
Flank muscle	3.34	3.15	0.13	0.15
2-piece top sirloin butt	29.83	31.82	0.55	<0.001
Bottom sirloin ball tip	3.44	-	0.23	-
Bottom sirloin tri-tip	4.73	5.46	0.11	<0.001
Round tip	14.91	17.61	0.30	<0.001
Top round	30.02	30.31	0.44	0.28
Eye of round	9.66	9.48	0.17	0.002
Bottom round flat	18.27	16.50	0.27	<0.001
Lean trimmings (85% lean)	19.79	19.91	0.41	0.71
Fat	4.69	4.74	0.08	0.46
Bone	1.29	1.29	0.02	0.84
Subprimal total value	214.98	217.12	2.54	0.04
Hindquarter total value	240.75	243.07	2.79	0.01

[a]SEM is the standard error of the least-squares mean.

RETAIL CUTTING PHASE OF INNOVATIVE WHOLESALE CARCASS FABRICATION TO OPTIMIZE BEEF VALUE

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Summary

Innovations in beef carcass fabrication to improve retail cut yield and overall carcass value were evaluated. Alternating sides from thirty beef carcasses were assigned to either an innovative or conventional style of fabrication. In this phase of the project, selected subprimals from fabrication were evaluated in retail cutting tests. In general, the innovative retail subprimals had yields equal to or greater than the conventional subprimals. Innovative carcass fabrication may allow for greater utilization of wholesale cuts to improve carcass value and to offer greater retail merchandizing opportunities.

Introduction

Numerous attempts have been made to increase the value of the beef chuck and round, and therefore increase the value of the entire beef carcass through programs such as the Beef Value Cuts Program (NCBA, 2001) and the Muscle Profiling and Bovine Myology studies (Jones et al., 2001). Single muscle cut merchandising has allowed the industry to provide a higher quality, more consistent product for consumers (NCBA, 2001). With current retail trends to merchandize individual muscle cuts, it may be more advantageous to remove intact muscles and/or muscle groups from the carcass rather than producing wholesale cuts based on tradition. This study was conducted to examine alternative methods of beef carcass fabrication. This phase of the project was designed to determine if retail cut merchandizing will be influenced by alternative carcass fabrication.

Experimental Procedures

Retail cutting

All subprimals generated in the carcass fabrication phase (Pfeiffer, 2004) that were decidedly different between cutting styles were immediately vacuum packaged, heat shrunk, boxed, and held in refrigerated storage (2° C) for retail cutting analysis. Subprimals from the conventional method were cut following the Institutional Meat Purchase Specifications (IMPS) described by NAMP (2003) and USDA (1996). Cutting test details are explained in Voges (2004). Retail cuts were identified by Universal Product Code (UPC) numbers (Industry-Wide Cooperative Meat Identification Standards Committee, 2003).

Cutting tests

The conventional brisket and the innovative brisket were separated into its two muscles, *M. Pectoralis profundus* and *M. Pectoralis superficiales,* through the natural seam. The *M. Pectoralis profundus* from the innovative brisket was separated into two equal size pieces. The posterior end (approximately 2.75 in length) of the *M. Pectoralis profundus* was deemed too thin (approximately ≤ .60 in thick) and was removed and merchandized as lean trimmings. All pieces were trimmed practically free of fat on both surfaces.

The conventional chuck roll was portioned by cutting two or three .75 in-thick under blade steaks from the rib end before cutting under blade pot roasts, approximately 2 in-thick, from the remainder of the chuck roll. Where possible, beef for stew was prepared by dicing meat into approximately 1.2 in cubes. The innovative chuck roll (similar to the IMPS #116D Chuck Eye Roll) was portioned by cutting beef chuck eye steaks approximately 1.0 in thick, from the rib end until deemed no longer appropriate. The remainder of the subprimal was separated into two equal portion chuck eye roasts.

Both the conventional ribeye roll and the innovative (similar to the IMPS #112A with the fifth rib section included) ribeye roll were merchandized as 1.0 in-thick boneless ribeye steaks. Steaks were trimmed of excess fat and the lip was reduced to 1.0 in.

The conventional and innovative bottom round flat were merchandized in the same manner. Both subprimals were initially fabricated by removing the ishiatic head of the *M. Gluteobiceps* and preparing a bottom round roast. The remainder of the *M. Gluteobiceps* was portioned into .75 in-thick bottom round steaks by cutting perpendicular to the muscle fiber orientation; beef for stew was prepared when appropriate. The conventional and innovative top sirloin cap were portioned into 1.0 in-thick top sirloin cap steaks by cutting perpendicular to the muscle fiber orientation.

The conventional round tip was separated into the *M. Rectus femoris* and *M. Vastus lateralis*. All visible connective tissue was removed before cutting 1.0 in-thick steaks from the *M. Rectus femoris*, sirloin tip center steaks, and *M. Vastus lateralis*, sirloin tip side steaks. The *M. Vastus intermedius, M. Vastus medialis*, and tips from the *M. Rectus femoris* and *M. Vastus lateralis*, where appropriate, were used to create beef for stew and/or beef round for kabobs. The conventional bottom sirloin butt, ball tip was sliced parallel to the cut face into 1.0 in-thick ball tip steaks and sirloin cubes for kabobs. The innovative *M. Quadriceps femoris* was separated into the *M. Rectus femoris* and *M. Vastus lateralis*. All visible connective tissue was removed before cutting 1.0 in-thick sirloin tip center steaks from the *M. Rectus femoris*, and 1.0 in-thick sirloin tip side steaks from the *M. Vastus lateralis*. The *M. Vastus intermedius*, *M. Vastus medialis*, and tips from the *M. Rectus femoris* and *M. Vastus lateralis*, where appropriate, were used to create beef for stew and/or beef round for kabobs.

The *M. Serratus ventralis* from the innovative style were separated into a thicker (anterior) and thinner (posterior) portion before trimming or cutting. The thinner portion was trimmed of all heavy connective tissue and portioned into four rectangular-shaped steaks, parallel to the muscle fiber orientation. The thicker portion was trimmed of all heavy connective tissue and cut into 1.0 in-thick strips, perpendicular to the muscle fiber orientation. The strips then were sectioned into 2 or 3 pieces, creating steaks that were 1.0 in-thick and approximately 4.75 inches in length, similar to chuck short ribs.

Statistical analysis
Subprimal and retail cut weights, percentages, and values were analyzed using the MIXED procedure of SAS (Version 9, SAS Institute, Inc., Cary, NC). Models included cutting style and quality grade as main effects, and carcass number was included as a randomized effect. Least squares means were generated, and when an alpha-level of $P < 0.05$ was found, they were separated using the PDIFF option.

Results and Discussion

Beef subprimals (Table 1) were evaluated for mean retail yields and processing times, and comparisons were made between cutting styles and USDA quality grade. There were no ($P > 0.05$) differences between quality grades, and data were pooled across quality grades. Retail portioning of the innovative brisket (Table 2) produced an additional retail cut in comparison to the conventional brisket. This is important because much of the *M. Pectoralis profundus* not included in the conventional brisket would normally be included in lean trimmings.

Saleable yield was greater ($P < 0.001$) for the innovative chuck roll compared to the conventional (Table 3). In addition, the saleable yield of the innovative subprimal included less ($P < 0.01$) lean trimmings, no beef for stew, and required less ($P < 0.001$) total fabrication time than the conventional style. Based on these features, the innovative chuck roll may be more easily merchandized by retailers.

Comparison of the top sirloin cap (not presented in tabular form) showed a higher saleable yield percentage ($P < 0.001$) for the innovative style, though steak and lean trimmings yields were not affected ($P > 0.05$). Fabrication style of the bottom round flat did not affect ($P > 0.05$) steak or lean trimmings yields. McKenna et al. (2003) reported 48.68% bottom round steak yield for USDA Select subprimals compared to our findings of 50.10% (conventional) and 51.68% (innovative) for USDA Select and Choice subprimals.

Fabrication of the *M. Quadriceps femoris* (Table 4) produced a greater ($P < 0.05$) total steak yield and a greater total saleable yield from the innovative style. The 48.48% steak yield is also greater than that reported by McKenna et al. (2003) (39.95-46.1%) for the IMPS #167A Beef Round, Tip (Knuckle), Peeled. Due to the reduction in cut surface area, the innovative cut produced less ($P < 0.001$) purge. It is also important to note that the innovative side produced only single muscle steaks *(M. Vastus Lateralis* and *M. Rectus femoris*), whereas a portion of the conventional steak yield was composed of more variable, multiple muscle, ball tip steaks (UPC #1308).

The innovative ribeye roll was heavier ($P < 0.001$) than its counterpart due to the extra rib section that was present (not shown in tabular form). Thus, the steak number also was greater ($P <$

0.001), yielding two more steaks per subprimal, which is consistent with the findings of Reuter et al. (2002).

Fabrication of the *M. Serratus ventralis* (Table 5) from the innovative style yielded flanken style steaks similar to the IMPS #123D Beef Short Ribs, Boneless and serratus steaks that were similar in appearance to the flat iron steak cut from the *M. Infraspinatus* (NCBA, 2001). The innovative fabrication style allows for greater utilization of the *M. Serratus ventralis*.

Implications

These cutting test data will be used to allow the beef industry to evaluate new fabrication styles and the effect on retail cutting yields and times. These data also will allow retailers to make merchandising and purchasing decisions for their operations.

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Table 1. USDA (1996) Institutional Meat Purchase Specifications (IMPS) descriptions of conventional subprimals used for retail cutting tests

IMPS #	Subprimal
112A	Beef Rib, Ribeye, Lip-On[a]
116A	Beef Chuck, Chuck Roll
120	Beef Brisket, Deckle-Off, Boneless
167A	Beef Round, Tip (Knuckle), Peeled
171B	Beef Round, Outside Round (Flat)

[a] Lip = *M. serratus dorsalis, M. longissimus costarum* and related intermuscular fat lateral to the *M. longissimus thoracis* (USDA, 1996).
[b] (1 × 1) = Lip does not exceed 1.0 in
[c] IM = Individual muscle.
[d] (1 × 0) = The flank side shall be lateral to, but not more than 1.0 in from, the *M. longissimus lumborum* at the rib end to a point on the sirloin end immediately lateral to the *M. longissimus lumborum* (USDA, 1996).
[e] Pc = Piece.

Table 2. Least-squares means of retail yields (%) and processing times (s) for fabrication of briskets stratified by conventional (CONV) and innovative (INNOV) cutting styles

Item	UPC[a]	CONV	INNOV	SEM[b]	*P* > F
Net weight, lb		11.13	16.91	0.15	<0.001
Retail yield		————	% ————		
Flat front[c]	1623	38.01	20.08	1.22	<0.001
Flat back[d]	1623	-	22.47	0.64	-
Point[e]	1628	21.99	16.53	0.83	<0.001
lean trimmings (90% lean)	1653	14.80	16.39	1.61	0.28
Fat		24.50	23.50	1.40	0.37
Purge		0.69	0.93	0.19	0.14
Cutting loss		0.01	0.11	0.06	0.23
Total saleable yield		74.80	75.46	1.43	0.53
Processing time, per subprimal		————	s ————		
Bag opening time		8.7	13.6	1.2	0.01
Trimming/cutting time		336.1	456.8	28.1	0.01
Total time		344.8	470.4	28.4	0.01

[a]UPC = Universal product code.
[b]SEM is the standard error of the least-squares means.
[c]Anterior portion of the *M. Pectoralis profundus.*
[d]Posterior portion of the *M. Pectoralis profundus.*
[e]Includes only the *Mm. Pectorales superficiales.*

Table 3. Least-squares means of retail yields (%) and processing times (s) for fabrication of chuck rolls stratified by conventional (CONV) and innovative (INNOV) cutting styles

Item	UPC[a]	CONV	INNOV	SEM[b]	*P* > F
Net weight, lb		16.18	6.13	0.23	<0.001
Steak number		2.67	2.17	0.16	<0.05
Roast number		6.00	2.00	0.13	<0.001
Retail yield			%		
Chuck steak		15.65	17.10	1.13	0.31
Chuck roast		72.90	77.39	0.91	0.003
Beef for stew	1727	3.51	-	0.45	-
Lean trimmings (90% lean)	1653	4.69	2.08	0.62	0.01
Fat		2.24	2.39	0.53	0.71
Purge		0.95	0.89	0.22	0.78
Cutting loss		0.07	0.15	0.04	<0.21
Total saleable yield		96.74	96.57	0.61	<0.67
Processing time, per subprimal			s		
Bag opening time		9.5	8.1	0.9	0.08
Trimming/cutting time		206.9	89.8	10.9	<0.001
Total time		216.4	97.9	11.2	<0.001

[a]UPC = Universal product code.
[b]SEM is the standard error of the least-squares means.

Table 4. Least-squares means of retail yields (%) and processing times (s) for fabrication of the quadriceps stratified by conventional (CONV) and innovative (INNOV) cutting styles

Item	UPC[a]	CONV	INNOV	SEM[b]	*P* > F
Net weight, lb		12.06	11.95	0.15	0.28
Side steak number		4.33	5.67	0.17	<0.001
Center steak number		3.83	6.17	0.25	<0.001
Ball tip steak number		3.50	-	0.14	-
Retail yield			%		
Tip side steak	1543	18.39	24.80	0.71	<0.001
Tip center steak	1550	14.41	23.68	0.83	<0.001
Ball tip steak	1308	13.53	-	0.99	-
Total steak		46.33	48.48	0.81	<0.05
Beef for stew	1727	8.69	10.82	0.83	0.03
Beef Round for kabobs	1576	11.40	8.30	0.95	0.005
Lean trimmings (90% lean)	1653	27.98	27.80	0.84	0.84
Fat		2.89	2.78	0.51	0.80
Purge		2.72	1.73	0.32	0.02
Cutting loss		0.53	0.08	0.11	0.006
Total saleable yield		94.40	95.40	0.67	0.09
Processing time, per subprimal			s		
Bag opening time		14.7	7.8	0.9	<0.001
Trimming/cutting time		428.3	499.5	31.5	0.06
Total time		443.0	507.3	31.8	0.08

[a]UPC = Universal product code.
[b]SEM is the standard error of the least-squares means.

Table 5. Least-squares means of retail yields (%) and processing times (s) for fabrication of the *M. Serratus ventralis* stratified by USDA quality grade

Item	UPC[a]	Choice	Select	SEM[b]	*P* > F
Net weight, lb		9.63	9.33	0.13	0.48
Flanken steak[c] number		14.50	13.17	0.61	0.15
Serratus steak[d] number		4.00	4.00	0.00	1.00
Retail yield		----------- %	-----------		
Flanken steak[c]		42.22	45.39	1.83	0.25
Serratus steak[d]		15.20	15.90	1.15	0.68
Lean trimmings (90% lean)	1653	36.53	34.30	2.09	0.47
Fat		3.19	2.08	0.49	0.14
Purge		2.55	2.05	0.72	0.63
Cutting loss		0.31	0.28	0.11	0.87
Total saleable yield		93.96	95.59	0.98	0.27
Processing time, per subprimal		----------- s	-----------		
Bag opening time		10.4	9.3	1.2	0.54
Trimming/cutting time		407.0	402.6	21.0	0.89
Total time		417.4	412.0	21.8	0.86

[a]UPC = Universal product code.
[b]SEM is the standard error of the least-squares means.
[c]Anterior (thick) portion of the *M. Serratus ventralis.*
[d]Posterior (thin) portion of the *M. Serratus ventralis.*

RETAIL CUTTING CHARACTERISTICS FOR CHUCK AND ROUND SUBPRIMALS FROM TWO GRADE GROUPS

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Summary

USDA Choice (Ch) and Select (Se) beef chuck and round subprimals were obtained to conduct retail cutting tests. The subprimals selected included the shoulder clod, trimmed (IMPS #114C); shoulder clod, top blade, roast (IMPS #114D); chuck roll (IMPS #116A); top (inside) round (IMPS #168); outside round (flat) (IMPS #171B); and eye of round (IMPS #171C). Subprimals were merchandised into bone-in or boneless retail cuts and associated components by experienced retail meat merchandisers. Only saleable yields of the inside and outside round were affected by USDA quality grade, where Se rounds had higher yields ($P < 0.05$) than Ch rounds, due mainly to an increase of excess fat trim from Ch rounds. Although Se subprimals had less trimmable fat, an increase was found in purge loss. A challenge that retailers face when merchandising chuck and round subprimals is the variety of retail cuts that are often generated, which can cause processing times to be long and add labor requirements. Ultimately, this could lead to an increase in retail prices or limited merchandising options.

Introduction

Merchandising chuck and round subprimals can often be challenging and require reduced prices. This creates a problem because these subprimals represent about 38% of the weight of an average beef carcass (Griffin et al., 1992). Through efforts to optimize value from these areas it has been found that merchandising single-muscle cuts allows the industry to provide a more consistent, higher quality product to consumers (NCBA, 2001). With the shift of consumers toward smaller, single-muscle cuts, McKenna et al. (2003) found that percentage retail yields decreased and processing times increased with this type of cutting style. In addition, Beef Value Cuts have been shown to have desirable characteristics in terms of palatability and visual appeal, but there is a lack of standardized information regarding cut out yields and labor requirements of subprimals fabricated to this endpoint (McKenna et al., 2003).

In order for retailers to evaluate the price/value relationship of beef subprimals, the CARDS (Computer Assisted Retail Decision Support) software was developed (Garrett et al., 1991). This program serves as a valuable reference to assist retailers in the process of making decisions regarding meat purchasing and merchandising. This project was designed to evaluate cuts not previously included for the program and to pinpoint deficiencies and/or inconsistencies in the data to update the Beef CARDS database with these cuts. Emphasis was put on providing processing yields and time allocations in the expanded database. This should allow for improvement and expansion of the existing Beef CARDS program for the benefit of the retail and foodservice industry. Because of the extensive number of cutting tests conducted and the need to narrow the scope to be reported, the information presented herein encompasses the chuck and round cuts.

Experimental Procedures

Product Selection

Beef subprimals (n = 116) from the chuck and round (Table 1), representing USDA Choice and Select grades, were obtained from a major beef processor and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. Specifications for all subprimals complied (within packer variations) with Institutional Meat Purchase Specifications (IMPS) as described by USDA (1996) and NAMP (2003).

Cutting tests

Controlled retail cutting tests were conducted as described in Voges (2004). A refrigerated cutting room in the Rosenthal Meat Science and Technology Center was modified to simulate a retail market environment, and experienced meat merchandisers were enlisted to perform cutting yield tests. Universal Product Code (UPC) descriptions (Industry-Wide Cooperative Meat Identification Standards Committee, 2003) were used as the naming convention for retail cuts.

Trimmed shoulder clods were cut initially by removing accessory muscles from the *Mm. triceps brachii* and converting them into Beef for Stew. The *M. triceps brachii caput longum* then was cut into 1-in Shoulder Center Steaks and the *M. triceps brachii caput laterale* was cut into 1-in Shoulder Top Steaks. Top blade roasts were trimmed of all fat and connective tissue. The *M. infraspinatus* was filleted horizontally into two separate flat pieces with the heavy connective tissue removed before portioning into Shoulder Top Blade Steaks.

Chuck rolls were cut initially by removing the *M. trapezius* and *M. latissimus dorsi*. The *M. serratus ventralis* was removed and designated as a Chuck Eye Edge Pot Roast. The remaining pieces of the *M. serratus ventralis* were cut into boneless short ribs. Chuck steaks then were cut from the posterior end of the remaining chuck roll section until seam fat was no longer present between the *M. longissimus thoracis* and the *M. rhomboideus thoracis*. Chuck Eye Steaks, were separated from the Underblade Steaks, Boneless and the Chuck Eye Roasts then were cut into 2-in portions from the remainder of the chuck roll. The remaining anterior end of the chuck roll was separated into Beef for Stew or Lean Trimmings.

For the Top (Inside) Rounds, Untrimmed, the *M. gracilis*, *M. pectineus,* and *M. sartorius* were removed and portioned into pieces for Beef Round for Cubed Steak. The Top Round Steak, 1st Cut was cut 1.5-in thick from the proximal edge of the *M. semimembranosus* and *M. adductor*. Subsequent Top Round Steaks were cut 0.5-in thick until the remaining distal portion was deemed not suitable for steaks. This portion, after trimming, was merchandised as a Top Round Roast, Cap Off.

Outside rounds (flat) were cut two ways. The initial cutting style consisted of removing the ishiatic head of the *M. gluteobiceps*, trimming all heavy connective tissue, and preparing it as a Bottom Round Roast. The remainder of the *M. gluteobiceps* was portioned into 1.5-in Bottom Round Steaks by cutting perpendicular to the muscle fiber orientation with remaining product merchandised as material for Beef Round for Cubed Steak. The second style consisted of removal of the ishiatic head and the distal portion of the *M. gluteobiceps* producing two Bottom Round Roasts. Two or three subsequent 1.5-in Bottom Round Steaks were cut, and the remaining proximal portion of the *M. gluteobiceps* was designated as a Bottom Round Rump Roast.

Eye of rounds (IM) were cut three ways. Initially, all styles were trimmed practically free of fat and connective tissue. The first style consisted of cutting the *M. semitendinosus* in half with one portion cut into 0.5-in to 0.75-in Eye of Round Steaks and the other left intact as an Eye of Round Roast. In the second style, the subprimal was cut in half to make two Eye of Round Roasts. The third style merchandised the entire muscle as an Eye of Round Roast.

Statistical analysis

The experiment was planned as a completely randomized design. Data were analyzed, by subprimal, using SAS (SAS Institute, Inc., Cary, NC) PROC GLM with quality grade tested as the main effect. Least squares means were generated, and when an alpha-level of $P < 0.05$ was found, least squares means were separated with the PDIFF option.

Results and Discussion

Retail yields and processing times for the chuck and round subprimal cut are reported in Tables 2-9. These cutting tests will be useful to beef merchandisers in making informed purchase and cutting decisions to optimize value of closely-trimmed beef subprimals. Having standardized cutting tests and associated time requirements allows the beef industry to have benchmark information not previously available.

U.S. Select shoulder clods had a higher percentage of shoulder top steaks ($P < 0.01$) and boneless shoulder pot roasts ($P < 0.03$), thus allowing them to produce a higher percentage (3.5%) of total saleable yield similar to the findings of Garrett et al. (1991) and McKenna et al. (2003). The U.S. Choice shoulder clods possessed more trimmable fat, and required a longer amount of time to process (Table 2). Retail yields for shoulder clods were higher (85-88%) than those found by McKenna et al. (2003) (73-78%), but lower than the retail yield reported by Garrett et al. (1991) using a traditional fabrication style.

Contrary to the shoulder clod, U.S. Select top blade roasts yielded a greater percentage of fat, while U.S. Choice top blade roasts produced a greater amount of purge (Table 3). No difference

($P > 0.05$) was found in saleable yield between U.S. Choice and U.S. Select supporting McKenna et al. (2003) findings. McKenna et al. (2003) also reported slightly higher saleable yields, mainly due to the increase of fat in the present study.

U.S. Choice chuck rolls tended to possess a greater percentage of underblade steaks and fat. U.S. Select chuck rolls had higher yield percentages for lean trimmings and beef for stew when compared to U.S. Choice chuck rolls (not in tabular form).

U.S. Choice inside rounds had a higher percentage of fat ($P < 0.001$), thus resulting in a greater amount of cutting ($P < 0.03$) and total time ($P < 0.04$) required when compared to U.S. Select inside rounds. U.S. Select inside rounds displayed a significantly higher percentage of roasts and purge when compared with U.S. Choice rounds (Table 4).

Retail yield cutting percentages and times for the initial cutting style of outside rounds consisting of steaks, bottom round roasts, and cubed steaks are reported in Table 5. U.S. Select outside rounds displayed a higher percentage of steaks ($P < 0.02$) and U.S. Choice outside rounds had a three-percentage points decrease ($P < 0.05$) in saleable yield than U.S. Select outside rounds, with most of the difference accounted for by more ($P < 0.05$) trimmable fat when compared to U.S. Choice rounds. Additionally, purge and cutting loss was significantly greater for U.S. Select rounds preventing an even larger difference in saleable yield when compared to U.S. Choice rounds. The second outside round cutting style including steaks, rump roasts, and bottom round roasts, displayed significant differences between U.S. Choice and U.S. Select (Table 6), with U.S. Select outside rounds yielding a higher percentage of bottom round roasts ($P < 0.001$) and having greater amount of purge loss when compared with U.S. Choice rounds. The U.S. Choice outside rounds had a significantly higher percentage of lean trim and trimmable fat, and required a greater amount of time for cutting ($P < 0.03$) and total time ($P < 0.04$). The total saleable yield is very similar to the data found by Garrett et al. (1991) (92%) and by McKenna et al. (2003) (91%). The second cutting style had a saleable yield of 89-92%, which is greater than the initial cutting style's saleable yields of 87-90%. This is most likely due to the greater amount of fat trim in the initial style. Less lean trim between styles primarily caused the second cutting style to produce a greater percentage (78-86%) of roasts and steaks when compared to the initial cutting style (65-73%).

U.S. Select eye of rounds, cut to include steaks and a roast, had a significantly larger percentage of purge loss when compared to U.S. Choice eye of rounds that displayed a significantly larger cutting loss percentage (Table 7). U.S. Choice eye of rounds cut to include two roasts appeared to yield a higher percentage of roasts when compared to fatter U.S. Select eye of rounds (Table 8). Retail yields and processing times for eye of rounds left as intact roasts are presented in Table 9. U.S. Choice eye of rounds tended to have a greater percentage of roast weight thus resulting in a higher percentage of total saleable product when compared to fatter U.S. Select eye of rounds. U.S. Select eye of rounds had a higher percentage of trimmable fat. The initial cutting style of steaks and roasts produced a greater percentage of lean trim and required a longer processing time when compared with the cutting styles containing only roasts. McNeill et al. (1998) and Weatherly et al. (2001) found similar results, observing an increase in total processing time as the number of retail cuts from subprimals increased.

Implications

In addition to providing these cutting tests for comparative purposes, there are several key points to be made based on our findings. Only total saleable yields of the inside round and outside round were affected by USDA quality grade, where U.S. Select rounds had higher ($P < 0.05$) yields than U.S. Choice rounds. This difference was driven by a higher percentage of fat trimmed from the U.S. Choice rounds compared to the U.S. Select rounds. It was also found that several U.S. Select subprimals had less fat than the same U.S. Choice cuts and greater purge losses. Specifically, greater ($P < 0.05$) purge losses were found for the U.S. Select inside round, outside round, and eye of round compared to U.S. Choice round subprimals. Voges (2004) found little or no effect for USDA quality grade on total saleable yield from the rib and loin subprimals.

Finally, a challenge that retailers face when merchandising cuts from the round and chuck is the variety of retail cuts that are often generated, which can cause processing times to be quite long and add to the labor requirements. These cutting test data will be used to update the Beef CARDS software program. By incorporating new information into this dynamic decision-making program, users will be able to evaluate pricing and labor costs to determine how purchase and merchandising factors affect profitability.

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Table 1. USDA (1996) Institutional Meat Purchase Specifications (IMPS) descriptions of chuck and round subprimals used for retail cutting tests

IMPS #	Subprimal
114C	Beef Chuck, Shoulder Clod, Trimmed
114D	Beef Chuck, Shoulder Clod, Top Blade, Roast
116A	Beef Chuck, Chuck Roll
168	Beef Round, Top (Inside)
171B	Beef Round, Outside Round (Flat)
171C	Beef Round, Eye of Round (IM[a])

[a] IM = Individual muscle.

Table 2. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Chuck, Shoulder Clod, Trimmed (IMPS #114C), from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 9)	U.S. Select (n = 9)	SEM[b]	*P*-value
Net weight, lb		13.05	12.35	0.71	0.53
Retail yield		------------------- %	-------------------		
Shoulder center steak	1162	19.80	16.82	1.12	0.11
Shoulder top steak	1163	8.87	14.53	1.12	0.01
Shoulder pot roast, boneless	1132	5.52	10.69	1.4	0.03
Beef for stew	1727	23.60	23.54	0.67	0.95
Lean trimmings (90% lean)	1653	27.91	30.37	1.31	0.22
Fat		13.76	11.93	1.35	0.37
Purge		0.89	0.76	0.21	0.68
Cutting loss		0.10	0.00	0.11	0.30
Total saleable yield		85.32	88.82	1.69	0.19
Processing time, per subprimal		------------------- s	-------------------		
Bag opening time		8.9	7.8	0.8	0.36
Trimming/cutting time		514.7	500.2	37.1	0.79
Total time		523.6	508.0	37.2	0.78

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 3. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Chuck, Shoulder Clod, Top Blade, Roast (IMPS #114D), from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 9)	U.S. Select (n = 9)	SEM[b]	*P* - value
Net weight, lb		4.96	4.67	0.33	0.57
Retail yield		------------------- %	-------------------		
Shoulder top blade steak (flat iron)	1166	50.55	48.86	1.58	0.46
Lean trimmings (90% lean)	1653	31.43	32.01	1.67	0.81
Fat		17.35	18.81	1.25	0.42
Purge		0.71	0.40	0.20	0.29
Cutting loss		0.00	0.00	0.07	0.60
Total saleable yield		81.98	80.87	1.21	0.53
Processing time, per subprimal		------------------- s	-------------------		
Bag opening time		7.0	7.1	0.6	0.83
Trimming/cutting time		280.3	262.7	25.5	0.63
Total time		287.3	269.8	25.5	0.63

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 4. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Top (Inside) (IMPS #168), from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 9)	U.S. Select (n = 9)	SEM[b]	*P* - value
Net weight, lb		24.26	20.07	1.06	0.01
Retail yield		----------	% ----------		
Top round roast, cap off	1454	23.79	28.92	1.32	0.02
Top round steak	1553	21.11	20.81	0.99	0.83
Top round steak, 1st cut (London Broil)	1556	7.09	8.29	1.38	0.55
Cap		6.38	7.44	0.40	0.08
Beef round for cubed steak	1577	5.05	6.73	0.66	0.09
Lean trimmings (90% lean)	1653	16.71	15.15	0.90	0.24
Fat		18.93	10.94	1.09	<0.001
Purge		0.90	1.75	0.22	0.02
Cutting loss		0.04	0.00	0.04	0.24
Total saleable yield		80.13	87.34	1.13	0.004
Processing time, per subprimal		----------	s ----------		
Bag opening time		11.4	15.7	1.4	0.04
Trimming/cutting time		606.0	509.5	28.7	0.03
Total time		617.3	525.2	28.8	0.04

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 5. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Outside Round (IMPS #171B) cut to include roasts, steaks, and cubed steak from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 6)	U.S. Select (n = 6)	SEM[b]	*P*- value
Net weight, lb		12.35	14.20	0.44	0.02
Retail yield		----------	% ----------		
Bottom round steak	1466	47.05	49.88	0.72	0.02
Bottom round roast	1464	12.33	13.33	0.55	0.22
Beef round for cubed steak	1577	5.89	9.87	1.81	0.14
Lean trimmings (90% lean)	1653	22.34	17.20	2.13	0.11
Fat		10.82	6.03	0.73	0.001
Purge		1.44	3.38	0.51	0.02
Cutting loss		0.13	0.31	0.04	0.01
Total saleable yield		87.61	90.28	0.84	0.05
Processing time, per subprimal		----------	s ----------		
Bag opening time		14.3	12.8	1.0	0.30
Trimming/cutting time		405.8	306.1	33.4	0.06
Total time		420.1	318.9	33.9	0.06

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 6. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Outside Round (IMPS #171B) cut to include steaks and roasts from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 6)	U.S. Select (n = 6)	SEM[b]	*P* - value
Net weight, lb		12.92	13.83	0.82	0.44
Retail yield		----------	% ----------		
Bottom round steak	1466	6.88	7.59	1.41	0.72
Bottom round rump roast	1519	30.83	31.58	0.78	0.50
Bottom round roast	1464	40.48	46.83	0.95	<0.001
Lean trimmings (90% lean)	1653	11.31	6.09	1.15	0.01
Fat		8.73	4.33	1.08	0.02
Purge		1.54	3.57	0.53	0.02
Cutting loss		0.25	0.007	0.09	0.09
Total saleable yield		89.49	92.09	1.22	0.16
Processing time, per subprimal		----------	s ----------		
Bag opening time		10.9	12.8	15.0	1.87
Trimming/cutting time		337.3	240.4	27.3	0.03
Total time		348.3	255.4	27.7	0.04

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 7. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Eye of Round cut to include steaks and a roast from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 6)	U.S. Select (n = 6)	SEM[b]	*P* - value
Net weight, lb		5.73	6.59	.082	0.14
Retail yield		----------	% ----------		
Eye of round steak	1481	38.84	37.27	1.78	0.55
Eye of round roast	1480	52.65	52.62	2.26	0.99
Lean trimmings (90% lean)	1653	3.56	3.80	0.63	0.80
Fat		3.63	4.49	1.02	0.57
Purge		0.87	1.72	0.17	0.006
Cutting loss		0.44	0.10	0.06	0.002
Total saleable yield		95.06	93.69	1.07	0.39
Processing time, per subprimal		----------	s ----------		
Bag Opening time		9.16	7.74	0.89	0.29
Trimming/cutting time		100.41	90.81	10.77	0.54
Total time		109.57	98.55	11.25	0.51

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 8. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Eye of Round cut into two roasts from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 6)	U.S. Select (n = 6)	SEM[b]	*P* - value
Net weight, lb		5.18	5.45	0.22	0.38
Retail yield		-------------------	% -------------------		
Eye of round roast	1480	93.50	92.61	0.87	0.49
Lean trimmings (90% lean)	1653	1.41	2.76	0.58	0.20
Fat		3.84	4.48	0.85	0.61
Purge		1.63	1.74	0.34	0.83
Cutting loss		0.45	0.08	0.16	0.20
Total saleable yield		93.31	92.17	1.15	0.54
Processing time, per subprimal		-------------------	s -------------------		
Bag opening time		6.96	6.33	0.66	0.52
Trimming/cutting time		55.32	59.16	7.27	0.72
Total time		62.28	65.49	7.64	0.77

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 9. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Round, Eye of Round cut into one roast from different USDA quality grades

Item	UPC[a]	U.S. Choice (n = 6)	U.S. Select (n = 6)	SEM[b]	*P* - value
Net weight, lb		5.09	5.45	0.71	0.52
Retail yield		-------------------	% -------------------		
Eye of round roast	1480	92.01	89.76	1.63	0.36
Lean trimmings (90% lean)	1653	2.52	2.24	0.73	0.79
Fat		4.03	6.84	1.33	0.17
Purge		1.24	1.39	0.29	0.70
Cutting loss		0.20	0.09	0.13	0.56
Total saleable yield		94.53	91.16	1.36	0.12
Processing time, per subprimal		-------------------	s -------------------		
Bag opening time		6.51	6.89	0.28	0.55
Trimming/cutting time		74.18	67.07	9.65	0.61
Total time		80.69	73.93	9.90	0.64

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

RETAIL CUTTING CHARACTERISTICS FOR RIB AND LOIN SUBPRIMALS FROM TWO GRADE GROUPS

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Summary

USDA Choice and Select beef subprimals were obtained to conduct retail cutting tests. The subprimals selected included ribeye roll, lip-on, bone-in; ribeye roll (0 × 0); ribeye, lip-on (2 × 2); ribeye, lip-on modified (1 × 1); strip loin, bone in; strip loin, boneless; and top sirloin butt, boneless, 2-piece. Subprimals were merchandised into bone-in or boneless retail cuts and associated components by experienced retail meat merchandisers. USDA quality grade had little or no effect on retail cutting yields and processing times for subprimals from the rib and loin. Efforts to further increase retail yields from rib and loin subprimals should include minimizing purge and increasing cutting efficiencies in addition to reducing fat trim. Retailers should utilize purchase specifications in matching raw materials to merchandising schemes. These data will serve as an update to the CARDS (Computer Assisted Retail Decision Support) software program.

Introduction

CARDS (Computer Assisted Retail Decision Support) is a computer software program that was developed so retailers could evaluate the price/value relationship of beef subprimals (Garrett et al., 1991). This program continues to serve as a valuable reference to assist retailers in the process of making meat purchasing and merchandising decisions.

Research previously conducted on beef retail yield and fabrication times (Garrett et al., 1991) led to research on pork (Lorenzen et al., 1996a; Lorenzen et al., 1996b), lamb (Lorenzen et al., 1997), and veal (McNeill et al., 1998), and allowed for CARDS program development for these species. CARDS was designed originally for the retail sector; however, the foodservice industry later requested similar information. Weatherly et al. (2001) determined cutting yields and time requirements for beef subprimals as they were portioned into ready-to-cook foodservice cuts. The objective of this study was to perform a thorough evaluation of rib and loin cuts included in the present version of Beef CARDS in order to pinpoint deficiencies and/or inconsistencies in the data and to obtain current yield and time data for a new updated list of subprimals.

Experimental Procedures

Product selection

Beef subprimals (n = 120) from the rib and loin (Table 1), representing USDA Choice and Select grades, were obtained from a major beef processor and shipped to the Rosenthal Meat Science and Technology Center at Texas A&M University. Selected subprimals represented the normal weight variation and standard packer fat trim levels associated with commodity boxed beef. Specifications for all subprimals complied (within packer variations) with Institutional Meat Purchase Specifications (IMPS) as described by USDA (1996) and NAMP (2003).

Cutting tests

A refrigerated cutting room in the Rosenthal Meat Science and Technology Center was modified to simulate a retail market environment for the purpose of conducting controlled retail yield tests. Meat merchandisers from different regions of the United States and with extensive retail meat industry cutting experience were enlisted for this study. Discussion between meat merchandisers and investigators resulted in the development of merchandising schemes for each subprimal to represent best current industry practices. Universal Product Code (UPC) descriptions (Industry-Wide Cooperative Meat Identification Standards Committee, 2003) were used as the naming convention for retail cuts.

Vacuum packaged subprimals were weighed before and after opening, and purge loss was determined. Subprimals were cut following defined merchandising schemes, retail cuts, unless otherwise specified, were trimmed not to exceed 0.125 in of fat, and when trimmings were generated, the targeted visual lean percentage was 90%. Processing times were recorded as an estimate of labor requirements for each merchandising scheme. Timed activities for each cutting test included two major phases: opening (retrieval of the subprimal from vacuum-packaged bag) and cutting (removal of external and seam fat, connective tissue, and separation of individual muscles, as well as producing tray-ready retail cuts as applicable). The two phases were combined for total processing time.

Ribeye Rolls, Lip-On, Bone In were merchandised two ways. One style consisted of cutting the bone-in ribeye rolls into three Ribeye Roasts, Lip-on, Bone In: the 6th and 7th rib, the 8th and 9th rib, and the 10th through 12th rib sections. For the second style, the ribeye roll was cut into 1.25 in Ribeye Steaks, Lip-On, Bone In.

Ribeye Rolls (0 × 0) were knife-cut end-to-end into 1.0 in Ribeye Steaks. Ribeye Rolls, Lip-On (2 × 2) and (1 × 1) (IMPS #112A Modified) were merchandised two ways. One style consisted of the subprimal being cut into 1.0 in. Ribeye Steaks, Lip-On, Boneless and the second style consisted of cutting 1.0 in Ribeye Steaks, Lip-On, Boneless throughout the small (posterior) end with the large (anterior) end remaining intact as a Ribeye Roast, Lip-On, Boneless.

Strip Loins and Strip Loins, Boneless were cut into 1.0 in Top Loin Steaks and Top Loin Steaks, Boneless, respectively. Center-cut strip steaks and vein steaks (steaks that had *M. gluteus medius* on both sides of the cut) were recorded separately.

Top Sirloins, Boneless, 2 Pc were vacuum packaged together. Bag opening time, initial weight, bag weight, and purge weight were collectively measured before separate cutting tests were performed on the Beef Loin, Top Sirloin Butt, Center-Cut, Boneless (IM) and the Beef Loin, Top Sirloin, Cap (IM). Top Sirloin Steaks, Boneless, Cap Off and Top Sirloin Cap Steaks, Boneless were cut 1.0 in thick and perpendicular to muscle fiber orientation.

Statistical analysis

The experiment was planned as a completely randomized design. Data were analyzed, by subprimal, using SAS (SAS Institute, Inc., Cary, NC) PROC GLM with quality grade tested as the main effect. Least squares means were generated, and when an alpha-level of $P < 0.05$ was found, least squares means were separated with the PDIFF option.

Results and Discussion

Retail yields and processing times for the rib and loin subprimals cut are reported in Tables 2-11. These cutting tests will be useful to beef merchandisers in making informed purchase and cutting decisions to optimize value of closely-trimmed beef subprimals. Having standardized cutting tests, including time requirements to perform various tasks, allow the beef industry to have benchmark information not previously available in the public domain.

Roast percentage and total saleable yield was very similar between U.S. Select and U.S. Choice bone-in ribeye rolls cut into roasts (IMPS #109E) (Table 2). U.S. Choice bone-in ribeye rolls portioned into steaks produced a greater amount of trimmed fat and purge than the U.S. Select bone-in ribeyes resulting in cutting and total time to be significantly higher in U.S. Choice bone-in ribeye rolls (Table 3). Total saleable yield was higher in the initial cutting style fabricated into roasts (95%) compared to subprimals cut into steaks (90-95%).

U.S. Choice boneless ribeye rolls (0 × 0) (IMPS #112) displayed a slight increase in the amount of fat produced, as well as the time necessary to cut boneless ribeye steaks and U.S. Select ribeye rolls produced a higher percentage of trimmed ribeye steaks (Table 4). U.S. Select boneless ribeye rolls (2 × 2) (IMPS #112A) cut only into steaks required a significantly longer cutting time, thus resulting in a significantly longer total processing time (Table 5) when compared to U.S. Choice ribeye rolls. U.S. Choice ribeye rolls tended to be fatter and U.S. Select ribeye rolls produced a higher percentage of total saleable product (Table 5 and 6). In the second cutting style, including steaks and roasts, total saleable yield was very similar between grade groups (Table 6). When comparing cutting styles, a greater percentage of fat and lean trim was produced from the cutting style containing all steaks. U.S. Choice boneless ribeye rolls (1 × 1) (IMPS #112A modified) required significantly more fat trimming than U.S. Select ribeye rolls (Table 7). U.S. Select ribeye rolls also produced a greater amount of purge, as well as 3.2 % more ribeye steaks.

U.S. Select bone-in strip loins (IMPS #175) tended to have a greater percentage of center top loin steaks and consequently a higher percentage of saleable yield when compared to U.S. Choice bone-in strip loins (Table 8). Retail yields and processing times for boneless strip loins (IMPS

#180) are presented in Table 9. U.S. Select strip loins had a significantly greater percentage of purge loss when compared to the U.S. Choice strip loins. The retail cutting percentages are relatively similar between U.S. Choice and U.S. Select grade strip loins; however, there does appear to be a slight increase in the percentage of U.S. Select lean trim.

U.S. Choice center-cut top butts had a greater percentage of trimmable fat ($P < 0.04$), as well as a greater amount of lean trim, thus resulting in a requirement for a longer cutting time (Table 10). U.S. Select center-cut top butts also tended to produce a slightly higher percentage of steaks thus resulting in a higher saleable yield. U.S. Choice top sirloin caps (IMPS #184D) had a higher percentage of steaks when compared to the U.S. Select top sirloin caps (Table 11). U.S. Select top sirloin caps possessed a higher percentage of purge loss when compared to their U.S. Choice counterparts. Saleable yield for U.S. Choice top sirloin caps (98%) was higher than Weatherly et al. (2001) findings, which were reported to be between 94 and 96%.

In addition to providing these cutting tests for comparative purposes, there are several key points to be made based on our findings. USDA quality grade had little or no effect on retail cutting yields and processing times for subprimals from the rib and loin. Some historical differences in retail yield between USDA quality grades may have been due to the differences in trimmable fat now being removed at the packer level. Therefore, beef merchandisers may choose to utilize either U.S. Choice or U.S. Select rib and loin subprimals based on parameters other than yield.

Even though many of the cutting tests revealed relatively high retail yields (ranging from 80.27% to 98.22%), there still are missed yield opportunities because of fat trim, purge and cutting losses. To further increase retail yields from the rib and loin subprimals, efforts can not be focused exclusively on reducing fat trim specifications, but may need to include methods of minimizing purge and increasing cutting efficiencies. Retail yields for a class of subprimals are based on two key factors: purchase specifications and merchandising schemes. Purchase specifications allow retailers to select from a variety of products to find those that closely match how products should be merchandised based on historic consumer preference and seasonal demand. Evidence of how purchase specification and merchandising scheme impacts retail yields is best demonstrated by our ribeye cutting information.

Implications

These cutting test data will be used to update the Beef CARDS software program. By incorporating new information into this dynamic decision-making program, users will be able to evaluate pricing and labor costs to determine how purchase and merchandising factors affect profitability.

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Table 1. USDA (1996) Institutional Meat Purchase Specifications (IMPS) descriptions of rib and loin subprimals used for retail cutting tests

IMPS #	Subprimal
109E	Beef Rib, Ribeye Roll, Lip-On[a], Bone-In
112	Beef Rib, Ribeye Roll
112A	Beef Rib, Ribeye, Lip-On[a]
112A Modified	Beef Rib, Ribeye, Lip-On[a] Modified (1 × 1)[c]
175	Beef Loin, Strip Loin (1 × 0)[d]
180	Beef Loin, Strip Loin, Boneless (1 × 0)[d]
184E	Beef Loin, Top Sirloin, Boneless, 2 Pc[e]

[a] Lip = *M. serratus dorsalis, M. longissimus costarum* and related intermuscular fat lateral to the *M. longissimus thoracis* (USDA, 1996).

[b] (1 × 1) = Lip does not exceed 2.54 cm.

[c] IM = Individual muscle.

[d] (1 × 0) = The flank side shall be lateral to, but not more than 2.54 cm from, the *M. longissimus lumborum* at the rib end to a point on the sirloin end immediately lateral to the *M. longissimus lumborum* (USDA, 1996).

[e] Pc = Piece.

Table 2. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll, Lip-On, Bone In (IMPS #109E), cut into roasts from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		17.20	18.37	0.44	0.11
Retail yield		------------------	%	------------------	
Ribeye roast, lip-on, bone in	1193				
6th – 7th rib roast		24.20	25.74	0.57	0.09
8th – 9th rib roast		27.06	27.27	0.52	0.78
10th – 12th rib roast		43.62	42.03	0.66	0.12
Lean trimmings (90% lean)	1653	0.75	0.47	0.31	0.54
Fat		4.09	4.32	0.65	0.81
Purge		0.29	0.19	0.08	0.42
Cutting loss		0.01	0.00	0.03	0.63
Total saleable yield		95.62	95.51	0.63	0.90
Processing time, per subprimal		------------------	s	------------------	
Bag opening time		11.4	17.8	1.2	0.004
Trimming/cutting time		120.7	126.0	24.1	0.88
Total time		132.1	143.9	24.3	0.74

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 3. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll, Lip-On, Bone In (IMPS #109E), cut into steaks, from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		16.54	14.11	1.72	0.5
Retail yield		------------------	%	------------------	
Ribeye steak, lip-on, bone in	1197	87.52	90.13	0.63	0.08
Lean trimmings (90% lean)	1653	2.99	2.35	0.64	0.50
Fat		8.08	6.33	0.84	0.18
Purge		0.28	0.17	0.09	0.41
Cutting loss		1.12	0.96	0.07	0.13
Total saleable yield		90.51	92.48	0.86	0.14
Processing time, per subprimal		------------------	s	------------------	
Bag opening time		12.8	12.7	1.6	0.95
Trimming/cutting time		319.8	264.4	16.9	0.05
Total time		322.7	277.1	17.3	0.05

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 4. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll (IMPS #112), from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		9.79	8.09	0.71	0.23
Retail yield		-------------------	%	-------------------	
Ribeye steak	1209	95.18	97.24	1.02	0.29
Lean trimmings (90% lean)	1653	1.88	0.83	1.03	0.55
Fat		1.81	1.31	0.29	0.34
Purge		1.19	0.68	0.45	0.51
Cutting Loss		0.00	0.00	0.00	0.00
Total saleable yield		97.06	98.07	0.24	0.10
Processing time, per subprimal		-------------------	s	-------------------	
Bag opening time		8.1	6.6	1.0	0.42
Trimming/cutting time		102.1	69.0	7.3	0.08
Total time		110.2	75.6	8.2	0.10

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 5. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll, Lip-On (IMPS #112A) cut to include steaks from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		13.98	15.10	0.46	0.11
Retail yield		-------------------	%	-------------------	
Ribeye steak, lip on, boneless	1203	84.08	84.91	0.76	0.44
Lean trimmings (90% lean)	1653	3.78	4.28	0.47	0.47
Fat		11.13	9.89	0.89	0.33
Purge		0.95	0.84	0.23	0.72
Cutting loss		0.06	0.11	0.06	0.55
Total saleable yield		87.87	89.19	0.91	0.32
Processing time, per subprimal		-------------------	s	-------------------	
Bag opening time		11.7	11.3	1.2	0.85
Trimming/cutting time		221.2	272.3	16.5	0.05
Total time		232.7	283.6	16.3	0.05

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 6. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll, Lip-On (IMPS #112A), cut into steaks and roasts from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		15.90	14.58	0.55	0.12
Retail yield		---------- % ----------			
Ribeye steak, lip-on, boneless	1203	43.54	49.08	2.96	0.21
Ribeye roast, lip-on, boneless	1194	44.19	38.00	2.66	0.12
Lean trimmings (90% lean)	1653	2.97	3.89	0.46	0.18
Fat		8.47	8.02	0.91	0.73
Purge		0.80	0.89	0.21	0.78
Cutting loss		0.03	0.13	0.08	0.39
Total saleable yield		90.70	90.97	0.92	0.83
Processing time, per subprimal		---------- s ----------			
Bag opening time		11.8	10.9	1.1	0.61
Trimming/cutting time		198.4	213.6	22.0	0.63
Total time		210.2	224.5	21.2	0.63

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 7. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye Roll, Lip-On, Modified 1 × 1 (IMPS #112A modified), from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		9.39	13.78	4.83	0.26
Retail yield		---------- % ----------			
Ribeye steak, lip-on, boneless	1203	40.98	44.18	2.16	0.37
Ribeye roast, lip-on, boneless	1194	47.11	45.97	2.41	0.75
Lean trimmings (90% lean)	1653	2.51	2.28	1.14	0.89
Fat		9.40	6.33	0.72	0.02
Purge		0.00	1.06	0.95	0.41
Cutting loss		0.22	0.19	0.14	0.90
Total saleable yield		90.60	92.43	1.40	0.42
Processing time, per subprimal		---------- s ----------			
Bag opening time		7.3	11.9	0.3	0.01
Trimming/cutting time		140.1	149.3	15.8	0.70
Total time		147.4	161.2	15.7	0.57

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 8. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Strip Loin (IMPS #175) from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		14.02	13.23	1.32	0.38
Retail yield		------------------- % -------------------			
Top loin steak, bone in (center)	1398	60.94	66.75	2.40	0.14
Top loin steak, bone in (vein)[c]	1398	17.62	15.44	1.53	0.35
Lean trimmings (90% lean)	1653	4.36	3.62	0.54	0.37
Fat		12.45	12.22	1.28	0.91
Purge		0.37	0.29	0.11	0.62
Cutting loss		1.36	1.25	0.11	0.48
Total saleable yield		82.93	85.81	1.60	0.25
Processing time, per subprimal		------------------- s -------------------			
Bag opening time		13.5	12.8	2.4	0.84
Trimming/cutting time		435.8	427.1	12.5	0.64
Total time		449.3	440.0	13.8	0.65

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.
[c] Steaks with the *M. gluteus medius* present on both cut surfaces.

Table 9. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Strip Loin, Boneless (IMPS #180) from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		10.74	10.39	0.71	0.73
Retail yield		------------------- % -------------------			
Top loin steak, boneless (center)	1404	67.39	66.88	1.43	0.81
Top loin steak, boneless (vein)[c]	1404	17.92	17.04	1.58	0.70
Lean trimmings (90% lean)	1653	1.88	2.35	0.42	0.50
Fat		11.26	11.21	0.89	0.97
Purge		1.50	2.36	0.08	<0.001
Cutting loss		0.04	0.16	0.08	0.30
Total saleable yield		87.20	86.27	0.82	0.45
Processing time, per subprimal		------------------- s -------------------			
Bag opening time		8.5	8.5	0.6	0.99
Trimming/cutting time		223.2	227.2	9.9	0.78
Total time		231.7	235.7	10.1	0.79

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.
[c] Steaks with the *M. gluteus medius* present on both cut surfaces

Table 10. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Top Sirloin Butt, Center-Cut, Boneless, (IM) (IMPS #184B) from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		8.05	9.28	0.15	0.04
Retail yield		-------------------	%	-------------------	
Top sirloin steak, boneless, cap off	1426	79.39	82.72	1.41	0.17
Lean trimmings (90% lean)	1653	10.26	9.32	0.96	0.53
Fat		8.82	6.03	0.68	0.04
Purge		0.12	0.25	0.04	0.14
Cutting loss		0.00	0.00	0.01	0.86
Total saleable yield		89.65	92.05	1.21	0.24
Processing time, per subprimal		-------------------	s	-------------------	
Trimming/cutting time		147.7	133.2	11.8	0.43

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.

Table 11. Least squares means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Top Sirloin, Cap (IM) (IMPS #184D) from different USDA quality grades

Item	UPC[a]	U.S. Choice (n=6)	U.S. Select (n=6)	SEM[b]	*P*-value
Net weight, lb		1.46	1.81	0.13	0.08
Retail yield		-------------------	%	-------------------	
Top sirloin cap steak, boneless	1421	75.06	73.23	1.98	0.55
Lean trimmings (90% lean)	1653	23.17	24.84	2.14	0.61
Fat		0.00	0.00	0.00	-------
Purge		1.56	2.66	0.53	0.24
Cutting loss		0.22	0.23	0.44	0.98
Total saleable yield		98.22	98.07	0.80	0.90
Processing time, per subprimal		-------------------	s	-------------------	
Trimming/cutting time		9.5	9.3	1.3	0.90

[a] UPC = Universal product code.
[b] SEM is the standard error of the least squares means.


Physiology

EXIT VELOCITY IS A RELIABLE TOOL FOR EVALUATING CATTLE TEMPERAMENT

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Summary

Poor temperament has negative impacts on beef cattle production and may be an important trait to consider for a breeding herd. Evaluating animal temperament has been conducted in a variety of different manners over the years. A useful tool for discerning cattle temperament must be reliable, repeatable, and linked to the individual animal's stress responsiveness. In this study we compared three different methods of temperament assessment over multiple observations of the same bulls and compared them to parameters of cattle stress response. Exit velocity as a measure of animal temperament may be useful to beef producers as it is a quick, labor friendly, and simple tool. Exit velocity measures showed a greater relationship to physiological endpoints of stress than the other methods compared. In addition, individual temperament assessments via exit velocity, changed the least over time.

Introduction

Cattle temperament can be characterized as a fear response to humans. Similar fear responses may also arise from interactions with herd mates, encounters with foreign species, or sudden stimuli, which may be simply loud noises. Animals with a calmer temperament will have less of a response to certain stimuli while animals with a wilder temperament will be easily excited and/or exhibit a greater fear response. Cattle with wilder temperaments exhibit lower weight gains (Burrow and Dillon, 1997; Voisinet et al., 1997b), produce tougher meat (Voisinet et al., 1997a), and yield increased amounts of bruise trim due to injuries acquired during transportation (Fordyce et al., 1988). Various techniques have been utilized to assess animal temperament; however, most are of a subjective nature and have not been validated for their ability to gauge temperament over the long-term. Our objectives were to compare temperament assessments, using multiple techniques, over repeated observations, as well as the relationship of the temperament appraisals with the stress hormone cortisol (CS).

Experimental Procedures

Sixty-six yearling, fall-born (2002) American Gray Brahman bulls were utilized to identify the repeatability of temperament measures, assessed by exit velocity, pen score, and chute score, and the relationship of such measures to concentrations of CS. The cattle were part of a commercial bull herd owned and managed by J. D. Hudgins Inc., (Hungerford, TX), and remained on the ranch property for the duration of the trial. On three separate occasions (Time 1, Time 2, and Time 3), with an interval of sixty days between each sampling time, data were collected at a working facility on the J. D. Hudgins ranch. The cattle were herded through a chute system where they were weighed, assigned a chute score, and timed for exit velocity as they were released from the chute system. The bulls were subsequently herded through a second working chute and restrained with a hydraulic squeeze. While the cattle were restrained, blood samples were obtained via tail-bleeding. Upon exiting the second working chute, the bulls were confined to a pen in small groups where they were assigned pen scores.

Three methods of temperament assessment were utilized during the data collection. These methodologies included two subjective measures: chute score (CHUTE) and pen score (PEN), and one objective measure of exit velocity (EV). Chute scores (Grandin, 1993) were based on visual appraisal of each bull while it was confined, but not restrained, in a working chute. The scores were based on a 1 to 5 scale, a score of 1 equated to a completely calm animal whereas a score of 5 equated to an extremely excited animal. Pen scores (Hammond et al., 1996) were based on visual assessments of each bull while being confined to a pen (15 x 20 ft) with five of its peers. The scores were based on a 1 to 5 scale, with a score of 1 equating to a completely calm animal and a score of 5 equating to an extremely excited animal. While making the pen score appraisal, the assessor would attempt to approach the bulls to gauge their response. Exit velocity (Burrow et al., 1988) was determined as the rate at which the animals exited the working chute and traversed a fixed distance (~ 6 ft). Infrared sensors were used to remotely trigger the start and stop of a timing apparatus, (FarmTek Inc., North Wylie, TX).

The EV data obtained from the first collection day were transformed into an exit velocity ranking (EV RANK) in order to create a discrete variable based on EV. This ranking was a 1 to 3 scale with 1 representing the bulls slower than one standard deviation from the mean EV and 3 equating to bulls faster than one standard deviation from the mean. Repeated measures ANOVA was conducted using the MIXED model procedure of SAS (SAS Inst., Inc., Cary, NC), for a factorial analysis of time and EV RANK effects on EV and serum concentration of CS. Pearson correlation coefficients were calculated between EV, CS, CHUTE, and PEN, both within and across each of the three points of data collection, using the CORR procedure of SAS.

Results and Discussion

On the first of three data collection days, all measures of temperament were positively correlated to each other (Table 1). In addition, both PEN and EV were positively correlated with CS, but CHUTE was not. So while the various methodologies for temperament assessment may measure slightly different aspects of animal behavior, they do relate to one another and, in the case of EV and PEN, to increased circulating glucocorticoids. Such relationships did not hold true through subsequent data collections. At Time 2, neither PEN nor CHUTE were related to EV, however, PEN and CHUTE were positively correlated to each other (Table 2). Due to the occurrence of unforeseen but documented external stressors while collecting data, concentrations of CS at Time 2 were markedly elevated and thus excluded from our analysis. As a result, comparisons between the various assessments of temperament and physiological stress indicators could not be made for this time point. At Time 3, there were no correlations between any of the temperament assessments (Table 3); however, both PEN and EV were again positively correlated to serum concentration of CS. It is to be noted that the correlation between EV and CS was greater than between PEN and CS, as indicated by both a higher r value and a greater significance level. So while the correlations between different temperament assessment methodologies changed dramatically over the three time points of data collection, the relationship between EV and CS remained constant from Time 1 to Time 3.

Pearson correlation coefficients were calculated for the various temperament parameters across all times of data collection in order to identify the consistency of each method's assessment of temperament. Chute scores were not correlated ($P > 0.3$) to each other at any of the three data collections. Exit velocity at Time 1 (EV1) was positively correlated to both EV2 ($r = 0.32$, $P = 0.011$) and EV3 ($r = 0.31$, $P = 0.015$). In addition, EV2 was correlated ($r = 0.47$, $P < 0.001$) to EV3. Similarly, PEN1 was correlated to both PEN2 ($r = 0.31$, $P = 0.01$) and PEN3 ($r = 0.32$, $P < 0.01$), and PEN2 was correlated ($r = 0.52$, $P < 0.001$) to PEN3. Unlike with the CHUTE, both the measures of EV and PEN were correlated throughout the three points of data collection. Also, it may be of importance that correlations among EV measures, as well as PEN, were strongest between Time 2 and Time 3. One speculation concerning any measure of temperament would be that as the novelty of human-animal interaction decreased so would animal temperament scores, as ascertained through human contact. The greater correlations between the later two measures of temperament may suggest a leveling of each animal's response to human handling, and may in fact be more accurate assessments of the individual bull's temperament. Concerning serum concentrations of cortisol, CS1 was correlated ($r = 0.62$, $P < 0.001$) with CS3.

We analyzed how the serum concentrations of CS and exit velocities changed over time and relative to the original EV rankings. Over the course of data collections EV was influenced by time ($P < 0.001$) as the mean EV decreased from Time 1 (2.82 ± 0.07 m/sec) to Time 3 (2.11 ± 0.10 m/sec). At Time 2 EV (2.25 ± 0.12 m/sec) differed ($P < 0.001$) from Time 1 but not from Time 3 ($P = 0.25$). The decrease in EV over time supports the idea of animal temperament decreasing with repeated handling; however, the fact that there was no significant change in EV from Time 2 to Time 3 may suggest a limit to such an acclimation to human-animal interactions. Exit velocity was also associated ($P < 0.001$) with the original EV RANK throughout the two subsequent data collections (Figure 1). Thus, the assessments of bulls with a particularly calm temperament (i.e. EV RANK = 1) or rather excitable temperament (i.e. EV RANK = 3) proved to hold true through the next two periods of data collection. Time also influenced ($P < 0.001$) serum concentrations of CS, with a slight decline in mean CS observed between Time 1

(14.56 ± 0.65 ng/mL) and Time 3 (11.12 ± 0.82 ng/mL). Even though these concentrations of CS differ statistically, the biological implications of a 2 to 4 ng/mL difference are difficult to infer. Relative to temperament, concentrations of CS were associated ($P = 0.008$) with EV RANK (Figure 2). The relationship of serum concentrations of CS to measures of temperament remained between Times 1 and 3. As the EV RANK was based on EV from Time 1 alone, and relative differences in concentrations of CS were observed 120 d later; this measure of temperament appears to be associated with future physiological stress responses.

Implications

These data suggest that assessment of cattle temperament with exit velocity measures may be more useful than other subjective methodologies such as pen score or chute score. While all measures of temperament indicated an adaptation of the animals to interactions with humans, both PEN and EV variations were far less affected than CHUTE, over the three points of data collection. The relationship between EV and concentrations of CS was stronger than that of CS and PEN and there was no such relationship between CS and CHUTE. Thus, temperament assessed with such subjective methodologies does not correspond to the stress responses as well as the measure of exit velocity. Exit velocity is therefore a valuable tool for both the assessment of cattle temperament and a possible predictor of temperament through the future of the individual animal's lifetime.

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Table 1. Correlations between bull temperament measures and serum concentration of cortisol, at Time 1 (n = 66).

	Exit Velocity	Pen Score	Chute Score	Cortisol
Exit Velocity	-	r = 0.35 P = 0.005	r = 0.36 P = 0.003	r = 0.26 P = 0.042
Pen Score	-	-	r = 0.512 P < 0.001	r = 0.29 P = 0.019
Chute Score	-	-	-	r = 0.09 P = 0.462

Table 2. Correlations between bull temperament measures at Time 2 (n = 66).

	Exit Velocity	Pen Score	Chute Score
Exit Velocity	-	r = -0.04 P = 0.729	r = 0.20 P = 0.105
Pen Score	-	-	r = 0.40 P < 0.001

Table 3. Correlation between bull temperament measures and serum concentration of cortisol, at Time 3 (n = 66).

	Exit Velocity	Pen Score	Chute Score	Cortisol
Exit Velocity	-	r = 0.10 P = 0.421	r = -0.15 P = 0.233	r = 0.44 P < 0.001
Pen Score	-	-	r = 0.14 P = 0.269	r = 0.25 P = 0.043
Chute Score	-	-	-	r = 0.08 P = 0.511

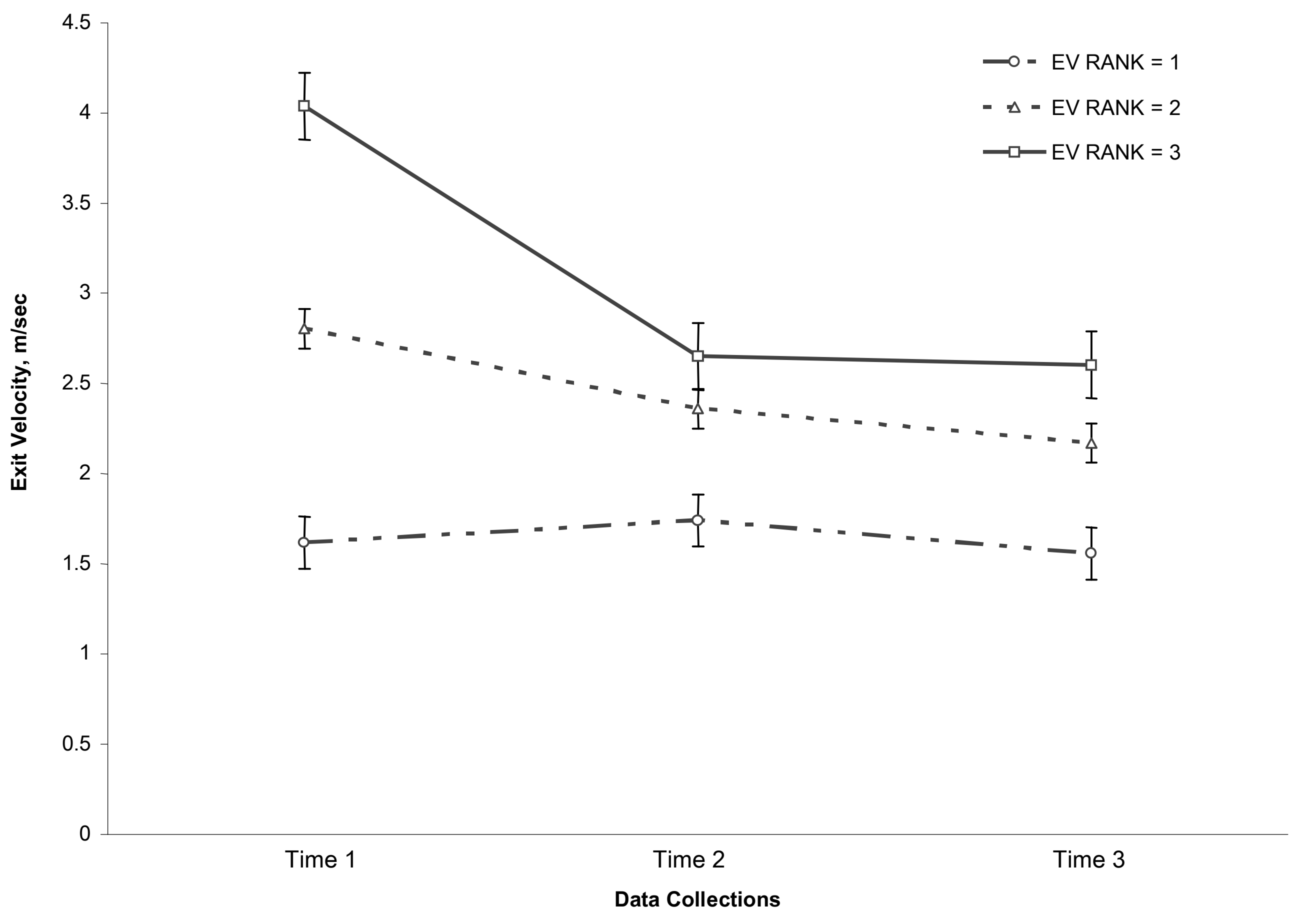

Figure 1. Mean exit velocity measures over the three data collections for each exit velocity ranking.

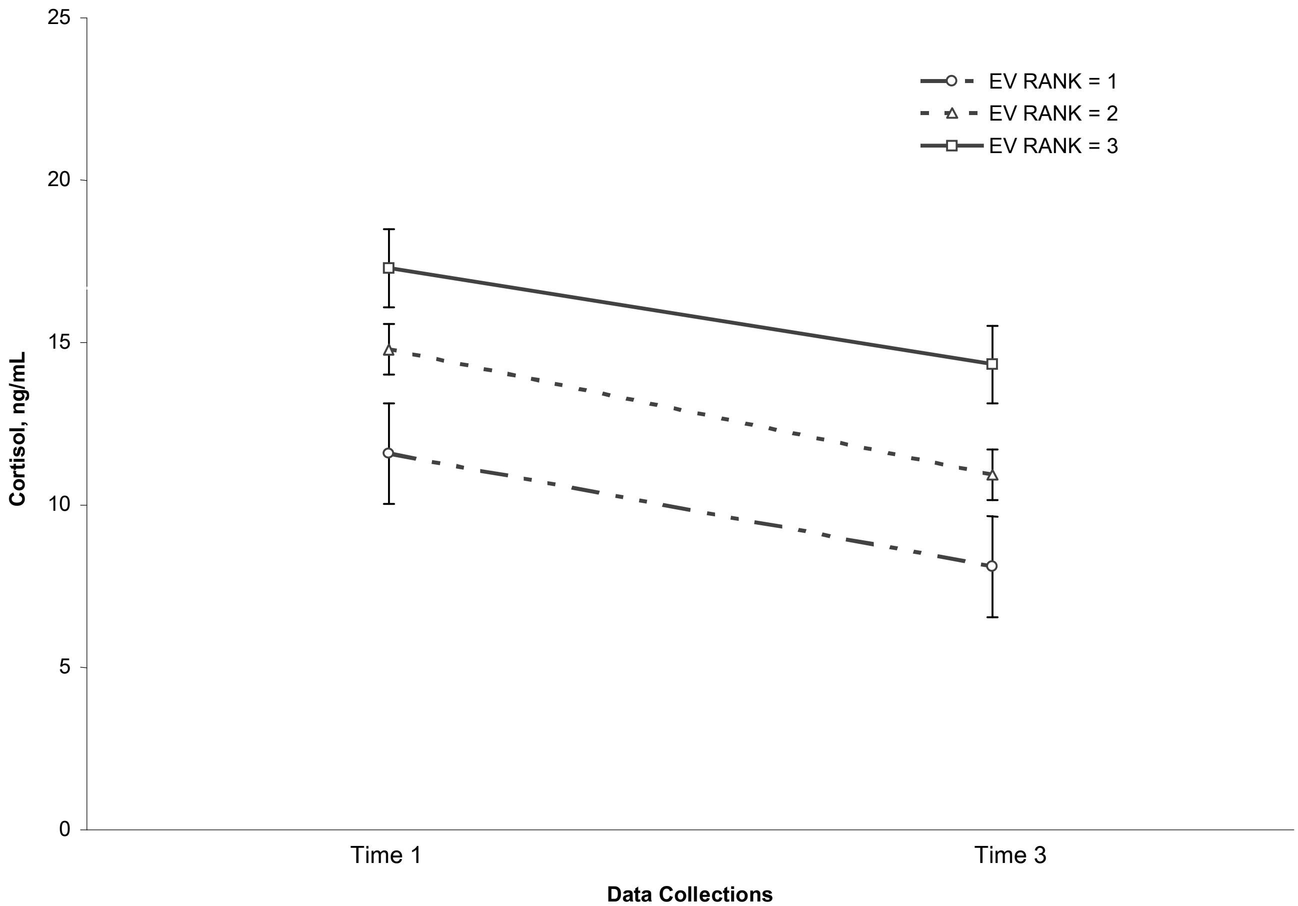

Figure 2. Mean serum concentrations of cortisol for Time 1 and Time 3 for each exit velocity ranking.

Range and Pasture

TOOLS FOR DISTINGUISHING BETWEEN FORAGE QUALITY AND QUANTITY AS SOURCES OF NUTRITIONAL PROBLEMS IN RANGE BEEF CATTLE

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Summary

This study investigated the feasibility of calibrating cow forage intake at the ranch level using the tools of NIRS fecal analysis to estimate quality of consumed forage, a computer model to estimate cow performance, and body condition scoring to estimate apparent forage intake. Using unadjusted forage intake estimates, the computer model overestimated cow body condition scores. Model estimated body condition scores were not different from observed condition scores using either year-one monthly apparent forage intake values or apparent intake calculated as a continuous average.

Introduction

Nutritional models have been developed to estimate beef cattle performance. Fox (1995) suggested that these models require 1) adequate information and 2) user understanding to adjust models to ranch levels.

On rangelands, forage intake information is difficult to obtain. Estimating total forage standing crop is possible. However, estimating the portion of the standing crop grazing animals will consume is difficult. Studies report 80% of grazed diets coming from 1 to 6% of the standing crop (Arnold and Dudzinski, 1978; Cruz and Ganskopp, 1998) and 85% from two grasses during three seasons (Kirby and Stuth, 1982). O'Reagain and Grau (1995) reported that least-preferred species tillers were grazed only when 80 to 100% of preferred and intermediate species tillers were defoliated.

Animal performance is useful for estimating forage intake on a group or pasture-basis (Moore, 1996) and with grazing, lactating dairy cattle (Macoon et al., 2003). This study investigated a systems approach to 1) improve model performance estimates and 2) differentiate forage quality and quantity problems.

Experimental Procedures

This study was conducted in 6 cow-calf herds on 5 ranches in 5 counties from 1997 to 2004. Each ranch was initially scheduled for a two-year study. One ranch participated for only one year, 3 for two years, and one ranch with two herds for three years.

Forage diet quality was estimated from NIRS-analysis of composite fecal samples taken each month of the study on each ranch. Each composite fecal sample was made of sub-samples from about 10 different cows. Ranch personnel selected a day of the month that was convenient for them to collect fecal samples and all subsequent samples were taken within 5 days of this scheduled date. This sampling procedure was used to avoid a sample being taken at the beginning of one month and the end of the next month, 60 days apart, which would result in missing a forage quality estimate for a month. Samples were shipped either fresh or frozen with an ice pack to the GAN (Grazing Animal Nutrition) Lab at Texas A&M University for NIRS-analysis. Sample analysis was used to estimate crude protein (CP) and digestible organic matter (DOM) concentrations of forage consumed by cows.

When fecal samples were taken, cows were body condition scored on a 1 to 9-basis. In all but one herd, cows were condition-scored by ranch personnel.

Herd information including cow average production stage (gestation day, lactation day), cow breed, cow age, and calf weaning weights and ages was collected each month. Environmental conditions including current and previous 30-day maximum and minimum daily temperatures and relative humidity levels were estimated. Herd and environmental information and diet quality estimates were entered in the NutBal-PRO model to estimate cow performance over the next 30 days. In this study, maximum temperatures were never set above 85° F based on NRC (1996) recommendations and previous experience with the model. Temperatures above this level tended to overestimate condition score loss.

Model body condition score estimates using unadjusted (expected) forage intake were compared to observed condition scores. If the model overestimated BCS gain and all other information entries appeared to be correct, the model was re-run reducing forage intake until model-estimated and observed BCS matched as close as possible. The adjusted forage intake level required to match observed BCS was recorded as apparent forage intake. Apparent forage intake was used in two ways to test the feasibility of improving model BCS estimates. First, first-year monthly apparent forage intake values were used in the same month in year two. Second, apparent forage intake values were used to create a continuous average forage intake value which was calculated by averaging apparent forage intake for all previous months and using that value in the model to estimate body condition score for the next month.

Results and Discussion

Average estimated crude protein of forage consumed across all ranches was 8.9%, while average estimated digestible organic matter was 60.4%. Estimated average consumed forage quality differed among ranches ($P < 0.0001$), with ranges of 8 to 11% and 59 to 62% for crude protein and digestible organic matter, respectively.

Yearly average body condition score estimates using expected forage intake values on three ranches and four herds were greater ($P = 0.003$) than observed BCS (Figure 1). Using first-year monthly apparent forage intake values to estimate BCS in year 2, yearly average observed and estimated BCS were similar ($P = 0.37$, Figure 1). Although this approach improved BCS estimates, values that could be applied more immediately would be more useful. In addition, because of yearly variation in rainfall and forage production, using monthly forage intake estimates from one year to estimate forage intake during the same month in a future year might not be feasible. For example, in one instance in this study, a difference in apparent forage intake of 15 pounds was observed between the same month in two successive years.

Across all five ranches and six herds, body condition score estimates based on continuous forage intake (Figure 2) were not different ($P = 0.7757$) from observed BCS. However, BCS estimates based on expected forage intake were greater than either observed BCS or estimates using continuous intake values ($P < 0.0001$). Body condition score estimates using expected forage intake overestimated observed BCS by 0.5 to 1.5 condition score 34% of the time compared to 9% for estimates based on continuous forage intake.

Average expected forage intake (Figure 3) differed among ranches ($P < 0.0001$). Expected intake averaged 29 pounds per day and varied from 26 to 32 pounds. On a percent of condition score 5 body weight-basis, average expected intake was 2.6 percent and varied from 2.4 and 2.8 percent. These differences were due to differences in cow size and cow production levels among ranches. These expected intake levels appear to be reasonable based on the fact that the traditional definition of an animal unit uses an average annual intake level of 26 pounds for a 1000-lb cow, which is 2.6% of body weight. Cattle are certainly capable of higher intake levels as demonstrated by a dairy cow which was documented to have consumed 7% dry matter intake on a body weight basis (Schingoethe et al. 1988). However, overestimates of body condition scores using these expected values appear to indicate that these intake levels were generally not achieved among cows in the study herds. This observation is not surprising considering reports of 80% of grazed diets coming from 1 to 6% of the standing crop (Arnold and Dudzinski 1978; Cruz and Ganskopp 1998). Therefore, forage quantity can be nutritionally limiting even if grass standing crop appears adequate.

Apparent forage intake averaged 23 pounds per day and tended to differ ($P = 0.1367$) across ranches with a range from 19 to 24 pounds. As a percent of body weight, these intake levels were equivalent to an average of 2.0 percent with a range of 1.7 to 2.1 percent. Maximum apparent intake was 3.1 percent with an average of 2.7, which are close to average expected intake levels. Minimum apparent forage intake was 1.1 percent of body weight. In a review of the literature, Holechek et al. (2001) reported average dry-matter intake levels for grazing cattle of about 2% of body weight with levels ranging from 1.2% to 2.8%. Specifically, Pinchak et al. (1990) reported values for cattle of 1.95 to 2.45% across a year in Texas.

Average expected intake across all ranches was greater ($P < 0.0001$) than either average apparent or average continuous intake. Eighty-one percent of expected forage intake values were between 25 and 35 pounds per day compared to 29% for apparent intake. No expected intake values were below 20 pounds per day, while 38% of apparent intake values were below this level. Average difference between expected and apparent forage intake was 7 pounds and varied from 5 to 13 pounds across ranches (Table 1).

Regression analysis showed that apparent forage intake deviation from expected forage intake explained 44% of the variation in body condition score change. Addition of digestible organic matter estimates to the regression model explained an additional 13% variability for a total of 57% for the two variables combined. Crude protein estimates did not explain any additional variation in body condition score change. Below about 7.5 lbs forage intake-deviation, body condition score change tended to be negative.

Implications

Forage availability and forage intake are as important as forage quality regarding grazing cattle performance. In fact, forage quantity can be nutritionally limiting even if grass standing crop appears adequate. The approach used in this study of combining consumed forage quality estimates using fecal NIRS analysis, a computer model to describe animal and environmental variables affecting performance, and body condition scoring to estimate apparent forage intake improved animal performance estimates. This approach also has nutritional analysis value for distinguishing between forage quality and forage quantity as limiting nutritional factors.

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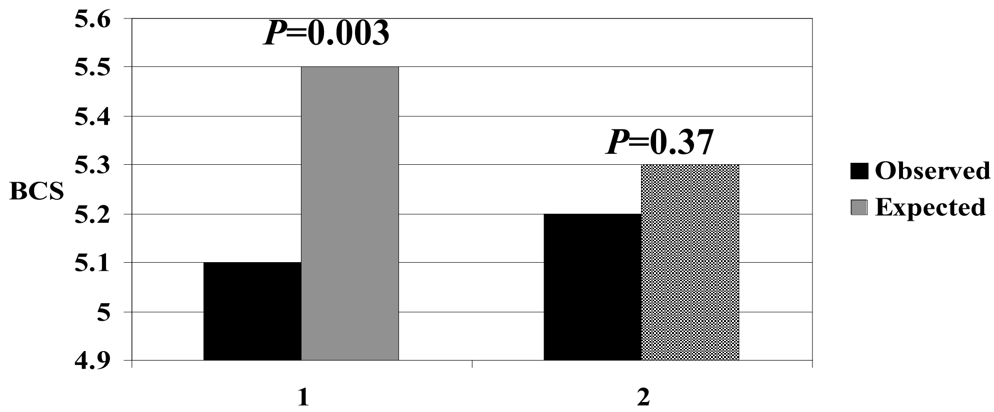

Figure 1. Model-estimated body condition score versus observed condition score on three ranches in four herds using expected forage intake during year 1 and year-one individual monthly apparent forage intake values during the same months in year two.

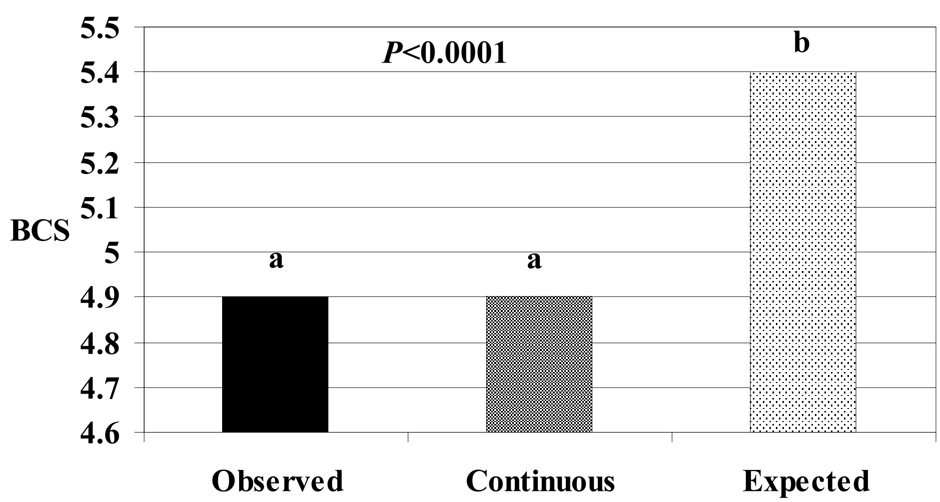

Figure 2. Model-estimated body condition scores using expected forage intake and continuous apparent forage intake across five ranches and six herds.

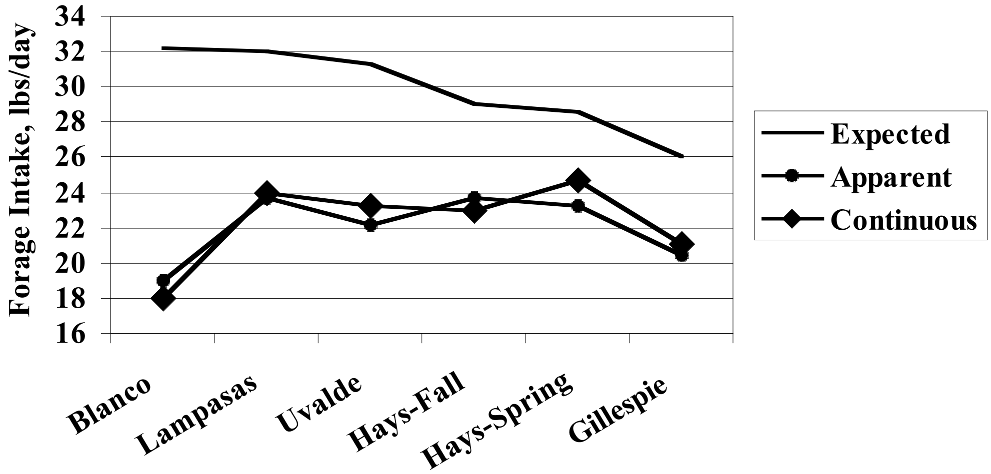

Figure 3. Expected forage intake differed ($P < 0.0001$) among the five study ranches. Apparent forage intake tended ($P = 0.1367$) to differ among ranches.

Table 1. Average deviation of apparent forage intake from expected forage intake among the five study ranches and six herds.

Ranch	Observations	Average Deviation, lbs/day	SEM[1]
Blanco	7	-13.2	1.67
Gillespie	22	-5.6	0.95
Hays-Fall	35	-5.3	0.94
Hays-Spring	35	-5.3	0.94
Lampasas	12	-8.2	1.35
Uvalde	22	-9.1	1.35

[1]SEM = standard error of the mean.

ANALYZING BEEF CATTLE RANGE PASTURE-USE WITH GPS/GIS TECHNOLOGY

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Summary

On each ranch studied, grazing distribution was uneven. Reasons for grazing distribution problems differed among ranches. Rock was a major deterrent on Edwards Plateau Ranch 1. On Edwards Plateau Ranch 2, slope, rock, and brush density may have been factors. On the Rio Grande Plain Ranch, brush cover, brush density, and brush motte size appear to be major barriers to grazing. However, even where brush was substantially suppressed, grazing was not uniform due to apparent forage preferences. Controlling water access is a potential tool for improving grazing distribution by attracting animals to less preferred areas.

Introduction

Uneven grazing distribution impacts effective stocking rates by reducing grazeable acres. Undetected or uncorrected, these problems increase grazing pressure on areas that are used.

Living factors affecting grazing distribution include plant species, forage quantity, forage quality and/or palatability, shade, shelter, animal behavior, insect pests, predators, and human activity among others. Non-living factors include weather, soil, topography, water, salt, mineral and other feed supplements, and fencing, as well as others. The greater the differences among areas the more likely animals are to concentrate on some areas and avoid others.

Problems such as water distribution may be easily identified, but not easily corrected. Other distribution problems such as forage preferences or human activities may not be easily identifiable. The purpose of these studies was to characterize pasture use and investigate reasons for use and non-use of different areas as well as to explore the effect of controlling access to water on grazing distribution patterns of cows.

Experimental Procedures

From 1999 through 2004, using mature cows fitted with GPS collars, trials were conducted on three different ranches in the Edwards Plateau and one in the Rio Grande Plains. Depending on GPS-collar availability, from 4 to 6 mature cows that were either raised on the study ranches or had been residents for several years were fitted with Lotek 2000 or 2200 GPS collars capable of estimating the position of each animal within 5 to 10 yards of their actual location after differential correction. In early trials with limited collar data storage, GPS position fixes were taken every 15 minutes for 6 days. In later trials, using collars with more data storage capacity, position fixes were taken every 5 minutes for 17 days. On Edwards Plateau Ranch 1, ten 6-day trials were conducted from 1999 to 2000 in spring- and fall-calving herds in separate management units. On Edwards Plateau Ranch 2, one 17-day trial was conducted in 2003. On Edwards Plateau Ranch 3, one 10-day trial was conducted in 2004. On a Rio Grande Plain Ranch, three 17-day trials were conducted in 2003.

To determine the influence of access to water on grazing distribution, data were collected during an 10-day trial on Edwards Plateau Ranch 1. During the first two days of the trial, cows had access to water at both ends of the pasture. Then, water was turned off at the south end of the pasture and left on at the north end for a 4-day period, two days for cows to adjust to the change with collars turned off and two days with collars turned on for data collection. Water was then turned off at the north end of the pasture and turned on at the south end for another 4-day period, two days for cows to adjust to the change with collars turned off and two days with collars turned on for data collection.

GPS position fixes were differentially corrected and projected on digital aerial photographs of the ranches using Arc View GIS software. Pasture fences were drawn on photos. Soils or range site maps were also projected on digital aerial photos. Arc View was used to 1) determine total number of position fixes and fixes per acre within pastures and soil types or range sites and 2) determine percent use of pastures and/or soil types or range sites. Ranch range sites are presented in Table 1.

Once GPS points were mapped, areas of use and nonuse were ground truthed to help determine field data collection methods needed to determine reasons for use or nonuse. Field data collected included brush density, rock cover, and herbaceous species composition. Distance to water and brush cover were estimated with Arc View from digital aerial photographs of ranches.

The Edwards Plateau Ranch 3 trial tested cow-use patterns related to findings on other ranches. Forty transects were established to estimate pasture characteristics including percent rock cover and brush density scores (0 = no brush, 5 = impenetrable). From transects, areas of varying rock cover and brush density were identified and the number of GPS locations for rock cover and brush density locations was determined.

Results and Discussion

Edwards Plateau Ranch 1

About 98 percent of this ranch is either Rumple-Comfort or Comfort Rock soil type. Within the Rumple-Comfort soil, there are two range sites, Gravelly Redland and Low Stony Hill. Comfort Rock soil is within a Low Stony Hill range site. These range sites are characterized in Table 1. Results from this ranch are presented by soil type because Rumple-Comfort soil range sites are not separated on soils maps.

Fall-calving and spring-calving cows were found in the Rumple-Comfort soil type 3 times more than in the Comfort Rock soil type ($P < 0.01$). Furthermore, some areas within the Rumple-Comfort soil were favored over the total area occupied by this soil type. For example, in one trial, Rumple-Comfort map Sites 3 and 4 accounted for 38% of total position fixes and 50% of Rumple-Comfort position fixes (Figure 1). These map sites made up about 9% of available pasture area during this trial. In a second trial, map Site 4 alone accounted for 48% of total position fixes and 80% of fixes within the Rumple-Comfort soil and made up about 12% of available pasture area.

Regarding grazeable acres, within the spring-calving management unit, cows used about 34 perecent of the Rumple-Comfort soil area compared to 17 percent of the Comfort soil area. Cows in the fall-calving management unit used 17 and 7 percent of the Rumple-Comfort and Comfort soil areas, respectively.

Over the range of rock cover (almost zero to 48 percent), rock cover was the only important variable of those considered (rock cover, density (plants/acre), and distance to water). Rock cover explained 63 percent of the variation in cow use (Figure 2). Essentially no use occurred above 30 percent rock cover.

Edwards Plateau Ranch 1 Water Access

With water available at both ends of the study pasture, cows used the Rumple-Comfort soil type more. With water available only at the north end of the pasture (Figure 3), cows showed a definite preference for the Rumple-Comfort soil type. When water was available only at the south end of the pasture (Figure 4) cows showed a lower preference, although not eliminated, for the Rumple-Comfort soil located mostly in the north end of the pasture.

These results indicate that access to water can be used to draw cows into non-preferred areas. Low-preference areas need to be between preferred areas and water to attract cows to them. Moving cattle (changing grazing distribution) with access to water is not as simple as turning water on and off. Other considerations exist.

Edwards Plateau Ranch 2

One trial was conducted on this ranch in a 794 acre pasture. Range sites in this pasture are characterized in Table 1. About 61 percent of GPS points occurred within the Redland range site, which made up only 25 percent of the pasture (Table 2). Although ground truthing was not conducted in this pasture, possible reasons for differences in range site preference include slopes in the Steep Adobe site, brush density in the Clay Loam site, and rocky soil surfaces in the Low Stony Hill site.

Rio Grand Plain Ranch

About 86 percent of this ranch is in three range sites, Sandy Loam (57%), Clay Loam (17%), and Gray Sandy Loam (12%). About 70 percent of position fixes were located in the Sandy Loam range site compared to about 15 percent in the Clay Loam site. Across all trials and pastures, the Sandy Loam site had about 1.5 and 1.7 times as many position fixes per acre as the Clay Loam and Gray sandy Loam sites, respectively.

Brush cover was negatively correlated with GPS position fixes per acre with correlations ranging from -0.59 to -0.92 in the Sandy Loam site, and from -0.40 to -0.85 in the Clay Loam site. Average brush cover was 32 percent in Sandy Loam sites and 69 percent in Clay Loam sites. Only in pastures where brush cover was less than 10 percent was apparent percent of grazed area above 70 percent (Table 3). Where brush cover ranged from about 39 to 67 percent, apparent grazeable acres varied from 10 to 59 percent. Pasture S4 apparent grazeable acres was about 12 percent (Table 3). As they enter this pasture, cows are confronted with a large area of dense brush that may discourage use. In comparison, pastures S5 and S6 have about the same amount of total brush cover but had apparent use levels above 50 percent. These pastures are relatively open for the first 0.5 to 0.75 miles into the pasture from the water source

Seven sets of paired transects were established within grazed pastures, located in adjacent grazed and ungrazed areas. Brush density along these transects was scored on a scale of 0 (no brush) to 5 (impenetrable brush). Average brush density scores were 3.7 for ungrazed transects and 1.2 for grazed (P < 0.05). Cows appear to have avoided areas with brush density scores greater than 3.

Herbaceous plant species frequencies were also recorded along these paired transects. Average frequency of dominant grass species on grazed transects was 34 percent compared to 7 percent (P < 0.05) for the same species on ungrazed transects. Six grass species accounted for more than 30% composition on grazed transects while only one grass, threeawn, occurred at greater than 30 percent along ungrazed transects.

Within a 27-acre Texas-shaped area in one pasture where brush had been suppressed with mechanical and herbicide treatments, position fixes per acre were 4 times greater for the two range sites within this treated area than in the same range sites in the rest of the pasture (Figure 5). Even though brush was suppressed, grazing distribution was not uniform, apparently due in part to differences in herbaceous species composition between adjacent grazed and ungrazed areas.

Edwards Plateau Ranch 3

The study pasture on this ranch was predominated by Gravelly Redland and Low Stony Hill range sites. The Gravelly Redland site was preferred by a 2.5 to 1 ratio over the Low Stony Hill site, which was similar to the ratio found for the soils associated with these same range sites on Edwards Plateau Ranch 1. Forty-five segments of transects used to characterize this pasture were identified with rock cover varying from 0 to 45%. Above 28% rock cover, 88% of these transect segments had no occurrence of GPS position fixes. Forty-six transect segments with brush density scores from 0 to 5 were identified. For these segments, occurrence of GPS fixes declined as brush density increased (Table 4) with no position fixes above a brush density score of 4, which is similar to the finding on the Rio Grande Plain ranch.

Implications

All study ranches had grazing distribution problems. Some problems like water and brush density can potentially be eliminated. Others like rock cover and forage preferences cannot be eliminated, but must be accounted for through management such as appropriate stocking rates. For example, some areas with heavy brush densities that also have heavy rock cover are best suited to other kinds of livestock or for wildlife habitat rather than clearing for cattle use. Understanding these grazing distribution factors and including this kind of information in management plans can avoid expensive mistakes and potentially reduce overuse of preferred areas.

Table 1. Range sites and descriptions for study ranches.

Region	Range Site	Soil	Slope, %
Edwards Plateau	Clay Loam	moderately deep to deep, fertile, can store large amounts water	0 - 8
	Gravelly Redland	moderately deep, 20-30 inches, gravelly upland clayey soils over hard, fractured limestone	3 - 12
	Low Stony Hill	shallow calcareous clays underlain w/ hard limestone up to 50% surface w/ hard limestone	0 - 8
	Redland	shallow, brown/reddish-brown fertile clays & clay loams underlain w/ fractured limestone at 20 inches or less, limestone fragments often on surface	0 - 5
	Steep Adobe	shallow, usually, gravelly, light-colored loams & clay loams over limestone, strongly calcareous	3 - 30
Rio Grande Plain	Sandy Loam	deep noncalcareaous fine sandy loam surface, sandy clay subsoil	0 - 5
	Lakebed	surfaces plane & depressional, may catch water from surrounding areas	< 1
	Clay Loam	deep soil w/ calcareous or noncalcareous clay loam, sandy clay loam, or silty clay loam, high fertility & water holding capacity	< 3
	Gray Sandy Loam	deep w/ calcareous fine sandy loam or sandy clay loam surface	< 2

Table 2. Edwards Plateau Ranch 2 range site and pasture use.

Range Site	Percent of Total GPS Points	Range Site Percent of Pasture Acres	Percent of Range Site Acres Used	GPS Points/acre
Clay Loam	2	4	28	16
Low Stony Hill	3	4	33	20
Redland	61	25	73	61
Steep Adobe	34	67	44	13

Table 3. Rio Grande Plain Ranch pasture brush cover and grazeable acres.

Pasture	Brush Cover, %	Apparent Percent of Pasture Grazed by Trial		
		January	May	August
Buffel	10	71	85	-
C	0	-	-	86
North Chain	39	51	-	-
South Chain	59	49	-	-
S1S2	67	-	30	15
S3	59	-	10	13
S4	59	-	28	34
S5	58	-	-	59
S6	56	-	-	56

Table 4. Edwards Plateau Ranch 3 occurrence of cow-use within transects segments associated with varying amounts of rock cover and different brush density scores[1] indicated by GPS position fixes of cattle with GPS collars.

Pasture Measurement	GPS Position Fix Occurrence within Transect Segments, %
Rock cover, %	
< 28	68
> 28	12
Brush density score	
< 1	81
< 2	73
> 3	25
> 4	0

[1]Brush density score, 0 = no brush to 5 = impenetrable.

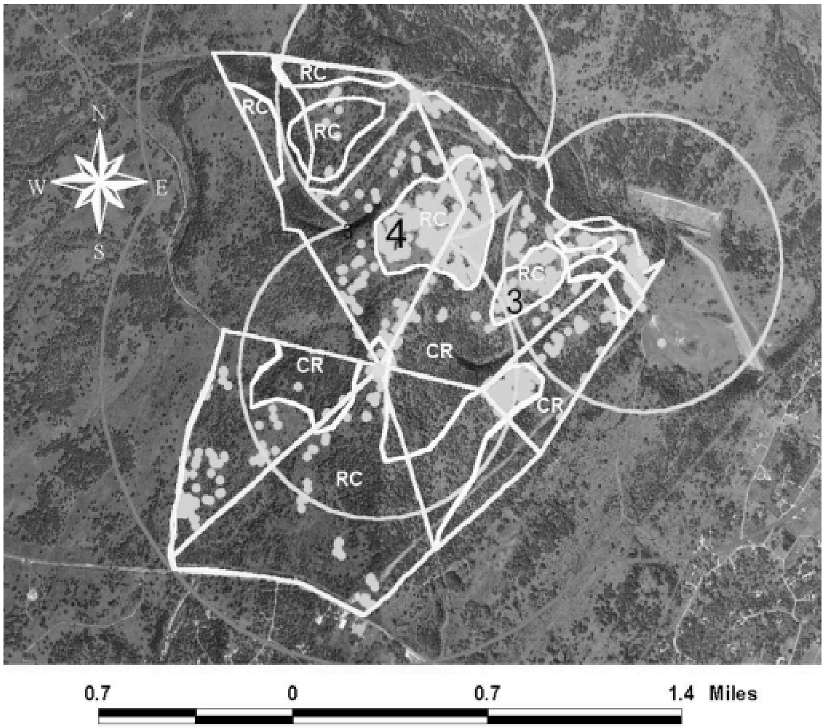

Figure 1. Dots indicate April trial GPS fixes. Map sites 3 and 4 made up 12% of the area available to cows, but had 38% of the total GPS fixes and 50% of the Rumple-Comfort (RC) fixes.

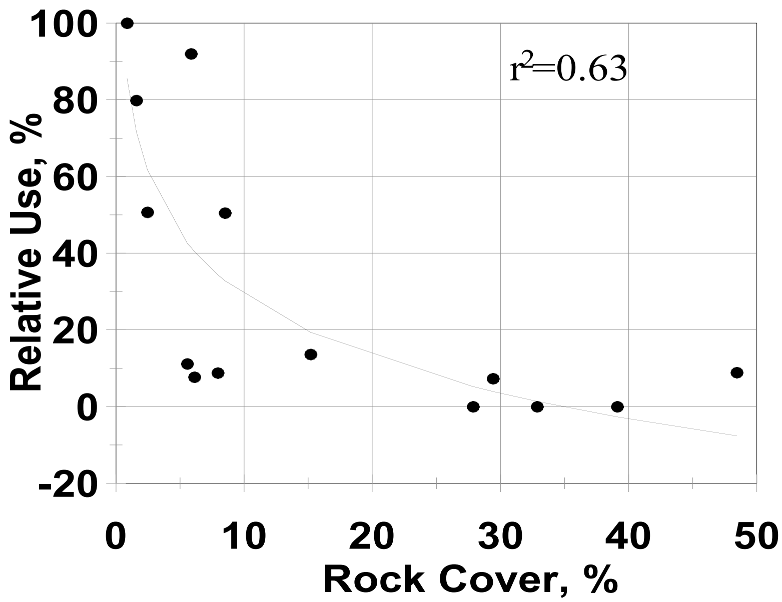

Figure 2. Relationship between rock cover and cow use on Edwards Plateau Ranch 1.

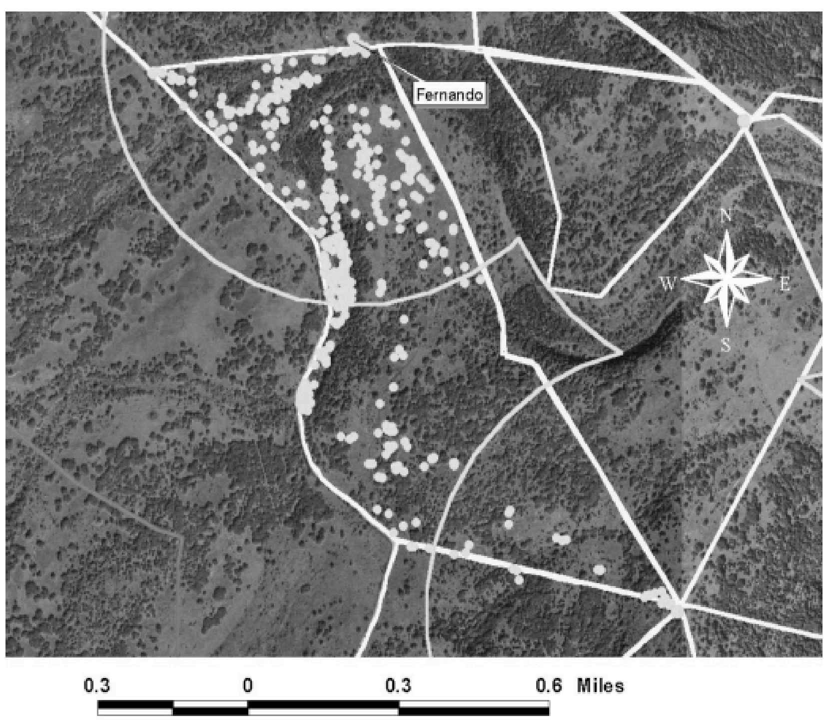

Figure 3. Dots indicate cattle distribution with water available only at north end of pasture near the preferred Rumple-Comfort soil. There was a 3.8 to 1 preference for the Rumple-Comfort soil over the Comfort Rock soil based on GPS location fixes per acre.

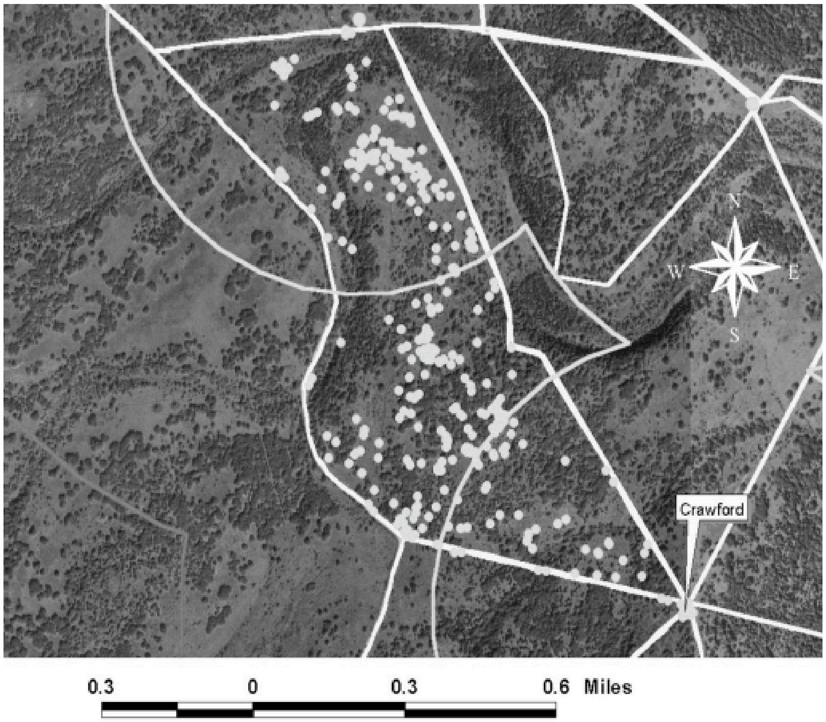

Figure 4. Dots indicate cattle distribution with water available only at south end of pasture near the less preferred Comfort Rock soil. Preference for the Rumple-Comfort soil was reduced but not eliminated as indicated by a 1.9 to 1 preference ratio for the Rumple-Comfort soil over the Comfort Rock soil compared to the 3.8 to 1 preference ratio with water available only at the north end of the pasture.

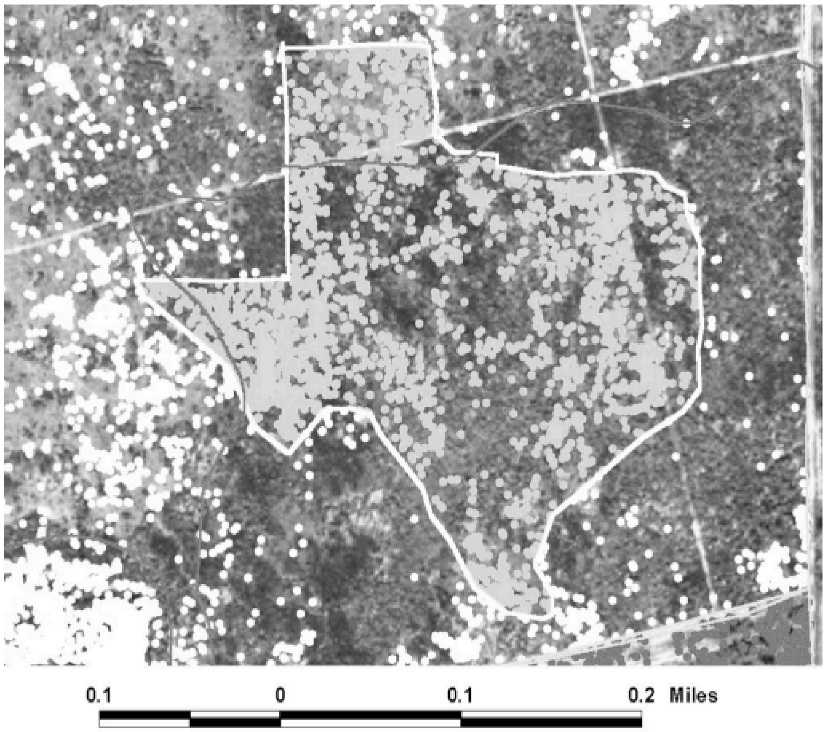

Figure 5. Brush was suppressed inside Texas outline on the Rio Grande Plain Ranch. Dots indicate GPS positions. GPS points per acre were 4 times greater in treated Sandy Loam and Gray Sandy Loam than in the same untreated sites within the same pasture.

Reproduction

PRODUCTION TRAITS DIFFER IN DIFFERENT BREEDTYPES OF SUCKLED BEEF COWS

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Summary

Mature Brahman (B) and Romosinuano (R) crossbred cows grazing high quality rye-ryegrass pasture receiving 2 lb·hd^{-1}d^{-1} of 4:1 corn:soybean meal ration differed in postpartum production traits. R cows with Simmental-sired calves (SXR) weaned heavier calves whereas B cows with Angus-sired calves (AXB) had higher ADG than both SXR and straightbred Brahman (BXB) calves. Additionally, B cows had shorter PPI and less time to conception than R cows. Although the two breedtypes had similar milk production, its impact on calf production differed by breedtype. Specifically, level of milk production affected calf ADG, weaning weight, and BCS at weaning in SXR calves whereas little effect occurred in calves of B cows. B low milk producers required more time to resume estrous cyclicity, took more time to conceive, but required fewer services per conception than cows that were higher milk producers. R cows had no differences between levels of milk production for PPI; however, moderate milk producers required less time to conceive and had a better first service conception rate than the other cows. High producing R cows also required fewer services per conception than the other cows.

Introduction

Profitability of a cow-calf operation arises from pounds of calf weaned and ability of cows to produce a calf every year. This requires cows to wean heavy calves and become bred within 80 days of calving. During the early postpartum period cows prioritize nutrients to milk production and maintenance of body condition before energy is used to resume estrous cyclicity. Thus, level of milk production can have a profound impact not only on calf productivity, but also the length of time required to resume estrous cyclicity and subsequent reproductive performance. It has been previously been documented that milk production impacts calf ADG and weaning weight (Reynolds et al., 1978; Clutter and Nielson, 1987) and length of postpartum interval (Beal et al., 1990; Lalman et al., 2000), but the effect of milk production on postpartum reproductive efficiency in suckled beef cows has not been well investigated. The objective of this study was to determine the affect of milk production and breedtype on postpartum production traits in mature Brahman and Romosinuano crossbred cows.

Experimental Procedures

The effect of milk production on postpartum productivity was studied in suckled Brahman (B) cows with Angus-sired (AXB, n = 8) and Brahman-sired calves (BXB, n = 36) and Romosinuano crossbred (R) cows with Simmental-sired calves (SXR, n = 39). Within 24 hours after calving cows were weighed, body condition scored (BCS), blood samples collected via caudal venipuncture, calves identified and weighed. The pairs were maintained in dry-lot pens for the first week after calving and then moved to pasture for the remainder of the trial. While in pens the diet consisted of free choice Coastal bermudagrass hay and 3:1 corn:soybean meal supplement (4 lb·hd^{-1}d^{-1}). Once moved to rye-ryegrass pasture the diets included a 4:1 corn:soybean meal supplement (2 lb·hd^{-1}d^{-1}).

Four hour milk production was assessed between day 26 and 28 post-calving. The cows were initially milked out by administering oxytocin intravenously and hand milking. Cows and calves were then housed separately for 4 hours until the milking process was repeated with oxytocin and hand milking. The milk was then weighed to determine total quantity produced. Cow and calf body weight, cow body condition score, and cow blood samples were also obtained at milking. Cows were classified as moderate producers if milk production was within 0.5 standard deviation of the mean for their breedtype and as low producers if they produced more than 0.5 standard deviation less than the mean or high if they produced more than 0.5 standard deviation greater than the mean for their breedtype.

Once on pasture, cows were maintained with sterile bulls equipped with chinball marking harnesses for estrus detection until the end of a 45-d AI season. Cows were randomly assigned to

AI technician based on age, breed, and sex of calf. Semen from a single ejaculate from one bull was used for AI within breeds. Brahman cows were inseminated with semen from a Brahman bull and the Romosinuano crossbred cows were inseminated with semen from an Angus bull. Heat check was performed a minimum of twice daily to ensure that insemination would occur 12 hours after standing heat first occurred. Following the AI season, fertile bulls with chinball marking harnesses were placed with the cows for a 28-d cleanup breeding season. A mature Brahman bull was placed with the Brahman cows and two Angus bulls were placed with the Romosinuano crossbred cows. Cows were then checked daily to record natural service breeding dates.

From calving through the 45-d AI season, cows and calves were weighed and cow BCS was assessed on a weekly basis. Cow blood samples, collected by caudal venipuncture, were also obtained weekly. Upon the completion of the AI season, calf and cow weights and cow BCB were recorded at 28-d intervals until weaning. Any cows that did not exhibit estrus by the end of the AI season continued with the weekly bleeding regimen for at least one week after estrus had been detected. Pregnancy was determined by rectal palpation on days 35 and 58 following the AI breeding season and again at weaning.

To confirm estrus data obtained by the use of bulls and to verify ovarian function, the blood samples were assayed for progesterone concentration via radioimmunoassay (Williams, 1989). Progesterone concentrations greater than 1 ng/ml were considered indicative of a functional corpus luteum. Postpartum interval was then determined relative to estrus associated with formation of a functional corpus luteum. The blood samples from calving through day 45 were also assayed to quantify the nutritional status of the cow by measuring circulating concentrations of IGF-I by radioimmunoassay (Strauch et al, 2003).

Results and Discussion

Calf Productivity

Milk production was correlated to calf ADG in R ($r = 0.56$, $P = 0.001$) and B cows with BXB calves ($r = 0.46$, $P = 0.05$), but not B cows with AXB calves. Within R, low milk producers had lower calf ADG than moderate milk producers ($P = 0.008$) and high milk producers ($P = 0.004$, Table 1). Although low milk producers tended to have calf ADG lower than moderate and high milk producers, level of milk production in B cows did not affect calf ADG. The AXB calves had higher ADG than the BXB calves ($P = 0.004$) and SXR calves ($P = 0.0002$); however, the B and R calves did not differ (Table 2). Sex of calf had no impact on calf ADG within any of the breeds.

Calf weaning weight was significantly correlated to milk production in R ($r = 0.49$, $P = 0.006$), but not B. Level of milk production in B cows did not affect weaning weight in either the Angus-sired or Brahman-sired calves. However, R low milk producers had calves with lower weaning weights than moderate milk producers ($P = 0.04$) and high milk producers ($P = 0.03$, Table 1). SXR calves were heavier at weaning than the BXB calves ($P = 0.005$), but not the AXB calves (Table 2). Weaning weights did not differ between the Angus-sired and Brahman-sired calves. Sex of calf had no impact on weaning weight within any of the breeds.

Milk production tended to be correlated to calf BCS at weaning in R ($r = 0.32$, $P = 0.08$), but not in B. Level of milk production in B cows did not affect calf BCS at weaning, but within R low milk producers had lower calf BCS than moderate milk producers ($P = 0.007$, Table 1). R high and low milk producers did not differ between BCS of calves at weaning. Calf BCS at weaning did not differ between the breedtypes (Table 2) and sex of calf did not affect calf BCS at weaning.

Cow Productivity

Though R cows produced more milk than B, the difference was not significant (Table 3). Milk production was negatively correlated with PPI in B ($r = -0.43$, $P = 0.03$), but not R. Within B, low milk producers took longer to resume estrous cyclicity than high milk producers ($P = 0.008$), and tended to take longer than moderate milk producers ($P = 0.09$, Table 4). Level of milk production had no effect on PPI within R. Overall, R cows took longer to resume estrous cyclicity than B cows ($P = 0.01$, Table 3).

R tended to have a negative correlation between days to conception and milk production ($r = -0.34$, $P = 0.08$), but not B. High milk producers tended to take fewer days from calving to conception than low and moderate milk producers within B ($P = 0.07$). Additionally, moderate milk producers within R tended to take fewer days from calving to conception than low milk producers ($P = 0.07$, Table 4). Overall, R cows took more days to conception than B cows ($P < 0.001$, Table 3).

The number of services per conception was correlated to milk production in B (r = 0.44, P = 0.03), but not R cows. B cows with lower milk production required fewer services per conception than moderate (P = 0.007) and high (P = 0.01) milk producers (Table 4). R high milk producers required numerically fewer services per conception than moderate and low milk producers but the difference was not significant. There was no difference in the number of services per conception between B and R cows (Table 3).

Milk production tended to be correlated to first service conception rate in R (r = 0.33, P = 0.08), but not B cows. Moderate milk producers had higher first service conception rates than low milk producers in the R cows (P = 0.01, Table 4). There was no difference in first service conception rates for the B cows. First service conception rates did not differ between the breeds (Table 3).

Cow ADG from calving until weaning did not differ between the breeds (Table 3). Level of milk production had no effect on cow ADG. Level of milk production also had no effect on change in BCS from calving until weaning. The breeds, however, did differ in change in BCS with R cows increasing BCS from calving until weaning whereas B cows experienced a decrease in BCS (P < 0.001, Table 3). Circulating IGF-I concentrations at calving did not differ between the breeds, nor were they indicative of level of milk production in B and R cows.

The specific goals of the cow-calf producer dictate what breedtype and level of milk production within breedtype are appropriate to that operation as these factors greatly affect productivity of cows and calves. Although milk production did not differ between R and B cows, the level of milk production did affect postpartum productivity differently between breedtypes. Milk production altered calf ADG, weaning weight, and BCS at weaning in R calves whereas little effect occurred in calves of B cows. Also, effect of level of milk production on cow productivity differed between the breedtypes. B low milk producers required more time to resume estrous cyclicity, took more time to conceive, but required fewer services per conception than cows that were higher milk producers. R cows had no differences between levels of milk production for PPI; however, moderate milk producers required less time to conceive and had better first service conception rate than the other cows. High producing R cows also required fewer services per conception than the other cows. Comparing overall productivity of the two breeds, SXR calves weaned heavier than Brahman-sired calves. However, the AXB-sired calves had higher ADG than SXR and BXB calves. Also, B cows had shorter PPI and fewer days to conception than R cows.

Implications

Understanding the effect of level of milk production on postpartum productivity for different breedtypes can enable cow-calf producers to better select breedtypes and levels of milk production that best suit production goals. Additionally, this knowledge will allow for better management of cows during the postpartum period to optimize productivity of both cows and calves.

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Table 1. Effect of level of milk production on calf productivity

	AngusXBrahman (n = 8)			BrahmanXBrahman (n = 36)			SimmentalXRomosinuano (n = 39)		
Variable	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
ADG, lb/d	2.21 ± 0.15	2.14 ± 0.16	2.05 ± -	1.76 ± 0.08	1.97 ± 0.04	1.95 ± 0.04	1.65 ± 0.08 [a]	1.90 ± 0.04 [b]	1.95 ± 0.04 [b]
Wean BCS	5.33 ± 0.33	5.25 ± 0.25	5.00 ± -	5.50 ± 0.29	5.50 ± 0.19	5.71 ± 0.24	5.11 ± 0.16 [a]	5.58 ± 0.10 [b]	5.38 ± 0.16 [a,b]
Wean Wt, lb	459.00 ± 27.50	494.50 ± 6.50	453.00 ± -	411.25 ± 16.16	455.38 ± 11.28	429.29 ± 17.11	438.11 ± 19.71 [a]	488.85 ± 9.45 [b]	496.75 ± 14.66 [b]

[a,b] Means in the same row, within breedtype, followed by the same letter do not differ (P < 0.05)

Table 2. Effect of breedtype on calf productivity

Variable	Angus X Brahman (n = 8)	Brahman X Brahman (n = 36)	Simmental XRomosinuano (n = 39)
ADG, lb/d	2.10 + 0.08 [a]	1.90 + 0.03 [b]	1.86 + 0.03 [b]
Wean BCS	5.32 + 0.23	5.46 + 0.09	5.45 + 0.07
Wean Wt	454.12 + 15.26 [a,b]	417.28 + 6.94 [a]	471.67 + 9.95 [b]

[a,b] Means in the same row followed by the same letter do not differ ($P < 0.05$)

Table 3. Effect of breedtype on postpartum cow productivity

Variable	Brahman (n = 44)	Romosinuano crossbred (n = 39)
Milk production, lbs	2.80 ± 0.14	3.01 ± 0.12
PPI, d	69.64 ± 4.85 [a]	84.20 ± 3.33 [a]
Days to conception	84.35 ± 3.47 [b]	104.36 ± 3.31 [b]
Services/conception	1.08 ± 0.11	0.93 ± 0.10
First service conception rate, %	72.00 ± 9.17	73.33 ± 8.21
BCS change	0.02 ± 0.12 [b]	0.83 ± 0.16 [b]
Calving IGF-I, ng/ml	58.68 ± 5.10	64.50 ± 4.68

[a] $P < 0.01$, [b] $P < 0.001$

Table 4. Effect of the level of milk production on cow reproductive function

	Brahman (n = 44)			Romosinuano crossbred (n = 39)		
Variable	Low	Moderate	High	Low	Moderate	High
PPI, d	87.71 ± 9.07 [a]	69.00 ± 7.04 [a,b]	54.63 ± 6.15 [b]	83.22 ± 3.33	81.38 ± 4.05	89.88 ± 7.63
Days to conception	89.35 ± 2.58 [a]	90.30 ± 6.27 [a]	73.50 ± 4.18 [b]	115.75 ± 6.47	98.00 ± 4.40	103.14 ± 5.63
Services/conception	0.57 ± 0.20 [a]	1.30 ± 0.15 [b]	1.25 ± 0.16 [b]	1.11 ± 0.26	0.92 ± 0.08	0.75 ± 0.16
First service conception rate, %	57.14 ± 20.20	60.00 ± 16.33	100.00 ± 0.00	44.44 ± 17.57 [a,b]	92.31 ± 7.69 [c]	75.00 ± 16.37 [b,c]

[a,b] Means in the same row, within breedtype, followed by the same letter do not differ ($P < 0.05$)

POSTPARTUM PRODUCTIVITY OF SUCKLED BEEF COWS SUPPLEMENTED WITH THE FIBROLYTIC ENZYME CATTLE-ASE™

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Summary

Mature cows grazing high quality rye-ryegrass pasture receiving 2 $lb \cdot hd^{-1}d^{-1}$ of 4:1 corn:soybean meal ration have similar BW, ADG, and BCS during the postpartum period as cows receiving the same pasture and ration plus Cattle-Ase™. Calves of these cows differed in body weights as a result of breedtype and sex, but not Cattle-Ase™ supplementation. Cattle-Ase™ supplementation did improve Brahman cow BCS and ADG, and straightbred Brahman calf ADG through the end of supplementation. Improvements, however, diminished after supplementation ended. Although Cattle-Ase™ did improve some parameters of postpartum productivity, it was not effective at improving efficiency of postpartum reproduction. This lack of response limits the usefulness of Cattle-Ase™ for cow/calf operations.

Introduction

Maintaining cows on a yearly calving interval is critical to the economic success of a cow-calf operation. As such, cows have only 80 days to recover from pregnancy, resume estrous cyclicity, and conceive. During the early postpartum period cows prioritize nutrients to milk production and maintaining body condition before energy is used to resume estrous cyclicity. Thus, plane of nutrition can not only impact calf performance and cow body condition, but it can also greatly impact the length of time required to resume estrous cyclicity and subsequent reproductive performance. Fibrolytic enzymes, such as Cattle-Ase™, have been shown to increase feed digestibility (Feng, et al., 1996; Beauchemin et al., 2003), improve ADG, feed:gain ratio, and nitrogen retention in steers (Richardson et al., 1998), increase milk production in dairy cows (Lewis et al., 1999; Zheng et al., 2000), and decrease age at puberty in heifers (Strauch et al., 2003a). To date the influence of fibrolytic enzyme supplementation on postpartum productivity has not been investigated.

Experimental Procedures

The effect of Cattle-Ase™ (Loveland Industries Inc., Greeley, CO) supplementation on postpartum productivity was studied in suckled multiparous Brahman (B) cows with Angus sired (AXB, n = 8) and Brahman sired calves (BXB, n = 36) and Romosinuano crossbred (R) cows with Simmental sired calves (SXR, n = 39). Within 24 hours after calving cows were weighed, body condition scored (BCS), blood samples collected via caudal venipuncture, calves identified and weighed, and the cow-calf pair randomly allotted based on breed, sex of calf, and age of cow to either a control (C) or Cattle-Ase™ (ASE) ration. The pairs were maintained in dry-lot pens for the first week after calving and then moved to pasture for the remainder of the trial. While in pens the diet consisted of free choice Coastal bermudagrass hay and 3:1 corn:soybean meal supplement (4 $lb \cdot hd^{-1}d^{-1}$). Once moved to rye-ryegrass pasture the diets included a 4:1 corn:soybean meal supplement (2 $lb \cdot hd^{-1}d^{-1}$). Cattle-Ase™ was supplemented at a rate of 2.5 g/hd/d and was added to the corn:soybean meal supplement while in pens and on pasture. The treatment groups were rotated between pastures weekly to minimize any differences due to pasture variables.

Once on pasture, cows were maintained with sterile bulls equipped with chinball marking harnesses for estrus detection until the end of a 45-d AI season. Cows were randomly assigned to AI technician based on treatment group, age, breed, and sex of calf. Semen from a single ejaculate from one bull was used for AI within breeds. Brahman cows were inseminated with semen from a Brahman bull and the Romosinuano crossbred cows were inseminated with semen from an Angus bull. Heat check was performed a minimum of twice daily to ensure that insemination would occur 12 hours after standing heat first occurred. Following the AI season, fertile bulls with chinball marking harnesses were placed with cows for a 28-d cleanup breeding season. A mature Brahman bull was placed with the Brahman cows, and two Angus bulls were placed with the Romosinuano crossbred cows. Cows were then checked daily to record natural service breeding dates.

From calving through the 45-d AI season, cow and calves were weighed and cow BCS assessed on a weekly basis. Cow blood samples collected by caudal venipuncture were also obtained on a weekly basis. Upon the completion of the AI season, calf and cow weights and cow body condition scores were recorded at 28-d intervals until weaning. Any cows that did not exhibit estrus by the end of the AI season continued with the weekly bleeding regimen for at least one week after estrus had been detected. Pregnancy was determined by rectal palpation on days 35 and 58 following the AI breeding season and again at weaning.

To confirm estrus data obtained by the use of bulls and to verify ovarian function, the blood samples were assayed for progesterone concentration via radioimmunoassay as described by Williams (1989). Progesterone concentrations greater than 1 ng/ml were considered indicative of a functional corpus luteum. Postpartum interval was then determined relative to estrus associated with formation of a functional corpus luteum. The blood samples from calving through day 45 were also assayed to quantify the nutritional status of the cow by measuring circulating concentrations of IGF-I by radioimmunoassay (Strauch et al., 2003b).

Results and Discussion

Cow Body Weight and Body Condition Score

Cow body weight was not different among the treatment groups at calving, end of supplementation, or at weaning in either B or R. ASE increased cow ADG through the end of supplementation in B ($P < 0.01$), but not R (Table 1). Cow ADG until weaning was not affected by treatment in either breed, nor did it differ between the breeds. Cow BCS at calving and end of supplementation were not different among treatment groups for either B or R. At weaning B cows supplemented with ASE had lower BCS than C ($P < 0.01$), but no difference in BCS at weaning occurred within R (Table 1). B BCS change to the end of supplementation tended to be greater ($P = 0.06$) in ASE compared to C, but no treatment affect occurred within R (Table 1). Although BCS in both breeds increased from calving to end of supplementation, R BCS increased more than B ($P < 0.001$). BCS change until weaning was not affected by treatment in either B or R. R cows had an overall gain in BCS from calving to weaning whereas B cows had an overall decrease in BCS, causing the overall magnitude of BCS change between the breeds to be significant ($P < 0.01$). Similar to results reported by Richardson and Titi (1998), ASE supplementation improved ADG and BCS through the end of supplementation in the B cows. This improvement, however, diminished after cessation of supplementation as cow BCS at weaning was lower in cows that had received ASE. The effect of ASE differs between breedtypes as the R cows did not experience any improvement in weight, BCS, or ADG from supplementation. It can be postulated that the R cows naturally utilize the high quality forages more efficiently than the B cows thereby limiting the beneficial affects that may be gained by ASE supplementation. This can be supported by the improvement in BCS in R compared to the slight decrease in BCS seen in B cows though both breedtypes were maintained on the same pastures.

Calf Weight and Average Daily Gain

Calf birth weight, weight at end of supplementation, and weaning weight did not differ among treatments for BXB or SXR (Table 3). Calf weight at end of supplementation and at weaning also did not differ among treatments for AXB. Calf birth weight, however, was greater in AXB males for the ASE treatment ($P = 0.08$) and females for the C treatment ($P = 0.006$). Calf breedtype, however, did affect calf weight at birth, end of supplementation, and at weaning (Table 4). At birth and end of supplementation, SXR calves were heavier ($P < 0.01$). At weaning, SXR calves still were heavier than BXB calves ($P < 0.01$), and AXB calves tended to be heavier than BXB calves ($P = 0.08$). Sex of the calf did not influence birth weight in BXB, but it did affect birth weight in AXB and SXR ($P < 0.05$ and $P < 0.01$, respectively). Calf weight at the end of supplementation and at weaning did not differ between sexes within the breedtypes. Treatment did not affect calf ADG to the end of supplementation or weaning in AXB or SXR, but ASE supplementation increased ADG through the end of supplementation in both male and female BXB calves ($P = 0.005$ and $P = 0.05$, respectively, Table 3). AXB tended to have higher ADG through the end of supplementation than BXB ($P = 0.07$), but not SXR(Table 4). AXB did have higher ADG through weaning than BXB ($P = 0.008$) and SXR ($P = 0.001$). Although most of the differences among the calves for weight and ADG were the result of sex and breedtype, ASE supplementation did improve calf ADG through the end of supplementation in the BXB calves.

Reproductive Traits

Postpartum interval was not affected by treatment, but R required more time to resume estrous cyclicity than B (P < 0.01, Table 2). First service conception rate tended to differ between AI technicians (P = 0.09). ASE supplementation did not affect first service conception rate (Table 1), nor did breedtype affect first service conception rate. The number of services per conception did not differ among treatments or between breeds. The number of days to conception was not affected by treatment, but B conceived earlier post-calving than R (P < 0.01, Table 2).

ASE supplementation did not improve postpartum reproduction in either breed. The B cows; however, were more efficient at resuming estrous cyclicity and being bred earlier in the postpartum interval than R. This may be the result of differences in the prioritization of nutrients between the two breeds. It can be suggested that the B cows shunt extra nutrients to the resumption of postpartum reproductive function whereas R cows appear to use extra nutrients to build more body reserves before allowing reproductive function to resume.

IGF-I

Circulating concentrations of IGF-I for the initial 45 days after calving were not affected by treatment or breedtype (data not shown). Over this time period circulating IGF-I concentrations decreased in both B and R; however, the decrease was not significant (data not shown). IGF-I concentration at calving was found to be negatively correlated to PPI in B (r = -0.30, P = 0.05) and R (r = -0.40, P = 0.02).

The lack of response of IGF-I to ASE supplementation corresponds to the limited affect ASE supplementation had on cow productivity. The decreasing concentrations of IGF-I are as expected since it was measured during lactation, which is characterized by high-energy demands and mobilization of energy stores. Cows with a higher nutritional status at calving, as determined by higher circulating IGF-I concentrations, required less time to resume estrous cyclicity than those with lower concentrations. As such, IGF-I concentrations at calving may be a good predictor of which cows are more likely to maintain a yearly calving interval.

Implications

The results of this study indicate that Cattle-Ase™ supplementation is not effective at improving overall postpartum productivity in mature, suckled beef cows grazing high quality rye-ryegrass pastures. The improvements in the B cow ADG and BCS, and BXB ADG; however, suggest that Cattle-Ase™ may be useful in different scenarios, such as those with breedtypes that digest forages less efficiently than those used in this study, with cows maintained on lower quality forages, or in operations where improved weight gain is economically more important than improved reproductive function.

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Table 1. Treatment means for Brahman and Romosinuano crossbred cows

	Brahman (n = 44)		Romosinuano crossbred (n = 39)	
Variable	Cattle-Ase	Control	Cattle-Ase	Control
End suppl ADG, lb/d	0.31 ± 0.12 [b]	-0.11 ± 0.12 [b]	0.36 ± 0.11	0.15 ± 0.12
Initial BCS	5.73 ± 0.15	6.16 ± 0.16	5.35 ± 0.21	5.38 ± 0.23
End suppl BCS	6.20 ± 0.15	6.32 ± 0.11	6.21 ± 0.18	6.30 ± 0.23
Wean BCS	5.53 ± 0.16 [c]	6.11 ± 0.16 [c]	5.83 ± 0.19	5.84 ± 0.22
End suppl BCS chng	0.48 ± 0.12 [a]	0.16 ± 0.12 [a]	0.87 ± 0.13	0.93 ± 0.20
PPI, d	68.78 ± 4.61	56.84 ± 4.92	79.31 ± 4.29	80.97 ± 5.44
Services/conception	0.91 ± 0.12	1.11 ± 0.14	0.95 ± 0.12	0.95 ± 0.11
Days to conception	78.56 ± 5.16	79.95 ± 3.91	98.10 ± 4.42	102.33 ± 5.16

[a] $P < 0.10$, [b] $P < 0.05$, [c] $P < 0.01$

Table 2. Breedtype differences for cow productivity

Variable	Brahman (n = 44)	Romosinuano crossbred (n = 39)
PPI, d	62.34 ± 3.47 [a]	80.22 ± 3.47 [a]
Services/conception	1.00 ± 0.09	0.95 ± 0.08
Days to conception	78.54 ± 3.22 [a]	100.62 ± 3.45 [a]
First service conception rate, %	63.64 ± 7.34	71.80 ± 7.30

[a] $P < 0.01$

Table 3. Treatment means for Angus X Brahman (AXB), Brahman X Brahman (BXB), and Simmental X Romosinuano (SXR) calves

	Angus X Brahman (n = 8)		Brahman X Brahman (n = 36)		Simmental X Romosinuano (n = 39)	
Variable	Cattle-Ase	Control	Cattle-Ase	Control	Cattle-Ase	Control
Calving BW, lb	29.55 ± 0.62	32.61 ± 1.99	31.06 ± 0.82	33.69 ± 1.40	37.42 ± 0.92	36.80 ± 1.32
End suppl BW, lb	133.18 ± 9.34	138.41 ± 8.03	128.74 ± 4.10	123.13 ± 4.08	166.65 ± 6.18	159.36 ± 6.65
Wean BW, lb	201.82 ± 6.70	211.02 ± 12.87	188.23 ± 3.80	191.11 ± 5.13	218.09 ± 5.99	210.89 ± 6.80
End suppl ADG, lb/d	2.27 ± 0.12	2.33 ± 0.13	2.24 ± 0.06[a]	1.95 ± 0.06[a]	2.25 ± 0.06	2.14 ± 0.07
Wean ADG, lb/d	2.06 ± 0.10	2.13 ± 0.13	1.92 ± 0.04	1.87 ± 0.04	1.89 ± 0.04	1.83 ± 0.05

[a] $P < 0.05$

Table 4. Effect of breedtype on calf productivity

Variable	Angus X Brahman (n = 8)	Brahman X Brahman (n = 36)	Simmental X Romosinuano (n = 39)
Calving BW, lb	68.37 ± 2.48 [a]	71.22 ± 1.82 [a]	81.62 ± 1.77 [b]
End Suppl BW, lb	298.75 ± 12.74 [a]	277.05 ± 6.36 [a]	358.41 ± 9.96 [b]
Wean BW, lb	454.12 ± 15.26 [a,b]	417.28 ± 6.94 [a]	471.67 ± 9.95 [b]
End Suppl ADG, lb/d	2.30 ± 0.08	2.10 ± 0.05	2.20 ± 0.04
Wean ADG, lb/d	2.10 ± 0.08 [a]	1.90 ± 0.03 [b]	1.86 ± 0.03 [b]

[a,b] Means in the same row followed by the same letter do not differ ($P < 0.05$)

.SYNCHRONIZATION OF OVULATION FOR TIMED AI IN BRAHMAN-INFLUENCED CATTLE

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Summary

Objectives of studies reported herein were to evaluate the effectiveness of the CO-Synch + CIDR (COS-C) protocol in *Bos indicus*-influenced cattle in south Texas compared to traditional management and to characterize ovarian, hormonal, and estrual events associated with COS-C in order to optimize its potential for success in *Bos indicus*-influenced cattle. Pregnancy rates using the COS-C protocol and timed artificial insemination (TAI) at 48 hours after CIDR removal averaged about 39%. Lower than expected results were caused by failure of 40% of females to develop a synchronized follicular wave after GnRH-1, and because only 71% had a follicle likely to ovulate within 24-30 hours after TAI at 48 hours. Data indicate that delaying TAI to 66 hours after CIDR removal could increase pregnancy rates significantly. However, additional work will be required to determine whether this alone will result in pregnancy rates similar to those reported for *Bos taurus* cattle.

Introduction

Several recently-developed protocols for synchronization of estrus and ovulation in beef cattle are available for use in TAI management programs. Recently, the CO-Synch protocol (COS; combination of GnRH and prostaglandin F2α; PGF) has been combined with an exogenous source of progesterone (CIDR, Controlled Internal Drug Release; COS-C) to produce TAI pregnancy rates that are consistently greater than 50% in *Bos taurus* breeds in the Midwestern U.S. However, in the southern regions of the U.S, the common use of *Bos indicus*-influenced cattle may create additional challenges due to increased excitability of these types of cattle and (or) small differences in timing of ovarian events. The objectives of studies reported herein were to 1) evaluate the effectiveness of the COS-C TAI protocol in *Bos indicus*-influenced cattle in south Texas compared to traditional management (TM) and 2) characterize ovarian, hormonal, and estrual events associated with COS-C in order to optimize its potential for success in *Bos indicus*-influenced cattle.

Experimental Procedures

Experiment 1: Field Trials.

Objectives of this experiment were to compare pregnancy rates in cattle synchronized with the COS-C protocol compared to a traditional management scheme. All cattle were required to have a minimum body condition score (BCS) of 4.8 (1-9 scale), and if suckled, be at least 50 days postpartum. Cows were stratified by parity and BCS at each location, and assigned randomly to either a TM control or a synchronized group (COS-C). The COS-C regimen included the insertion of a CIDR (Pfizer Animal Health, Kalamazoo, MI) and an injection of GnRH (GnRH-1; 100 µg Cystorelin, Merial, Iselin, NJ) on day 0, removal of the CIDR and injection of PGF (25 mg Lutalyse; Pfizer Animal Health, Kalamazoo, MI) on day 7, and injection of GnRH (100 µg GnRH-2) and TAI at 48 h after PGF and CIDR removal (day 9). All females in each replicate were placed with clean-up bulls 5-7 days after TAI where they remained until the end of breeding season (90 days). Pregnancy rates were determined by transrectal ultrasonography (Dynamic Imaging, Concept/MCV, Livingston, UK) 30 days after TAI. Final pregnancy rates were assessed by palpation per rectum 45 days after the end of the breeding season. Control (TM) cattle were not available at all locations for management comparisons to COS-C. Therefore, while there were 266 cows and heifers synchronized for TAI, only 170 were managed with a contemporary set of TM females (n = 165) for other comparisons.

Experiment 2. Follicular, luteal and hormonal characteristics of CO-Synch + CIDR (COS-C) and CO-Synch(COS) synchronization protocols.

Objectives of this experiment were to characterize ovarian phenomena associated with COS-C and COS (CIDR not included) in cattle synchronized for TAI at 48 hours after the PGF injection on Day 7. One hundred Brahman x Hereford (F-1) cows were divided into four replicates of 25 females each. Criteria and stratification procedures were similar to Experiment 1. Cattle were placed in pens 8 days before the onset of treatments. Half of the cows within each replicate (n=12-13) received the COS-C treatment and half the CO-Synch (COS) treatment alone without the CIDR. Transrectal ultrasonography and blood sampling were performed every other day from day -8 to day 0, and then daily from day 0 until ovulation or day 12. Serum was assayed for progesterone. Pregnancy determination was performed as in Exp1.

Experiment 3. Distribution of estrus and ovulation in cows programmed with the Select Synch + CIDR synchronization protocol.
Objectives of this experiment were to use the Select-Synch plus CIDR protocol (GnRH-2 and TAI omitted) in order to determine the optimal time for use of GnRH-2 and TAI in the COS-C protocol used in Experiments 1 and 2. Fifty postpartum, suckled Brahman x Hereford (F-1) females were used. Criteria and stratification procedures were similar to Experiment 1. Cows in the study were first-calf heifers (n = 32), and mature, multiparous cows (n = 18). Females were placed in pens as in Experiment 2. Heat detection was performed twice daily from d 7 through day 12. Ovaries were examined by transrectal ultrasonography on the day of CIDR removal, and then every 12 hours until ovulation or day 12. Beginning at CIDR removal, females were observed for estrus by visual observation every 3 hours through day 12. Blood samples were collected on days -21, -11, 0, 7, 8 and 9 for assay of serum progesterone to estimate cyclicity at the onset of treatments and the efficiency of CL regression after PGF.

Results and Discussion

Experiment. 1.
Mean age, BCS, body weight, and days postpartum averaged (± SEM) 4.7 ± 0.2 years, 5.1 ± 0.03, 1029 ± 15.6 lb, and 70 ± 1.1 days, respectively. Timed AI pregnancy rates in all females synchronized with COS-C are summarized in Table 1. Conception rates for TAI at 48 hours after CIDR removal averaged about 39%. Conception rates were not affected by location, year, BCS, days postpartum, parity, sire or AI technician. Table 2 summarizes cumulative pregnancy rates after 30 and 60 days of breeding (TAI and/or natural service) for the COS-C group and the contemporary control groups (TM). Overall, cumulative pregnancy rates were greater ($P < 0.05$) in synchronized cows at 30 and 60 days of the breeding season than in the TM group.

Previous reports on use of the CO-Synch + CIDR synchronization regimen in *Bos taurus* cattle have indicated TAI conception rates consistently over 55% (Lamb et al., 2001, Larson et al., 2004 a, b), including studies in which TAI was performed at 48 hours after CIDR removal. However, more recent studies have indicated marked improvements in pregnancy rates in *Bos taurus* females by performing TAI at 66 hours after CIDR removal compared to 48 hours (Bremer et al., 2004; Schafer et al., 2004). These latter observations and results of Experiment 1 indicate that an adjustment in timing of AI from 48 to 66 hours after CIDR removal could improve TAI conception rates in *Bos indicus*-influenced cattle as well.

In Experiment 1, cumulative pregnancy rates after 30 and 60 d of breeding season averaged 68% and 92.8%, respectively, confirming that the cattle used for these experiments were highly fertile. As a general rule of thumb, obtaining optimal results using pharmacological synchronization tools are obtained with cattle having a BCS at or near 5 on a 1-9 scale, and in individuals that are at least 50 d postpartum at TAI (Lamb et al., 2001; Williams et al., 2002). These conditions were met in the current studies; moreover, individual variation in TAI conception rates was not affected by BCS or DPP. Results indicated that adjustments in the timing of insemination may be needed in order to optimize TAI conception rates using these synchronization protocols. Alternatively, other factors may reduce the effectiveness of these protocols in *Bos indicus*-influenced females that have not yet been identified. These issues are addressed further in Experiments 2 and 3 below.

Experiment 2
Ovarian and reproductive outcomes are summarized in Table 3. Mean (± SEM) age, BCS, body weight, and days postpartum for all cows averaged 8.8 ± 0.3 years, 5.3 ± 0.07, 1194 ± 16.3 lb, and 77 ± 0.66 days, respectively. No

statistical differences in the major ovarian and reproductive endpoints were observed between COS-C and COS. Therefore, data for both treatments are presented as pooled means. Data are also presented relative to cycling status at the onset of treatments. The number of non-cycling cows ovulating after GnRH-1 was greater ($P < 0.01$) than for cycling cows. However, cycling cows had the greater ($P < 0.05$) response after GnRH-2. More ($P < 0.01$) cows that ovulated after GnRH-1 developed a synchronized follicular wave compared to cows that did not ovulate (Table 4). Moreover, there was a trend ($P = 0.15$) for ovulation rates after GnRH-2 to be greater in cows that ovulated in response to GnRH-1 than cows that did not. Ovulation and TAI pregnancy rates after GnRH-2 were increased ($P < 0.01$) in cows that developed a synchronized follicular wave after GnRH-1 compared to cows that did not develop a new wave (Table 5).

Using approaches similar to those described herein, administration of GnRH-1 in a group of cows occurs randomly relative to stage of the estrous cycle. Pursley et al. (1995) reported that only 60-80% of the animals with a large follicle present at the time of the first GnRH injection will ovulate in response to that injection. However, Vasconcelos et al. (1999) indicated that ovulation rates can exceed 70% when GnRH is given between days 5-9 and 17-21 of the estrous cycle, but were less than 50% when the treatment occurred on days 1-4 or 10-16 of the cycle. In Experiment 2 of the current studies, 40% of the cows ovulated and 39% exhibited follicular regression after GnRH-1.

The lower TAI conception rate of cows without a synchronized follicular wave (31%) in Experiment 2 emphasizes the importance of a new follicular wave after GnRH-1 (Table 5). Although Twagiramungu et al. (1994) reported that both ovulation and follicular regression were equally effective for inducing new follicular wave emergence, Martinez et al. (2000) suggested that synchrony of the induced follicular wave is less variable in heifers that ovulate after GnRH-1 than for heifers that do not ovulate.

All ovulations occurred within a 48 h period after GnRH-2 and TAI. Only 45% of the animals that ovulated became pregnant (Table 3), suggesting that many of the follicles that ovulated were immature and thus had reduced viability. Results from Experiment 2 did not provide evidence that differences in TAI conception rates between cycling and non-cycling cows at the onset of treatments could account for the low TAI conception rates in Experiments 1 and 2. Moreover, incomplete regression of corpora lutea (CL) after PGF also did not account for reduced pregnancy rates as greater than 90% of females with CL on day 7 exhibited regression of the CL (Table 3).

Experiment 3

Results of Experiment 3 are presented in Table 6. Only 56% of the cows in this study ovulated within 131 hours after CIDR removal and PGF on day 7. This was much lower than expected and was lower than in Experiment 2 (72%) where ovulation rate was also documented. This was likely caused by one or perhaps two factors. First, there was a larger number of first-calf heifers in Experiment 3 than in Experiment 2. In addition, the Select-Synch protocol does not employ the second GnRH (GnRH-2) injection; therefore, all ovulations in Experiment 3 were spontaneous and none were induced as in Experiments 1 and 2. Neither ovarian cycling status nor parity affected the number of cows exhibiting estrus or ovulating. Mean (± SEM) age, BCS, body weight, and days postpartum were 5.81 ± 0.5, 5.6 ± 0.1, 1243 ± 22.4 lb and 60 ±1.1 days, respectively. The interval from CIDR removal to standing estrus was 70 ± 2.9 h, and the earliest ovulation detected was at 69 h after CIDR removal. No cows were observed in estrus during the first 48 hours after CIDR removal. The majority (75%) of estrual events was observed between 60 and 72 hours after CIDR removal (Figure 1). Cows that showed standing estrus had more ($P < 0.01$) ovulations than cows not standing. Results of this experiment further support the contention that delaying the timing of GnRH-2 and TAI to 66 hours or later would improve conception rates.

Implications

Lower than expected conception rates in Experiments 1 and 2 were attributed primarily to a suboptimal number of cows with a synchronized follicular wave after GnRH-1 and to the application of GnRH-2/TAI at 48 hours after CIDR removal/PGF. Experiment 3 confirmed that timing of AI in Experiments 1 and 2 were not optimal relative to the presence of a large follicle, estrus and ovulation after removal of the CIDR and injection of PGF. Additional work will determine whether a delay in TAI to 66 h will result in improvements in TAI conception rates.

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Table 1. Timed AI (TAI) pregnancy rates in virgin heifers, postpartum primiparous heifers, and pluriparous cows synchronized with CO-Synch + CIDR (COS-C).

Source	Treatment	N	TAI Pregnancy Rate, %
Nulliparous	COS-C	89	39.3
Primiparous	COS-C	34	35.3
Pluriparous	COS-C	143	39.9
Total	COS-C	266	39.1

Table 2. Cumulative pregnancy rates after 30 and 60 days of breeding in nulliparous heifers, primiparous heifers, and pluriparous suckled cows synchronized with CO-Synch + CIDR (COS-C) followed by TAI or managed using traditional methods (TM).

		Pregnancy Rate, %		
Source	Treatment	N	30 Days	60 Days
Nulliparous	COS-C	62	75.8	95.2
	TM	71	71.8	88.7
Primiparous	COS-C	34	67.6	100.0
	TM	28	60.7	89.3
Pluriparous	COS-C	74	75.7	94.6
	TM	66	51.5	90.9
Total	COS-C	170	74.1[a]	95.9[a]
	TM	165	61.8[b]	89.7[b]

[a, b] Percentages with uncommon superscript letters differ $P < 0.05$.

Table 3. Ovarian and reproductive outcomes in postpartum suckled cows synchronized with CO-Synch + CIDR (COS-C) or CO-Synch (COS), and for cycling and non-cycling cows.

Variable	COS-C and COS Combined	Ovarian Status	
		Cycling	Non-cycling
No. Cows	100	78	22
Estrous cycling, %	78	-	-
Response to GnRH-1, %			
Ovulating	40	33[c]	64[d]
Follicle regression	39	40	36
Not responding	21	27[c]	0[d]
New follicular wave after GnRH-1, %			
Synchronized[a]	60	56	73
Not synchronized[b]	31	35	18
No emergence	9	9	9
Day of emergence	2.5 ± 0.12	2.4 ± 0.15	2.75 ± 0.23
CL regression, % (No.)	92 (75/81)	91(61/67)	100(14/14)
Ovulatory Response to GnRH-2, %			
0-24 h after TAI	15	14.1	36.3
24-48 h after TAI	57	62.8	18.2
Total	72	76.9[c]	54.5[d]
TAI pregnancy, %			
Ovulation 0-24 h after AI	9	10.3	4.5
Ovulation 24-48 h after AI	24	23	27.3
Total	33	33.3	31.8

[a] Cows that developed a follicular wave from d 1 to d 4 after GnRH-1.
[b] Cows that developed a follicular wave before day 1 and after day 4.
[c,d] Percentages within row with uncommon superscripts letters differ ($P < 0.01$).

Table 4. Effects of the response to the first GnRH injection (GnRH-1) on subsequent ovarian and reproductive outcomes in cows synchronized with CO-Synch + CIDR (COS-C) or CO-Synch (COS).

Variable	Ovulatory Response to GnRH-1	
	Ovulating	Not Ovulating
	No. (%)	No. (%)
No of cows	40	60
Synchronized follicular wave		
Yes	35 (88)[a]	25 (42)[b]
No	5 (22)	35 (58)
Ovulated after GnRH-2		
Yes	32 (80)	40 (67)
No	8 (20)	20 (33)
TAI pregnancy	15 (37)	18 (30)

[a,b] Percentages within rows with uncommon superscripts differ ($P < 0.01$).

Table 5. Effects of synchronized follicular wave emergence after GnRH-1 on subsequent ovarian and reproductive outcomes in cows synchronized with CO-Synch + CIDR (COS-C) or CO-Synch (COS).

Variable	Occurrence of Synchronized Follicular Wave after GnRH-1	
	Yes	No
	No. (%)	No. (%)
No of cows	60	40
Ovulation after GnRH-2		
Yes	51 (85)[a]	21 (52)[b]
No	9 (15)	19 (48)
TAI pregnancy	26 (43)[a]	7 (17)[b]

[a,b] Percentage within row with uncommon superscripts letters differ ($P < 0.01$).

Table 6. Estrual, follicular, and ovulatory characteristics of postpartum, suckled Brahman x Hereford cows programmed with Select Synch + CIDR.

Variable	All Cows	Estrus		
		Standing	Non-Standing	None
No.	50	27	14	9
Mean follicle size, mm				
At CIDR removal (range)		10.1 ± 0.4^a (6.1 - 13.5)	8.8 ± 0.6^b (6.0 - 12.8)	8.62 ± 0.3^b (7.2 - 10.2)
48 h after CIDR removal (range)		12.6 ± 0.4^c (9.6 - 14.7)	10.4 ± 0.4^d (8.3 - 13.8)	10.83 ± 0.4^d (9.7 - 13.9)
Ovulating, %	56	93^c	21^d	0^d
Mean ovulatory follicle size, mm (range)	12.9 ± 0.3 (9.4 - 15.1)	12.9 ± 0.3 (9.4 - 15.1)	13.5 ± 0.5 (12.5 -14.1)	-
Mean interval from CIDR removal to:				
Standing estrus, h (range)		70 ± 2.9 (49 - 108)	-	-
Ovulation, h (range)	99 ± 2.8 (68 - 127)	99 ± 3 (68-127)	104 ± 11 (82 - 117)	-
Mean interval from estrus to ovulation, h (range)		29 ± 2.2 (5 - 55)	-	-

[a,b] Percentage within row with uncommon superscripts letters differ ($P < 0.05$).
[c,d] Percentage within row with uncommon superscripts letters differ ($P < 0.01$).

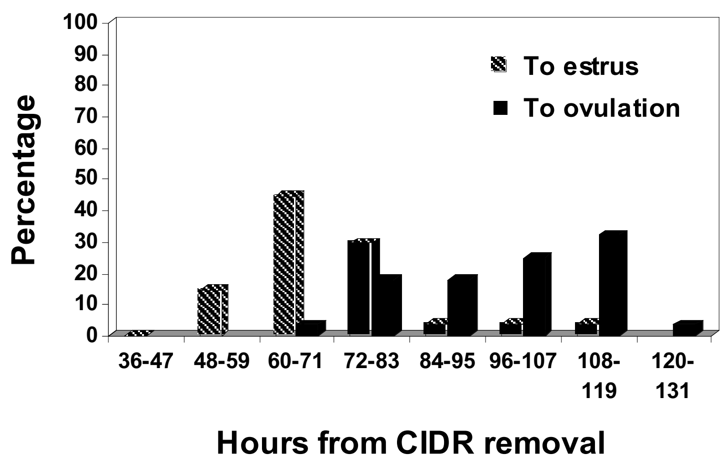

Figure 1. Interval from CIDR removal to visual estrus (n = 27) and ovulation (n = 28) of early postpartum suckled crossbred Brahman cows treated with Select Synch + CIDR.

PHYSIOLOGY AND MANAGEMENT OF THE POSTPARTUM SUCKLED BEEF COW

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Introduction

After an approximate 30-day period of uterine repair and involution, the resumption of normal postpartum ovarian cycles is regulated mainly by the rate of recovery of the central reproductive axis (brain and pituitary). Mechanisms controlling the re-initiation of patterns of gonadotropin secretion that are needed to support follicular development and ovulation include physiological recovery of the pituitary from gestational steroid effects, nutritional status (body condition), suckling, season of calving, and genetics. The purpose of this review is to 1) summarize our understanding of mechanisms controlling the length of the postpartum anovulatory period in the suckled beef cow, and 2) consider management approaches that can exploit our understanding of postpartum physiology to enhance reproductive performance.

Physiology of Postpartum Reproduction

Gestational Effects on the Hypothalamic-Pituitary Axis

Pituitary stores of LH are very low at parturition in cattle, owing to the effects of high circulating concentrations of placental-derived estradiol that are observed during late gestation. High circulating concentrations of estradiol inhibit the synthesis of the β subunit, and to some degree, the α subunit of the LH molecule in the anterior pituitary. Storage and release of follicle-stimulating hormone (FSH) does not change appreciably during the postpartum period. Following parturition, the rapid decline in circulating estrogens allows a rapid re-accumulation of anterior pituitary LH, which requires 2 to 3 weeks to complete. During this period of recovery, circulating concentrations of LH and frequency of LH pulses are usually low. This occurs initially because of a lack of releasable LH in all cows, regardless of whether they are suckled, nonsuckled, or milked. That synthesis and accumulation of pituitary LH requires only a low level of GnRH stimulation accounts for the ability of the pituitary to accumulate LH during this period. After the second or third week, the pulsatile release of LH increases in weaned beef cows and milked dairy cows, resulting in the resumption of ovarian follicular development and ovulation. However, in suckled cows, the suppressive effects of suckling on hypothalamic GnRH secretion continue to prevent an increase in pulsatile LH release. Eventually, the suckled cow escapes from the effects of suckling, or is weaned, and the frequency and amplitude of GnRH pulses increases dramatically, the frequency of LH pulses increases, and ovarian cycles resume (Figure 1). Although the ability of the hypothalamus (lower part of brain) to stimulate a surge release of LH through estradiol positive feedback is blunted or absent immediately after calving, the normal feedback response returns within about 2 weeks postcalving.

Effects of Suckling and the Maternal-Offspring Bond

For over a half century it was assumed that chronic sensory stimulation of the teat (suckling) was the primary cause of lactational anovulation/anestrus in all species, including cattle. However, our laboratory and others have shown that sensory pathways within the teat and udder are unnecessary for suckling to suppress LH secretion. Neither chronic milking nor the physical presence of the calf in the absence of suckling have measurable effects on the pulsatile pattern of LH release, and neither denervation of the udder nor mastectomy shortens the postpartum anovulatory/anestrus interval if calves remain with their dams. Additional work in our laboratory has clearly shown that the maternal-offspring bond is a requisite feature of postpartum anovulation/anestrus. Beef females forced to suckle an alien calf for up to 6 days undergo the same brain-related changes that occur with weaning: a rapid increase in the frequency of LH pulses, development of a preovulatory follicle, ovulation, and the resumption of ovarian cyclicity (Figure 1). Formation of a selective maternal bond by the cow plus the physical interaction of the calf in the inguinal region (bunting, oral manipulation of the flank, or suckling) appear to be responsible for neural changes that create the anovulatory state. These include an increase in sensitivity to estradiol negative feedback and an increase in neurotransmitter tone that causes a suppression of GnRH secretion for variable periods. However, the time of day during which calves suckle (eg., night vs. day) has no effect on length of the postpartum interval to first ovulation or conception.

Genetic Effects and Season of Calving

The resumption of the appropriate pattern of gonadotropin secretion to promote ovarian cyclicity can be affected by at least two other factors: genotype of the cow and season of calving. Purebred *Bos indicus* cattle tend to be affected more strongly by both the negative effects of suckling and undernutrition than most purebred *Bos taurus* females. Crossbreeding either within or between species results in greatly improved reproductive performance, including a reduction in length of the postpartum interval. Size of the cow and lactation potential represent genotypically-driven features that also impact length of postpartum anovulation. Both of these factors increase nutritional requirements, which in turn affect reproductive performance if nutrients are limiting. Finally, the role of season of calving can affect the length of the postpartum anovulatory interval by 15 to 20 days or more. Although not usually considered to be seasonal breeders, cattle are universally affected by photoperiod to some degree. Cows bred to calve during the late summer or early fall will invariably have shorter postpartum anovulatory intervals than cows bred to calve in winter or early spring. However, because the calving season is often managed to coincide with maximum forage quality and quantity, herds are more frequently managed to calve in the spring.

Nutritional Status and Body Condition

Undernutrition, particularly a deficit in dietary energy intake, is probably the most prevalent natural and man-made cause of delayed rebreeding in cattle. Moreover, the effects of undernutrition have their greatest effects when they occur during late gestation. Cows that calve in thin body condition have greatly extended intervals to first postpartum estrus and ovulation. This occurs because of a slowing of the pituitary repletion of LH after calving and heightened effects of suckling on GnRH secretion. As a result, LH secretion is low and the development of ovulatory follicles is delayed for periods often exceeding 100 days or more. Many experiments have been conducted showing the effects of cow body condition and postpartum nutrition on reproductive performance. Although some of the effects of low body condition at calving can be remedied by increasing feed intake after calving, this is not the most economical approach.

Effects of Dietary Fat Intake and Metabolism

For many years, we examined the potential of dietary fat supplementation to enhance reproductive performance. The basis for this work lies within an array of digestive, metabolic, and reproductive effects that occur when significant quantities of fat are consumed by cattle. Increasing dietary fat consumption by cattle affects follicular growth dynamics by increasing the number of follicles in the medium-sized classification by 1.5- to 5-fold within 3 to 7 weeks. This effect does not depend upon the dietary level of metabolizable energy or weight gain of cattle in moderately thin to obese condition. Changes in medium-sized follicle populations occur coincident with a tendency for small follicle populations (less than or equal to 3 mm) to decline. Subsequent studies have revealed that the greatest increase in medium follicle populations occurs in response to plant oil consumption. Sources of plant oil have included whole cottonseed, soybean oil and rice bran.

Maximum follicular growth responses to plant oil supplementation have occurred when plant oil was fed at 4 to 6% of diet dry matter, with lesser increases noted with lower levels of added fat. Animal tallow, calcium salts of saturated fatty acids or fish oil have been shown to have less robust effects on follicular growth than plant-derived oils. Moreover, postpartum beef cows calving in thin body condition (score of less than 4 on 1-9 scale) were unable to develop medium or large follicles at a rate equal to those with a body condition score of 4 or greater after 3 weeks of fat consumption. Feeding ruminant animals large quantities of fat (> 5% of total dry matter intake) can result in a marked negative effect on fiber digestibility and on dry matter intake (3). This occurs for at least two reasons, including the physical coating and protection of ingesta from microbial action, and the selection against microorganisms with cellulolytic capability. The level of fat that can be fed is also dependent upon the form of the feedstuff from which it is derived, and 5% of total dry matter may not be the maximum tolerable amount under all conditions. For example, fat contained in whole oilseeds can be fed at much higher levels than free oils mixed throughout the diet, as mastication is not complete enough to release all of the oil simultaneously from the seeds; therefore, the oil is released into the rumen more slowly. Due to the lack of reactive double bonds, saturated fatty acids, such as those that predominate in animal tallow, pass through the rumen undegraded and are considered bypass fats. Some of the effects that these bypass fats have on the metabolism and physiology of the animal are potentially quite different from those created by polyunsaturated fatty acids metabolized in the rumen, although their caloric values are similar. Table 1 summarizes the effects of dietary fat supplementation in cattle on follicular growth and function potential as reported by various laboratories.

Supplementation of postpartum, lactating beef cows with whole cottonseed beginning 30 days before the start of the breeding season increased the number of cows cycling at the start of the breeding season by up to 18%. This response was most evident when environmental conditions resulted in a loss of body condition during the postpartum period, in spite of supplementation (Table 2). Work at other locations has confirmed that fat supplementation reduces the postpartum anovulatory interval and enhances rebreeding performance. However, the latter trials were conducted with saturated or bypass fat. Therefore, we speculate that performance would be further enhanced if polyunsaturated plant oils had been used, since ovarian responses to saturated fats appear less robust than to polyunsaturated fats. Longitudinal studies under field conditions to confirm this speculation have not been reported. As is the case for any technology or management strategy that improves specific aspects of ovarian physiology and cyclic activity, actual improvements in pregnancy rates, weaned calf crop, or total kg of calf produced is dependent upon an array of interactive management practices and environmental conditions. No studies have been conducted to demonstrate that the long-term use of fat supplementation during the postpartum, rebreeding period will contribute to an improved economic outcome.

Management of Postpartum Reproduction

Selection for Fertility

Heritability of reproductive traits has traditionally been considered low, making genetic progress for reproductive efficiency slow. However, much of this lack of robustness is caused by environmental x genotypic interactions which make it difficult to accurately assess genetic worth. As already stated, crossbreeding has a large positive effect on reproductive efficiency. Use of physiological or genetic markers for reproduction has begun to be examined for their value in identifying superior individuals early in their life. One approach used at the Animal Reproduction Laboratory in Beeville was to examine responsiveness of the pituitary to GnRH early after calving (days 5-8 postpartum) and in heifers during pubertal development. We found that great variability exists in pituitary responsiveness to GnRH, forming essentially a normal distribution. In this herd, which has been selected for fertility, cows with high responses to GnRH did not have postpartum anovulatory intervals different from Low responding cows. However, cows exhibiting an early LH peak after a pharmacological challenge with GnRH had a longer postpartum interval than those with a late peak. The same measures in heifers did not predict age at puberty. Nevertheless, further work is needed in these areas, as the heritability for pituitary responsiveness to the gonadotropins has been shown to be near 0.45 in sheep.

Nutritional Management

Body condition scoring (BCS) is an important element in management of beef cattle. On a 1 to 9 scale (1 = emaciated; 9 = obese), it is desirable to maintain cows in at least a BCS of 5 (good condition). However, cattle are managed throughout the world in environments that often result in BCS falling below this recommended level, and economics may not allow its prevention by supplemental feeding. Therefore, if BCS is allowed to vary with changes in environment and forage availability, attempts should be made through management to achieve a BCS as high as possible before calving. A low BCS at calving has greater negative effects than losses in BCS after calving or after conception. If cows calve in excellent to moderate (BCS 5-6) condition, they can often rebreed early enough to withstand nutritional challenges during lactation. Therefore, they should be managed to recover body condition during the dry period and before the next parturition. Alternatively, positive effects on reproductive performance can be realized if cows calving in less than optimum BCS are fed to gain body weight and condition after calving. However, <u>this is not a very economical approach</u> as significant amounts of supplemental nutrients will be used for milk production as opposed to reproduction. Therefore, it is best for cows to calve in good body condition and then use strategic supplementation with protein to enhance intake and digestion of low to medium-quality forages for maintaining body condition. Use of high fat supplements to stimulate ovarian follicle development can also improve postpartum reproductive performance, particularly in cows in thin to moderate body condition. However, improvements in reproductive performance of cows fed supplemental fat have been highly variable. Variability in response is due in part to similar variations in the types of cattle supplemented, time and duration of supplementation, source of supplemental fat, and body condition of cattle supplemented. Therefore, although a host of important physiological responses to fat supplementation have been documented, management strategies used to test the effects of supplemental fat have often failed to rely on proven physiological principles. The following summarizes some of the more practical sources of high fat supplements. Principles of fat supplementation that will optimize the potential for benefit are described above in *Effects of dietary fat intake and metabolism.*

Practical Supplementation Strategies using fat

The majority of the early work studying fat supplementation effects on reproduction employed either whole oilseeds, soybean oil, or Megalac®, which contains calcium salts of palm oil. Depending upon oil content, oilseeds were fed at a rate of 15 to 30% of the diet on a dry matter basis, and supplied 4 to 6% added fat. Oilseeds, particularly cottonseed, provide a unique blend of energy, protein, fiber, and fat and make an excellent supplemental feed when fed at 0.9 to 2.2 kg per head daily. An issue that has been raised regarding the use of whole cottonseed is that of gossypol toxicity. Beef cows consuming up to 20 g daily of dietary free gossypol for up to 2 months, via diets containing direct solvent- extracted cottonseed meal (high gossypol) and whole cottonseed, exhibited no detrimental effects on reproductive endocrine function, estrous cycles, or pregnancy rates. Although high levels of gossypol do produce increased red blood cell fragility, this effect does not appear to create a clinically-significant pathology in beef cows under normal management conditions. Moreover, the levels of gossypol present in typically fed quantities of whole cottonseed for protein or fat supplementation (as described above) provided only a fraction of the amount of gossypol fed in the studies summarized above. In mature female cattle, the only reports of gossypol toxicity have been in the dairy industry involving diets containing up to 45% direct solvent cottonseed meal for 14 weeks. This type of cottonseed meal is rarely if ever encountered in today's market. The reader is referred to a complete treatise on the subject of gossypol-containing feeds and gossypol toxicity in beef cattle (Jones et al., 1991).

Oilseeds are not universally available nor economically practical under all conditions in which beef cattle supplementation is employed. Therefore, other alternatives are needed. One of these alternatives is molasses-based liquid supplements containing soybean oil soap stocks. Technology to maintain fat in a homogenous suspension for long periods continues to be the major challenge, and optimization of blends containing urea, sugars, fat and other constituents to promote consistent intake will be required. Recently, dry fat supplements containing 18 to 20% plant oil have been marketed for grazing beef (CONCEPT; Purina Mills, St. Louis, MO) and dairy cattle (High Fat Product; ADM, Decatur, IL) to exploit the benefits of fat supplementation on reproductive performance. Animal tallow has been used in supplements designed to enhance reproductive performance; however, there are marked palatability problems associated with high feedstuff concentrations of tallow. Therefore, it appears that plant-derived oils, when recommended for use at levels shown to maximize ovarian physiological responses, will continue to be the source of choice. Alternative commercial supplements or other by-products containing up to 20% plant oils are needed. Yellow grease, a by-product of the restaurant trade (20 to 25% linoleic acid), can be used as one of those alternatives.

Suckling Management

An increased understanding of how suckling mediates its negative effects on postpartum reproduction has aided our attempts to develop management protocols to reduce those effects. The following is a list of procedures that have been utilized to obviate the effects of suckling.

1. <u>Temporary Calf Removal</u>. This practice has been used since the early 1970's, particularly in association with estrous synchronization protocols. For example, removal of calves for 48 hours beginning at the time of removal of a progestin implant (SYNCRO-MATE-B; CRESTAR; EAZY-Breed CIDR) or after GnRH treatment (OvSynch) will improve synchrony and timed-AI conception rates. However, in our experience, 48-hour calf removal, when used as the only tool, is inadequate to achieve ovulation in more than 30% of anovulatory cows. This occurs because many cows that are responding to calf removal will again be suppressed by suckling if the calf is returned at 48 hours. Moreover, this first ovulation is usually not accompanied by estrus. As it is not prudent to leave calves off of cows for more than 48 hours due to health considerations, we recommend 48-hour calf removal only when it can be combined with synchronization treatments that tend to induce ovulation in anovulatory cows.

2. <u>Early Weaning</u>. This technique is used

when it is more economical to feed the calf than it is to feed the lactating cow. It is usually reserved for severe drought conditions and can allow managers to rebreed their cows without the high nutrient requirements associated with lactation.

3. Once-Daily Suckling. This is also a tool that is beneficial, particularly with first-calf heifers, when environmental conditions are challenging. First-calf, grazing heifers have been shown to return to estrus at a dramatically earlier rate than heifers suckled *ad libitum.* Twice-daily suckling has also been shown in some studies to provide benefits, but a survey of the literature indicates that the expected response is much more variable and, in our opinion, much less dependable than once-daily suckling.

4. Alien Suckling. As reviewed above, we now know that the maternal bond between a cow and her suckling calf is an important element in suckling-mediated anovulation. However, if cows are forced to suckle an alien for up to 6 days, cows will be "physiologically weaned" and ovarian cycles will resume. In the U.S., there are few if any management systems in which this tactic is practical. However, in countries in which cattle are managed for dual purposes (eg, milk and beef production), the use of alien suckling could prove beneficial and practical. Using this system, small groups of cows are usually intensively managed on a daily basis for both milking and suckling by the calf. Therefore, it should be possible to temporarily replace the cow's own calf with an alien for approximately 1 week under controlled suckling conditions. This will result in the induction of ovulation in anovulatory cows, continue to allow milking of the cow, and provide adequate milk for the alien during the 6-day period. However, we have observed that suckled, Brahman-influenced cows tend to resist milk let-down when suckled by an alien; therefore, these calves often obtain milk only from the teat cisterns. As a result, total milk production is likely to decline during the 6-day alien suckling period.

5. Alien Cohabitation. This is a modification of the system described above and has been implemented successfully in estrous synchronization protocols. Since alien suckling does not have negative effects on gonadotropin secretion, we hypothesized that cohabitating alien or unrelated calves with cows during synchronization could substitute for 48-hour calf removal and perhaps benefit the husbandry of calves weaned from their own dams. In those experiments, approximately 30% of Brahman x Hereford (F-1) females allowed some degree of suckling by an alien calf when housed in pens together with alien calves. Total suckling time by these calves over the 48-hour period averaged 14.7 to 24 minutes, and the number of calves attempting suckling ranged from 24 to 44%. Alien suckling did not reduce calf weight losses compared to weaned calves. However, timed AI conception rates in cows treated with SYNCRO-MATE-B were equal for cows subjected to 48-hour weaning and alien cohabitation, but greater than cows allowed to suckle their own calves *ad libitum*.

Summary and Conclusions

An extended and variable period of anovulation/anestrus occurs in suckled beef cows after parturition. This phenomenon exerts both biological and economic limitations on the efficiency of beef production world-wide. Intensive research efforts over the last 50 years have identified factors that regulate the length of the postpartum anovulatory interval, including post-gestational recovery of the central reproductive axis, nutrition, suckling, season of calving, and genotype. Moreover, a detailed understanding of many of the physiological, cellular, and molecular mechanisms underlying these effects has evolved and has, in some cases, yielded enlightened approaches to cattle management. Increased consumption of dietary fat influences ovarian follicular growth, steroid hormone production, growth factor synthesis or accumulation in follicular fluid, corpus luteum function, and postpartum intervals to first ovulation in cattle. However, methods to consistently improve rebreeding performance have not been demonstrated consistently and field trials that carefully construct management trials based on proven biological principles remain to be conducted. Overall, major challenges remain in our efforts to link increased scientific understanding with management strategies and biotechnologies that are economically relevant.

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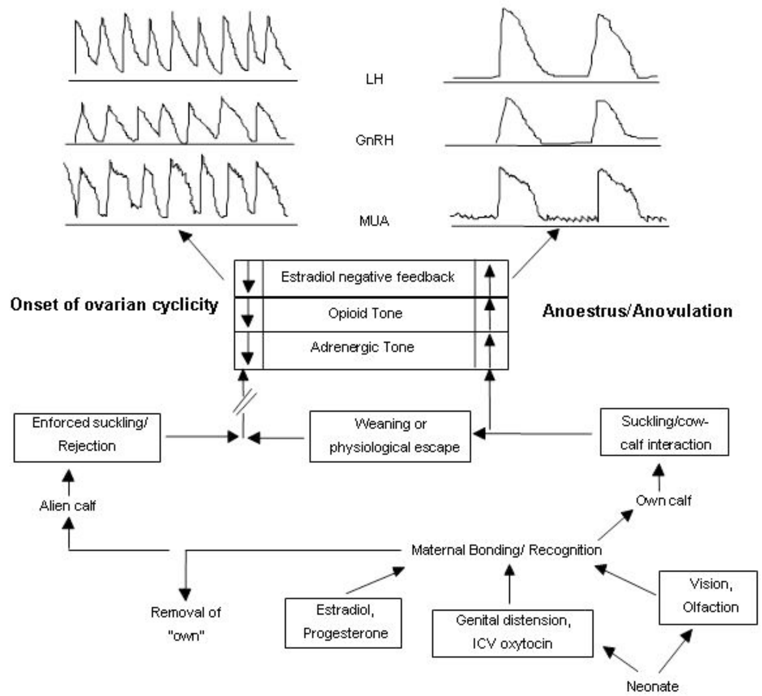


Figure 1. Model describing the role of the neonate, maternal behavior, suckling, and cow-calf interactions in neuroendcrine regulation of the hypothalamic pulse generator during the postpartum period of beef cows. See text for details (From Williams and Griffith, 1995 with permission).

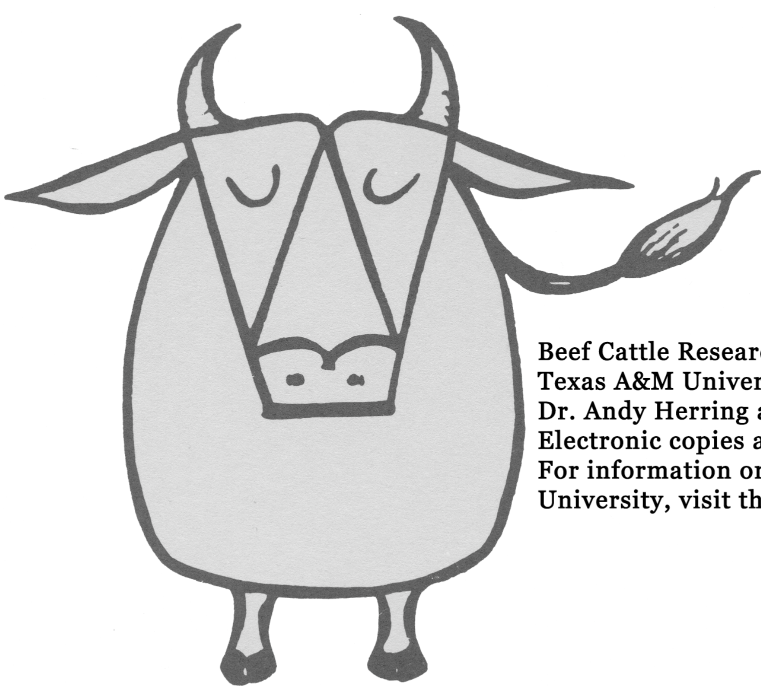
Table 1. Summary of effects of dietary fat supplementation in cattle on ovarian follicular growth and steroidogenic potential of follicle cells in vitro (From Williams and Stanko, 2000 with permission)

Source	Characteristics Affected
Wehrman et al., 1991; Ryan et al., 1992; Hightshoe et al., 1991; Lucy et al., 1991; Thomas and Williams, 1996; Thomas et al., 1997; Lammoglia et al., 1996; Stanko et al., 1997; De Fries., et al., 1998	Increased number of medium-sized follicles (polyunsaturated fat > saturated and highly polyunsaturated fat effects)
Wehrman et al., 1991; Ryan et al., 1992	Increased granulosa cell progesterone production in vitro; increased follicular fluid progesterone
Ryan et al., 1992; Thomas and Williams, 1996	No effect on superovulation rate
De Fries et al., 1998	Increased number of large follicles; increased size of largest follicle

Table 2. Effects of feeding high fat supplements to suckled, postpartum beef cows for 1 mo prior to the start of breeding on incidence of luteal activity at the start of the breeding season in grazing beef cows (From Wehrman et al., 1991 with permission)

Group[a]	Year	No. Cows	Luteal activity, %
High fat	1	61	72.0
Control	1	59	57.6
High fat	2	31	42.0
Control	2	32	18.8
High fat	Both	92	61.9[b]
Control	Both	91	43.9[c]

[a]High Fat and Control supplements were isocaloric and isonitrogenous
[b,c]Means with differing superscripts differ (*P* < .05)



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