2006 Beef Cattle Research in Texas

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The past year has seen widespread areas of Texas struggle with drought conditions to the extent that many ranches have considerably reduced cattle numbers. The saving grace has been that we have continued to see strong cattle prices. Many questions remain as the implementation of the National Animal ID program is anticipated. As we have had an additional case of BSE in the USA since this time last year, the consumer/public reaction has been very encouraging. We have reopened several export markets, including Japan, which were closed after the December 2003 BSE case. The Texas beef cattle industry continues to remain strong and have a very important impact on the state economy and the lives of its citizens.

As of January 2006, there were 14.1 million cattle in Texas. There are approximately 150,000 Texas cattle producers accounting for 5.5 million beef cows and almost 7 million stocker calves that operate under widely varying environments and production systems across the state. There are close to 3 million cattle on feed in Texas feedlots on any given day, and the packing plants within the state have capacity to process approximately 7 million cattle annually. Nationwide, Texas ranks first for numbers of total cattle and calves, beef cows, beef cattle operations, and fed cattle marketed. Texas produces approximately 30% of the beef consumed in the United States. Cash receipts for all cattle and calves in Texas for 2004 were $8.1 billion.

Texas beef producers are fortunate to have access to several state organizations dedicated to helping Texas cattle producers deal with emerging production issues, improving profitability and satisfying beef consumers, such as Texas Department of Agriculture, Texas & Southwestern Cattle Raisers Association, Texas Cattle Feeders Association, Texas Farm Bureau, Texas Beef Council, Texas Animal Health Commission, and the Independent Cattlemen's Association of Texas.

The reports contained within this publication highlight some of the projects conducted through the Texas A&M University System Ag Program that can have direct impacts on the Texas beef cattle industry, and beyond. These efforts are due to many scientists, graduate students and staff that care deeply about the success of the Texas and United States beef cattle industries.

Andy D. Herring
Associate Professor
Holder of John K. Riggs '41 Beef Cattle Professorship

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INVESTIGATION OF GENETIC MECHANISMS INFLUENCING DISPOSITION IN *BOS INDICUS*-BRITISH CROSSBRED CATTLE

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Summary

Disposition (temperament) has been evaluated on 196 heifers and 269 steers that are half *Bos indicus* (Nellore and/or Brahman) and half British (Angus and/or Hereford). All 465 head were evaluated shortly after weaning. To date, 147 of the steers have been evaluated shortly before and at the time of slaughter; 78 of the females have been evaluated as first calf heifers, and 17 have been evaluated as second calf heifers. Of the 465 calves that have been evaluated, 318 were produced by embryo transfer; the recipient cows were all evaluated shortly after calving. For the evaluations shortly after weaning and shortly before slaughter, scores are assigned for four component traits and for overall disposition; for the other evaluations, only an overall disposition score was assigned. For the overall disposition scores assigned at different ages, the correlations have been moderate to high (from 0.31 to 0.72).

Introduction

In addition to the obvious advantages in ease of handling, disposition is associated with growth (Burrow and Dillon, 1997), carcass (Busby, 2005), and tenderness (Voisinet et al., 1997) traits. Of course, although there are major differences within breeds, the *Bos indicus* breeds, such as the Brahman and Nellore, tend to have more excitable dispositions than the British beef breeds, such as the Angus and Hereford. A genomics project has been initiated with the primary objective of finding genes with major effects on cow fertility and secondary objectives of finding genes with effects on disposition, feed efficiency, and carcass and meat traits. Embryo transfer full sib families as well as natural service half sib families are being produced, with the goal of twenty heifers per family in the full sib families. This is a preliminary report on animal disposition from that study, based on the information that has been collected up to this time.

Experimental Procedures

In 2002, a genomics project was initiated at the Angleton station; the project was moved to the McGregor station in 2003. Embryo transfer families of F_2 Nellore/Angus calves (i.e., the sires and dams are F_1 Angus-Nellore) are being produced; the goal was to produce twenty heifers per family in ten families, but some of the original donor cows were replaced because of poor embryo production. The ten embryo transfer families are out of ten donor cows and by a total of four bulls. The first calves from the study were born in 2003. In addition to the embryo transfer full-sib families, four half-sib families are being produced by mating F_1 Angus-Nellore sires to F_1 and F_2 Brahman-Hereford and Brahman-Angus dams. These calves are produced in multiple-sire pastures and require DNA identification of sires. The sires of the embryo transfer families are included in the bulls that produce these natural service calves. Note that the calves within any one of these half sib families are also half sibs to the calves in at least two of the embryo transfer families.

The cattle in the project are scored for disposition shortly after weaning. The steers are scored again at about eighteen months of age, both while in the feeding pens and at the time of slaughter. The females are scored each following year when their calves are born.

For the scoring shortly after weaning, four evaluators score each calf for aggressiveness, nervousness, flightiness, gregariousness, and overall disposition. The overall disposition is an assessment of disposition and not an average of the other four scores. The calves are separated (gate cut) into groups of about 15 head and placed in separate holding pens. Two calves at a time are cut out of the holding pen into an alley that is about 25 yards long with two evaluators at each end approximately 20 yards apart. The two calves in the alley are given a chance to settle down, and one is cut back into the holding pen. The calf that is left in the alley is then scored and turned out of the alley into a different pen.

For each component, the animals are assigned a score from one to nine by each evaluator, where a score of one represents a calm, quiet or docile disposition and a score of nine represents a wild or crazy disposition.

For scoring the steers prior to slaughter, they are scored on the same scale of one to nine for the same components of disposition, but by a single evaluator. In this case, they are scored while with the other steers in their feeding pens. For scoring at the time of slaughter, they are scored from one to nine for overall disposition, only.

For scoring the females when their calves are born, a score from one to five is assigned, where one represents a docile disposition and five represents a wild and/or aggressive disposition. In addition, the recipient cows are scored for disposition shortly after calving on the same scale of one to five.

Correlation analyses were performed among the various measures of disposition. Analyses of disposition shortly after weaning included effects of sire, family within sire, birth year season combination, two-way interaction of calf sex x family within sire combination, and/or sequence within pen within birth year season combination. Sex and pen within season were also investigated, but were not significant.

Results and Discussion

The first seven calf crops (spring and fall of 2003, 2004, and 2005 and spring of 2006) of embryo transfer calves have been produced. The steers from the first four calf crops have been fed individually and slaughtered. The heifers produced in the project are exposed to Angus bulls (at about 14 months of age) to calve at two years of age; fall-born heifers are exposed again at about 20 months of age. The two year-old fall-born females that calve in the fall at two years of age are held over to have their second calf in the spring when they are 3 ½ years of age. Thereafter, all cows are bred for spring calves. Cows in the oldest group (i.e., the cows born in the spring 2003) currently are raising their second calves. The steers from the spring 2005 calf crop have recently been placed on feed to evaluate individual feed consumption and gain. Calving for the spring 2006 embryo transfer calf crop was completed in April. Table 1 gives the current inventory status of the project by family. The calves from the first six calf crops have been scored for disposition by the panel of four evaluators.

Table 2 gives means, standard deviations, and numbers of observations for different measures of disposition taken shortly after weaning, shortly before slaughter, at the time of slaughter, and at the time of calving. For the scores assigned shortly after weaning, the scores from the four different evaluators were averaged before the data were analyzed.

Table 3 gives the simple correlations between the different measures of disposition taken shortly after weaning. Note that the different component scores are highly correlated (0.82 or higher, in all cases) with each other and with the overall disposition score.

Table 4 gives the simple correlations between the different measures of disposition taken on the steers in their feeding pens shortly before slaughter (at about 18 months of age). Please note that (as with the scores taken shortly after weaning) the scores for nervousness, flightiness, and gregariousness were highly correlated (0.60 or higher) with each other and with the overall disposition score. However, in contrast to the scores taken shortly after weaning, the scores for aggressiveness were negatively correlated (but not significant) with the scores for nervousness, flightiness, and gregariousness; the correlation between aggressiveness and overall disposition scores was small and positive (0.20).

This apparent difference in the relationship between aggressiveness and the other measures of disposition at the two different ages deserves some additional discussion. This difference seems to be due to both (1) the difference in tameness of the cattle at the two different ages and (2) the manner in which the scores are given at the two different ages. Regarding tameness, the steers have been on feed in the individual feeding facility for about five months at the time of the second scoring, and have become accustomed to the presence of people on a regular basis; as a measure of their increased tameness, the average overall disposition score improved from 3.98 to 3.24 between the times of the two observations (Table 6).

Regarding the manner in which the scores are given at the two different ages, as discussed in an earlier section of this report, in the evaluation shortly after weaning, the calves are evaluated individually in an alley with two evaluators at each end of the alley. Most of the calves move up and down the alley and are anxious to get out of the alley. In the process of running up and down the alley, many of them run by the evaluators; some try to hit the evaluators as they go by them. Under these circumstances, the calves that are given high (undesirable) scores for aggressiveness are usually given high scores for the other components of disposition as well as for overall disposition. In the evaluation of the steers shortly before slaughter (about 18 months of age), a single evaluator goes into the pen to make the evaluation. If a steer wants to get away from the evaluator, he can run around the outside edge of the pen. Under these different circumstances, the steers that are afraid, and want to get away from the evaluator, seldom, if ever come very close to the evaluator. They are, correspondingly, given a low (desirable) score for aggressiveness. The small number of steers that are given higher scores for aggressiveness are, at least in most cases, quite tame and will walk up to the evaluator; however, during the evaluation they try to hit (butt) the evaluator. In some cases, they will lick the evaluator and/or follow him around the pen and then try to hit him.

Correlations among scores for overall disposition at different ages are reported in Table 5. Note that disposition of the recipient was not significantly correlated to any of the measures of overall disposition of the animal. Scores for overall disposition taken at different points in the animal's life were all positive; except for the correlation between score at weaning and score in second calf heifers (only 17 cows have had their second calf), the correlations between these score taken at different ages were significant.

Family means and standard deviations for overall disposition score (from the evaluation shortly after weaning) are presented in Table 6. Least squares means from two different statistical models are given; the models differed in whether sequence within pen within birth year season combination was included as an independent variable. In the model where sequence was included, it was an important (P < .0001) source of variation. Of the 23 different pen by year-season combinations, the regression was positive in 21 of them (as high as 0.26 in one pen by year-season combination); for the two pens where the regression was negative, the values were very close to zero (-0.002 and -0.004). However, it is questionable whether sequence should be included in the model, because the sequence is at least partly caused by differences in disposition (i.e., the calves that are harder to cut out of the pen are later in the sequence).

Note that for both models there is a substantial amount of variation for disposition both within and between the families, indicating that, if major genes cause differences in disposition, we should be able to detect them in this study.

Implications

If the information on disposition leads to the identification of loci with major effects on disposition, this could lead to tests that would allow genotyping at these loci for use in marker assisted selection and/or marker assisted management.

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Table 1. Inventory Results of the McGregor Genomics Project as of June 12, 2006

Family	Sire	Dam	Live Calves (heifers/steers)	Confirmed Pregnancies	Transfers Pending (fresh/frozen)	Frozen Embryos
70	297J	431H	31 (13/18)	1	2 (2/0)	0
71	297J	760H	46 (20/26)	5	20(9/11)	0
72	432H	511G	38 (14/24)	1	7(7/0)	0
73[2]	432H	732H	8 (1/7)			0
74[2]	437J	640H	6 (3/3)		6(0/6)	3
75	437J	728H	32 (17/15)	6		1
76[2]	551G	664J	7 (2/5)			0
77	551G	787G	38 (14/24)	3		0
78[1]	2855	429H	0			0
79[1]	2855	636H	1 (0/1)			
80	551G	429H	55 (18/37)		24(5/19)	0
81	437J	636H	52 (17/35)	6	3(3/0)	0
82	432H	559J	12 (5/7)	2	4(3/1)	0
83	437J	637H	31 (17/14)	4	4(4/0)	0
84	551G	911H	20 (10/10)	5	10(5/5)	0
85	432H	590D				4
86	297J	388J				6
		Sums	377 (151/226)	33	80(38/42)	14
95	297J	multiple	52 (25/27)			
96	432H	multiple	120 (62/58)			
97	437J	multiple	34 (11/23)			
98	551G	multiple	17 (9/8)			
		NS Sums	223 (107/116)			
	Overall	Sums	600 (258/342)			

[1]Replaced by families 80 and 81 due to poor quality semen.

[2]Replaced by families 82, 83, and 84 due to unsuccessful donors.

Table 2. Average disposition scores, standard deviations and numbers of observations by category and component.

Category	Trait	n	Mean	Std Dev
Recipient	Overall Disposition	335	2.36	0.94
Weaning Scores[a]	Aggressiveness	465	2.84	1.74
	Nervousness	465	4.34	1.98
	Flightiness	465	4.10	2.07
	Gregariousness	465	3.98	1.96
	Overall Disposition	465	3.98	2.05
Steer Scores[b]	Aggressiveness	147	1.18	0.78
	Nervousness	147	3.44	1.56
	Flightiness	147	3.40	1.56
	Gregariousness	147	2.01	1.48
	Overall Disposition	147	3.24	1.33
Slaughter Pen Scores[c]	Overall Disposition	147	2.36	1.04
First Calf Heifers	Overall disposition	78	2.21	1.19
Second Calf Heifers	Overall disposition	17	1.88	0.93

[a] Scores taken shortly after weaning
[b] Taken shortly before slaughter in the feeding pen
[c] Taken at the time of slaughter

Table 3. Phenotypic correlations among scores for aggressiveness, nervousness, flightiness, gregariousness, and overall disposition in calves scored shortly after weaning

	Nervousness	Flightiness	Gregariousness	Overall
Aggressiveness	0.85435	0.85853	0.82022	0.89438
	<0.0001	<0.0001	<0.0001	<0.0001
Nervousness		0.97978	0.95661	0.98422
		<0.0001	<0.0001	<0.0001
Flightiness			0.95682	0.98335
			<0.0001	<0.0001
Gregariousness				0.96180
				<0.0001

Table 4. Phenotypic correlations among scores for aggressiveness, nervousness, flightiness, gregariousness, and overall disposition in steers scored shortly before slaughter in the feeding pens

	Nervousness	Flightiness	Gregariousness	Overall
Aggressiveness	-0.07893 0.3420	-0.07801 0.3476	-0.10222 0.2180	0.20195 0.0142
Nervousness		0.97225 <0.0001	0.64219 <0.0001	0.88815 <0.0001
Flightiness			0.63365 <0.0001	0.88918 <0.0001
Gregariousness				0.60126 <0.0001

Table 5. Correlations among scores for overall disposition

	All Weaning	Steers Feeding	Steers Slaughter	1st Calf Heifers	2nd Calf Heifers
Recipient	0.10404 0.0639 n = 318	0.09612 0.3068 n = 115	-0.13753 0.1427 n = 115	-0.08853 0.5367 n = 51	-0.31399 0.4488 n = 8
Weaning		0.45785 <0.0001 n = 147	0.31169 0.0001 n = 147	0.43442 <0.0001 n = 78	0.35354 0.1639 n = 17
Feeding			0.31622 0.0002 n = 147	NA	NA
1st calf heifers					0.71597 0.0012 n = 17

Table 6. Least squares means by family for overall disposition score in calves scored shortly after weaning, with and without sequence within pen within birth year season in the model

Sire	Family	N	Overall Disposition + Sequence[a]	Std. Dev.	Overall Disposition - Sequence[b]	Std. Dev.
297J	70	30	3.19	1.92	3.11	1.92
	71	33	2.77	1.90	2.35	1.83
	95	31	3.95	2.00	3.81	1.95
432H	72	32	4.49	2.04	4.40	1.92
	73	8	3.93	2.15	3.17	2.18
	82	12	4.99	2.08	4.58	2.01
	96	77	3.85	2.46	3.51	2.19
437J	74	7	5.94	1.90	5.98	1.96
	75	24	4.43	1.86	4.39	1.86
	81	42	5.38	2.14	5.26	2.01
	83	27	3.71	1.97	3.69	1.92
	97	21	4.33	2.20	4.10	2.20
551G	76	7	2.58	1.98	2.04	2.06
	77	32	4.28	1.98	4.00	1.92
	80	46	3.80	2.17	3.56	2.10
	84	20	4.08	1.92	4.01	1.92
	98	15	4.21	1.86	3.68	1.90

[a] Sequence within pen within birth year season was included in the statistical model.
[b] Sequence within pen within birth year season was not included in the statistical model.

REPORT ON THE 2004 -2005 AMERICAN BRAHMAN BREEDERS ASSOCIATION NATIONAL CARCASS EVALUATION PROGRAM

J. C. Paschal

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Summary

The 2004-05 American Brahman Breeders Association National Carcass Evaluation Program was conducted at Graham Land and Cattle C. Feedyard. A total of 78 purebred steers entered by 10 ranches were placed on feed for an average of 228 DOF. Feedyard performance and carcass merit were measured. The purebred Brahman steers had an ADG of 2.5 lb/d and graded USDA SE. Tenderness, as measured by Warner Bratzler Shear Force, averaged 7.84 lbs.

Introduction

In 1991, the first TAMU Ranch to Rail Program was conducted at Randall County Feedyard near Amarillo. The success of this program has broadened the knowledge of cattle feeding by many ranchers that had not previously fed any cattle. The results of the program gave many the confidence to adopt new practices to improve the performance and health of their cattle and make them more acceptable to the industry and improve the value they received for them in the marketplace (Floyd-Allen, 2002; Kistler et al., 2002).

The American Brahman Breeders Association, Houston, Texas, first conducted their National Carcass Evaluation Program in 2001 to assist their breeders in feeding out small groups of purebred Brahman steers to evaluate their performance in the feedyard as well as their carcass merit. The steers are fed at Graham Land and Cattle Co. Feedyard near Gonzales, Texas. Steers arrive within a designated week in the Spring and in the Fall and then are weighed, processed and placed on feed. Typically, the steers are placed on a starter ration for 14 d, then a slightly hotter "step-up" ration for 14 days, a "grower ration" for 60 days and the "finishing" ration for the duration of the feeding period.

At harvest, the steers are sold to Sam Kane Beef Processor in Corpus Christi, Texas where carcass data are collected 48 hr postmortem, and a ribeye steak is collected for 14-d shear force (tenderness) measurement. A report is then complied on the ranch and sire groups based on the individual results. The carcass information is being used in the calculation of carcass merit EPD (Franke et al., 2006). Since 2001, 410 steers have been (or are being) fed in the program. This is a report on the 2004-05 feedout results.

Experimental Procedures

In the Spring of 2004, 78 purebred Brahman steers representing 10 ranches arrived at Graham Feedyard and were weighed, processed and placed on feed. On-feed weight, USDA feeder cattle muscle and frame scores, and calf value per pound was assigned and recorded at this time. Steers were placed on a starter ration for two weeks and then moved on to two successively more energy dense rations for an additional two weeks and two months, respectively. A finishing ration was fed for the remainder of the feeding period. Sick steers were treated under the direction of the consulting feedyard veterinarian. When the pen feed consumption over the last 5 days began to peak, the steers were sold in the beef to Sam Kane's Beef Processor in one group (averaging 228 DOF) to approximate .3 in fat thickness. The steers were weighed by lot off feed prior to transport. As is customary, these weights were reduced (shrunk) 4% to determine a sale weight which was used to calculate ADG.

At slaughter, a subjective determination of the viscera was obtained focusing on the condition of the lungs for visible lesions or abscesses and liver for abscesses, liver flukes or other abnormal conditions. The lungs were scored from 1 (clear) to 5 (>75% affected). At Sam Kane Beef Processor, all carcasses (including these) were subjected to high voltage electrical stimulation to improve tenderness. Carcasses were weighed hot prior to cooling.

Carcass measurements were collected 48 hr postmortem. A 1-inch thick ribeye steak was collected, individually bagged and aged for 14 d for Warner Bratzler Shear Force (WBSF) tenderness determination that was completed in TAMU Meat Science Section Sensory Laboratory by Dr. Rhonda Miller. Other objective carcass measurements included a single fat thickness between the 12^{th} and 13^{th} rib (FAT), ribeye area (REA), hump size and location. Hump size was measured at its deepest point from the base near the spine to the outside fat cover and was perpendicular to the spine. Location denotes the location of the measurement in terms of cervical or thoracic vertebrae. Subjective measurements included marbling score, skeletal, lean and average maturity. Dressing percent was calculated by dividing total carcass weight by total sale weight, so all cattle had the same dressing percent.

Results and Discussion

The average on feed weight of the 78 steers was 537 lbs, but they ranged from 335 to 890 lbs. The average USDA feeder cattle and muscle score was Medium 2. The average price (based on current market conditions in South Texas) was $1.01 per lb, giving an average calf value of $537.47 per head (range $351.75 - $801.00). The 76 calves remaining on feed (2 died) were fed for an average of 228 days and gained an average of 568 lb (241 to 790 lb). The ADG of the steers averaged 2.50 lb (1.08 to 3.44 lb). This performance was typical purebred Brahman steers. The average sale weight of the 76 steers was 1062 lbs, but they ranged from 592 to 1513 lb.

The average carcass weight was 658 lb (367 - 938 lb) and the average dressing percent was 62%. This is similar to long term averages observed at Sam Kane Beef Processor but 1% lower than more recent figures. Fat thickness averaged .24 in (.05 - .70 in.). Ribeye are averaged 12.3 sq. in. which is acceptable but the range was 8.0 - 16.5 sq. in. Since heavier carcasses tend to have larger REA, the REA divided by the carcass weight (in hundredweights, cwt) represents an indication of muscling partially accounting for the increase in carcass weight (REA/CWT). The REA/CWT averaged 1.88 sq. in. per cwt, slightly more than the desired 1.8 sq. in. Percent kidney, pelvic and heart fat averaged 2.0% (1.0 - 3.0%). Lean, skeletal and average maturity scores were all in A maturity denoting carcasses 30 months of age or less. Marbling scores average SLIGHT 78 but ranged from Slight 00 - Small 80. The average quality grade was SELECT 80 (High Select) and ranged from SELECT 00 (Low Select) to Choice 27 (Low Choice). A total of 27.6 percent of the carcasses were Choice (although all Low Choice) and 72.4 percent were Select. The average yield grade was 2.1 and ranged from 1.1 to 2.9. A total of 98.7 % of the carcasses were yield grade 1 or 2.

Of interest to cattle producers of Bos indicus influenced breeds and their crosses is the acceptance or discounting of their cattle and their carcasses based on external factors like hump size or tenderness. Some alliances will not accept cattle over a certain hump size. In the Ranch to Rail-South Program, the average hump size of all carcasses measured in the program over a 10 year period averaged 3.99 inches for cattle that averaged 35% Bos indicus influence. These purebred Brahman steers average hump size was 7.6 in (5.0 - 12.0 in) with 27.6% being centered over the 1st thoracic vertebra and the remaining 72.4% being centered over the 2nd thoracic vertebra.

The average WBSF was 7.84 lb (5.40 - 12.56 lb) which was very acceptable due to genetic selection coupled with high voltage electrical stimulation, and ageing. A total of 42 steers had WBSF of 8 lb or less (55.3%), 31 hd were between 8 and 10 lb (40.8 %) and only 3 were above 10 lb (3.9%). The average WBSF observed in a four year sample of Ranch to Rail-South cattle was 6.5 lbs (Paschal et al., 2003b).

Implications

It is important for breeders of purebred Brahman cattle to evaluate their cattle for factors affecting feedyard performance and carcass merit (including tenderness) of their cattle. This information can be used in selection decisions as well as marketing programs. It is currently being used in the calculation of carcass merit and tenderness EPD.

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REPORT ON THE 2004 -2005 SANTA GERTRUDIS BREEDERS INTERNATIONAL NATIONAL STEER FEEDOUT

J. C. Paschal and J. R. Meeks

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Summary

The 2004-05 Santa Gertrudis Breeders International National Steer Feedout was conducted at King Ranch Feedyard. A total of 82 purebred steers sired by 31 sires were placed on feed for an average of 191 DOF. Feedyard performance, carcass merit and feedyard profitability was measured. The steers had an ADG of 3.62 lb/d, graded USDA SE+ 3.2, returned $165.95 over costs. Average tenderness, as measured by Warner Bratzler Shear Force, was 7.25 lbs.

Introduction

In 1991, the first TAMU Ranch to Rail Program was conducted at Randall County Feedyard near Amarillo. The success of this program has broadened the knowledge of cattle feeding by many ranchers that had never fed any cattle. The results of the program gave many the confidence to adopt new practices to improve the performance and health of their cattle and make them more acceptable to the industry and improve the value they received for them in the marketplace (Floyd-Allen, 2002; Kistler et al., 2002,).

In 2003, the Santa Gertrudis Breeders International, Kingsville, Texas, Breed Improvement Committee proposed a National Santa Gertrudis Steer Feedout to allow their breeders to feedout small groups of purebred steers to evaluate their performance in the feedyard as well as their carcass merit. The steers are fed at King Ranch Feedyard near Kingsville, Texas. Steers arrive within a designated week in the Spring or the Fall and then are weighed, processed and placed on feed. At harvest, the steers are sold to Sam Kane Beef Processor in Corpus Christi, Texas where carcass data are collected 48 hr postmortem, and a ribeye steak is collected for 14-d shear force (tenderness) measurement. A report is then complied on the ranch and sire groups based on the individual results. The carcass information will be used in the calculation of carcass merit EPD. To date, 22 breeders have evaluated 106 Santa Gertrudis sires with 511 head of steers. This is a report on the 2004-05 feedout results.

Experimental Procedures

In the fall of 2004, 83 purebred Santa Gertrudis steers representing 31 sires arrived at King Ranch Feedyard and were weighed, processed and placed on feed. On feed weight, USDA feeder cattle muscle and frame scores, and calf value per pound was assigned and recorded at this time. Calf value was a simple multiplication of the on feed weight and the value per pound. All the steers were fed as one group. Steers were placed on a starter ration for two weeks and then moved on to two successively more energy dense rations for an additional two weeks each. A finishing ration was fed for the remainder of the feeding period. Sick steers were treated under the direction of the consulting feedyard veterinarian. When the pen feed consumption over the last 5 days began to peak, the steers were sold in the beef to Sam Kane's Beef Processor in one of two groups (averaging 191 DOF) to approximate .5 in fat thickness. The steers were weighed individually off feed prior to transport. As is customary, these weights were reduced (shrunk) 4% to determine a sale weight which was used to calculate ADG.

At slaughter, a subjective determination of the viscera was obtained focusing on the condition of the lungs for visible lesions or abscesses and liver for abscesses, liver flukes or other abnormal conditions. The lungs were scored from 1 (clear) to 5 (>75% affected). At Sam Kane Beef Processor, all carcasses were subjected to high voltage electrical stimulation to improve tenderness. Carcasses were weighed hot prior to cooling.

Carcass measurements were collected 48 hr postmortem. A 1 inch thick ribeye steak was collected, individually bagged and aged for 14 d for Warner Bratzler Shear Force (WBSF) tenderness determination that was completed in TAMU Meat Science Section Sensory Laboratory by Dr. Rhonda Miller. Other objective carcass measurements included a single fat thickness between the 12th and 13th rib (FAT), ribeye area (REA), hump size and location. Hump size was measured at its deepest point from the base near the spine to the outside fat cover and was perpendicular to the spine. Location denotes the location of the measurement in terms of cervical or thoracic vertebrae. Subjective measurements included marbling score, skeletal, lean and average maturity. Dressing percent was calculated by dividing hot carcass weight by sale weight.

All costs were assigned to the consignors by the feedyard, which include medicine, processing, feed, and total costs.

Individual costs for feed were determined by number of head days for each animal. Feed and total cost of gains values were calculated by dividing the feed cost and total cost by the total weight gain. The steers were sold live and this fed price was multiplied by their sale weight to obtain a fed steer value. Net return was calculated by subtracting calf value and total cost from fed steer value. Feeding margin was calculated as the difference in fed price and total cost of gain multiplied by total gain and represents the amount of profit (or loss) made during the feeding period. The marketing margin is the difference in fed price fed price and calf price multiplied by on feed weight. Adding the feeding and marketing margins result in the net return.

Results and Discussion

The average on feed weight of the 82 steers was 613 lbs, but they ranged from 426 to 926 lbs. The average USDA feeder cattle and muscle score was Medium 2. The average price (based on current market conditions in South Texas) was $1.05 giving an average calf value of $635.36 per head (range $511.20 - $833.40). The average age of these calves was 463 d and ranged from 279 to 521 d. The calves were fed for an average of 191 days and gained an average of 646 lb (417 to 794 lb). The ADG of the steers averaged 3.35 lb (2.06 to 4.1 lb). These feedyard results were typical purebred Santa Gertrudis steers. The average sale weight of the 81 steers was 1258lbs, but they ranged from 989 to 1618 lb. Medicine costs averaged $1.97 per head ($0 - $22.05). Only 8 (9.6%) of the steers became sick and only one died (1.2%), from tetanus. The feeding performance of these steers was consistent with that observed in six years of feeding purebred and F_1 Santa Gertrudis steers in the Mini Ranch to Rail Program (unpublished data).

The average carcass weight was 787 lb (606 - 1037 lb) and the average dressing percent was 62.5% (57.8 - 67.4%). This is similar to long term averages observed at Sam Kane Beef Processor but 1% lower than more recent figures. Fat thickness averaged .55 in (.2 - 1 in.). Ribeye are averaged 12.4 sq. in. which is acceptable but the range was 10.4 - 16.7 sq. in.. Since heavier carcasses tend to have larger REA, the REA divided by the carcass weight (in hundredweights, cwt) represents an indication of muscling partially accounting for the increase in carcass weight (REA/CWT). The REA/CWT averaged 1.6 sq. in. per cwt, slightly less than the desired 1.8 sq. in. Percent kidney, pelvic and heart fat averaged 2.5% (1 - 3.5%). Lean, skeletal and average maturity scores were all in A maturity denoting carcasses 30 months of age or less. Marbling scores average SLIGHT 93 but ranged from Slight 00 - Modest 60. The average quality grade was SELECT 80 (High Select) and ranged from SELECT 00 (Low Select) to Choice 53 (Average Choice). A total of 35.8 percent of the carcasses were Choice (although mostly Low Choice) and 64.2 were Select. The average yield grade was 3.4 and ranged from 2.0 to 5.1. A total of 74.1% of the carcasses were yield grade 2 or 3. The carcass merit of these cattle (with the exception of the fat thickness and yield grade results which were higher in this report) was similar to the Mini Ranch to Rail Program.

Of interest to cattle producers of Bos indicus influenced breeds and crosses is the acceptance or discounting of their cattle and their carcasses based on external factors like hump size or tenderness. Some alliances will not accept cattle over a certain hump size. In the Ranch to Rail-South Program, the average hump size of all carcasses measured in the program over a 10 year period averaged 3.99 inches for cattle that averaged 35% Bos indicus influence. These purebred Santa Gertrudis steers average hump size was 4.3 in (3 - 5.5 in) with 11.25% being centered over the 7th cervical vertebra and 87.5% centered over the 1st thoracic vertebra.

The average WBSF was 7.25 lb (3.9 - 12.26 lb) which was very acceptable due to genetic selection coupled with high voltage electrical stimulation, and ageing. A total of 59 steers had WBSF of 8 lb or less (72.8%), 17 hd were between 8 and 10 lb (21%) and only 5 were above 10 lb (6.1%). The average WBSF observed in a four year sample of Ranch to Rail-South cattle was 6.5 lbs (Paschal et al., 2003b).

Processing costs averaged $5.80 per head and ranged from $0 - $7.04 per head. One lot was pre-processed prior to arrival. Feed costs averaged $310.75 per head ($14.64 - $424.65). Total costs averaged $324.20 ($26.12 - $437.13) and increased primarily due to sickness and increased DOF Feed and total costs of gain averaged $.49 and $.52 ($.38 - $.77 and $.40 - $.80) per lb gain. Over the two marketing periods the price of the fed steers averaged $.90 per lb ($.88 - $.91 per lb) resulting in an average value of the fed steers of $1,128.33 per head with a range of $899.81 - $1,4023.49. Net return averaged $165.88 per head but ranged from $-725.32 (for the one dead) to $306.80. Although these may vary by lot, feedyard and year, they are in the range of those reported by Paschal et al (2003a).

The feeding margin averaged $248.75per head and ranged from $0 to $406.20 while marketing margin averaged $92.81 per head and ranged from -$699.20 (the dead) to $9.26). The feeding margin was high because the fed price of the steers (average $.90/lb live) was much higher than the total cost of gain ($.52/lb) and the steers gained exceptionally well (averaging 646 lbs in 191 d). The marketing margin was low due to high calf prices (average $1.05/lb) relative to the fed price of the steers ($.15/lb lower) for these weight calves. In Bos indicus influenced calves, the feeding margin usually contributes the largest effect to net return due to discounts received as feeders.

Implications

It is important for breeders of purebred cattle to evaluate them for factors affecting feedyard performance, carcass merit (including tenderness) and overall profitability of their cattle, especially *Bos indicus* influenced breeds. This information can be used in selection decisions as well as marketing programs and in some designed programs for the calculation of feedyard and carcass merit EPD. It also serves to convey the current level of performance of the breeds to the general industry to reduce or eliminate misconceptions concerning specific breeds or breed crosses.

Acknowledgments

The authors express their appreciation for the collaboration of officers and breeders of Santa Gertrudis Breeders International, Kingsville, King Ranch, Inc. and King Ranch Feedyard , Kingsville, Sam Kane Beef Processor, Corpus Christi, and to the faculty and staff of the TAMU Animal Science Sensory Laboratory, College Station, for their participation and assistance in this project.

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Carcass and Meat Science

USE OF CALF INFORMATION TO PREDICT CARCASS TRAITS

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Summary
Individually, feeder calf grade, or early ultrasound data, when combined with weight did not account for substantial predictive power for most carcass traits in Beefmaster steers fed for a lean carcass program. Ranch of origin was an important source of variation when it was combined with ultrasound, weight and feeder calf grade in these purebred Beefmaster steers.
Combining additional sources of variation such as ranch of origin and sire within ranch along with phenotypic and ultrasound data was useful in these Beefmaster cattle, and the concept appears to hold promise for increased predictive power in regard to carcass traits.

Introduction
USDA feeder calf grades and weight are the basis of pricing young cattle in the USA. Ultrasound data are increasingly collected by seedstock producers and are also used to sort feedlot cattle in some cases. Use of more precise information is needed to efficiently manage and market feedlot cattle for specific carcass programs. The growing interest in marketing fed cattle on a value or grid basis, where prices are based on individual carcass merit, highlights the need for timely and accurate data on individual animals (Lusk et al., 2003). Many people feel that certain types of cattle should not be produced because they don't fit certain carcass programs. However, the large inefficiency in our beef cattle industry occurs when cattle of various genetic and management backgrounds are all managed the same for the same target market, or do not have a target market until after they are killed.

This paper will discuss a specific research project where the objective was to investigate prediction models where early measures of initial weight and feeder calf grade, ultrasound data, and background (sire and ranch) information could be used to explain variation in carcass component traits and carcass value of cattle fed for a specific target carcass program. This paper will also discuss some previous data analyses where the influence of ranch of origin on carcass traits was studied.

Experimental Procedures
Purebred Beefmaster steers (n = 160) were received at a commercial feedlot at Gonzales, TX in October and November, 2004 as part of the Beefmaster Breeders United (BBU) steer feedout project. Of these, 71 were from a single owner and arrived four weeks before other cattle and had no pedigree information, and, 68 were from four other owners and did have documented pedigree information. These cattle were fed for a lean carcass program with end point target for fat thickness of .40 to .45 in. Average weight at start of the trial was 713 lb, and the average final weight was 1,232 lb.

All cattle were evaluated for USDA feeder calf muscle and frame grades, were individually weighed and were ultrasound scanned on November 11, 2004 (corresponding to 7 or 35 d on feed). Cattle were individually weighed and ultrasound scanned at 56-d intervals and were harvested in two groups in May and June of 2005 at a commercial beef plant in Corpus Christi, TX .

Ultrasound data collected included ribeye area, percent intramuscular fat, 12th rib fat thickness, rump fat thickness, and gluteus medius depth. Multiple regression was utilized to evaluate all ultrasound measures and weight at each scan date. From these various traits, a "best" prediction model using the ultrasound and weight traits was selected for each scan date. Four sources of information were evaluated in an attempt to evaluate how much variation in carcass traits were accounted for by (A) feeder calf grade and weight, (B) ultrasound data and weight, (C) feeder calf grade, ultrasound data, weight plus ranch, and (D) all of the above information plus sire of calf. Evaluation of source D information therefore excluded all steers without pedigree information. R-square values were calculated through PROC GLM of SAS.

Results and Discussion
It has been recognized for a long time that there is a lot of variability among cattle ranches for production traits. Table 1 shows the average level of performance for feedlot and carcass traits in the Texas Ranch to Rail program across several years. The average actual performance for production traits is not drastically different across years, however, the average net return per steer, and, the range in net return per head across ranches has been widely different. The shift in cattle and grain market prices dictates the average net return. However, in every year no matter how good or how bad market conditions have been there are producers in each year that make money, and producers in every year that lose money in this retained ownership program where cattle are marketed on a general carcass grid.

If producers are better informed about the potential performance of their cattle, they can tailor their management and marketing more efficiently. Ultrasound has been used for several years now to estimate carcass composition in live animals for marketing of feedlot cattle as well as collecting data for breed performance programs and EPDs. As ultrasound data are collected closer to time of slaughter, they are more related to the actual carcass traits. Table 2 shows the correlations between the ultrasound trait and the actual carcass trait in the Beefmaster steers across the four scan times (taken at 56-day intervals). The correlation can be viewed as the percentage of relationship or similarity between two traits (on a 0 to 1 scale – 0 = no relationship, 1 = perfect relationship). After 168 days of the trial, there was a high correlation between the ultrasound and the carcass traits. The trick in using this information is determining how early in the feeding period it is useful to potentially sort cattle into outcome groups.

Table 3 shows the percentage of variation in six carcass traits that were accounted for by four different sources of information (A – D), and these same values are graphed in Figure 1. Information source A (feeder calf muscle and frame grade plus current weight) accounted for a moderate degree of variation in carcass weight and carcass value (which was heavily influenced by weight), but did not account for differences in fat thickness, marbling, ribeye area or yield grade. Information source B (ultrasound and weight) accounted for more variation that feeder calf grade, and became more useful as time on feed progressed. Information source C (feeder calf grade, ultrasound data, weight, plus ranch) was more useful in accounting for differences in carcass traits early in the feeding period, particularly for ribeye area and marbling. Finally, information source D (feeder calf grade, ultrasound information, weight, ranch plus sire) accounted for the most variation in these carcass traits. At day-0 of the trial, information source D accounted for substantial variation of 47% for fat thickness, 65% for ribeye area, 61% for yield grade, 64% for carcass weight, 56% for marbling, and 64% for carcass value.

This percentage of the variation that is accounted for is important because it is directly related to how closely a predicted value will be to an actual value. The correlation between the predicted and actual values will be approximately the square root of this value (i.e. if 81% of the variation is accounted for by a statistical analysis, the correlation between the predicted and actual values will be close to 90%). This trial shows that with these sources of information, a large portion of the variation in carcass traits can be predicted early in the feeding period in Beefmaster cattle managed in this type of program. If these same cattle had been managed and fed for a different target end point or program, these values may have been substantially different.

In a review article, Williams (2002) discussed how sorting cattle in the feedlot with ultrasound at various times prior to harvest could increase profitability from $11 to $27 per animal depending upon target market, feedlot, etc. One particular study also showed that simple sorting regimes using only a few factors returned more dollars than more complex regimes. As we develop guidelines for cattle producers to follow for improved production efficiency and profitability, we must keep them simple enough to be sustainable.

When sire information is available it is likely to be useful in predicting variation in carcass traits, and, we expect this because heritability values in all carcass traits have been shown to be heritable. However, sire information is not known in many cases by commercial producers. Even when sire information is not known, when combining data from multiple ranches within a breed, individual ranch differences can be large, and these individual ranch differences are even more pronounced when different breeding programs are employed. Table 4 shows that in the 2003-2004 Ranch to Rail-South steers, large differences existed among ranches for all feedlot and carcass traits evaluated.

Implications

Individually, feeder calf grade, or early ultrasound data, when combined with weight did not account for substantial predictive power for most carcass traits in Beefmaster steers fed for a lean carcass program. Ranch of origin was an important source of variation when it was combined with ultrasound, weight and feeder calf grade in these purebred Beefmaster steers. Combining additional sources of variation such as ranch of origin and sire within ranch along with phenotypic and ultrasound data was useful in these Beefmaster cattle, and the concept appears to hold promise for increased predictive power in regard to carcass traits; however, this type of research but needs more study with other cattle types and other feedlot management and marketing programs. Producers should strive to identify management strategies and marketing outlets that complement their cattle for increased production efficiency.

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Table 1. Summary of Texas Ranch to Rail Project 1992- 2001

	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-01
no. ranches	152	380	250	258	186	166	101	111	74
no. cattle	1582	3268	2873	2911	2072	1904	1137	1311	775
In value ($/hd)	486.16	486.38	419.04	345.03	353.47	469.21	384.96	464.03	462.28
Mean ADG	2.87	2.89	3.05	2.98	2.96	2.77	3.04	3.01	2.76
% Ch	37.5	33.0	38.0	36.0	38.0	36.0	39.0	51.0	53.0
% St	3.5	7.0	3.0	9.0	6.0	9.0	6.0	4.0	3.0
% YG 1 & 2	73.0	71.0	68.0	68.0	77.0	81.0	82.0	58.0	75.0
% YG 4 & 5	2.0	2.0	5.0	4.0	6.0	1.0	2.0	10.0	2.0
Medicine ($/hd)	5.80	12.19	4.76	9.44	3.02	5.82	2.85	4.47	8.82
% Sick	21.9	34.1	NA	29.4	14.4	26.6	13.9	16.6	22.5
% Death Loss	1.0	1.3	0.7	1.3	1.6	1.5	2.3	1.4	2.2
Feedyard costs ($/hd)	290.73	345.01	301.21	353.29	337.68	339.14	278.48	311.37	348.59
Cost of gain ($/cwt)	49.53	60.12	51.70	68.88	61.52	62.71	53.11	50.91	61.39
Income ($/hd)	932.45	803.92	784.91	709.37	787.43	753.91	734.54	902.04	952.96
Net Profit/Loss ($/hd)	155.56	(27.47)	64.66	(28.32)	96.28	(54.44)	71.10	124.64	142.09
Range net/hd/ranch ($)	(0.21) 307.03	(310.01) 174.64	(112.34) 209.61	(307.91) 137.04	(286.72) 208.07	(268.36) 99.45	(104.04) 181.93	(167.00) 276.93	(248.29) 279.06

Texas Cooperative Extension, Department of Animal Science – Texas A&M University (Harborth, 2003)

Table 2. Correlations between ultrasound measurement and carcass trait of interest across scan times in Beefmaster steers.

	Scan time[a]			
Pair of traits	1	2	3	4
UIMF-Marbling	.30	.41	.53	.66
UREA-REA	.15	.30	.49	.75
UFAT-Fat	.30	.55	.69	.70
Weight-HCW	.58	.63	.69	.79

[a]Scans taken at 56-day intervals.
[b]UIMF, UREA, UFAT = ultrasound intramuscular fat, ribeye area and 12th rib fat, respectively.

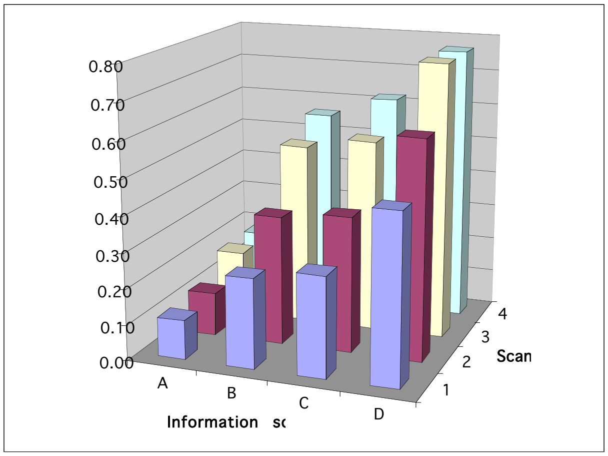
Table 3. Percentage of variation in carcass traits of Beefmaster steers accounted for by prediction models due to scan session (1 – 4) and source of information (A – D)[1]

	Fat thickness					Ribeye area			
	A	B	C	D		A	B	C	D
1	0.11	0.25	0.28	0.47	1	0.06	0.02	0.20	0.65
2	0.12	0.36	0.38	0.61	2	0.16	0.22	0.40	0.75
3	0.18	0.51	0.54	0.77	3	0.16	0.24	0.38	0.78
4	0.18	0.56	0.62	0.77	4	0.27	0.59	0.65	0.82

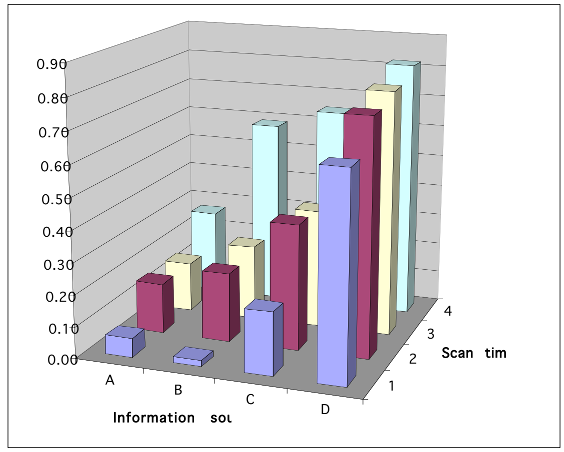
	Yield Grade					Carcass weight			
	A	B	C	D		A	B	C	D
1	0.20	0.25	0.34	0.61	1	0.36	0.34	0.46	0.64
2	0.10	0.24	0.31	0.69	2	0.42	0.40	0.49	0.72
3	0.21	0.41	0.54	0.76	3	0.49	0.50	0.58	0.75
4	0.10	0.47	0.58	0.81	4	0.68	0.70	0.76	0.86

	Marbling					Carcass value			
	A	B	C	D		A	B	C	D
1	0.02	0.14	0.35	0.56	1	0.49	0.47	0.51	0.64
2	0.04	0.17	0.35	0.59	2	0.62	0.58	0.63	0.73
3	0.05	0.42	0.47	0.65	3	0.59	0.58	0.63	0.79
4	0.10	0.54	0.55	0.76	4	0.86	0.80	0.81	0.91

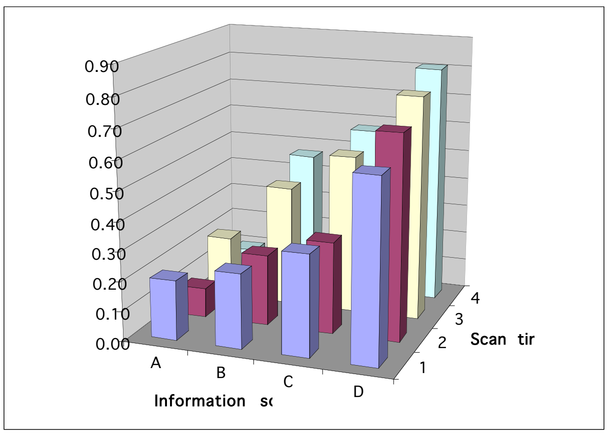
[1]Source of information: A = Frame score, muscle score and weight, B = Ultrasound data and weight, C = Information from A and B plus ranch, D = Information from A, B and C plus sire.



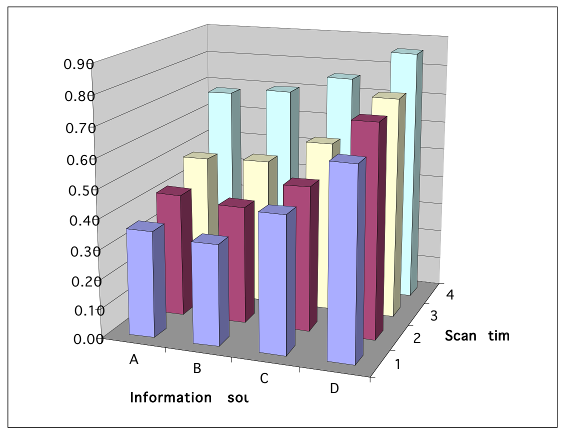
1a. Fat thickness



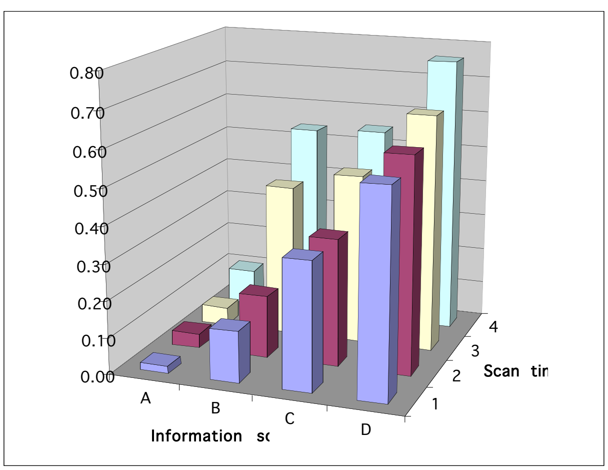
1b. Ribeye area



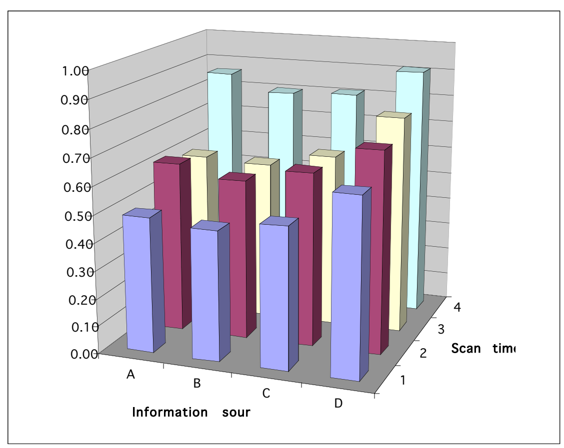
1c. Yield grade



1d. Carcass weight



1e. Marbling score



1f. Carcass value

Figure 1. Percentage of variation in carcass traits accounted for by combinations of source of calf information (A - D) and scan time (days 0, 56, 112, and 168). See text for definitions.

Table 4. Significance of various effects on carcass and feedlot traits in 2003-2004 Texas Ranch to Rail-South steers (n = 430).

Effect	ADG	REA	MARB	FAT	HCW	[a]IVALUE	[b]MED	[c]DOF	[d]CVALUE
Muscle score (M)	NO	NO	NO	YES	NO	YES	NO	NO	NO
Frame score (F)	NO	NO	NO	YES	NO	YES	NO	NO	NO
M x F	NO	NO	NO	YES	NO	YES	NO	NO	NO
Sire biological type	YES	NO	NO	YES	YES	YES	NO	YES	YES
Lung lesion score	NO	NO	NO	NO	YES	NO	NO	NO	NO
Ranch	YES	YES	YES	YES	YES	YES	YES	YES	YES
Number of treatments	NO	NO	YES	YES	NO	YES	YES	YES	NO
Initial weight	NO	YES	NO	YES	YES	YES	NO	YES	YES
Percent variation in trait accounted for by effects	33	37	30	32	48	98	92	88	35

[a]Initial value, [b]Medicine costs, [c]Days on feed, [d]Carcass value (Groschke et al., 2006)

EFFICACY OF GROWTH BASED PREDICTIONS OF CARCASS FAT THICKNESS AND MARBLING AT HARVEST USING ULTRASOUND MEASUREMENTS

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Summary

The objectives of this study were to formulate a more accurate prediction of carcass fat thickness (FAT) and marbling (MAR) based on individual weight gains and ultrasound measurements, while also clearly identifying those sources of variation that influence the accuracy of the prediction method. Calves were sired by Mashona bulls and out of females from a three-breed diallele mating system (Angus, Brahman, and Romosinuano), and early weaned (mean age = 74 d). Calves were then placed in confinement (FL) or pasture (PS) growing programs for an average of 141 d and finished on a common diet. Ultrasound FAT and MAR measurements were collected twice. Carcass FAT and MAR were predicted as functions of carcass weight gain estimated from live weights. Projections were compared to actual carcass values and percentage differences were indicative of projection accuracy. Results suggest accuracy of FAT and MAR predictions from growth-based equations is influenced by weight gain between ultrasound and endpoint, although scans out to 120 d pre-harvest may be accurate. Known sources of variation in accuracy could be used to scale predictions based on breed and gender to improve accuracy, and thus a growth-based, rather than time based, prediction system might be generated.

Introduction

Beef carcass value is based on the amount and distribution of adipose tissue. While increasing amounts of intramuscular fat increases carcass value, relative increases in subcutaneous fat decreases value. Therefore a certain amount of production risk is associated with continued feeding strategies in order to enhance intramuscular accretion. An accurate prediction of carcass fat would allow a producer to hedge against a loss in potential carcass value due to increased carcass waste. Changes in body composition are drastic over a feeding period and average daily gain values are reflective of those changes. Brethour (2000) established the use of ultrasound measurements to predict body composition. Bruns et al. (2004) established the changes in fat thickness and marbling score relative to change in hot carcass weight. Owens et al. (1995) established the relationship between empty body weight and body weight. This study was designed to evaluate growth-based equations derived from published relationships between carcass traits and growth traits for predictions of carcass FAT and MAR at slaughter using ultrasound measurements.

Experimental Procedures

Central Florida calves sired by Mashona bulls out of females from a three-breed diallele mating system (Angus, Brahman, and Romosinuano), were weaned (mean age = 74 d) for 40 d, and transported to central Texas for growing and finishing. Calves were stratified by breed type and gender and placed in confinement (FL) or on pasture (PT) for an average of 141 d during a growing phase, finished on a common diet, then harvested after approximately 300 (Grp1), 345 (Grp2), or 405 (Grp3) d on feed. Ultrasound FAT and MAR measurements were collected twice. Initial ultrasound FAT and MAR (US1) were collected 158, 207, and 264 d, and a second (US2) 74, 123, and 180 d prior to harvest for Grp1, 2, and 3, respectively (Table 1). Carcass FAT and MAR were predicted as functions of carcass weight gain estimated from live weights. Projections were compared to carcass values (48 h chill). Percentage differences (projected vs. actual) were analyzed as responses indicative of projection accuracy with harvest group, breed, gender, treatment, and 2-way interactions between harvest group, gender, and treatment as effects in the model.

Results and Discussion

Cattle from all slaughter groups had similar fat thickness ($P = 0.58$) and marbling score ($P = 0.64$) at harvest (Table 2). Because the prediction equations were used to create harvest groups, this result suggests that equations were effective in determining a consistent endpoint despite extensive variation in initial body composition among individuals. However, timing of ultrasound session relative to slaughter date influenced the accuracy ($P < 0.05$) of predictions. Previous studies have shown that FAT projection accuracy increases as days prior to slaughter decreases due to less change in overall fat thickness (Wall et al., 2004; Brethour, 2000). Our results suggest the accuracy for FAT projection was within 10% at either

158 or 180 d prior to slaughter but ranged from -88% to 35% during other spans. The equation used for predicting FAT was based on the first derivative of a quadratic relationship between FAT and hot carcass weight (Bruns et al., 2004). Early observations (light BW) would result in estimation of a slower accretion rate of FAT due to the underlying equation. Despite these inaccuracies in projecting FAT, the MAR projection was within 8% of actual values for ultrasound measurements taken within 123 d of slaughter, but decreased as time between scan and harvest increased. Wall et al. (2004) reported consistent projections for MAR at 65 or 100 d prior to slaughter, due to the linear nature of MAR deposition.

Breed type heavily influenced actual fat thickness ($P > 0.01$) and marbling score ($P > 0.01$) at slaughter (Table 3). Angus influenced cattle tended to have greater fat thickness pooled across all slaughter groups, compared to other breeds. Angus influenced cattle had higher marbling scores, while Brahman influenced had considerably lower scores at various slaughter dates. Breed type did not affect projection accuracy of FAT from either ultrasound session ($P = 0.18$), suggesting that within breed accretion rates were similar. However, breed type did affect projection accuracy for MAR from both ultrasound sessions ($P = 0.04$). Projection accuracy for MAR was greater when ultrasound data from US2 were used as basis of projection, yet relative separation among breeds was similar for US1 and US2. Projection accuracy from US2 was within 6% for calves with Angus influence, but over 20% for non-Angus, Brahman influenced calves. The greater accuracy for MAR prediction for Angus-influenced cattle may result from the use of prediction equations based on data generated from a serial slaughter experiment which included only Angus-sired cattle (Bruns et al., 2004). The over estimation of MAR for Brahman influenced calves suggests that accretion rate in these biotypes was lower than in the Angus based cattle. This difference, and the consistency of separation, may allow for a correction factor or breed coefficient to be added to the prediction equation to accommodate breed differences.

Gender impacted actual fat thickness ($P = 0.02$) and marbling score ($P > 0.01$) at harvest (Table 4). Heifers had greater fat thickness relative to steers and consistently produced carcasses with higher marbling scores. When fed a similar length of time, heifers would be expected to have greater carcass adiposity due to differences in composition of gain. Gender also impacted the accuracy of FAT projections (steer 32.5% vs. heifer 11.8%; $P > 0.01$). Likewise, gender influenced projection accuracy of MAR from both US1 (steers 43.9% vs. heifers 16.4%; $P > 0.01$) and US2 (steers 21.9%, heifers 0.5%; $P > 0.01$). The over prediction of both FAT and MAR for steers is likely due to greater rates of carcass gain in steers coupled with slower rates of fat accretion. Both of these factors would result in over prediction of fat components using our equations.

Dietary treatment during the growing period did not influence fat thickness ($P = 0.39$) but did impact marbling score ($P > 0.01$) at slaughter (Table 5). Interestingly, while FAT was similar, PS cattle had higher marbling scores following the finishing phase. Cattle were placed into slaughter groups based on an estimated fat thickness generated by the prediction equation, so a lower initial FAT measurement would require an extended feeding period. The PS fed cattle had lower fat thickness following initial treatment period, allowing for a longer finishing phase and greater marbling accretion. Treatment only influenced FAT accuracy based on US1 ($P > 0.01$), underestimating PS cattle by 58.4%. At the time when US1 measurement was taken, PS cattle likely had less FAT due to growing period treatment, thus the equation could not account for the accelerated accretion rate that would follow. Treatment did not affect FAT accuracy from US2, nor MAR accuracy from either session. A common diet had been fed long enough by the time US2 was taken that accuracy was not altered due to treatment.

Results suggest accuracy of FAT and MAR predictions from growth-based equations is influenced by weight gain between ultrasound and endpoint, although scans out to 120 d pre-harvest may be accurate. Known sources of variation in accuracy could be used to scale predictions based on breed and gender to improve accuracy, and thus a growth-based, rather than time based, prediction system might be generated.

Implications

Using growth-based prediction equations could further reduce the production risk associated with the variation in individual weight gain, which is inherent to time-based projections. Average daily gain values could be used to estimate carcass weight gain and potentially forecast an appropriate harvest weight relative to a desired carcass endpoint.

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Table 1. Days from ultrasound session to slaughter.

	Days from Ultrasound	
Item	US1	US2
Group 1	158 d	74 d
Group 2	207 d	123 d
Group 3	264 d	180 d

Table 2. Mean percentage differences for predicted vs. actual FAT and MAR values relative to harvest group.

	Harvest Group				
Item	Group 1	Group 2	Group 3	SE	*P* > F
FAT					
Actual[a]	0.58	0.55	0.54	0.035	0.58
US1	0.6%	-21.5%	-88.1%	11.95	<0.01
US2	20.6%	35.7 %	10.1%	6.81	0.02
MAR					
Actual[b]	424.8	430.4	409.4	17.65	0.64
US1	24.1%	26.9%	39.5%	4.93	0.04
US2	4.9%	7.8%	20.8%	3.82	<0.01

[a]Carcass fat thickness, inches

[b]Carcass marbling score, sm=400, mt=500

Table 3. Mean percentage differences for predicted vs. actual FAT and MAR values within breed.

	Breed Effect							
Item	MAA	MAB	MBB	MBR	MRA	MRR	SE	P>F
FAT								
Actual[a]	0.74	0.57	0.59	0.48	0.51	0.45	0.075	<0.01
US1	-44.4 %	-27.4%	-52.5%	-26.4%	-26.1%	-41.2%	25.43	0.86
US2	7.8%	22.7%	2.8%	29.4%	32.1%	38.1%	14.48	0.18
MAR								
Actual[b]	507.5	435.7	374.2	352.6	450.7	408.6	37.55	<0.01
US1	16.6%	21.8%	43.4%	44.2%	20.3%	34.8%	10.49	<0.01
US2	2.6%	5.8%	21.8%	20.1%	4.5%	12.2%	8.13	0.04

[a]Carcass fat thickness, inches
[b]Carcass marbling score, sm=400, mt=500

Table 4. Mean percentage differences for predicted vs. actual FAT and MAR values within gender.

	Gender Effect			
Item	Heifers	Steers	SE	*P* > F
FAT				
Actual[a]	0.60	0.51	0.03	0.02
US1	-41%	-31%	9.2	0.40
US2	11%	32%	5.2	<0.01
MAR				
Actual[b]	465	378	13.6	<0.01
US1	16%	43%	3.8	<0.01
US2	0.5%	21%	2.9	<0.01

[a]Carcass fat thickness, inches
[b]Carcass marbling score, sm=400, mt=500

Table 5. Mean percentage differences for predicted vs. actual FAT and MAR values within treatment.

	Treatment Effect			
Item	Feed Lot	Pasture	SE	*P* > F
FAT				
Actual[a]	0.54	0.57	0.02	0.39
US1	-14.3%	-58.4%	9.02	<0.01
US2	26.3%	18.0%	5.13	0.21
MAR				
Actual[b]	393	450	13.3	<0.01
US1	30.8%	29.6%	3.72	0.80
US2	14.6%	7.8%	2.88	0.07

[a]Carcass fat thickness, inches
[b]Carcass marbling score, sm=400, mt=500


Environment

HYDROGEN SULFIDE EMISSIONS FROM SOUTHERN GREAT PLAINS BEEF FEEDLOTS: A REVIEW

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Summary

A review of available published information on hydrogen sulfide (H_2S) emissions from beef cattle feedlots is reported in this paper. Most U.S. states have set limits for property-line H_2S concentrations to protect public health. Additionally, the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning & Community Right to Know Act (EPCRA) set reporting requirements for industries which emit more than 100 lbs/day of H_2S. Most studies report measurements of ambient H_2S concentrations near open-lot, beef cattle feedyards by Jerome meter. One study provided H_2S concentrations at the fenceline and H_2S emission rates from pen surfaces derived from a isolation flux chamber. Based on the limited number and duration of observations reported in the literature, it appears that property line concentrations will be below Texas regulatory thresholds. However, it is not possible to assess whether the 100 lb/day reporting requirement of CERCLA and EPCRA will be reached as almost no reported measurements of H_2S emission rates from runoff retention structures are available. Measurements of the H_2S emission rates from these structures is urgently needed to complete this assessment.

Introduction

Hydrogen Sulfide (H_2S) is emitted from animal feeding operations as a product of anaerobic breakdown of organic materials. There has been limited research efforts towards quantifying the H_2S emissions from open lot feedyards in the high plains of Texas, New Mexico, Oklahoma, Kansas and Colorado where more than 40% of U.S. beef cattle are fed and finished. As aerobic conditions are primarily observed in the feedyard manure packs, the ambient and property-line H_2S concentrations recorded are not as high as those associated with those intensive animal feeding operations where anaerobic conditions are primarily employed in treatment and storage systems. Exposure to high levels of H_2S can be fatal, while elevated levels can contribute to human health effects. Most states have regulations that set limits for ambient and/or property-line H_2S concentrations to protect public health. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning & Community Right to Know Act (EPCRA) set reporting requirements for industries which exceed 100 lbs/day of long list of compounds including H_2S.

Results & Discussion

There have been a number of studies looking at ambient H_2S concentrations near open-lot beef cattle feedyards in Nebraska (Koelsch et al., 2004) and Texas (Rhoades et al., 2003; Koziel et al., 2004; See, 2003). Koelsch et al. (2004) monitored H_2S as total reduced sulfur (TRS) concentrations at three open-lot beef cattle feedyards in Nebraska reporting mean H_2S concentrations downwind of pens ranging from 0.006 to 0.013 ppm, with 19 of 2,067 total observations greater than 0.100 ppm. Mean concentrations downwind of ponds were 0.002 to 0.014 ppm, with 11 out of 1,888 total observations greater than 0.10 ppm and two greater than 10 ppm. Koelsch et al. (2004) concluded that "TRS levels in the vicinity of beef cattle feedlots are not likely to exceed current regulatory thresholds used by midwestern states". Rhoades et al. (2003) measured H_2S (TRS) concentrations upwind and immediately downwind of pens and ponds at three feedyards over a 12-month period in 2002-2003. The authors used a Jerome meter to measure short duration (i.e. over a two-minute interval) concentrations. Three to four readings were made at each location and averaged, thus each mean reading would be representative of about a 10 minute time span. The H_2S readings were taken during the day, usually between 9 AM and 3 PM. Koelsch et al. (2004) showed a diurnal pattern in H_2S emissions with higher emissions in the later afternoon when the temperatures were warmer. See (2003) also reported higher H_2S concentrations between 2 PM and 4 PM. Because all of Rhoades et al. (2003) data were taken in the daytime, it is unknown if these data are representative of true 24-hr emissions. The measurements of TRS made by Rhoades et al. (2003) showed average concentrations of 0.026 ppm at the feedyard pen fence and 0.037 ppm immediately downwind of feedyard retention ponds. See (2003) reported H_2S concentrations downwind of pens and pond for data collected during summer from a beef cattle feedyard in the Texas Panhandle. Hydrogen sulfide concentrations were measured using a Jerome meter and datalogger every 15 minutes for 44 hours downwind of pens and 22 hours downwind of the pond. See reported mean downwind H_2S concentrations of 0.005 and 0.005 ppm for the pens and ponds, respectively. Koziel et al. (2004) measured ambient H_2S concentrations at an open-lot beef cattle feedyard over three seasons (fall, winter, and spring) using a TEI 45C pulsed fluorescence analyzer housed in a instrument trailer. The trailer was located on the western side of the feedyard, immediately adjacent to the pens. Because the trailer was stationary, the wind direction variable, and its location upwind of the feedlot for one of the dominant wind directions, the instrument was not always recording downwind concentrations, the mean values presented in their research are likely skewed on the low side and not representative of true downwind mean concentrations. Mean H_2S concentrations for fall, winter, and spring seasons were 0.008, 0.001, and 0.002 ppm, while maximum H_2S concentrations were 0.030, 0.003, and 0.035 ppm, respectively. Koziel et al. (2004) concluded that "measured H_2S concentrations were always lower than the ambient air ground level concentration maximums for the State of Texas."

There is very limited data available on H_2S emissions from open-lot beef cattle feedyard pens with the only reported emission rates from open-lot beef cattle feedyards being collected as part of the Federal Air Quality Initiative project. Gay et al. (2003) reported a mean TRS emission rate of 103 $\mu g/m^2/min$ from naturally ventilated, loose housed, beef steer housing facilities in Minnesota. Duyson et al. (2003) attempted to measure H_2S emissions using a wind tunnel and Jerome meter, however the concentrations were too low to quantify. Baek et al. (2003a,b) and Koziel et al. (2005) measured H_2S emission rates using a flux chamber (NC State design) and TEI 45C pulsed fluorescence analyzer. The data of Baek et al. (2003a,b) and Koziel et al. (2005) are summarized in Table 1. Based on these H_2S emission rate estimates, this equates to an extrapolated emission rate of 0.065-0.088 lb/d (0.029-0.040 kg/d) per 1,000 head using a stocking rate of 14.7 m^2/head. For a typical 50,000 head feedyard, this equates to an emission rate of 3.2-4.4 lb/day from the pens only.

No published estimates of H_2S emission rate from the runoff retention structures at open lot beef feedyards have been found in the published literature. Conditions in these runoff retention structures are usually slightly acidic and anaerobic with accumulating, decomposing organic matter. These conditions are conducive to H_2S generation and emission. While the area of the runoff retention structures is less than the pen area in a typical feedyard, it could be safely assumed that the emission rate is greater on a per area basis and these emissions may dominate the overall emissions from the facility.

Implications

Based on the measurements of downwind H_2S concentrations available from the published literature, it appears that there is a low probability that the average H_2S concentration downwind of a feedyard will exceed the ambient downwind H_2S regulatory values for Texas of 80 ppb (30 minute average), however that it is possible during critical atmospheric conditions. Assessment of the potential of a feedyard to exceed the CERCLA/EPCRA reporting requirement of 100 lbs/day is not currently possible given the lack of any published data regarding emissions from the potentially significant runoff retention structures. Measurements of the emission rates from these runoff retention structures is urgently needed to complete this assessment.

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Table 1. Hydrogen sulfide emission rates from two beef cattle feedyards measured using a flux chamber.

Reference	CAFO Type	Method	Emission Rate ($\mu g/m^2/min$)
Baek et al. 2003a,b	Beef Open-Lot	Flux Chamber	1.88
Koziel et al. 2005	Beef Open-Lot	Flux Chamber	1.39

THE COST OF CONTROLLING DUST IN FEEDLOTS

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Summary
Dust control is a growing concern for feedlot managers and environmentalists in the Texas Panhandle. Solid-set sprinklers are an effective way to control feedlot dust and create a better environment for cattle and neighboring communities. The cost to establish a solid-set sprinkler system is $20 to $31 per head capacity, depending on feedlot size. However, annual operational costs are only $0.39 to $0.46 per head capacity. This translates into a total annual cost of $2.79 to $4.09 per head capacity or $1.24 to $2.34 per head marketed based on a 25 year useful life. Therefore, minimal reductions in death loss and improvements in animal performance would be required to pay for the system. In addition, the positive externalities associated with improved public relations could far outweigh all costs.

Introduction
A growing issue for livestock producers, the general public, and environmental regulators is feedlot dust control. Feedlot dust is a critical problem that contributes to cattle death and illness, air pollution, and is a nuisance to neighboring communities. One of the most economic damaging problems to a feedlot is the bovine respiratory tract disease. Bovine respiratory tract disease causes 75% of all illness and 64% of all cattle death in feedlots (MacVean et al., 1986). Livestock producers can improve the environment, minimize neighbor complaints, and increase cattle productivity through implementation of dust management practices. Studies indicate water sprinklers are recommended to help control dust by keeping the surface manure moisture above 30 percent (Sweeten et al., 1988) which reduces dust potential directly and facilitates compaction to the maximum practical extent (Auvermann, Texas Cooperative Extension, Amarillo, TX, personal communication). This analysis specifically addresses the initial investment and operational costs associated with a solid-set sprinkler system.

Experimental Procedures
Project costs for installing a solid-set sprinkler system were estimated for three different size feedlots: 10,000, 30,000, and 50,000 head capacity. Capital costs include cost of the system, cost of the pipeline, and cost of a water storage tank. The cost of the sprinkler distribution system itself includes a pumping station, big gun sprinkler heads, pipeline manifolds, control valves and a computer with software to operate the sprinkler system. In addition, the design of each system is sufficient to apply at least 1/8 inch of water per day to the feedlot surface. The cost of a new well to pump groundwater, if needed, is not included in this analysis. Each of these expenses was estimated using average costs developed by the Natural Resources Conservation Services EQIP Program.

Fixed costs for a solid-set sprinkler system include interest and depreciation. Annualized costs are based on a useful life of 25 years with an annual interest rate of 6 percent. The straight-line method was used to calculate depreciation, and there was no salvage value assumed after the useful life of the system.

Operational costs include the annual energy cost, and maintenance and repair for the system. Energy costs include the cost of the energy required to pump the amount of water needed per day in addition to electrical maintenance and repair. Maintenance and repair costs include pump replacement and well maintenance for the system.

Energy costs were calculated based on sprinkler application of 1/8 inch of water net to 150 square feet per head of cattle per day of operation. Total pump head of 723 feet was calculated using 140 psi pump discharge to the sprinkler head (B. W. Auvermann, Texas Cooperative Extension, Amarillo, TX, personal communication) plus a pumping lift of 400 feet (L. L. New, Texas Cooperative Extension, Amarillo, TX, personal communication). In addition a pump efficiency of 60 percent was assumed. Annual sprinkler duty cycle used was 2,045 hours per year, running 12 hours per day, 8 months of the year, 70 percent of the time (G. L. Sokora, Natural Resources Conservation Service, Lubbock, TX, personal communication). A power rate of $0.08 per kwh was assumed to calculate energy costs. Energy requirements, 119 kwh per acre-inch, were estimated using the guidelines provided by Texas Cooperative Extension Agricultural Engineer, Leon New. In addition, an electrical maintenance and repair cost of $3.00 per hp per year was used (L. L. New, Texas Cooperative Extension, Amarillo, TX, personal communication) assuming a pumping capacity of 0.023 gpm per head of cattle (G. L. Sokora, Natural Resources Conservation Service, Lubbock, TX, personal communication). Total energy cost is a major component of operational cost and is approximately $0.37 per head capacity per year.

Pump replacement and well maintenance costs have also been calculated and included in the annual operational costs. On average, most systems require less than $1,000 per year to maintain. Pumps for the system should last 7 to 10 years before needing repaired or replaced (G. L. Sokora, Natural Resources Conservation Service, Lubbock, TX, personal communication). Replacing one pump every ten years for a 30,000 head feedlot would cost about $2,900, or $290 per year. In addition, well repair and maintenance has also been included in operational costs at the rate of $7,500 every 10 years (L. L. New, Texas Cooperative Extension, Amarillo, TX, personal communication).

Results and Discussion

Solid-set sprinkler systems are considered an effective way to control dust in feedlots. While the initial investment cost for a permanent fence-line sprinkler system can be high, once it is installed the operational expense, especially labor, is minimal (Davis et al., 1997).

Project Cost

Results of the analysis indicate that the average initial cost to install a solid-set sprinkler, including the sprinkler system, pipeline, and storage tank, is quite high. Project costs ranged from $307,371 ($31/head) for a 10,000 head feedlot to $1,014,743 ($20 per head) for a 50,000 head feedlot (Table 1). The cost of the sprinkler distribution system itself includes a pumping station, big gun sprinkler heads, pipeline manifolds, control valves and a computer with software to operate the sprinkler system. Each expense was estimated using average costs developed by the Natural Resources Conservation Services for use in the EQIP Program.

Fixed Costs

Fixed costs for a solid-set sprinkler system include the initial investment, interest and depreciation. Annualized costs are based on a useful life of 25 years with an annual interest rate of 6 percent. The initial project cost combined with interest and depreciation over a useful life of 25 years resulted in an annualized fixed cost ranging from $3.63 per head capacity for a 10,000 head feedlot to $2.40 per head capacity for a 50,000 head feedlot (Table 2).

Operational Costs

Operational costs include the annual energy cost, and maintenance and repair for the system. The total energy cost is a major component of the operational cost and is approximately $0.33 per head capacity per year. Energy costs combined with pump replacement and well maintenance costs resulted in a total operational cost ranging from $0.46 per head for a 10,000 head feedlot to $0.39 per head for a 50,000 head feedlot (Table 3).

Total Cost

Estimated annual fixed costs, as well as operational costs, have been combined to determine the total costs associated with a solid-set sprinkler system to control dust in a feedlot (Tables 4 & 5). Annualized fixed cost ranges from $3.63 per head capacity for a 10,000 head feedlot to $2.40 per head capacity for a 50,000 head feedlot. In addition, operational costs range from $0.46 per head capacity for a 10,000 head feedlot to $0.39 per head capacity for a 50,000 head feedlot. Total costs in terms of $/head are $4.09, $2.96, and $2.79 per head for a 10,000, 30,000, and 50,000 head capacity feedlot, respectively. Total costs decrease as the number of head capacity increases due to economies of scale.

Three different turnover rates were used to convert dollars per head capacity to dollars per head marketed. A five year average from the Southwestern Public Service Company Fed Cattle Survey determined the average cattle turnover rate for feedlots of 2.01 (head marketed / head capacity) (SPS, 1996-2000). With these three turnover rates, annual fixed cost, operational cost, and total cost were calculated on a per head marketed basis. Dependent upon the capacity of the feedlot and the respective turnover rate, the annualized total cost to install and operate a solid set sprinkler system ranges from $2.34 per head marketed to $1.24 per head marketed (Table 5).

Implications

The cost to establish a solid-set sprinkler system is $20 to $31 per head capacity, depending on the size of the feedlot, while annual operational costs are only $0.39 to $0.46 per head capacity. This translates into a total annual cost of $2.79 to $4.09 per head capacity or $1.24 to $2.34 per head marketed based on a 25 year useful life. Therefore, minimal reductions in death loss and improvements in animal performance would be required to pay for the system. In addition, the positive externalities associated with improved public relations could far outweigh all costs.

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Table 1. Estimated project cost for a solid-set sprinkler system for various feedlot capacities

Head Capacity	Sprinkler System	Pipeline	Irrigation Reservoir	Project Cost	Project Cost ($/Head Capacity)
10,000	$200,025	$8,346	$99,000	$307,371	$30.74
30,000	$456,750	$20,803	$171,000	$648,553	$21.62
50,000	$752,550	$27,193	$235,000	$1,014,743	$20.29

Table 2. Annualized fixed cost for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities

Head capacity	Project cost	Annualized fixed cost	Depreciation	Annualized total cost	Annualized cost ($/head capacity)
10,000	$307,371	$24,045	$12,295	$36,339	$3.63
30,000	$648,553	$50,734	$25,942	$76,676	$2.56
50,000	$1,014,743	$79,380	$40,590	$119,970	$2.40

Table 3. Annual operational costs for a solid-set sprinkler system for various feedlot capacities

Head capacity	Energy cost	Pump replacement	Well maintenance	Operational cost	Operational cost ($/head capacity)
10,000	$3,700	$145	$750	$4,595	$0.46
30,000	$11,100	$290	$750	$12,140	$0.40
50,000	$18,500	$435	$750	$19,685	$0.39

Table 4. Total annual cost including fixed and operational costs ($/head capacity) for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities

Head capacity	Fixed cost ($/head capacity)	Operational cost ($/head capacity)	Total cost ($/head capacity)
10,000	$3.63	$0.46	$4.09
30,000	$2.56	$0.40	$2.96
50,000	$2.40	$0.39	$2.79

Table 5. Total annual cost including fixed and operational costs ($/head marketed) for a solid-set sprinkler system based on a 25 year useful life for various feedlot capacities and turnover rates

Head capacity	Turnover rate (head marketed/ head capacity)	Fixed cost ($/head marketed)	Operational cost ($/head marketed)	Total cost ($/head marketed)
10,000	1.75	$2.08	$0.26	$2.34
	2.00	$1.82	$0.23	$2.05
	2.25	$1.62	$0.20	$1.82
30,000	1.75	$1.46	$0.23	$1.69
	2.00	$1.28	$0.20	$1.48
	2.25	$1.14	$0.18	$1.32
50,000	1.75	$1.37	$0.22	$1.60
	2.00	$1.20	$0.20	$1.40
	2.25	$1.07	$0.17	$1.24

FUEL PROPERTIES OF MANURE OR COMPOST FROM PAVED OR UN-PAVED CATTLE FEEDLOTS

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Summary

Research was conducted to determine the effects of feedlot surfacing materials (soil vs. coal-ash paved) and partial composting on feedlot biomass (FB) characteristics for use in thermochemical energy conversion involving reburn or co-firing with coal or lignite. FB was harvested from 12 fly ash-paved pens and 6 soil-surfaced pens and windrow-composting was initiated. Higher heating value (HHV) before composting was more than twice as high for manure from paved low-ash (LA-FB) vs. soil-surfaced high-ash (HA-FB) pens, and ash content dry matter basis was 66% lower for FB from paved (20.2%) vs. un-paved pens (58.7%). Partial composting (PC) for 51-55 days reduced HHV by 2-20% to 5,704 BTU/lb (at 19.6% moisture) and 2,230 BTU/lb (at 17.0% moisture) for low-ash (LA-FB-PC)/paved pens and high-ash (HA-FB-PC)/un-paved pens, respectively.

Introduction

The Texas High Plains is at the center of the so-called "cattle feeding capitol of the world", with 42% of U. S. fed beef production within a 200 mile radius of Amarillo TX, including neighboring states of OK, NM, KS and CO. Environmental quality and natural resource challenges facing the livestock feeding industry in the Southern Great Plains include: declining groundwater supplies in the Ogallala Aquifer, air quality emissions, particulate matter, odor, ammonia, hydrogen sulfide, volatile organic compounds, water quality protection, nutrient/soil management, mortality disposal, and energy cost-efficiency. New manure management approaches may become necessary for a sustainable beef cattle feeding industry in this region. Continued robust growth of the High Plains cattle-feeding industry is made possible by rising grain imports from other states, which now exceed 50%, according to industry estimates. With declining irrigated acres and applied nutrient amounts per acre, together with tradeoffs to lower water-use and less nutrient-intensive crops, longer hauling distances will be needed to accommodate phosphorus limitations on manure/wastewater application. Alternative utilization strategies for feedlot manure including use as an energy feedstock may become increasingly attractive for sustainable and efficient manure utilization within the cattle-feeding industry.

Particulate matter (PM) emissions, i.e. feedyard dust, which may result in complaints, are typically regulated at the state or local level in addition to involving National Ambient Air Quality Standards for PM10 and PM2.5 (Sweeten at al., 2000). Technologies that will control feedlot PM to manageable levels are being developed under a CSREES-funded project (Sweeten et al., 2005), which includes frequent manure harvesting, as a management tool to enable producers to reduce dust emissions (Auvermann et al., 2000).

Energy use at cattle feeding operations is substantial (Sweeten, 1996), and costs continue to escalate. Potential exists for on-site production & utilization of renewable energy including biomass conversion (Annamalai et al., 2005b). Renewable energy options involving animal wastes include: (a) methane capture from anaerobic waste storage/treatment units for manure in slurry form, and (b) thermochemical conversion using pyrolysis, combustion (including co-firing with coal or lignite) (Arumugam et al., 2005b), gasification (Priyadarsan et al., 2004; 2005), or reburn processes (Arumugam et al., 2005a; Annamalai et al., 2005a). Thermochemical conversion greatly reduces the volume of volatile materials, with residue (ash) material containing noncombustible minerals including N, K, P, and Cl which could be transported greater distances than bulk manure, if these materials can be utilized beneficially. Thermochemical conversion may provide a means of utilizing composted carcasses that could result from normal mortalities or major disease outbreaks on a local or regional scale. Several large, commercial feedyards have successfully incorporated carcass composting with feedlot manure

The Texas A&M University System is contributing major efforts to determine the effects of feedlot and open-lot dairy manure management practices on manure characteristics for use in biomass energy conversion systems involving reburn or co-firing with coal or lignite as base fuel. A research program focus is being placed on manure quality, i.e., maximizing higher heating value (HHV), minimizing ash content, and/or minimizing mineral contaminants (S, Cl, Na, K, P, etc) that can contribute to ash agglomeration or slagging in combustion units (Sweeten et al., 2003). Prior work detailed the changes in typical commercial feedlot manure (feedlot biomass, FB) quality that progressively occur with composting for 1, 32, and 125 days. FB can be important reburn fuel due to its volatile matter, reactive N as urea and NH4 content which reacts with NOx (Annamalai et al., 2005a). Reburn tests have showed greater NOx emissions reduction using pulverized partially-composted FB (up to 80-90%) than with baseline coal as reburn fuel.

Hence, current attention is being placed on (a) reburn technology to reduce nitrogen oxide (NO_x) (Annamalai and Sweeten, 2005) and heavy metals (e.g. mercury, Hg) emissions); (b) utilization of ensuing combustion ash as potential construction or fertilization material (Megel et al., 2006), and (c) preparing, characterizing, and supplying manure from the TAES/ARS experimental feedlot at Bushland, or from commercial feedlots, to specification for use in combustion, gasification, and/or reburn experiments to be conducted in pilot facilities in the TAMU Mechanical Engineering Department (MENG)/Renewable Energy Laboratory, Texas Engineering Experiment Station (TEES) (Annamalai et al., 2003). The experimental biomass materials include cattle feedlot manure produced from experimental cattle rations (Heflin et al., 2002; Greene and Vasconcelos, 2005) and from alternative surfacing materials (paved or unpaved feed pens). Experimental materials are either un-composted or partially composted (30-60 days) to improve chemical and physical uniformity, followed by solar drying and particle size reduction. The purpose of this research program was to evaluate feedlot biomass as a renewable energy resource for thermochemical processes. Specific objectives were as follows:

(1) Characterize harvested cattle feedlot manure from paved vs. un-paved feedpens as a biomass energy feedstock for combustion, gasification, reburn, or pyrolyis pilot plant test burns.
(2) Determine difference in harvested feedlot manure biomass chemical control or heating value as a function of feedlot surfacing materials and partial composting.

Experimental Procedures

The FB reported on in this study resulted from a 135-day beef cattle feeding trial at the TAES/ARS experimental feedyard in Bushland, TX, which concluded in May 2005 (McCollum and Bungenstab, 2005). The feeding trial used cattle rations containing trace amounts of a commercial bicarbonate acid buffer supplement (0.0 to 0.5 % weight basis). When the feeding trial was terminated, manure (FB) was harvested using a skid-steer loader from the 12 feedpens (8-hd each) that were paved with 6-8 inches of hydrated compacted mixture of fly ash & crushed bottom ash from a coal-fired power plant. The 12 paved pens produced 85,000 lbs as-collected weight of FB (called LA-FB), or an average of 7,083 lbs/pen. Similarly, the manure was harvested from the 6 unpaved soil-surfaced 8-hd pens. The 6 un-paved (traditional soil-surfaced) pens yielded 56,000 lbs as-collected weight or 9,333 lbs/pen (called HA-FB). The bulk as-collected manure was placed in two separate windrows according to type of pen surfacing material (LA-FB or HA-FB). A bulk sample of un-composted manure from LA-FB was collected from the windrow (10 sub-samples) using the skid loader prior to the start of composting (~952.5 kg, or 2,100 lbs.). This material was coarsely ground in a small hammer mill and placed in a greenhouse on June 2, and June 8, 2005 to facilitate drying. Similarly, the stockpiled un-composted manure from HA-FB feedpens was randomly collected (10 sub-samples) (~317.5 kg or 700 lbs bulk sample), coarsely ground in the small hammer mill, and placed in the greenhouse on June 10, 2005 for drying. Three composite (2 kg) samples composed of 10 sub-samples each of the un-composted as-collected LA-FB and HA-FB were taken before and after grinding just prior to greenhouse drying and were submitted for analysis.

Because of the low moisture content of the as-collected FB, water was added to start the composting process. Approximately 3,000 gallons of water was added on June 9, 2005 to the LA-FB windrow; and following heavy rainfall, approximately 800 gallons of water was added to the HA-FB windrow on June 13, 2005. The LA-FB and HA-FB was partially composted (PC) for 55 days and 51 days, respectively. Samples were removed from both windrows on August 2, 2005. These composite samples (2 kg each) were submitted for analysis.

The bulk samples of LA-FB and HA-FB collected both prior to and after partial composting were processed by a hammer mill and dried in a greenhouse to <10% moisture (wb). Then, for the PC materials, approximately 3,400-3,800 lbs of the LA-FB-PC, and 1,000 lbs of HA-FB-PC cattle manure were processed (pulverized) in a Vortec Impact Mill ® to further reduce the overall particle size (50% passing a 70 μm sieve) to accommodate co-firing or reburn experiments. Random samples (n = 3) were extracted from 10 sub-samples collected from each type of FB material: LA-FB, HA-FB, LA-FB-PC, and HA-FB-PC. These samples were sent to Hazen Research Inc., Golden, CO for analysis. Proximate & ultimate analysis, elemental analysis of ash-residue, and trace minerals (S, P, Cl, Na, metals, etc.) were obtained. For analysis of metals and elemental analysis of ash, only one composite sample was analyzed for each type of manure. Bulk density of material in both windrows was determined prior to composting using two alternative standard methods: ASAE (2005) Standard S269.4 and ASTM Standard D1895 B. ASAE standard method S269.4 was modified slightly by using a 0.028m^3 (1 ft^3) wood container rather than a 0.057 m^3 (2 ft^3) specified container size. The ASAE standard required the material to be successively poured from 2 ft. height and gravity-tamped 5 times until the container was filled. The manure was weighed after the fifth drop and addition of FB. This test was replicated 3 times with random bulk samples each of the HA-FB and LA-FB. Gravimetric moisture contents after 24 hours at 75°C in a drying oven were determined on each material tested. The ASTM standard required the material to be compacted in a know volume without gravity tamping, again replicated 3 times per LA-FB or HA-FB. Moisture contents were determined similarly.

Results and Discussion

Bulk densities were determined only for the un-composted FB, which showed major differences as a function of pen surfacing material. LA-FB from paved feedlots had a bulk density only two-thirds that of HA-FB from un-paved/soil-surfaced feedlots. Specifically, bulk density of LA-FB (at a moisture content of 6.40 +/- 0.24 % w.b.) averaged 31.97 +/- 0.29 lbs/cu.ft. using the modified ASAE standard and 26.81 +/- 0.03 lbs/cu.ft. using the ASTM standard. By contrast, HA-FB (at 4.95 +/- 0.02 % moisture w.b.) exhibited bulk densities of 46.65 +/- 0.86 lbs/cu.ft. with the modified ASAE standard and 40.61 +/- 0.71 lbs/cu.ft. with the ASTM standard. The packed FB materials (5 drops from 6 inches and refills) resulting from the modified ASAE standard exceeded that of the unpacked FB material from the ASTM method by approximately 19% and 15%, respectively, for LA-FB and HA-FB.

Results of proximate, ultimate, and elemental analysis were compared for unpaved vs. paved feedlot surface and for un-composed vs. partially composted FB. Moisture content was similar for the as-collected HA-FB (19.81 $\pm$ 1.24%) and LA-FB (20.27 $\pm$ 1.27%w.b.) prior to composting. But, HA-FB had much greater ash content (58.73% vs. 20.20 % d.b.) and only half the volatile matter (33.77 vs. 64.56% d.b.) and fixed carbon (7.50 vs. 15.24% d.b.) as LA-FB (Table 1). Higher heating value (HHV) was much lower (about half) for HA-FB than for LA-FB, both on an as-received basis (2,710 +/- 34 vs. 5,764 +/- 147 BTU/lb w.b.) and dry basis (3,380 +/- 14 vs. 7,229 +/- 92 BTU/lb d.b.). The LA-FB showed 10% higher HHV on a dry ash free (DAF) basis than HA-FB (9,059 +/- 13 vs. 8,200 +/- 327 BTU/lb DAF). LA-FB contained about twice the total carbon and hydrogen as HA-FB, and ~ 50% higher N and S. On an energy basis (lbs S per million BTU), sulfur content was lower in the LA-FB. Chlorine content of the manure was essentially the same for both HA-FB and LA-FB (average of 0.376% d.b.).

In terms of elemental composition of sample-ash (Table 2) compared to HA-FB, the LA-FB appeared to contain lower Si, Al, Fe and Ti, but was higher in Ca, Mg, Na, K, P, S, Cl, and Ba. However, these results were based on only one composite sample per FB type.

Both PC materials were similar in moisture at 17.00 $\pm$ 0.26% and 19.64 $\pm$ 2.54% w.b. for HA-FB-PC and LA-FB-PC, respectively. On a dry basis the LA-FB-PC, had 1/3 as much ash, twice the volatiles, and more than 3 times the Fixed Carbon and over twice the total Carbon and Hydrogen as HA-FB-PC. LA-FB-PC had 164% higher HHV as HA-FB-PC (d.b.) and 16% higher heating value on a dry-ash free (DAF) basis as HA-FB-PC. LA-FB-PC contained 80% more Nitrogen than HA-FB-PC, improving its usefulness for reburn fuel applications. But, LA-FB-PC had 68% more sulfur, twice the Cl, and 74% higher phosphorus than HA-FB -PC. LA-FB-PC had only 1/8 the ash and only 2/3 the S as HA-FB-PC on a heating value basis.

Compared to HA-FB-PC (Table 2), sample-ash from LA-FB-PC contained 2/3 less silica; less than half the Al, Ti and Fe; 2-3 times more Ca, Mg, Na, K, and S; was nearly 5-times higher in P and an order of magnitude higher in Cl.

As shown in Table 1, partial composting for 51–55 days increased ash and further reduced volatile matter, fixed C, total C, hydrogen and N both in HA-FB-PC and LA-FB-PC, compared to un-composted FB sources. Partial composting reduced HHV by 20% in HA- FB and only 2% in LA-FB. Sulfur content was changed very slightly with partial composting, but inexplicably the Cl content increased in the LA-FB-PC. Results did not indicate major differences in elemental composition of sample-ash for either HA-FB or LA-FB resulting from partial composting, but insufficient data was available to detect trends.

For comparison, samples of Texas lignite (TXL) and Wyoming Powder River Basin (PBR) coal were analyzed in the same manner as the FB materials, as shown in Table 3. Moisture contents were 38.34 +/- 0.34% w.b. and 32.88 +/- 0.36 % w.b., respectively, which was considerably higher than for the FB materials. Ash contents were much lower for the coal 8.40 +/- 3.11% d.b. vs. 18. 59 +/- 0.85% d.b. for TXL. The latter value is only slightly lower than for LA-FB and LA-FB-PC. Sulfur was higher (0.98 +/- 0.15% d.b.) in TXL than for PRB coal (0.41 +/-0.03 % d.b.) or either of the FB sources. On a dry matter basis, total carbon was much higher for TXL and PRB coal (60.30 +/-0.92 % and 69.32 +/- 2.82 % d.b., respectively) than either LA-FB or HA-FB. N was slightly lower and P and Cl much lower for either TXL or PRB coal compared to LA-FB or HA-FB. Compared to feedlot biomass (Table 1), HHV was considerably higher for both TXL and PRB coal (Table 3) on an as-received basis (6,143 +/- 127 BTU/lb w.b. and 7,823 +/- 282 BTU/lb w.b.); dry basis (9,962 +/-170 and 11,657 +/- 455 BTU/lb d.b.); and DAF basis (12,236 +/- 84 vs. 12,724 +/- 97 BTU/lb DAF). Elemental ash analyses (Table 2) appeared similar for TXL and PRB coal, but with differences vs. FB for several parameters. Additional analyses will be needed to verify any trends.

Implications

A residual 39,000 lbs bulk sample from the HA-FB windrow was provided (July 5, 2005) to a commercial company (Panda Energy Group) for use in commercial fluidized-bed combustion pilot plant test burns in Idaho. Mixtures of HA-FB and cotton gin residue (CGR) were used at weight ratios of 100/0, 75/25, & 50/50 in Idaho. Resulting fluidized-bed combustion ash (18,000 lbs) was returned to TAES-Amarillo for further testing in cooperation with West Texas A&M University (WTAMU) to determine engineering properties and soil fertility value. Results were discussed in Megel et al. (2006).

The processed LA-FB-PC material was used by the Texas Engineering Experiment Station (TEES) to evaluate reburn fuel injector configurations with pulverized coal: FB fuel blends of 90:10; 50:50 or 100:0%. (Annamalai et al., 2006). Procedures and results of these tests will be reported elsewhere.

Several conclusions emerged including: major differences (dry-matter basis) were determined between HA-FB and LA-FB for the following parameters: ash -- 58.7 vs. 20.2%; volatile matter --33.8 vs. 64.6%; fixed carbon -- 7.5 vs. 15.2%; heating value (HHV) -- 3,380 vs. 7,229 BTU/lb; N -- 1.91 vs. 3.11%; and S --0.42 vs. 0.67%, while Cl was similar (~0.38%). Bulk density of LA-FB was 2/3 that of HA-FB, averaging 29 vs. 44 lbs/ft^3 depending on methods used. Ash content of LA-FB was about one-third that of HA-FB (20% vs. 59%). Elemental analysis of sample-ash from LA-FB and LA-FB-PC was higher than from HA-FB or HA-FB-PC in Ca, P, Cl, K, Mg, Na, and S, but was lower in Si, Al, Ti, and Fe. However, metals contents were similar for both sources of FB. Partial composting increased ash; reduced C & N; and lowered HHV by 2% and 20% for LA-FB-PC and HA-FB-PC, respectively. Heating value on a dry-ash free DAF-basis averaged 8,995 BTU/lb for LA-FB-PC, and averaged 7,941 BTU/lb for HA-FB-PC. Project data on feedlot manure characteristics and HA-FB materials provided for pilot plant tests were used by a commercial company to help design a feedlot biomass (FB)/ cotton gin residue (CGR) combustion facility to provide heat energy to an ethanol plant near Hereford, TX.

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Table 1. Dry-basis comparison of un-composted and partially-composted FB from soil surfaced and crushed fly ash feed pens.

	HA-FB, Dry, %		HA-FB-PC, Dry, %		LA-FB, Dry, %		LA-FB-PC, Dry, %	
Parameter	**SS 101-103**		**SS 107-109**		**FA 104 -106**		**FA 110-112**	
	Before composting		8/2/05 -51 day compost		Before composting		8/2/05 -55 day compost	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Proximate:								
Moisture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ash	58.73	1.65	64.88	0.74	20.20	1.11	20.53	0.52
Volatile	33.77	1.26	31.07	1.31	64.56	0.94	65.11	0.59
Fixed C	7.50	0.45	4.05	0.95	15.24	0.27	14.36	0.28
Total	100.00		100.00		100.00		100.00	
HHV, BTU/lb	3,380	14	2697	60	7229	92	7097	17
MMF, BTU/lb	9,259	457	9015	228	9247	26	9119	45
MAF/DAF, BTU/lb	8,200	327	7682	169	9056	13	8931	38
Ultimate:								
Moisture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Carbon	21.69	1.14	17.97	0.25	43.09	0.49	42.05	0.14
Hydrogen	2.62	0.13	1.68	0.10	5.22	0.05	4.55	0.29
Nitrogen	1.94	0.07	1.36	0.03	3.11	0.03	2.45	0.02
Sulfur	0.42	0.02	0.38	0.02	0.67	0.01	0.64	0.04
Ash	58.73	1.65	64.88	0.74	20.20	1.11	20.53	0.52
Oxygen (diff.)	14.59	0.81	13.73	0.37	27.70	0.63	29.78	0.36
Total	99.99		100.00		99.99		100.00	
Chlorine One Composite of 3 samples per FB Type								
Chlorine, Cl	0.375		0.338		0.377		0.905	
Phosphorus, P2o5%								
P-Ash Basis	2.74	0.08	2.43	0.05	12.87	0.85	13.30	0.69
P-Dry Basis	1.04	0.04	1.57	0.01	2.59	0.04	2.73	0.11
Contaminants, Energy Basis:								
Ash, lbs/MM BTU	173.78	5.13	240.66	7.13	27.96	1.89	28.94	0.81
SO2, lbs/MM BTU	2.51	0.13	2.79	0.13	1.86	0.05	1.79	0.11

Note: Sample designations refers to Soil-Surfaced (SS) Feedpens (n=6) and Crushed Fly Ash-Surfaced (FA) Feedpens (n=10), which represent high ash (HA) and low-ash (LA) conditions, respectively.

Table 2. Elemental analysis of FB sample ash from as-collected/un-composted FB from un-paved & paved pens (HA-FB and LA-FB), from partially composted FB (HA-FB-PC and LA-FB-PC), and from Texas lignite and PRB coal, 2005.

Ash Elemental Analysis* (%), Equal-Weight-Composite (n=1)						
	HA-FB, %, Dry Basis	LA-FB, %, Dry Basis	HA-FB-PC, %, Dry Basis	LA-FB-PC, %, Dry Basis	TXL %, Dry Basis	PBB Coal %, Dry Basis
Silicon, Si02	64.68	25.55	65.55	20.78	48.72	31.73
Aluminum, Al203	7.72	1.94	11.2	4.94	16.04	17.27
Titanium, Ti02	0.44	0.27	0.52	0.22	0.85	1.35
Iron, Fe203	2.90	1.37	2.99	1.71	7.44	4.61
Calcium, Ca0	7.09	20.20	7.47	21.0	11.70	22.20
Magnesium, Mg0	2.34	7.17	2.29	7.54	1.93	5.62
Sodium, Na20	1.38	4.94	1.38	5.26	0.29	1.43
Potassium, K20	4.50	12.70	4.66	14.60	0.61	0.67
Phosphorus, P205	2.81	11.11	2.43	13.77	0.10	0.80
Sulfur, S03	1.06	4.46	1.30	4.47	10.80	10.40
Chlorine, Cl	0.68	5.02	0.41	5.07	<0.01	<0.01
Carbon Dioxide, C02	1.35	1.71	0.51	0.59	0.08	0.37
Total Ash Analysis	96.95	96.44	100.71	99.95	98.56	96.45
Metals in Ash (mg/kg) equal-weight (n=1)						
Arsenic	4.12	3.96	3.85	2.81	24.7	17.6
Barium	669	2,620	800	700	1,590	6,230
Cadmium	<1	2	3.8	8.2	3.4	5.2
Chromium	<20	20	30	40	98	110
Lead	20	20	27	15	47	130
Mercury	<0.01	<0.01	0.03	0.04	0.01	<0.01
Selenium	<2	2	<2	4	<2	<2
Silver	<2	<2	<2	<2	<2	<2
Total Metals in Ash	693.12	2,667.96	864.68	770.05	1,763.11	6,492.80

* Data represents one composite (n=1) of 3 samples of each FB material, lignite or coal.
**FB, TXL or PRB Coal were calcined @ 1100 deg. F (600 deg. C) prior to analysis.

Table 3. Texas lignite (TXL) and Wyoming Powder River Basin (PRB) coal*

Parameter	**TXL 113-115 (n=3)**		**PRB 116-118 (n=3)**	
	Dry, %		Dry, %	
	Mean	Std. Dev.	Mean	Std. Dev.
Proximate:				
Moisture	0.00	0.00	0.00	0.00
Ash	18.59	0.85	8.40	3.11
Volatile	40.20	0.53	42.45	1.02
0.45Fixed C	41.21	0.80	49.15	2.15
Total	100.00		100.00	
Heating Value				
HHV, BTU/lb	9962	170	11657	455
MMF, BTU/lb	12487	70	12828	81
MAF/DAF, BTU/lb	12236	84	12724	97
Ultimate:				
Moisture	0.00	0.00	0.00	0.00
Carbon	60.30	0.92	69.32	2.82
Hydrogen	3.44	0.14	4.06	0.13
Nitrogen	1.11	0.02	0.98	0.04
Sulfur	0.98	0.15	0.41	0.03
Ash	18.59	0.85	8.40	3.11
Oxygen (diff.)	15.58	0.44	16.83	0.29
Total	100.00		100.00	
Chlorine One Composite of 3 samples				
Chlorine, Cl	0.016		0.013	
Phosphorus				
P-Ash Basis, P_205, %	0.13	0.01	0.57	0.14
P-Dry Basis, P_205, %	0.02	0.00	0.05	0.01
Contaminants, Energy Basis:				
Ash, lbs/MM BTU	18.67	1.17	7.28	3.02
SO2, lbs/MM BTU	1.98	0.32	0.70	0.02

* Lignite and coal samples provided by TXU Energy, Dallas, TX; Sampling Date = 10/10/05.
Data are means and standard deviations of 3 samples of each material.

Feeding and Nutrition

META ANALYSIS OF THE CATTLE VALUE DISCOVERY SYSTEM PREDICTIONS OF FEED INTAKE AND EFFICIENCY IN GROWING AND FINISHING CATTLE

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Summary

Two databases were compiled to evaluate the effectiveness of the Cornell/Cattle Value Discovery System (**CVDS**) in predicting dry matter required (**DMR**) and feed conversion ratio (**FCR**) between DMR and ADG (**DMR:ADG**) from observed animal performance and to examine phenotypic correlations between model predicted and observed intake and feed efficiency. The first database consisted of four studies of growing calves (n = 514) fed high-roughage diets. The second database contained four studies of finishing steers (n = 320) fed high-grain diets. In both databases, DMR was moderately correlated (>0.71) with DMI; The ratio of DMR:ADG was highly and moderately correlated with FCR (0.81 and 0.61) for growing and finishing databases, respectively; Likewise, the PID was highly correlated with net feed intake (**NFI**) in both databases (>0.77); PID was more negatively correlated with ADG (-0.60; -0.23) and less positively correlated with DMI (0.18; 0.44) in the growing compared to finishing database, suggesting that model predictions were more robust for finishing than for growing calves. These findings suggest an overall satisfactory prediction of DMR by the CVDS model, but more work is needed to improve the predictability for growing animals.

Introduction

The conversion of feed into animal products during the post-weaning growth phase has a large influence on the cost of producing beef (Tess and Kolstad, 2000; Herd et al., 2003). The Cornell/Cattle Value Discovery System (**CVDS**) was developed to predict growth and feed requirements of individual cattle fed in groups based on animal, diet, and environment information (Fox et al., 2004). An enhanced, dynamic version of the CVDS model was developed and evaluated (Tedeschi et al., 2004) to improve the accuracy of these predictions. The CVDS utilizes observed BW, ADG, carcass measurements, breed type, environmental conditions, and dietary ME to predict BW at 28% empty body fat (**AFBW**), feed DM required for maintenance, feed DM required for gain, and their sum of DM required (**DMR**). From these values the model predicts several feed efficiency indicators, such as DMR:ADG and predicted intake difference (**PID**), which is calculated as DMI minus DMR.

Previous studies have shown model predicted DMR to be highly accurate in allocating feed to individual animals fed in groups with values within 2% of actual pen intakes (Fox et al., 2004). Additional studies examining genetic correlations between model predicted DMR and actual feed intakes have found a very high correlation (>0.95) between DMR and DMI (Williams et al., 2005). Due to the accuracy of CVDS and its relationship to observed traits, it may be a useful tool in identifying efficient animals. Therefore, a thorough evaluation of the CVDS model is needed for growing and finishing animals in different scenarios of production. The objective of this study was to compare observed individual DMI with model-predicted DMR of growing and finishing cattle of different breeds using Meta analysis.

Experimental Procedures

Two databases were compiled based on growing or finishing diets. The growing database contained 4 studies of steers and heifers (n = 514; initial and final BW of 604 to 776 lb) fed high-roughage diets (Table 1). The finishing database contained 4 studies of steers (n = 321; initial and final BW of 790 to 1150 lb) fed high-concentrate diets (Table 1).

Within studies cattle were individually fed and managed in a similar manner. Animal performance and carcass traits were used to compute the AFBW for each animal in the finishing database. Ultrasound measurements and predicted HCW were used to compute the AFBW for growing database.

The MIXED (SAS Institute Inc., Cary, NC) procedure was used in the statistical analyses. In the first analysis, all variables (Y_{ij}) were adjusted with a mixed model, assuming variance components for the variance-(co)variance matrix; however, only the intercept was adjusted for study effect (a_i) using the statistical model described in Equation [1]. Phenotypic correlations between dependent variables were analyzed using the adjusted variables for the effects of study on the intercept only.

$$Y_{ij} = \mu_N + a_i + e_{ij}$$
$$where$$
$$a_i \sim iid\ N\left(0, \sigma_N^2\right); e_{ij} \sim iid\ N\left(0, \sigma_e^2\right)$$

[1]

In the second analysis, DMI was regressed on DMR, assuming study as random effect and unstructured variance-(co)variance matrix as shown in Equation [2]. Then, observed DMI was adjusted, based on fixed effects plus the residue of this random regression. In this analysis, both the intercept and the slope were adjusted for study effects.

$$DMI_{ij} = a_i + b_i \times DMR_{ij} + e_{ij}$$
$$where$$
$$\begin{pmatrix} a_i \\ b_i \end{pmatrix} \sim iid\ N\left(\begin{pmatrix} \beta_0 \\ \beta_1 \end{pmatrix}, \Psi\right); \Psi = \begin{pmatrix} \sigma_a^2 & \sigma_{ab} \\ \sigma_{ab} & \sigma_b^2 \end{pmatrix}; e_{ij} \sim iid\ N\left(0, \sigma_e^2\right)$$

[2]

The net feed intake (**NFI**) values were calculated as the difference between actual DMI and expected DMI from multiple linear regression of DMI on ADG and metabolic BW ($BW^{0.75}$), assuming studies as random effects and variance components for the variance-(co)variance matrix using the statistical model described in Equation [3].

$$NFI_{ij} = DMI_{ij} - PredDMI_{ij}$$
$$PredDMI_{ij} = a_i + b_i \times ADG_{ij} + c_i \times BW^{0.75} + e_{ij}$$
$$where$$
$$\begin{pmatrix} a_i \\ b_i \\ c_i \end{pmatrix} \sim iid\ N\left(\begin{pmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \end{pmatrix}, \Psi\right); \Psi = \begin{pmatrix} \sigma_a^2 & \sigma_{ab} & \sigma_{ac} \\ \sigma_{ab} & \sigma_b^2 & \sigma_{bc} \\ \sigma_{ac} & \sigma_{bc} & \sigma_c^2 \end{pmatrix}; e_{ij} \sim iid\ N\left(0, \sigma_e^2\right)$$

[3]

Results and Discussion

Figure 1 illustrates the relationships between actual FCR and CVDS predicted DMR:ADG, as well as the relationships between actual NFI and model-predicted PID. In the growing database, there was a stronger correlation between FCR and DMR:ADG (0.81) compared to finishing studies (0.61). In both growing and finishing databases, PID was highly correlated with NFI (0.77 and 0.80, respectively), suggesting the model was able to explain 59 and 64%, respectively, of the unaccounted DMI when only ADG and metabolic BW were used to predict DMI.

Table 2 lists the phenotypic correlations between other observed and CVDS predicted traits for both growing and finishing databases. These correlations resulted from the use of Equation [1] to account for study effects on the overall mean (intercept only). The PID values were more negatively correlated with ADG (-0.60; -0.23) and less positively correlated with DMI (0.18; 0.44) in growing and finishing databases, respectively. In both growing and finishing databases, DMR was moderately correlated (0.71) with DMI; FCR was highly and moderately correlated with DMR:ADG (0.81 and 0.61) for growing and finishing databases, respectively. DMR was highly correlated with ADG (>0.80) in both growing and finishing calves. As well, DMR was negatively correlated with actual FCR in both growing (-029) and finishing (-0.51) calves likely due to the high correlation with ADG in which DMR would tend to increase when ADG increased. DMR was negatively correlated with DMR:ADG in growing (-0.43), but not finishing calves (0.01).

These results showed that phenotypic correlations between DMR and DMR:ADG were inconsistent between growing and finishing calves. Further work is needed to understand the factors affecting this outcome; this might be because the Beef NRC (2000) equations were developed for finishing animals and they may not be suitable for growing animals without proper modifications.

A further analysis between the relationship between feed for maintenance, predicted both by CVDS and multiple linear regression (Equation [3]), and metabolic BW is illustrated in Figure 2 suggested that as metabolic BW increased, predicted feed for maintenance increased at a higher rate (slope) when computed using multiple linear regression compared to when using CVDS in both growing and finishing databases. Both Equation [3] and CVDS predicted similar differences in the rates of increase (slope) of feed for maintenance as metabolic BW increased, when comparing growing to finishing databases.

Figure 3 illustrates the relationship between feed for gain, predicted by both CVDS and multiple linear regression, and ADG. There were fewer differences in predictions of feed for gain for the finishing database than the growing database between multiple linear regression and CVDS. As ADG increased, rate of increase of feed for gain (slope) increased at a greater rate for the growing database when feed for gain was predicted by CVDS rather than multiple linear regression. Multiple linear regression predictions of feed for gain showed less divergence between growing and finishing databases than CVDS predictions.

As discussed previously, the CVDS model was able to explain 50% of the variation in actual DMI (r = 0.71; Table 2). Nonetheless, this analysis adjusted only the mean of DMI based on the mean of study effects assuming there would be no interaction between DMI and studies. However, Figures 2 and 3 indicated that model predictions might have a different behavior depending on the stage of growth of the animals.

Therefore, a second analysis was performed to adjust DMI for both the intercept (overall mean) and slope (interaction between DMI and studies) for study effects using Equation [2]. This analysis is an attempt to account for study effects that cannot be accounted for by the model, therefore, it would indicate the greatest value the model could have predicted DMI if there was no study effects. In reality, this random effect will always exist and hardly will be able to be accounted for deterministic models. With the adjusted DMI, the CVDS model was able to explain 71% of the variation (r = 0.84) in adjusted DMI in both databases with a mean bias of -2.6% (overprediction) and accuracy of 0.96 (range of 0 to 1). Figure 4 illustrates the relationship between DMR and DMI adjusted to study effects on the intercept and slope. When DMI was adjusted for study and DMR effects, the variation in DMI and DMR decreased significantly. These findings indicated that study variation was about 21% (71 – 50%). But more importantly, it suggested that another 29% of the variation (100 – 71%) can still be accounted for by mathematical models.

Implications

The CVDS prediction of DMR accounted for a large portion of the variation in the adjusted DMI for study, and its prediction of DMR was moderately correlated to DMI. Model predicted measures of feed efficiency appear to be highly related to observed measures of feed efficiency. Feed for Maintenance showed a similar relationship to metabolic BW whether calculated by CVDS or MLR. However, MLR predictions exhibited a higher rate of increase in FFM as metabolic BW increased in both growing and finishing calves. FFG comparisons to ADG indicated that predictions for finishing calves were more similar between MLR and CVDS than that of growing calves. The CVDS model can satisfactorily predict DMI of both growing and finishing cattle. However, the predictions for finishing cattle may be more robust than for growing cattle. More research is needed to improve the model predictions for growing animals. Differences between growing and finishing cattle might be due to inaccurate description of the energy content of the diet and fiber fermentability in the rumen. Therefore, holistic models aggregating performance and carcass composition with diet characterization are needed.

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Table 1. Compilation of studies in the growing and finishing databases

	Finishing studies				Growing studies			
Study	King Ranch	McGregor	Cornell 1	Cornell 2	Spade Ranch	King Ranch	Camp Cooley 1	Camp Cooley 2
No. Animals	115	119	50	37	169	115	114	115
Diet ME, Mcal/kg	2.99	2.73	2.85	2.97	2.06	2.14	2.10	2.10
Sex	Steer	Steer	Steer	Steer	Steer	Steer	Heifer	Heifer
Breed	Santa Gertrudis	Red Angus	Angus/ Simmental	Angus	Braunvieh	Santa Gertrudis	Brangus	Brangus

Table 2. Person correlation coefficients of CVDS predicted and observed traits adjusted for study effects (*P < 0.05)

	Growing Studies			Finishing Studies		
	DMR	DMR: ADG	PID	DMR	DMR:ADG	PID
ADG	0.931*	-0.710*	-0.596*	0.838*	-0.522*	-0.234*
MBW	0.653*	0.289*	-0.146	0.637*	0.317*	0.067
DMI	0.727*	-0.135	0.180*	0.712*	-0.035	0.439*
FCR	-0.505*	0.808*	0.862*	-0.288*	0.614*	0.729*
NFI	0.015	0.038	0.771*	0.041	0.058	0.802*

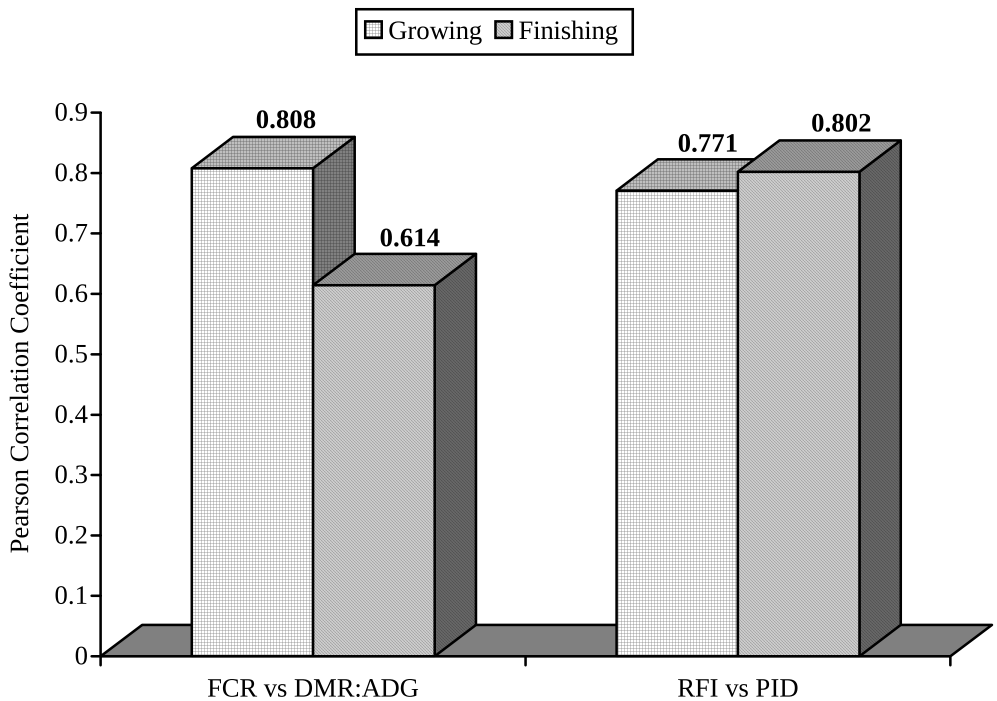

Figure 1. Partial Correlations for observed and CVDS-predicted efficiency traits, with PID calculated as DMI minus DMR, adjusted for effect of study (*P<0.0001)

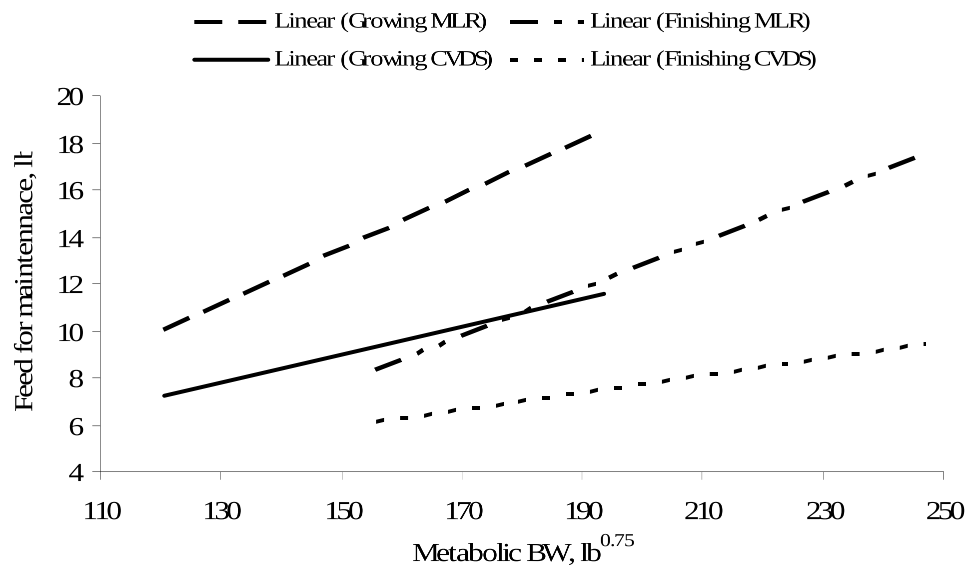

Figure 2. Comparison of feed for maintenance and MBW, with feed for maintenance values calculated by both CVDS and multiple linear regressions (MLR)

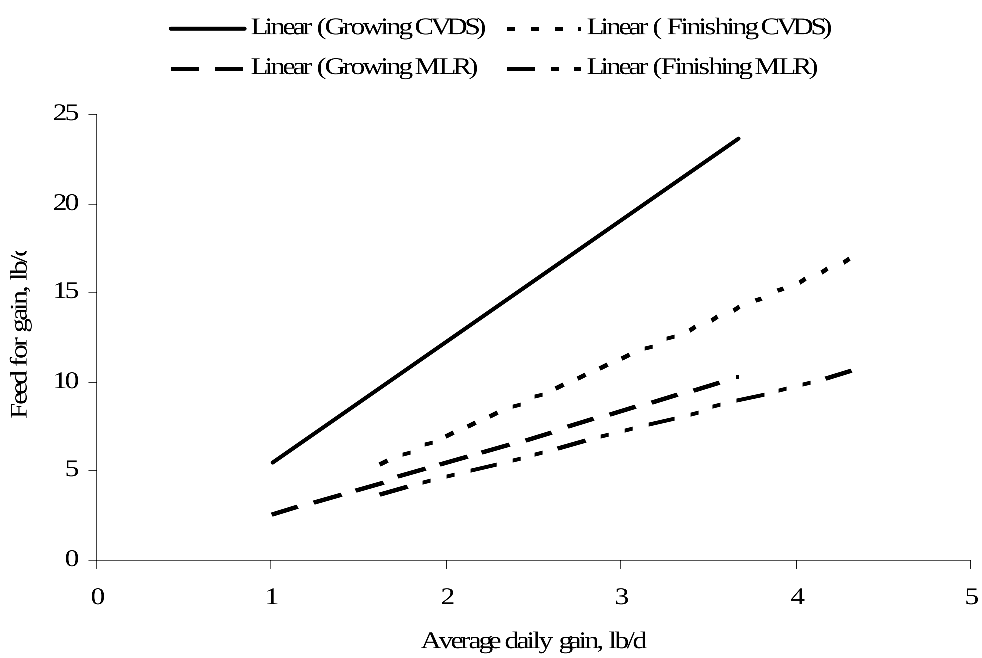

Figure 3. Comparison of feed for gain and ADG, with feed for gain values calculated by both CVDS and multiple linear regressions (MLR)

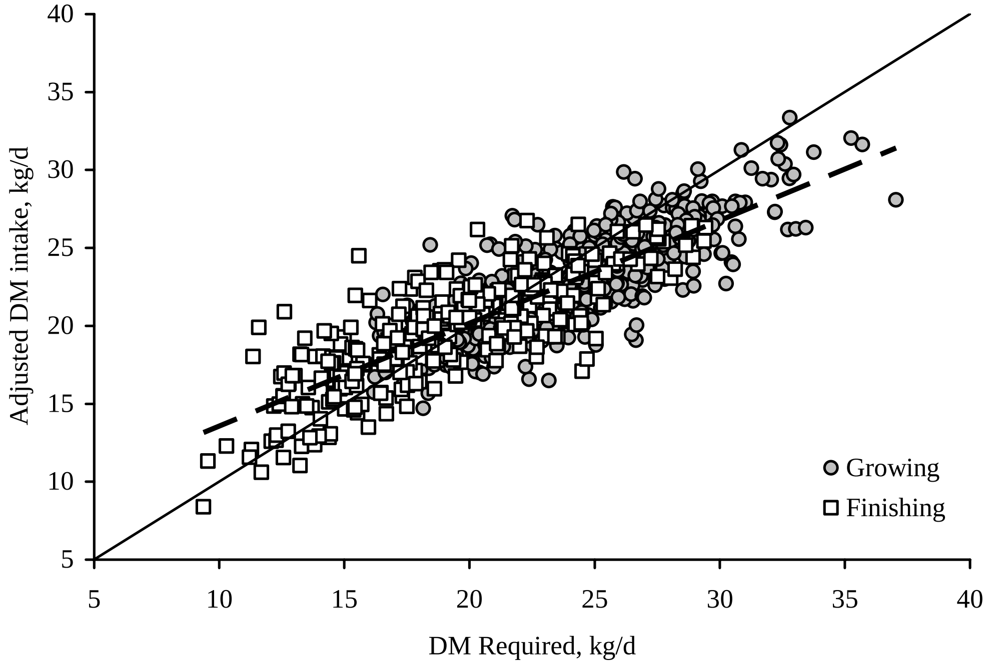

Figure 4. Comparison between model-predicted intake (DMR) and DMI adjusted for intercept and slope of study effects

EFFECT OF ORAL NITROETHANE ADMINISTRATION ON METHANE PRODUCTION AND RUMINAL FERMENTATION IN FED STEERS

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Summary

Methane production by bacteria within the gut of cattle represents an inefficient digestive process that can result in losses of as much as 15% of the dietary energy consumed by the animal. This digestive inefficiency costs the United States cattle feeding industry as much as $700,000 per day. Consequently, strategies that can effectively reduce methane production in beef cattle would substantially improve profitability as well as mitigate the impact of feedlot production systems on the environment. Nitroethane is a chemical that has been found to inhibit methane producing microorganisms in the laboratory. Presently, we tested the effects of nitroethane on methane production in cattle fed a high-roughage diet. Results confirmed that nitroethane inhibits methane-producing activity in cattle by as much as 40% without causing any impact on performance, possibly because microorganisms in the gut of these cattle were able to degrade nitroethane. These results demonstrate that nitroethane may be a viable feed additive to reduce feed input costs by reducing rates of ruminal methane production.

Introduction

Ruminal methane production is an inefficient digestive process resulting in the conversion of potentially energy-yielding, fermentable substrates into a form that can not be used by the host animal. In feedlot cattle, methane losses typically range from 2 to 4% of gross energy (GE) intake (Johnson and Johnson, 1995). Methane energy losses in feedlot cattle have been estimated to cost the United States cattle feeding industry $350,000 to $700,000/day. Costs are even higher in forage-fed cattle as methane losses can be as high as 15% of GE intake (Johnson and Johnson, 1995). Methane is a greenhouse gas that has been implicated in contributing to global warming. In the United States, approximately 20% of the total methane produced results from enteric fermentation, of which ruminant animals are major producers (EPA, 2004).

Certain nitrocompounds, such as nitroethane, inhibit ruminal methanogenesis by as much as 90% *in vitro* (Anderson *et al.*, 2003). Nitroethane is attractive as a methane inhibitor because it does not cause a shift in the production of volatile fatty acids (e.g., acetate, propionate and butyrate), and thus conserves fermentative efficiencies associated with microbial interspecies hydrogen transfer. Jung et al. (2004) also demonstrated that nitroethane was effective at inhibiting certain zoonotic pathogens. Presently, we report the effects of nitroethane on volatile fatty acid (VFA) accumulations, methane-producing activity and nitroethane-reducing activity in the rumen of cattle fed a high-roughage diet.

Experimental Procedures

Twenty-four Holstein steers, averaging 702 ± 14 lb, were randomly allocated in two replicates (3 steers/treatment per replicate) to treatments of 0, 30, 60 and 120 mg nitroethane/kg body weight (BW) per day. Treatments were orally administered as the sodium salt (Majak *et al.*, 1986) immediately before the morning (08:00) and afternoon (16:00) meals. The experimental diet consisted of 40% alfalfa, 30% bermuda grass, 11% cottonseed hulls, 11.5% corn, 7% molasses and 0.5% vitamin premix. Rumen fluid was collected from each steer, using a stomach tube, two hours after the morning feeding. Rumen fluid was placed into separate 60 mL serum vials, and immediately capped and returned to the laboratory for analysis of: (1) VFA concentrations, (2) *in vitro* measurements of methane-producing activity, and (3) nitroethane-reducing activity. The serum vials were directly and completely filled from the stomach tube to minimize oxygen exposure. Volatile fatty acid concentrations were measured by gas chromatography (Hinton *et al.*, 1990), methane-producing activity was determined via incubation of 5 g freshly collected rumen fluid with 5 mL anaerobic dilution solution (Bryant and Burkey, 1953) containing 60 mM sodium formate and 0.2 g finely ground alfalfa (to pass a 4 mm screen). The tubes were capped and incubated 3 h at 39°C under a H_2:CO_2 (50:50) atmosphere. Concentrations of methane present in the headspace were determined by gas chromatography (Anderson and Rasmussen, 1998). Nitroethane-reducing activity was determined in separate incubations prepared similarly, except for containing 5 mM nitroethane. Fluid samples collected at 0, 3, 6 and 24 h were analyzed for nitroethane using a colorimetric method specific for primary nitroalkanes (Majak *et al.*, 1982). Data were analyzed for main effects of nitroethane treatment, day of study and their interaction by a repeated measures analysis of variance.

Results and Discussion

Ruminal nitroethane-reducing activity (Figure 1) and methane-producing activity (Figure 2) differed markedly between the first and second replicates; therefore, the data from each replicate were analyzed separately. In the first replicate, an effect of day of study was observed on nitroethane-reducing activity as *in vitro* incubation of ruminal fluid collected before and on day 8 of treatment revealed that rates of nitroethane degradation increased ($P < 0.05$) from 0.02 ± 0.04 to 0.18 ± 0.12 μmol nitroethane/mL per h, thus suggesting an *in vivo* enrichment of nitroethane-reducing microbes (Figure 1). *Denitrobacterium detoxificans*, which is an obligate, nonfermentative, anaerobic-respiring bacterium, is the only currently known ruminal bacterium possessing appreciable nitroalkane-reducing activity, that is able to couple the reduction of nitroalkanes (e.g., nitroethane) to the oxidation of hydrogen or formate (Anderson *et al.,* 2000). While present at low numbers (≤ 1000 organisms/mL) in rumen fluid of cattle having no known exposure to nitroalkanes, the numbers of this bacterium can be enriched 1000-fold when nitrocompound are provided (Anderson *et al.,* 1996).

Incubation of ruminal fluid collected before and on day 2, 4 and 8 of the study revealed an effect of nitroethane treatment on methane-producing activity. Methane-producing activity from steers administered 60 or 120 mg nitroethane/kg BW were more than 25% lower ($P < 0.05$) than methane-producing activity of steers administered 0 or 30 mg nitroethane/kg BW (7.9 ± 2.1 and 8.0 ± 1.8 μmol CH_4/mL per h, respectively; Figure 2). An effect of day of study was also observed as methane-producing activities were reduced ($P < 0.05$) 23, 18 and 39% on days 2, 4 and 8 of treatment, respectively, when compared to pretreatment measurements (8.6 ± 1.5 μmol CH_4/mL per h; Figure 2).

In the second replicate, which immediately followed the first, pretreatment ruminal nitroethane-reducing activity (0.41 ± 0.04 μmol nitroethane/mL per h) was higher ($P < 0.05$) and methane-producing activity (3.2 ± 0.8 μmol CH_4/mL per h) lower ($P < 0.05$) compared to similar measurements obtained from the first replicate (Figures 1 and 2). These findings suggest the establishment of a competent nitroethane-reducing bacterial populations such as *D. detoxificans* during the pretreatment period, possibly acquired through contact with residual populations in the pen environment (i.e., from feed bunks, water troughs, etc.) and maintained on endogenous acceptors, other than nitroethane, present in the rumen of these cattle. At least one strain of *D. detoxificxans* is known to respire on nitrate (Anderson *et al.,* 2000), but whether it was nitrate or other undefined acceptors that were present is unknown. Transmission of high ruminal nitrate-reducing activity from cattle adapted to high levels of nitrate to unadapted cattle kept in separate pens has been reported (Cheng *et al.,* 1985). Considering that *D. detoxificans* can consume reductant at the expense of methanogenesis (Anderson *et al.,* 1998), it is reasonable to speculate that the presence of this bacterium may have contributed to the low methane-producing activity observed during the pretreatment period of the second replicate. Accordingly, the lack of treatment effect ($P = 0.53$), time of treatment effect ($P = 0.56$) or an interaction ($P = 0.24$) on methane-producing activity during the second replicate was likely due to the low activity observed during the pretreatment period.

Nitroethane treatment did not effect the production of volatile fatty acids in either replicate (Figure 3). This is consistent with earlier *in vivo* observations where nitroethane treatment did not affect the amounts or proportions of VFA produced within the rumen of sheep even though methane-producing activity was reduced as much as 69% (Anderson *et al.,* 2004). These results suggest that, whereas, nitroethane may initially inhibit ruminal methanogenesis through a direct chemical mechanism, reductions in ruminal methane production may also occur due to enrichment with other hydrogen- or formate-oxidizing bacterium capable of consuming electrons that otherwise could be used to reduce carbon dioxide to methane.

Implications

Results from this study support the concept that "nitro-supplementation" may be a viable strategy to reduce economic losses and mitigate potential environmental impacts associated with ruminal methane production in cattle. Future research is warranted to develop related nitrocompounds, which when reduced by rumen microbes, will yield compounds readily usable by the host animal.

Acknowledgements

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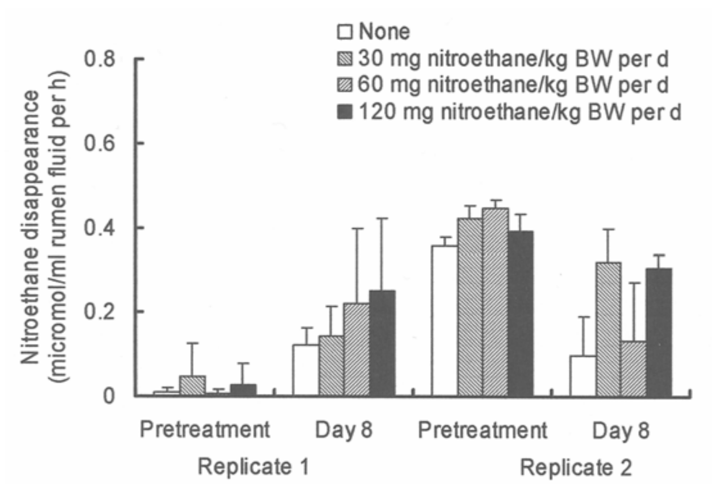

Figure 1. Effect of nitroethane dose on nitroethane-reducing activity in ruminal contents collected after the morning feeding for replicates 1 and 2. Nitroethane treatments were administered orally before morning and afternoon feedings.

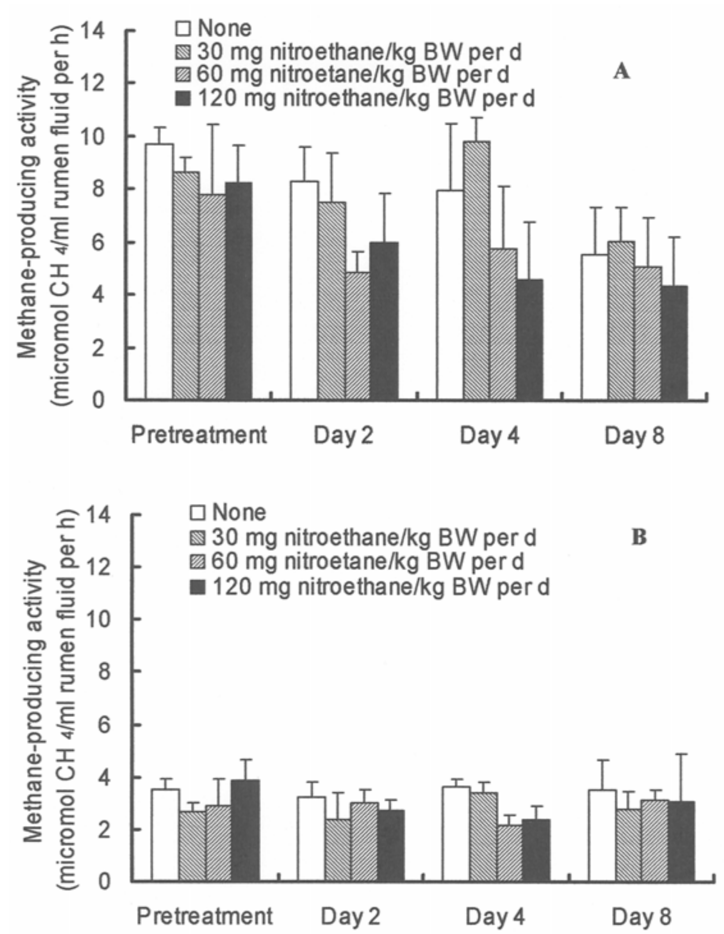

Figure 2. Effects of nitroethane dose and day of study on methane-producing activity in ruminal contents collected after the morning feeding for steers in replicate 1 (top panel A) and replicate 2 (bottom panel B). Significant nitroethane dose and day of study effects ($P < 0.05$) were observed in replicate 1, but not in replicate 2.

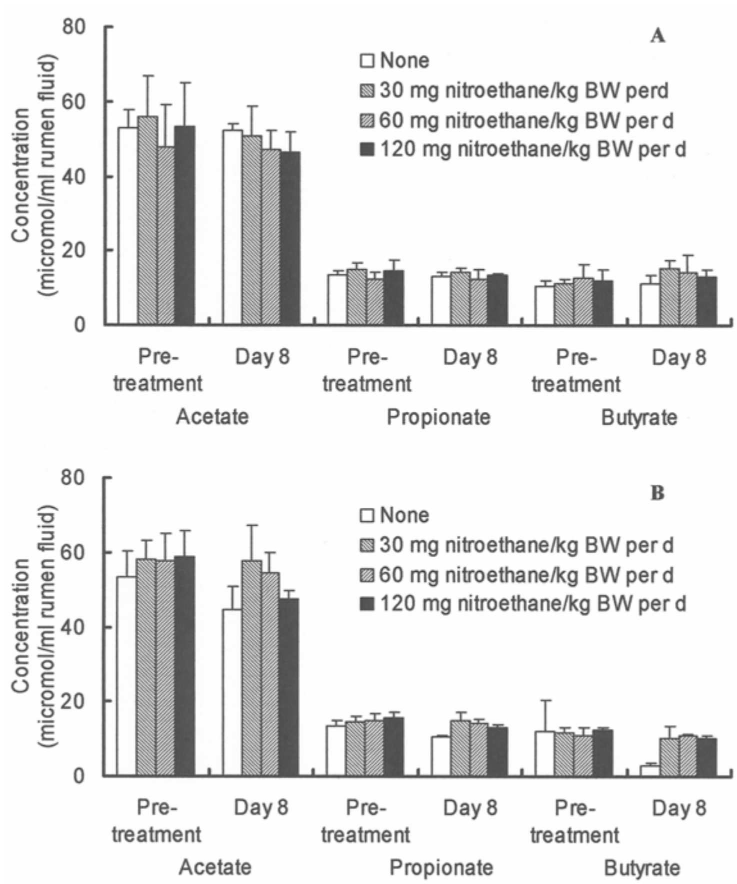

Figure 3. Effects of nitroethane dose and day of study on volatile fatty acid accumulations in ruminal contents collected after the morning feeding for steers in replicate 1 (top panel A) and replicate 2 (bottom panel B). Significant nitroethane dose and day of study effects were not observed in replicate 1, but a significant day of study effect was observed in propionate concentration in replicate 2.

EFFECTS OF ZINC SOURCE ON FEEDLOT PERFORMANCE AND CARCASS MERIT OF BEEF STEERS

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Summary

Two-hundred-seventy crossbred steers received either no supplemental zinc (**CT**), 90 mg/kg (or ppm) of Zn from $ZnSO_4$ (**S**), or 35 mg /kg of Zn from Availa Zn® + 55 mg/kg of Zn from $ZnSO_4$ (**AS**). Overall DMI and ADG (carcass basis) did not differ between treatments. Overall feed efficiency was improved 2% ($P < 0.10$) when steers received supplemental Zn, largely due to the response by AS. More yield grade 3 carcasses were produced by feeding S than by feeding AS (Chi-square, $P < 0.10$). Average marbling score and the number of carcasses grading at least low Choice were greater for CT than for the remaining treatments ($P < 0.10$), but return above feed cost based on carcass value did not differ among treatments. Supplemental zinc improved feed efficiency and reduced carcass quality, but resulted in similar net return. Feed efficiency was the most desirable for cattle receiving Availa Zn.

Introduction

Zinc is typically supplemented to finishing cattle between 50 and 100 mg/kg to promote optimum performance, and a number of zinc sources are commercially available. Feeding blends of zinc sulfate and one particular zinc-amino acid complex, Zinpro 100®, has become a common practice that is supported by research indicating a 3 to 4% improvement in ADG and feed efficiency by replacing a portion of zinc sulfate with Zinpro 100 (Anonymous, 2001). We previously observed (Brown et al., 2004) greater ADG by finishing yearling steers fed a more recently developed Zn-amino acid complex, Availa-Zn® (Zinpro Corp., Inc.), than steers receiving Zinpro 100 (3.82 vs 3.67 lb/d, respectively). The objective of this study was to further examine the influence of three zinc sources on feedlot performance and carcass characteristics of beef steers.

Experimental Procedures

Four-hundred-fifteen crossbred steers were procured from auction barns by an order buyer and were assembled at facilities in Okolona, MS. Steers were transported 880 miles to the study site; transit time averaged 16 hours. Steers were processed on arrival, and processing included individual identification, vaccination against viral antigens of IBR, PI_3, BRSV, and BVD type I and II (Titanium 5), administration of a clostridial bacterin-toxoid (Vision 7 with Spur), treatment for internal and external parasites (Cydectin), excision of existing implant(s), implanting with Ralgro, and horn tipping to a diameter of approximately 1 inch. Steers were reimplanted with Revalor-S and received 24 mL of Cylence to prevent lice infestation on day 56.

Steers were fed a common 55% concentrate for 7 days to normalize fill before starting the study. After feeding the common diet for 7 days, 270 steers were weighed before feeding and sorted into study pens (9 steers/pen, 10 pens/treatment). Initial study weight was the average of this weight and arrival weight. Dietary treatments were a basal diet without supplemental Zn (**CT**), 90 mg/kg of Zn from $ZnSO_4$ (**S**), and 35 mg/kg of Zn from Availa Zn® + 55 mg/kg of Zn from $ZnSO_4$ (**AS**).

Steers were adapted to the finishing diet by offering 55, 70 and 80% concentrate diets based on steam-flaked corn for 7, 7, and 7 days, respectively. Steers were fed a 90% concentrate diet (Table 1) once daily thereafter, and water tanks were cleaned each week throughout the study. Bunks were managed to contain from a few kernels to approximately 0.25 lb of refused feed/pen, and diets were manufactured and delivered once daily. Supplements were formulated using actual assayed Zn concentration (Table 1) determined before the study began.

Corn was processed approximately twice weekly by steaming grain for approximately 36 minutes before flaking to 29 lb/bu. Samples of diets were collected weekly from the bunk after feed delivery; dry matter was determined on a subsample, and remaining sample was composited gravimetrically within treatment over the entire study. Composite diet samples were assayed in triplicate for ash (6 h at 550°C), CP (Method 7.033; AOAC, 1990), ADF (Goering and Van Soest, 1970), EE, and minerals by a commercial laboratory. Weekly ingredient dry matter content with the exception of steam-flaked corn was used to update as-fed diet composition each week. Dry matter of steam-flaked corn was determined 5 days/week and the 5-day average was used to update as-fed diet composition each week.

Carcass-adjusted final weight was calculated by dividing actual hot carcass weight by the overall average dressing percentage. Feedlot performance, yield grade measurements, marbling score, and hot carcass weight data were analyzed with Mixed procedures (SAS Inst., Cary, NC) using pen as the experimental unit. The distributions of carcass yield and quality grades were analyzed as repeated measures with Genmod procedures

(SAS Inst., Cary, NC) using pen as the experimental unit. Means were separated using preplanned contrasts: 1) CT vs the average of S and AS; and 2) S vs AS.

Results and Discussion

Actual dietary Zn concentration of the CT diet was 33 mg/kg (Table 1), and diets supplemented with Zn contained 93 to 100 mg/kg more Zn. Overall DMI and ADG (Table 2) did not differ among treatments. However, feed efficiency was improved ($P < 0.10$) by providing additional Zn beyond that supplied by basal ingredients. The majority of the supplemental Zn response was due to Availa Zn ($P = 0.13$) rather than to zinc sulfate.

Consistent with the ADG data, hot carcass weight did not differ among treatments ($P > 0.10$). Carcass fat thickness at the 12th rib, Longissimus muscle area, Longissimus area/100 lb of carcass, and calculated yield grade were not influenced ($P > 0.10$) by treatment. However, marbling score was lower ($P < 0.10$) for steers receiving supplemental Zn than for CT. The number of carcasses grading at least low Choice was greater ($P < 0.10$) for CT than for steers receiving supplemental Zn, whereas the number of yield grade 3 carcasses was greater ($P < 0.10$) for S than for AS. Despite the reduction in carcass quality with supplemental Zn, gross return was not influenced by treatment in the present study.

A previous study conducted at this location (Brown et al., 2004) reported that ADG by steers receiving 60 mg/kg of Zn from zinc sulfate displayed performance similar to steers receiving an additional 30 mg of Zn/kg from either zinc sulfate, Zinpro 100, or Availa Zn, but carcass characteristics were not influenced by treatment. In that study, carcass-adjusted feed efficiency was numerically improved 2.5% for steers receiving Availa Zn, which was comparable to the improvement noted in the present study.

The lower carcass quality of steers fed supplemental Zn was not expected. Spears and Kegley (2002) indicated that individually fed steers fed a finishing diet containing supplemental Zn had higher marbling score and quality grade than steers that did not receive supplemental Zn during an 84-day growing period followed by 112-day finishing period. However, carcass fat thickness was also greater for steers receiving supplemental Zn. The impact of changes in body composition on feeding performance in the present study should be minimal because steers reached a similar fat thickness endpoint at the end of the study and were not fed to an excessive fat thickness. Mean marbling score was essentially at the division between Select and low Choice grades, and minor shifts in quality grade distribution are more likely to be detected than when the mean is close to this critical division.

Implications

Steers receiving Availa Zn converted feed into carcass weight more efficiently than steers that received no supplemental zinc or zinc sulfate only. The reduction in carcass quality grade for carcasses from steers fed supplemental Zn did not adversely affect gross return.

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Table 1. Ingredient and chemical composition of finishing diet dry matter (DM basis)

	Treatment[a]		
Item	CT	S	AS
Ingredient composition			
Corn, steam flaked (29 lb/bu)	78.0	78.0	78.0
Supplement[b]	3.0	3.0	3.0
Cottonseed meal, 41%	2.0	2.0	2.0
Cane molasses[c]	4.0	4.0	4.0
Yellow grease[d]	3.0	3.0	3.0
Alfalfa hay (2.5-inch screen)	10.0	10.0	10.0
Chemical composition[e]			
CP, % of DM	13.2	12.8	13.4
ADF, % of DM	5.8	6.1	6.3
EE, % of DM	6.0	5.7	6.2
NEm, Mcal/lb	1.01	1.01	1.01
NEg, Mcal/lb	0.70	0.70	0.70
Ash, % of DM	4.0	3.2	4.0
K, % of DM	0.97	0.96	0.99
Ca, % of DM	0.68	0.66	0.78
P, % of DM	0.30	0.30	0.30
Mg, % of DM	0.27	0.26	0.29
S, % of DM	0.24	0.24	0.25
Na, % of DM	0.19	0.17	0.18
Cl, % of DM	0.44	0.39	0.45
Cu, ppm	21	20	26
Fe, ppm	233	234	254
Mn, ppm	57	52	55
Mo, ppm	0.61	0.53	0.54
Zn, ppm	33	130	133

[a]CT = no supplemental Zn added, S = 90 ppm of Zn added from $ZnSO_4$, and AS = 35 ppm of Zn from Availa Zn + 55 ppm of Zn from $ZnSO_4$.

[b]Contained Zn as per treatment and the following (DM basis): 21.05% limestone, 6.0% KCl, 3.56% MgO, 4.17% ammonium sulfate, 5.0% salt, 18.0% urea, 38.92% cottonseed meal (41%), 0.0009% cobalt carbonate, 0.078% copper sulfate, 0.458% iron sulfate, 0.0012% EDDI, 0.103% MnO, 0.3% Se premix (0.2% Se), 0.14% vitamin A (30,000 IU/g), 0.108% vitamin E (500 IU/g), 0.337% Rumensin 80, 0.225% Tylan 40, and 1.0% mineral oil.

[c]Propionic acid was added at 0.5% (w/w) to prevent mold growth during storage.

[d]Rendox AET (Kemin Americas, Des Moines, IA) was added at 0.1% (w/w) to prevent oxidation.

[e]All values except NE were determined analytically from triplicate aliquots of composite diet samples collected from the bunk weekly; NE values were calculated from tabular values (NRC, 1996).

Table 2. Effect of dietary zinc source on overall feedlot performance and carcass traits by beef steers

Item	Treatment[a]			SE[b]
	CT	S	AS	
Pens	10	10	10	-
Animals	88	88	86	-
Initial shrunk body weight, lb	622	620	620	17
Adjusted final weight, lb	1295	1289	1299	14
Day 1 to 176				
DMI, lb/d	18.9	18.6	18.5	0.27
ADG, lb/d, carcass basis	3.83	3.82	3.88	0.07
DMI:ADG, carcass basis	4.94[c]	4.88[d, e]	4.79[d, f]	0.05
Hot carcass weight, lb	823	820	826	11
Marbling score[g]	404[c]	385[d]	387[d]	7.6
12th rib fat thickness, in	0.44	0.42	0.42	0.03
Longissimus muscle area, in^2	14.2	14.3	14.4	0.2
Longissimus area/100 lb	1.72	1.75	1.75	0.02
Calculated yield grade	2.54	2.45	2.43	0.08
Net return, $[h]	104.71	97.73	107.43	10.0
Prime, %	1.1	0	0	-
Average and high Choice, %	8.0	8.1	1.2	-
Low Choice, %	38.6	28.7[i]	40.7[j]	-
Select, %	51.1	58.6	53.4	-
Standard, %	1.2	4.6	4.7	-
≥ low Choice, %	47.7[c]	36.8[d]	41.9[d]	-
Yield grade 1, %	20.4	27.6	30.2	-
Yield grade 2, %	54.6	43.7	51.2	-
Yield grade 3, %	20.5	28.7[i]	15.1[j]	-
Yield grade 4 and 5, %	4.5	0	3.5	-

[a]CT = no supplemental Zn added, S = 90 mg/kg of Zn added from $ZnSO_4$, and AS = 35 mg/kg of Zn from Availa Zn + 55 mg/kg of Zn from $ZnSO_4$.
[b]Standard error of the least squares mean, n = 10.
[c,d]CT vs S and AS ($P < 0.10$).
[e,f]S vs AS ($P = 0.13$).
[g]Slight = 300 to 399, Small = 400 to 499, etc.
[h]Net return was calculated from a base grid price ($137.10/45.4 kg) and actual carcass data using the annual average premiums and discounts from 2002 through 2005 obtained from the USDA Agricultural Marketing Service annual 'National Carlot Meat Trade Review' (available at http://www.ams.usda.gov/lsmnpubs/mnsearch.htm). Values do not include data from carcasses that were dark, light (< 249 kg), heavy (> 454 kg), or bloodshot, and carcass maturity was excluded in assigning quality grade. Basal diet cost was assumed to be $120/ton of DM.
[i, j]S vs AS (Chi-square, $P < 0.10$).

IMPACT OF STEAM FLAKING AND GRAIN CHEMICAL TREATMENT ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS

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Summary

One hundred sixty-two crossbred steers were used to evaluate the influence of steam flaking and grain chemical treatment on feedlot performance and carcass characteristics. Treatments included 91% concentrate diets based on dry-rolled corn (DRC), dry-rolled corn treated with urea and amylase (DRT), or steam-flaked corn (SFC). Steers fed SFC consumed less ($P < 0.05$) than steers fed DRC (5.8%) or DRT (7.3%). Feed efficiency was improved ($P < 0.10$) 3.1% by feeding DRT and improved an additional 6.3% by feeding SFC. More carcasses from steers fed DRT graded average and high Choice ($P < 0.10$) compared to carcasses from steers fed SFC. There was also a shift toward more yield grade 3 carcasses ($P < 0.10$) from steers fed SFC compared to steers fed DRT. Feed efficiency was modestly improved by treating dry-rolled corn with urea and amylase, but the magnitude of improvement was less than that achieved by steam flaking.

Introduction

Cattle feedlots in the Southern Great Plains rely on steam flaked cereal grains (primarily corn) to improve the efficiency of production. Generally, steam flaking can improve the efficiency of feed conversion of corn by 10 to 12%. Natural gas is a common fuel source for boilers to generate the steam needed. The increase in natural gas prices over the past several years has increased the cost of steam flaking. Moreover, smaller feeders are unable to justify the capital outlay for steam flaking equipment and are not able to take advantage of the reduced cost of gain by feeding steam-flaked grain. Development of new technologies to process grain are needed that reduce equipment needs and(or) energy costs. The objective of the present experiment was to evaluate the feeding value of dry-rolled corn treated with urea and amylase in comparison to dry-rolled corn and steam-flaked corn.

Experimental Procedures

One hundred seventy-one crossbred steers were transported an average of 1266 miles from Abingdon and Lebanon, VA to the study site over 25 hours. Steers were received on 13 and 15 August 2005 and experienced a shrink of 6.2% from a pay weight of 865 lb. Steers were processed on arrival and adapted to a 91% concentrate diet (Table 1) over 21 days. Processing included individual identification, vaccination against viral antigens of IBR, PI_3, BRSV, and BVD type I and II (Titanium 5), administration of a clostridial bacterin-toxoid (Vision 7 with Spur), treatment for internal and external parasites (Ivomec Plus and Safe-Guard), excision of existing implant(s), and horn tipping to a diameter of approximately 1 inch.

One hundred sixty-two steers were blocked by weight, implanted with Revalor-S, and housed in 18 pens of 9 steers each. Dietary treatments were 91% concentrate diets (Table 1) based on dry-rolled corn (DRC), dry-rolled corn treated with urea and amylase (DRT), or steam-flaked corn (SFC). Dry-rolled and steam-flaked corn were prepared approximately twice weekly during the study. Corn received during the study was held in a common bin until divided for rolling or flaking. Corn was tempered to 19% moisture for at least 24 hours and was steamed for approximately 36 minutes before flaking to 27 lb/bu. The same rolls used to steam flake corn were adjusted and used to produce dry-rolled corn (42 lb/bu). To prepare DRT, DRC was combined with a 40% (w/w) urea solution (1.6% of grain weight), amylase (≥ 38,000 SKB units/gram from *Aspergillus niger*; Enzyme Development Corporation, New York, NY; 0.5 mL/lb of grain [as-fed basis]), and tap water equivalent to 30% of grain weight. Material was then mixed for 10 minutes and allowed to stand at ambient conditions until feeding the next day (18 hours).

Bunks were managed to contain from a few kernels to approximately 0.2 lb of refused feed/pen. Diets were manufactured and delivered once daily, and water tanks were cleaned each week. Samples of diets were collected weekly from the bunk after feed delivery; dry matter was determined on a subsample, and remaining sample was composited gravimetrically within treatment over the entire study. Composite diet samples were assayed in duplicate for ash, CP by combustion, ADF, EE, and minerals by a commercial laboratory. Samples of corn that was dry rolled, dry rolled and treated, and steam flaked were collected each week and composited over the study for starch availability analysis. Weekly ingredient dry matter content, with the exception of steam-flaked corn, was used to update as-fed diet composition each week. Dry matter of steam-flaked corn was determined 5 days/week and the 5-day average was used to update as-fed diet composition each week.

Carcass-adjusted final weight was calculated by dividing actual hot carcass weight by the overall average dressing percentage. Feedlot performance, yield grade measurements, marbling score, and hot carcass weight data were analyzed with Mixed procedures (SAS Inst., Cary, NC) using pen as the experimental unit. The distributions of carcass yield and quality grades were analyzed as repeated measures with Genmod procedures (SAS Inst., Cary, NC) using pen as the experimental unit.

Results and Discussion

One steer was diagnosed with polioencephalomalacia and was removed from the study. Remaining steers were fed for an average of 103 days. Steers receiving SFC consumed less (Table 2; $P < 0.05$) than steers fed DRC (5.8%) or DRT (7.3%), whereas steers receiving DRC tended to gain weight less rapidly on a carcass-adjusted basis (4.7%; $P < 0.15$) than steers receiving DRT. Carcass-adjusted feed efficiency was poorest ($P < 0.10$) for steers receiving DRC, but adjusted feed efficiency was improved 3.1% by feeding DRT and improved an additional 6.3% by feeding SFC compared to DRC.

Data were omitted from 5 carcasses (2 from DRT and 3 from SFC) originating from 4 pens because carcass data was not collected on these carcasses due to human error. Hot carcass weight, marbling score, fat thickness, Longissimus muscle area and calculated yield grade were not altered by treatment (Table 2). However, the distributions of carcass quality and yield grades were impacted by grain processing method. More carcasses from steers that received DRT graded average or high Choice ($P < 0.10$) and fewer graded low Choice ($P < 0.10$) compared to carcasses from steers that received SFC; the number of carcasses from steers that received DRC that graded low Choice tended ($P < 0.15$) to be lower than for steers that received SFC. However, the number of carcasses grading at least low Choice was not altered by treatment ($P > 0.15$). There was also a shift toward more yield grade 3 and fewer yield grade 2 carcasses ($P < 0.10$) from steers that received SFC compared to steers fed DRT.

Diets were formulated to contain a similar percentage of protein from NPN. The DRT grain contained 0.55% added urea, so 0.55% urea was added to the remaining diets. In addition, the equivalent of 0.32% urea was added by the steep:molasses blend and the equivalent of 0.1% urea was added in the form of ammonium sulfate to all diets.

The improvement in feed efficiency in the present study by steam flaking approximates the expected improvement (10 to 12%) based on previous summaries (Owens et al., 1997; Zinn et al., 2002). To determine the impact of grain processing on grain NE, estimates of actual diet NE content were calculated based on animal performance. Assuming that the NEm and NEg values for dry-rolled corn are 2.18 and 1.50 Mcal/kg and that all of the change in diet NE for applicable treatments in this study was due to the cereal grain, steam-flaked corn would have needed to contain 10.1% more NEm (equivalent to 2.40 Mcal/kg) and 13.0% more NEg (equivalent to 1.70 Mcal/kg) than dry-rolled corn to support the observed performance. Corresponding values for DRT would equal 2.22 and 1.54 Mcal of NEm and NEg/kg, respectively. Other recent estimates of steam-flaked corn NE from finishing studies suggest a range from 2.31 and 1.62 Mcal NEm and NEg/kg (Brown et al., 2000) to 2.50 and 1.79 Mcal of NEm and NEg/kg (Zinn et al., 1998). The estimate derived for the improvement in feed efficiency for DRT should be conservative considering the ambient conditions during the study. The vast majority of the study was conducted during the cooler fall and winter months, and catalytic activity of amylase would be expected to be highly dependent on ambient temperature.

The shift in carcass quality grade distribution was unexpected. Steers fed steam-flaked corn were generally fatter, yet more of these carcasses graded low Choice and fewer of these carcasses graded average and high Choice. However, treatment did not alter the number of carcasses grading at least low Choice.

Implications

Steers fed steam-flaked corn consumed less DM than steers fed DRC (5.8%) or DRT (7.3%), whereas steers receiving DRC tended to gain weight less rapidly on a carcass-adjusted basis than steers receiving DRT. Carcass-adjusted feed efficiency was poorest ($P < 0.10$) for steers receiving DRC, but adjusted feed efficiency was improved 3.1% by feeding DRT and improved an additional 6.3% by feeding SFC compared to DRC. Steers fed SFC produced more yield grade 3 and fewer yield grade 2 carcasses than steers fed DRT when fed for the same number of days. Although more carcasses from steers that received DRT graded average and high Choice, treatment did not influence the number of carcasses grading at least low Choice.

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Table 1. Ingredient and chemical composition of diets fed (DM basis)

	Treatment		
Item	SFC[a]	DRC[b]	DRT[c]
Ingredient composition			
Steam-flaked corn	75.0	-	-
Dry-rolled corn	-	75.0	-
Dry-rolled corn + BovaRoll	-	-	75.0
Finishing supplement[d]	2.95	2.95	3.5
Urea	0.55	0.55	-
Cottonseed meal, 41% CP	5.5	5.5	5.5
Steep:molasses (70:30)[e]	4.0	4.0	4.0
Yellow grease[f]	3.0	3.0	3.0
Alfalfa hay (2.5-inch screen)	9.0	9.0	9.0
Chemical composition[g]			
Grain DM, %	79.62	85.51	65.21
Grain available starch, % of total	58.8	34.1	38.4
CP, %	14.1	13.7	13.9
NEm, Mcal/kg	2.24	2.13	2.13
NEg, Mcal/kg	1.55	1.46	1.46
K, %	0.79	0.78	0.78
Ca, %	0.72	0.76	0.72
Fe, ppm	311	319	246
Mn, ppm	64	55	49
Cu, ppm	21	18	18
Zn, ppm	85	75	74
Mo, ppm	0.68	0.62	0.67

[a]Corn was tempered overnight to 19% moisture and processed to a bulk density of 27 lb/bu after steaming for 36 minutes.
[b]Processed to a bulk density of 42 lb/bu.
[c]Dry-rolled corn was combined with a 40% (w/w) urea solution (1.6% of grain weight, as-fed basis), 0.5 mL of amylase enzyme/lb of grain (as-fed basis), and tap water (total of 30% of grain weight, as-fed basis) in a feed mixer and mixed for 10 minutes. Grain was prepared daily and allowed to stand for 18 hours at ambient temperature before feeding.
[d]The supplement included urea, but urea is listed separately for clarity. The supplement was formulated to contain the following (DM basis): 14.47% Ca, 2.95% K, 1.6% S, 2.35% Mg, 7.14% salt, 5.7 ppm Co, 286 ppm Cu, 14 ppm I, 1149 ppm Mn, 8.5 ppm Se, 1964 ppm Fe, 1145 ppm Zn, 65,700 IU of vitamin A/kg, 428 IU of vitamin E/kg, 857 g of monensin/ton, 257 g of tylosin/ton, 17.6 or 33.3% ground corn, and 1.0% mineral oil.
[e]Contained 0.5% (w/w) propionic acid as a mold inhibitor.
[f]Contained 0.1% (w/w) of antioxidant (Rendox AET, Kemin Industries).
[g]NEm and NEg were calculated from tabular values (NRC, 1996) assuming that dry-rolled corn contain 2.18 and 1.50 Mcal of NEm and NEg/kg. Remaining values were determined analytically from a composite of weekly samples and are reported on a DM basis, with the exception of DM.

Table 2. Effect of grain processing method on feedlot performance and carcass characteristics

Item	Treatment			
	SFC[a]	DRC[b]	DRT[c]	SE[d]
Pens	6	6	6	-
Animals	53	54	54	-
Initial shrunk body weight, lb	878	878	877	27
Adjusted shrunk final weight, lb	1334	1315	1338	17
Day 1 to 103				
DMI, lb/d	22.9[e]	24.3[f]	24.7[f]	0.3
ADG, lb/d, live basis	4.48	4.28	4.45	0.10
ADG, lb/d, carcass-adjusted	4.43	4.26[i]	4.47[j]	0.10
DMI:ADG, live basis	5.14[e]	5.70[f]	5.57[f]	0.07
DMI:ADG, carcass-adjusted	5.19[e]	5.72[f, g]	5.54[f, h]	0.07
Observed diet NEm, Mcal/kg	2.26	2.10	2.13	-
Observed diet NEg, Mcal/kg	1.57	1.43	1.46	-
Hot carcass weight, lb	836	823	838	7.1
Marbling score	420	430	428	11
Fat thickness, in	0.46	0.44	0.42	0.02
Longissimuss muscle area, in^2	14.2	14.1	14.4	0.26
Yield grade	2.65	2.58	2.47	0.12
Prime, %	0	0	0	-
Average and High Choice, %	8.0[g]	14.8[g, h]	19.2[h]	-
Low Choice, %	56.0[g, i]	46.3[h, j]	38.5[h]	-
Select, %	34.0	37.0	42.3	-
Standard, %	2.0	1.9	0.0	-
$\geq$ low Choice, %	64.0	61.1	57.7	-
Yield grade 1, %	24.0	18.5	21.1	-
Yield grade 2, %	34.0[g, i]	51.9[h, j]	55.8[h]	-
Yield grade 3, %	38.0[i]	25.9[i, j]	23.1[j]	-
Yield grade 4 and 5, %	4.0	3.7	0.0	-

[a]Corn was tempered overnight to 19% moisture and processed to a bulk density of 27 lb/bu after steaming for 36 minutes.
[b]Processed to a bulk density of 42 lb/bu.
[c]Dry-rolled corn was combined with a 40% (w/w) urea solution (1.6% of grain weight, as-fed basis), 0.5 mL of amylase enzyme/lb of grain (as-fed basis), and tap water (total of 30% of grain weight, as-fed basis) in a feed mixer and mixed for 10 minutes. Grain was prepared daily and allowed to stand for 18 hours at ambient temperature before feeding.
[d]Standard error of the least squares mean, n = 6.
[e,f]Means with different superscripts differ ($P < 0.02$).
[g, h]Means with different superscripts differ ($P < 0.10$).
[i, j]Means with different superscripts tend to differ ($P \leq 0.15$).

EFFECTS OF MICRO-CELL® ON FEEDLOT PERFORMANCE BY YEARLING BEEF STEERS

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Summary

Two hundred crossbred yearling steers (795 lb initial weight) were used to examine the effects Micro-Cell LA and Micro-Cell PB on feedlot performance and carcass characteristics. Steers were assigned randomly to receive a basal diet top-dressed with tap water only (Control) or top-dressed with Micro-Cell LA for 28 days followed by Micro-Cell PB from day 29 to slaughter (LA/PB). Performance during the first 28 days did not differ among treatments ($P > 0.10$). Overall DMI, adjusted ADG, and adjusted feed efficiency were not altered by treatment ($P > 0.10$). Carcasses from steers fed Control were fatter ($P < 0.05$) than those from steers fed LA/PB. Other attributes of carcass yield and quality were not different between treatments ($P > 0.10$). Growth performance by yearling steers was not altered by feeding Micro-Cell. Carcasses from cattle fed Micro-Cell were leaner, which was likely a function of numerically lower feed intake.

Introduction

A number of direct-fed microbial products are available in the marketplace for utilization in the feedlot industry. Each product has unique features related to species and strain composition, and these features can impact product efficacy. Continued evaluation of the ability of direct-fed microbials to improve production efficiency by feedlot cattle is needed. The Micro-cell products distributed by Lallemand Animal Nutrition have been developed to target the starch adaptation phase during the first 3 to 4 weeks on feed, in addition to the remainder of the feeding period. Huck et al. (2000) reported that weight gain and feed efficiency by yearling heifers was improved approximately 5% by feeding Micro-cell LA during the first 28 days followed by feeding Micro-cell PB for the remainder of the feeding period. The objective of the present experiment was to evaluate the influence of Micro-Cell LA and PB on performance and carcass characteristics of yearling steers.

Experimental Procedures

Two-hundred-ten crossbred steers were procured from a local stocker producer. Processing on arrival included individual identification, vaccination against viral antigens of IBR, PI_3, BRSV, and BVD type I and II (Titanium 5), administration of a clostridial bacterin-toxoid (Vision 7 with Spur), treatment for internal and external parasites (Ivomec Plus and Safe-Guard), excision of existing implant(s), and horn tipping to a diameter of approximately 1 inch. Steers were fed ground alfalfa hay for approximately 2 weeks before the study began. On day 1, 200 steers were selected for the study (20 pens, 10 steers/pen), were weighed before feeding, and were implanted with Revalor-S. All body weight measurements were acquired using a single-animal scale. The scale was validated before each use using 20 certified weights (50 lb each) and calibrated as needed.

Dietary treatments were a basal diet top-dressed with water only (Control) or top-dressed with Micro-Cell LA (supplied 5×10^8 CFU of *Lactobacillus acidophilus*/animal daily) for 28 days followed by Micro-Cell PB (supplied 1×10^9 CFU of *Propionibacterium freudenreichii*/animal daily) from day 29 to slaughter (LA/PB). Steers were adapted to the finishing diet by offering 60, 70 and 80% concentrate diets based on steam-flaked corn for 9, 6, and 11 days, respectively. Steers were fed a 91% concentrate diet (Table 1) once daily thereafter. Bunks were managed to contain from a few kernels to approximately 0.25 lb of refused feed/pen and water tanks were cleaned each week throughout the study.

Corn was processed approximately twice weekly. Grain was tempered to 19% moisture for 24 h and was steamed for approximately 36 minutes before flaking to 27 lb/bu. Diets were manufactured and delivered once daily. Samples of diets were collected weekly from the bunk after feed delivery; dry matter was determined on a subsample, and remaining sample was composited gravimetrically within treatment over the entire study. Composite diet samples were assayed in duplicate for ash, CP by combustion, ADF, EE, and minerals by a commercial laboratory. Weekly ingredient dry matter content, with the exception of steam-flaked corn, was used to update as-fed diet composition each week. Dry matter of steam-flaked corn was determined 5 days/week and the 5-day average was used to update as-fed diet composition each week.

Carcass-adjusted final weight was calculated by dividing actual hot carcass weight by the overall average dressing percentage. Feedlot performance, yield grade measurements, marbling score, and hot carcass weight data were analyzed with Mixed procedures (SAS Inst., Cary, NC) using pen as the experimental unit. The distributions of carcass yield and quality grades were analyzed as repeated measures with Genmod procedures (SAS Inst., Cary, NC) using pen as the experimental unit.

Results and Discussion

No cattle were removed during the course of the study. Although dietary K and Ca were higher than intended (formulated to be 0.8 and 0.65% of DM, respectively), remaining nutrient concentrations were similar to formulation targets (Table 1).

Performance during the first 28 d (Table 2) did not differ among treatments (P > 0.10). Some level of feed intake restriction was imposed during the adaptation process as occurs in production across both treatments. It is possible that allowing greater feed intake by more aggressive adaptation may have provided ruminal conditions that were more conducive to a treatment response. Overall DMI, adjusted ADG, and adjusted feed efficiency were not altered by treatment (P > 0.10). Carcasses from steers fed Control were fatter (P < 0.05) than those from steers fed LA/PB, but remaining carcass characteristics were not different among treatments (P > 0.10).

Present data are in contrast to those reported for finishing heifers. Huck et al. (2000) indicated that heifers fed LA for 28 days followed by PB to slaughter gained 5% more rapidly and were 5% more efficient at converting feed into body weight. The numerically greater DMI by control cattle was likely a contributing to the fatter carcasses for this treatment. However, the distribution of carcass quality grade was not altered among treatments.

Implications

Performance of yearling steers was not altered by feeding Micro-Cell LA for 28 days followed by feeding Micro-Cell PB until slaughter. Carcasses from cattle fed Micro-Cell were leaner, which was likely a function of numerically lower feed intake.

Literature Cited

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Table 1. Ingredient and chemical composition of diets fed (DM basis)

Item	Dietary concentrate[a,b]			
	60%	70%	80%	91%
Ingredient composition				
Steam-flaked corn	49.0	57.75	66.25	75.0
Starter supplement[c]	2.0	1.0	1.0	-
Finishing supplement[d]	-	1.75	1.75	3.5
Cottonseed meal, 41% CP	3.0	3.0	4.5	5.5
Steep:molasses (70:30)[e]	4.0	4.0	4.0	4.0
Yellow grease[f]	2.0	2.5	2.5	3.0
Alfalfa hay (2.5-inch screen)	40.0	30.0	20.0	9.0
Chemical composition[g]				
CP, % of DM	-	-	-	13.6
ADF, % of DM	-	-	-	5.1
EE, % of DM	-	-	-	6.9
NEm, Mcal/lb	0.88	0.92	0.96	1.01
NEg, Mcal/lb	0.58	0.62	0.66	0.70
Ash, % of DM	-	-	-	5.1
K, % of DM	-	-	-	0.95
Ca, % of DM	-	-	-	0.80
P, % of DM	-	-	-	0.35
Mg, % of DM	-	-	-	0.27
S, % of DM	-	-	-	0.27
Na, % of DM	-	-	-	0.20
Cu, ppm	-	-	-	23
Fe, ppm	-	-	-	240
Mn, ppm	-	-	-	53
Mo, ppm	-	-	-	0.68
Zn, ppm	-	-	-	79

[a]60% diet was fed for 9 days, 70% was fed for 6 days, 80% was fed for 11 days, and 90% was fed for 2 days.

[b]Micro-Cell LA and PB were applied as a 1-L slurry to the appropriate pens immediately after feed delivery and mixed into the feed with a pitchfork; control pens received water only.

[c]Formulated to contain the following (DM basis): 10.19% Ca, 2.65% K, 2.77% S, 2.16% Mg, 12.5% salt, 10 ppm Co, 500 ppm Cu, 25 ppm I, 2000 ppm Mn, 15 ppm Se, 1850 ppm Fe, 2000 ppm Zn, 150,000 IU of vitamin A/kg, 1500 IU of vitamin E/kg, 1000 g of monensin/ton, 400 g of tylosin/ton, 35.06% ground corn, and 1.0% mineral oil.

[d]Formulated to contain the following (DM basis): 14.4% Ca, 2.95% K, 2.34% Mg, 1.61% S, 7.1% salt, 20.0% urea, 5.7 ppm Co, 285 ppm Cu, 14.2 ppm I, 8.5 ppm Se, 1950 ppm Fe, 1140 ppm Zn, 1140 ppm Mn, 65,700 IU of vitamin A/kg, 425 IU of vitamin E/kg, 857 g of monensin/ton, 257 g of tylosin/ton, 13.44% ground corn, and 1.0% mineral oil.

[e]Contained 0.5% (w/w) propionic acid as a mold inhibitor.

[f]Contained 0.1% (w/w) of antioxidant (Rendox AET, Kemin Industries)

[g]NEm and NEg were calculated from tabular values (NRC, 1996); remaining values were determined analytically.

Table 2. Effect of Micro-Cell LA/PB on feedlot performance and carcass characteristics

	Treatment[a]		
Item	Control	LA/PB	SE[b]
Pens	10	10	-
Animals	100	100	-
Initial shrunk body weight, lb	797	792	15.9
Adjusted final weight, lb[c]	1297	1290	22.3
Day 1 to 28			
DMI, lb/d	17.5	17.5	0.1
ADG, lb/d	3.32	3.32	0.09
DMI:ADG	5.29	5.29	0.1
Day 1 to 140			
DMI, lb/d	20.6	20.2	0.2
ADG, adjusted basis, lb/d	3.59	3.57	0.05
DMI:ADG, adjusted basis	5.78	5.70	0.05
Hot carcass weight, lb	830.6	825.4	5.4
Fat thickness, in	0.51f	0.47g	0.009
Longissimus area, in^2	14.5	14.2	0.21
Marbling score[d]	383	383	7.5
Yield grade	2.63	2.61	0.07
≥ Choice-, %	38.4	36.4	-
≤ Select, %	61.6	63.6	-

[a]Control = basal diet only throughout the study, LA/PB = basal diet + Micro-cell LA (supplied 5 x 10^8 CFU of *Lactobacillus acidophilus*) per animal daily from day 1 to 28 and basal diet + Micro-cell PB (supplied 1 x 10^9 CFU of *Propionibacterium freudenreichii*) per animal daily from day 29 to the end of the study.
[b]Standard error of the least squares mean, n = 10.
[c]Calculated as hot carcass weight / overall average dressing percent (0.64).
[d]Slight = 300 to 399, Small = 400 to 499, etc.

EVALUATION OF INTAKE, DIGESTIBILITY, AND PERFORMANCE OF CROSSBRED STEERS FED DIETS CONTAINING HIGH LEVELS OF UREA*

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Summary

Twenty-four crossbred steers were used to evaluate the effects of diets containing high levels of urea on intake and digestibility of nutrients and performance. Treatments (TRT) consisted of four levels (0, 0.65, 1.30, and 1.95% DM) of dietary urea, which replaced cottonseed meal in the concentrate mixture. There were no differences (P > 0.05) in the intakes of DM, OM, CP, ether extract (EE), non-fiber carbohydrates (NFC), and TDN among treatments. However, NDF intake decreased linearly as urea levels increased (P = 0.017). Additionally, no effects of urea levels were observed on apparent total digestibility of DM, OM, NDF, and NFC (P > 0.05). The CP apparent digestibility increased linearly (P = 0.014) with increasing levels of urea, but ADG was not influenced (P > 0.05) and averaged 2.51 lb/d. This experiment suggested that urea levels (up to 1.95% DM) might be fed to crossbred steers without affecting their growing performance.

Introduction

True protein supplements are expensive ingredients in diets of cattle. Therefore, substitution of a true protein with a non-protein N source may reduce the diet cost. Early reviews suggested that urea can be utilized if it makes up no more than one-third of the total supplemental N or 1% of dietary DM. However, some studies have demonstrated that performance was not affected by using higher urea contents of DM and/or by totally replacing the true protein of concentrate with urea. There is evidence (Zinn et al., 1994) that levels of urea supplementation in excess of that required to optimize microbial protein synthesis may enhance performance of cattle. This effect may be due to the alkalizing effects of urea as it is hydrolyzed within the rumen (Zinn et al., 2003). The objective of this study was to evaluate the influence of level of urea supplementation on intake, digestibility and performance of crossbred steers.

Experimental Procedures

Diets were formulated to provide increasing levels of dietary urea on total DM and consisted of 70% corn silage and 30% concentrate, formulated to be isonitrogenous (12.5% CP, DM basis). Treatments consisted of 0, 0.65, 1.30, and 1.95% of dietary urea (DM basis), which replaced cottonseed meal of the concentrate mixture. Twenty-four Holstein crossbred steers, averaging 770 lb BW, were randomly distributed in six blocks to evaluate intake and digestibility of nutrients and performance in feedlot. Steers were individually fed *ad libitum* twice per day at 0700 and 1500. The experiment was conducted for 99 d (15 d for diet adaptation and 3 periods of 28 d). Steers were sorted into six weight blocks and allotted randomly to one of four treatments (six steers per treatment). Orts were collected and weighed once daily. The amount of DM offered was adjusted daily to yield orts of about 5 to 10% of intake/day. Animals had access to water at all times. Feed ingredients and orts were sampled daily and composted by weight by period.

For each animal, the DMI was measured daily and samples of feces were collected during d 14 and 16 of second period with intervals of 28 h among the collection. The DMI was computed based on the 60^{o}C DM determinations for silage samples, concentrate mixture, and orts. After drying, ingredients, concentrate mixture, orts and feces samples were ground through a 1-mm screen, and period composites were prepared by mixing equal DM. Diet digestibility was determined using indigestible acid detergent fiber (IADF) as a marker. Composite samples were analyzed for total N, DM at 105^{o}C, ash, and OM (determined after ignition at 600^{o}C for 4 h in a muffle furnace), sequentially for NDF and ADF using heat stable α-amylase and Na_2SO_3 (Hintz et al., 1995), and for indigestible ADF (IADF; ADF remaining after a 10-d *in situ* incubation). Non-fiber carbohydrate (NFC) content was calculated by difference, NFC=100 - (CP+NDF+EE+ash).

Average daily gain was calculated as the difference between the initial and final BW divided by the total number of days of feeding (n = 84). Carcass yield was calculated as the sum between the left and the right carcass weights divided by the empty final BW. Feed efficiency was calculated as daily lb of gain/lb of DMI.

Data were analyzed as a randomized complete block design using the Mixed procedure of SAS. The model included the fixed effect of treatment and block as random effects. Orthogonal contrasts were conducted for linear and quadratic effects of degree of processing.

Results and Discussion

The nutrient composition of trial diets is presented in Table 1. Diets provided similar amounts of DM, OM, CP, ether extract (EE), NDF, and TDN to all steers. There were no differences on the intakes of DM, OM, CP, non-fiber carbohydrates (NFC), and TDN among treatments (Table 2). NDF intake, as lb/day or as % of BW, decreased linearly with increase of urea levels, partially due to a lesser NDF values of diets with more urea and, despite of lack significance, because of numerical decrease in DM intake with the increase of urea levels in diets. Dietary urea levels had a tendency of quadratic effect ($P = 0.051$) on EE intake. Milton et al. (1997b) evaluated the effects of dietary urea level (0, 0.5, 1.0, or 1.5% DM) on performance in finishing steers and observed that DMI responded cubically to urea level (DMI was lesser for steers consuming 0.5 and 1.5% urea DM).

Additionally, no effects of levels of urea were observed on ADG, feed efficiency and carcass yield (Table 3). Gleghorn et al. (2004) evaluated effects of CP concentration and degradability on performance in finishing beef steers, and no differences in ADG were observed among CP sources. For the interim periods and the overall trial results, ADG was numerically greater for cattle receiving all supplemental protein in the form of urea, intermediate for the blend of urea and cottonseed meal, and lesser for cottonseed meal. However, in a growth trial carried out by Milton et al. (1997a), steers with an initial average BW of 737 lb fed soybean meal supplemented high-grain diets gained 13% faster and were 9% more efficient at converting feed to gain than steers receiving urea. Otherwise, Zinn et al. (2003) evaluated the influence of levels of urea supplementation on growth performance of cattle fed a steam-flaked barley-based finishing diet, and observed that ADG was optimized by dietary inclusion of 0.8% urea. Knaus et al. (2001) evaluated effect of levels of undegradable intake protein (UIP) inclusion (0; 2.6 and 5.2%; DM basis), and a negative control “urea diet” containing no UIP and no soybean meal on performance in steers, and observed that ADG was close to predicted levels for the control diet (3.15 lb/d) as well as for the diet containing 2.6% UIP (3.19 lb/d), but, when the UIP inclusion was 5.2% or when urea was the only undegraded intake proteins for cattle supplement, ADG was reduced to 2.86 and 2.44 lb/d, respectively. Souza et al. (2002) did not find differences on ADG in steers fed diets with different urea levels (0; 0.5; 1.0 and 1.5%, DM basis), which averaged 2.32 lb/d. Shain et al. (1998) evaluated the effect of urea level (0, .88, 1.34, or 1.96%, DM basis) in finishing diets (based in dry-rolled corn) on cattle performance and no differences in DMI, daily gain, or feed efficiency were noted among steers receiving diets containing supplemental urea. However, steers fed diets supplemented with urea were 5.4% more efficient and gained 6.6% faster than steers receiving no supplemental urea. Milton et al (1997) evaluated the effects of dietary urea level (0, 0.35, 0.70, 1.05, or 1.40% DM) on performance in steers and observed that DMI, ADG, and feed efficiency increased with intermediate concentrations of urea but decreased with the highest concentration. Regression analysis indicated that the optimal dietary urea level was 0.5% of DM for ADG and feed efficiency.

No effects of urea levels were observed on apparent total digestibility of DM, OM, NDF, and NFC (Table 4), which were, on average, 70.1, 71.3, 54.0, and 86.8%, respectively. As expected, apparent total CP digestibility increased linearly ($P < 0.014$) with increasing dietary urea level. This increase can be due to urea be 100% soluble, so, when the cottonseed meal was substituted by urea, the digestibility of CP increased. Zinn et al. (2003) evaluated the influence of level of urea supplementation (0; 0.4; 0.8 and 1.2% DM) on digestive function and performance of cattle and observed linear increase in N digestibility. Rennó et al. (2005) evaluated the effect of urea levels (similar levels of this trial) on steers of four genetics groups and did not find differences among the treatments on total digestibility of all nutrients. Urea levels had a quadratic effect on EE digestibility with maximum of 86.47% at 0.89% urea in diet.

Implications

These findings suggest that levels of urea (up to 1.95% DM) might be fed to crossbred steers receiving high forage diets without affecting their growing performance. The lack of difference among the treatments is likely due to the high fermentability of OM in the rumen or recycling N into the rumen for those treatments with low levels of urea. More research is needed to identify these effects.

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Table 1. Composition of the diets.

Ingredients	Diets			
	Urea levels (% of DM)			
	0	0.65	1.30	1.95
Corn silage	70.00	70.00	70.0	70.00
Ground corn	11.63	16.79	21.82	26.99
Cottonseed meal	17.60	11.73	5.88	-
Urea	-	0.65	1.30	1.95
Ammonium sulfate	-	0.06	0.13	0.19
Sodium chloride	0.25	0.25	0.25	0.25
Dicalcium phosphate	-	-	0.10	0.20
Calcite limestone	0.50	0.50	0.50	0.40
Mineral premix[1]	0.02	0.02	0.02	0.02
	Nutrient content of diets			
DM	49.82	49.97	50.14	50.29
OM	95.03	94.51	93.89	95.21
CP	12.79	12.67	12.56	12.44
NDF	40.98	39.72	38.45	37.18
ADFI	10.01	9.25	8.49	7.73
EE	5.00	4.82	4.64	4.46
NFC	39.65	42.45	45.15	47.95
TDN[2]	69.09	70.23	72.91	70.89

[1]Composition (%): copper (22.50), cobalt sulfate (1.40), zinc sulfate (75.40), potassium iodate (0.50), sodium selenite (0.20); [2] Observed

Table 2. Effect of dietary urea on intakes of DM, OM, CP, EE, NDF, NFC, and TDN

Items	Urea levels %					*P*- value[1]	
	0	0.65	1.30	1.95	SE	Linear	Quadratic
	Intake (lb/day)						
DM	22.77	21.56	21.67	20.61	0.430	0.153	0.939
OM	21.25	20.54	20.66	19.58	0.393	0.2303	0.864
CP	2.84	2.71	2.71	2.44	0.053	0.066	0.680
EE	0.57	0.59	0.57	0.51	0.009	0.082	0.051
NDF	8.91	8.34	7.96	7.57	0.169	0.017	0.801
NFC	9.06	8.99	9.55	9.20	0.168	0.584	0.723
TDN	15.79	15.20	15.84	14.59	0.352	0.403	0.679
	Intake (% BW)						
DM	2.26	2.17	2.20	2.13	0.077	0.307	0.832
NDF	0.89	0.84	0.81	0.78	0.030	0.016	0.830

[1] Probability of a significant linear or quadratic effect of urea level of the diet.

Table 3. Effect of dietary urea on ADG, feed efficiency and carcass yield

Items	Urea levels %					*P*-value[1]	
	0	0.65	1.30	1.95	SE	Linear	Quadratic
ADG, lb/d	2.51	2.49	2.42	2.60	0.109	0.846	0.687
Feed efficiency	9.38	8.84	9.21	8.17	0.691	0.305	0.721
CY (%)	51.76	52.31	51.86	51.98	0.312	0.874	0.507

[1] Probability of a significant linear or quadratic effect of urea level of the diet.

Table 4. Effect of dietary urea on total apparent digestibilities of DM, OM, CP, EE, NDF, and NFC

Items	Urea levels %					P-value[1]	
	0	0.65	1.30	1.95	SE	Linear	Quadratic
DM	68.93	69.37	71.73	70.19	1.359	0.327	0.480
OM	70.37	70.56	72.90	71.29	1.321	0.402	0.506
CP	65.64	65.05	70.99	69.41	1.391	0.014	0.726
EE	82.95	86.89	85.12	82.09	1.451	0.512	0.029
NDF	53.58	52.29	54.89	55.27	1.782	0.351	0.646
NFC	86.93	88.07	87.39	84.80	1.461	0.296	0.220

[1] Probability of a significant linear or quadratic effect of urea level of the diet.

ENERGY AND PROTEIN REQUIREMENTS FOR MAINTENANCE AND GROWTH OF F_1 NELLORE X RED ANGUS BULLS, STEERS, AND HEIFERS

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Summary

A comparative slaughter trial was conducted with 36 F_1 Nellore x Red Angus calves (12 steers, 12 bulls, and 12 heifers), averaging 603 lb BW. The experimental design provided ranges in ME intake, BW, and ADG to predict NE_m, NE_g, and net protein for maintenance and gain (**NP_m** and **NP_g**) requirements. Initial body composition was based on the composition of the baseline group. There were no differences in the NE_m and NP_m requirements for maintenance among genders. The NE_g requirements for steers and heifers were similar ($P > 0.05$) but were 18.7% higher than that for bulls. The NP_g was not different among gender. Our findings suggest the NE_m of crossbred *Bos indicus* x *Bos taurus* might be lower than that of purebred *Bos taurus*. The NE_g for bulls were lower than that for steers and heifers. No differences in NE_m, NP_m, and NP_g were detected.

Introduction

The recommendations of the Beef Cattle National Research Council have been used to formulate diets for all types of breeds. Nevertheless, the nutrient requirement equations were based on *Bos taurus* cattle, with adjustments of NE_m for *Bos indicus* breeds. NRC (2000) also recognizes the effect of gender (steers, bulls, and heifers) on energy requirements for maintenance and growth, although few studies have compared gender in the same experimental conditions. The objective of this study was to use body composition data from a comparative slaughter trial to determine energy and protein requirement for maintenance and growth.

Experimental Procedures

The trial was conducted with 36 F_1 Nellore x Red Angus calves (12 bulls, 12 steers, and 12 heifers). The average age and initial shrunk BW (**SBW**) were 14-16 mo and 605 ± 42 lb for bulls, 14-16 mo and 612 ± 53 lb for steers, and 12-14 mo and 502 ± 42 lb for heifers. The baseline group was composed of three randomly selected calves of each gender. The diet DM was isonitrogenous (12.5% CP). Three animals of each gender were randomly assigned to treatments: fed at maintenance level (1.2 % BW, 70% of corn silage, DM basis) or fed at 0.75 or 1.5% BW of concentrate with corn silage being offered ad libitum. The animals were fed twice daily. There were three periods of 28 d, after 14 d of pre-trial, starting after the slaughter of the baseline group.

Digestion trials were conducted with all animals in each period to determine diet digestible energy (**DE**). The indigestible acid detergent fiber was used as a marker to estimate the fecal DM excretion. Urine volume was computed using creatinine as a marker in which urinary N excretion was calculated as N content × estimated urine volume.

Empty body gains of body components were calculated as the difference between initial and final weights of the respective body components. Heat production (**HP**, kcal/lb$^{0.75}$ EBW) was calculated as the difference between ME intake (**MEI**) and retained energy (**RE**). The average of the antilog of the intercept confidence interval (95%) of the linear regression between the log of heat production on MEI was used to estimate the requirement for NE_m (Lofgreen and Garrett, 1968). The ME required for maintenance (ME_m) was calculated by iteration, assuming that the maintenance requirement is the value at which HP is equal to MEI. The efficiency of energy utilization for maintenance (**K_m**) was calculated as NE_m/ME_m. The slope of the regression of RE on MEI was assumed to be the efficiency of energy utilization for growth (**K_g**). The net requirements of protein for maintenance (**NP_m**, g/kg EBW$^{0.75}$/d) was assumed to be 6.25 × the intercept of the linear regression of the N excretion (lb/1000lb EBW$^{0.75}$/d) on N intake (lb/1000lb EBW$^{0.75}$/d). The net energy requirement for gain (**NE_g**, Mcal/lb EBG) was calculated as a × EBW$^{0.75}$ × EBG^b, where a and b are, respectively, the antilog of the intercept and the slope of the linear regression of the logarithm of the RE on the logarithm of the empty body gain.

Statistical analyses were performed using the PROC GLM of SAS assuming a 3 × 3 factorial design of diet and gender. The model included the effects of diet, gender, and interactive effects of diet and gender. The comparison of intercept and slope among diets and gender was done by the PROC GLM procedure using the SOLUTION statement and the sum of squares type 3.

Results and Discussion

The initial SBW and mean body composition was similar between bulls and steers but, heifers had lower SBW and more fat (% of EBW) than males (P < 0.05). The growth performance, body composition, and energy balance data are shown in Table 1. There was no interaction between gender and diet for the ADG. Animals of treatment 1.5 had higher performance than those of treatments 0.75, which had higher ADG than those of maintenance treatment ($P < 0.05$). Bulls had higher ADG ($P < 0.05$) than steers and heifers. The analysis of EBG indicated interaction of gender and diet in which those bulls receiving 1.5%BW of concentrate had a higher EBG, likely because they tended to accumulate more protein and less fat in the gain than steers and heifers receiving the same diet (NRC, 2000). Although the data of ADG of animals on maintenance diet indicated loss of weight, bulls, steers, and heifers had similar EBG, which could be explained by differences in the gastrointestinal content between animals of maintenance treatment and the baseline group. The analysis of fat content (% of EBW) indicated effect of gender and diet, in which heifers had higher fat content than bulls and steers, and within diets fat content was higher, in a decreasing order, for treatments 1.5, 0.75, and maintenance. For protein content (% of EBW), there was no effect of gender, but protein content was different for diets within gender, where animals on ad libitum treatments (0.75 and 1.5) with higher fat content had lower protein on the empty body.

Gender had no effect on RE and HP (kcal/lb$^{0.75}$ EBW), but RE and HP were higher on animals consuming more energy, indicating that HP increased as MEI increased. Turner and Taylor (1983) suggested that HP is higher in animals with increased plane of nutrition mainly due to elevation of metabolism involved in the synthesis of RE. Williams and Jenkins (2003) proposed that ME consumed above the maintenance requirement is associated with an elevation of vital functions to support metabolism, and this heat production is driven by level of MEI. The intercept and the slope of the regression of the log of the HP on the MEI as well as NE_m requirement are shown in Table 3. There was no difference in the NE_m among gender. Steers had a 9 and 13% lower NE_m than bulls and heifers, respectively, but this difference was not statistically different ($P > 0.06$). The analysis of the pooled intercepts and slopes resulted in a common requirement for NE_m of 39.4 kcal/lb$^{0.75}$ EBW (71.2 kcal/kg$^{0.75}$ EBW), which is 7% lower than the NE_m of 42.6 reported by Lofgreen and Garrett (1968), and corroborate the assumption of NRC (2000) that *Bos indicus* bred cattle have lower NE_m requirements. This value is nearly identical to the value of 39.2 reported by Silva et al. (2002) in data compilation of F1 *Bos indicus* × *Bos taurus* bulls. Henrique et al (2005) using data of 320 Nellore purebred and crossbreds animals obtained from eight comparative slaughter studies under tropical conditions reported NE_m requirement of 40.4 kcal/lb$^{0.75}$ EBW. The lower NE_m requirements for Nellore breed could be attributed to the lower ratio of kidney-renal-pelvic fat: carcass fat, lower internal organs mass and lower protein turnover of these animals in relationship of *Bos taurus* bred. The K_m and K_g values (Table 3) were not different among gender and was on average 71.3 and 51.9%, respectively.

The mean values of N intake, excretion and balance are presented in Table 2. Daily nitrogen intake (lb N/100 lb EBW$^{0.75}$) was regressed against daily N excretion (lb N/100 lb EBW$^{0.75}$) to determine net protein requirement for maintenance. The net protein requirement for maintenance (**NP_m**) is assumed to be the sum of endogenous urinary nitrogen (**EUN**), metabolic fecal nitrogen (**MFN**), and dermal nitrogen losses, multiplied by the factor 6.25. When N excretion is regressed against a measure of N supply, the positive intercept at zero N intake provides an estimate of minimum N losses which should be similar to the sum of EUN and MFN. The pooled data indicated a NP_m requirement of 0.38 lb CP/100 lb SBW$^{0.75}$ (3.14 g CP/kg EBW$^{0.75}$/d). This value is similar the requirement of 3.25 g CP/kg BW$^{0.75}$ adopted by the AFRC (1992) and lower than the value of 3.8 g CP/kg SBW$^{0.75}$ adopted by the NRC (2000).

Table 4 shows the intercept and slope of the regression equations of logarithm of body fat, energy, and protein on the logarithm of the EBW. As animals grow the content of energy and fat increase whereas the content of protein decreases in the EBG (Berg and Butterfield, 1976). There were differences ($P > 0.05$) on the rate of fat deposition indicating the rate of increasing content of fat on EBG was higher, on decreasing order, in steers, heifers and bulls. The RE (Mcal/lb EBG) was lower for bulls than for steers and heifers and so the NE_g requirements for steers and heifers are higher than for bulls. The NRC (2000) assumes that NE_g requirements for bulls are 18% lower than for steers and that steers has 18% lower NE_g requirements than heifers. Our data indicated that steers and heifers had similar NE_g requirements and that bulls had 18.7% lower NE_g requirements than steers and heifers, but the NE_g requirements of bulls, steers, and heifers were 24, 27 and 44% lower than that proposed by the NRC (2000), probably due to differences in RE in the gain between pure *Bos taurus* and crossbreds *Bos taurus* × *Bos indicus*. The composition of the gain depends on physiological maturity of the animal, which is affected by gender and bred of the animal (NRC, 1984). Although not different ($P > 0.05$), steers had on average NP_g requirements 14% and 17% lower than bulls and heifers, respectively. Robelin and Daenicke (1980) accessing data of the effect of sex on body composition related that the percentage of protein in the EBG of steers and heifers was 10% lower than in bulls.

Implications

The requirement of NE_m and NP_m were similar for bulls, steers and heifers. Our findings support the hypothesis that crossbred *Bos indicus* × *Bos taurus*, have a lower NE_m requirement than pure *Bos taurus*. The NE_g was lower for bulls than for steers and heifers. Our data indicated no differences in NP_g for bulls, steers and heifers of Nellore x Red Angus crossbreds fed high levels of forage.

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Table 1. Effects of diet and gender on performance, body composition, and energy balance [a]

	Bulls			Steers			Heifers			SEM			*P*-value		
	Mant	0.75	1.5	Mant	0.75	1.5	Mant	0.75	1.5	G	T	G×T	G	T	G×T
iSBW, lb	609^{C}	638^{C}	640^{C}	684^{C}	649^{C}	642^{C}	546^{B}	523^{B}	579^{B}	9.81	9.81	19.3	0.014	0.718	0.932
fSBW, lb	603^{bC}	904^{cC}	1069^{dC}	594^{bC}	893^{cC}	983^{dC}	508^{bB}	765^{cB}	932^{dB}	11.6	11.6	22.7	0.007	<.001	0.810
EBW, lb	543^{bD}	843^{cD}	981^{dD}	534^{bC}	812^{cC}	869^{dC}	464^{bB}	675^{cB}	821^{dB}	9.06	9.06	17.8	<.001	<.001	0.340
EBW:SBW, %	89.7	93.2	92.1	89.9	90.9	88.8	91.6	88.5	88.2	1.10	1.10	2.15			
HCW, lb	339^{bD}	528^{cD}	618^{dD}	332^{bC}	502^{cC}	541^{dC}	290^{bB}	411^{cB}	510^{dB}	6.10	6.10	12.0	<.001	<.001	0.316
ADG, lb.d^{-1}	-0.07^{bC}	2.62^{cC}	4.05^{dC}	-0.42^{bB}	2.29^{cB}	2.77^{dB}	-0.40^{bB}	2.09^{cB}	3.08^{dB}	0.06	0.06	0.12	0.002	<.001	0.194
EBG, lb.d^{-1}	0.53^{e}	3.10^{gh}	4.38^{i}	0.40^{e}	2.82^{fg}	3.39^{h}	0.46^{e}	2.51^{f}	3.50h	0.04	0.04	0.08	<.001	<.001	0.036
EBG:ADG, %	-16.7^{b}	84.7^{c}	92.6^{c}	-128^{b}	80.7^{c}	82.0^{c}	-114^{b}	82.6^{c}	87.1^{c}	1.91	1.91	3.74			
Fat, %EBW	11.6^{bB}	15.2^{cB}	19.8^{dB}	11.2^{bB}	18.3^{cB}	20.2^{Bd}	12.6^{bC}	18.4^{cC}	24.2^{dC}	0.51	0.51	1.01	0.003	<.001	0.105
Protein, %EBW	18.3^{c}	18.8^{d}	18.0^{b}	19.0^{d}	16.7^{b}	17.6^{c}	19.0^{d}	17.9^{c}	17.0^{b}	0.28	0.28	0.54	0.285	0.011	0.052
Water, %EBW	64.0^{bC}	60.9^{cC}	57.6^{dC}	63.3^{bC}	59.9^{cC}	56.9^{dC}	61.6^{bB}	58.6^{cB}	54.0^{dB}	0.58	0.58	1.15	0.008	<.001	0.923
Ash, %EBW	6.11^{b}	5.10^{c}	4.55^{c}	6.52^{b}	5.14^{c}	5.32^{c}	6.82^{b}	5.12^{c}	4.77^{c}	0.22	0.22	0.43	0.364	<.001	0.693
RE, kcal/lb$^{0.75}$ EBW	10.6^{b}	36.8^{c}	55.5^{d}	12.1^{b}	41.6^{c}	51.7^{d}	8.10^{b}	37.6^{c}	57.8^{d}	2.95	2.95	5.80	0.944	<.001	0.300
HP, kcal/lb$^{0.75}$ EBW	51.7^{b}	87.2^{c}	96.1^{d}	58.9^{b}	86.1^{c}	105^{d}	62.2^{b}	89.4^{c}	104^{d}	3.59	3.59	7.05	0.060	<.001	0.451

[a] iSBW = initial SBW, fSBW = final SBW, HCW = hot carcass weight.

[b,c, d] Distinct lowercase letters in the same row, within gender, differ at $P< 0.05$ by least square means for diet effect.

[B, C, D] Distinct capital letters in the same row, differ at $P< 0.05$ by least square means for gender effect.

[e, f, g, h, i] Distinct lowercase letters in the same row, differ at $P< 0.05$ by least square means.

Table 2. Nitrogen intake, excretion, and balance by diet and gender [a]

	Gender/Treatment												*P*-value[b]		
	Bulls				Steers				Heifers						
	Maint	0.75	1.5	SEM	Maint	0.75	1.5	SEM	Maint	0.75	1.5	SEM	D	G	D × G
N intake	0.13^{c}	0.28^{d}	0.28^{d}	0.006	0.13^{c}	0.28^{d}	0.28^{d}	0.006	0.13^{c}	0.26^{d}	0.27^{d}	0.006	<0.001	0.06	0.28
N excretion	0.13^{c}	0.24^{d}	0.23^{d}	0.009	0.14^{c}	0.22^{d}	0.24^{d}	0.007	0.13^{c}	0.22^{d}	0.22^{d}	0.005	<0.001	0.15	0.28
N balance	-0.01^{c}	0.06^{d}	0.07^{d}	0.005	-0.01^{c}	0.05^{d}	0.05^{d}	0.004	0.00^{c}	0.06^{d}	0.05^{d}	0.005	<0.001	0.39	0.21

[a] Diet Maint, 0.75 and 1.5 = treatments of animals fed at maintenance level or fed concentrate at 0.75 or 1.5 % BW, respectively. Values are in lb/100 lb $EBW^{0.75}$.

[b] *P*-value for diet (D) and gender (G) effect and their interaction.

[c,d] Distinct lowercase letters in the same row, within gender, differ at $P< 0.05$ by least square means for diet effect.

Table 3. Regression of logarithm of heat production on ME intake to describe energy utilization by bulls, steers, and heifers [a]

Gender	Intercept	Slope (×1000)	n	r^2	RMSE	NE_m	ME_m	K_m, %	K_g, %
Bulls	1.86 ± 0.04	1.41 ± 0.14	7	0.93	0.025	40.1	55.4	72.1	54.5
Steers	1.82 ± 0.02	1.62 ± 0.07	9	0.98	0.014	36.4	51.6	70.6	47.0
Heifers	1.88 ± 0.03	1.38 ± 0.12	8	0.95	0.023	42.0	58.7	71.3	54.3
All	1.85 ± 0.01	1.47 ± 0.07	24	0.95	0.021	39.4	55.4	71.3	51.9

[a]Values are mean ± SE. RMSE = root of the mean square error, NE_m = net energy for maintenance (kcal/lb$^{0.75}$ EBW) calculated as the antilog of the intercept, MEm = ME for maintenance (kcal/lb$^{0.75}$ EBW) calculated by iteration assuming heat produced is equal to ME intake at maintenance, K_m (efficiency of use of ME for NEm) was calculated as NEm/MEm, and K_g (efficiency of use of ME for NE_g) was calculated as the slope of the regression of RE (kcal/lb$^{0.75}$ EBW) on ME intake (kcal/lb$^{0.75}$ EBW).

Table 4. Regression of logarithm of body protein, fat, or energy on logarithm of empty BW to describe the net retention by bulls, steers, and heifers [a]

Gender	Intercept	Slope	n	r^2	RMSE
		Fat			
Bulls	-5.37 ± 0.47[d]	2.77 ± 0.19[d]	8	0.97	0.07
Steers	-6.57 ± 0.72[c]	3.26 ± 0.31[e]	8	0.95	0.09
Heifers	-3.91 ± 0.72[e]	2.28 ± 0.29[c]	8	0.91	0.10
Alls	-4.47 ± 0.59	2.44 ± 0.24	24	0.82	0.15
		Energy			
Bulls	-1.30 ± 0.21	1.66 ± 0.08	8	0.98	0.03
Steers	-1.85 ± 0.26	1.88 ± 0.10	8	0.98	0.03
Heifers	-1.04 ± 0.31	1.60 ± 0.13	8	0.96	0.04
Alls	-1.07 ± 0.23	1.59 ± 0.09	24	0.93	0.06
		Protein			
Bulls	0.13 ± 0.06	0.67 ± 0.02	8	0.99	0.01
Steers	0.19 ± 0.16	0.63 ± 0.06	8	0.94	0.02
Heifers	-0.19 ± 0.17	0.78 ± 0.07	8	0.95	0.02
Alls	-0.10 ± 0.12	0.75 ± 0.05	24	0.92	0.03

[a] Values are mean ± SE. RMSE = root of the mean square error.

[c,d,e] Within a column, means without a common superscript letter differ (P< 0.05).

EFFECTS OF DIVERGENT SELECTION FOR SERUM IGF-I ON GROWTH, FEED EFFICIENCY AND CARCASS TRAITS IN ANGUS BULLS AND HEIFERS

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Summary

The primary objective of this study was to examine the effects of divergent selection for serum insulin-like growth factor (**IGF-I**) on feed efficiency in Angus calves. Bulls and heifers from low (n = 21) and high (n = 18) IGF-I selection lines produced at the Eastern Agricultural Research Station (Ohio State University) were used in this study. Calves were adapted to a forage-based diet (ME = 2.1 Mcal/kg), and feed intakes and growth rates measured for 77 d. Net feed intake (**NFI**) was calculated as the residual from linear regression of dry matter intake (**DMI**) on ADG and mid-test $BW^{.75}$. Heart rate measurements were obtained while calves were fed ad libitum and following a 48-hour fasting period. Feed conversion ratio (**FCR**) was moderately correlated with ADG and initial BW, but not DMI. In contrast, NFI was strongly correlated with DMI, but not ADG or initial BW. Calves with low NFI consumed 20% less ($P < 0.01$) DMI and had 17% lower ($P < 0.01$) FCR than calves with high NFI, even though ADG and final BW were similar. Calves from the low IGF-I selection line tended ($P = 0.06$) to have greater final BW than calves from the high IGF-I selection line, even though DMI and ADG were similar. In addition, calves from the low IGF-I selection line tended ($P = 0.10$) to have lower NFI than calves from the high IGF-I selection line. Full-feed heart rates were positively correlated with NFI, suggesting that calves with low NFI had lower energy expenditures. However, fasting heart rates were not correlated with NFI. Calves from the low IGF-I selection line tended ($P < 0.10$) to have 4% lower full-feed heart rates than calves from the high IGF-I selection line, but fasting heart rates were similar. These results suggest that selection for lower concentrations of serum IGF-I will result in cattle that have lower NFI.

Introduction

Feed efficiency is an important trait to consider in developing selection programs to identify cattle that are more economically and environmentally sustainable to produce. Considerable genetic variation is known to exist in efficiency of feed utilization, but the expense of measuring feed intake in cattle has precluded the implementation of selection programs that target this trait. Moreover, the traditional measure of feed efficiency (feed conversion ratio; **FCR**) is inversely related to growth and mature size, such that selection for improved FCR leads to increases in cow size. Net feed intake (**NFI**) is an alternative measure of efficiency that facilitates selection for improved feed efficiency in cattle independent of growth traits or mature size.

Identification of physiological indicator traits that are predictive of feed efficiency would be useful as early screening tests to reduce the number of animals that would need to be tested. Research from Australia has demonstrated that serum concentrations of insulin-like growth factor I (**IGF-I**) are genetically correlated to NFI in pigs (Bunter et al., 2002) and cattle (Moore et al., 2005). Moore et al. (2005) found that serum IGF-I concentrations were genetically correlated with NFI (0.54) in postweaning bulls and heifers. Likewise, we have found that serum IGF-I concentrations were positively correlated phenotypically with NFI (0.38) and FCR (0.36) in growing bulls (Brown et al., 2004).

Since 1989, Davis and coworkers have conducted a divergent selection study based on postweaning serum IGF-I concentrations in Angus cattle. Following approximately three generations of selection, Davis and Simmen (1997) found a negative genetic correlation between IGF-I concentration and postweaning gain; however, more recent analysis has revealed that serum IGF-I concentrations are no longer correlated with growth traits (Davis; unpublished data). To date, feed efficiency of calves selected for low and high serum IGF-I has not been evaluated. Therefore, the primary objective of this study was to examine the effects of divergent selection for serum IGF-I on performance and feed efficiency traits in Angus calves.

Experimental Procedures

Bulls and heifers from low (n = 21) and high (n = 18) IGF-I selection lines produced at the Eastern Agricultural Research Station (Ohio State University) were used in this study. Calves were blocked by sex and BW, and randomly assigned to pens (six calves per pen) at the O.D. Butler, Jr. Animal Science Complex. Bulls (9 low and 8 high IGF-I) and heifers (9 low and 13 high IGF-I) were adapted to a high-roughage diet (ME = 2.1 Mcal/kg) consisting of 35% chopped alfalfa, 15% pelleted alfalfa, 19.5% dry rolled corn, 21.5% cottonseed hulls, 7% molasses and 2% supplement and trained to eat from individual Calan-gate feeders for 24 d. Feed intake and BW were measured weekly during a 77-d test period. On d 0 and 77 of the test period, hip height and ultrasound measurements of 12th rib fat thickness, ribeye area and intramuscular fat were obtained. Immediately following d 77, calves were fitted with heart-rate sensors to obtain 48-h heart rate measurements. Heart rate measurements have been shown to be highly correlated with energy expenditures in cattle (Richards and Lawrence, 1984). Following the full-feed 48-h heart rate measurements, calves were fasted for 48 h and fasting 24-h heart rate measurements obtained.

Blood samples were collected during a postweaning performance test at the Eastern Agricultural Research Station, and serum harvested and analyzed for IGF-I concentration using an enzyme linked immunosorbent assay (ELISA). Blood samples were also collected on day 0 of the test, and serum analyzed for IGF-I concentration by radioimmunoassay.

Initial and final BW and ADG were derived from linear regression of BW on days on test. Net feed intake was computed as actual dry matter intake (**DMI**) minus expected DMI from linear regression of feed intake on ADG, mid-test $BW^{0.75}$, gender and gender by ADG and gender by mid-test $BW^{0.75}$ interactions. Feed conversion ratio was calculated as DMI divided by ADG.

Phenotypic correlations were computed for feed efficiency, performance, ultrasound composition, and physiological indicator traits using PROC CORR of SAS with the partial statement used to adjust for the fixed effect of gender. To further characterize NFI, calves were separated into low, medium and high NFI groups that were < 0.5, ± 0.5 and > 0.5 standard deviations from the mean NFI of 0.00 ± 2.01 lb/d, respectively. The effects of NFI group, selection line and gender on performance, feed efficiency, ultrasound composition and physiological indicator traits were analyzed using PROC GLM of SAS. The statistical model to evaluate the effect of NFI group included the fixed effects of NFI group, gender and the interaction term, while the model to evaluate the effects of selection line and gender included selection line, gender and the interaction term. All interaction terms were determined to be nonsignificant ($P > 0.15$) and so were excluded from final models.

Results and Discussion

Performance, feed efficiency and carcass traits.
Phenotypic correlations revealed that FCR was moderately correlated with ADG and initial BW, but not DMI, such that more efficient calves were those that were lighter at the start of the test and gained faster (Table 1). In contrast, NFI was strongly correlated in a positive manner with DMI, but was not correlated with initial BW or ADG. Previous studies have reported similar phenotypic and genetic correlations between feed efficiency and performance traits (Arthur et al., 2001; Nkrumah et al., 2004). Final rib fat thickness and ribeye area were both positively correlated with initial BW and DMI, but not with NFI or FCR. In contrast, previous studies have reported significant positive correlations (0.14 to 0.22) between NFI and rib fat thickness at the end of the test suggesting that more efficient calves are leaner (Arthur et al., 2001; Nkrumah et al., 2004).

To illustrate the magnitude of differences between calves with low and high NFI, calves were separated into low, medium and high NFI groups that were < 0.5, ± 0.5 and > 0.5 SD from the mean. Calves with low NFI consumed 20% less ($P < 0.01$) DMI and had 17% lower ($P < 0.01$) FCR than calves with high NFI, even though ADG and BW were similar (Table 2). Calves with low NFI had similar final hip height, as well as final rib fat thickness and ribeye area, compared to calves with high NFI.

Gender effects on performance, feed efficiency and carcass traits.
As expected, bulls were heavier ($P < 0.01$) at the start and end of the 77-d test compared to heifers (Table 3). Bulls consumed similar DMI, but had higher ($P < 0.01$) ADG, resulting in lower ($P < 0.01$) FCR compared to heifers. Bulls and heifers had similar NFI, as gender was included in the linear regression model in order to compute expected feed intake within each gender contemporary group. As expected, bulls had larger ($P < 0.01$) ribeye area and less ($P < 0.01$) rib fat thickness than heifers at the end of the test.

Selection line effects on performance, feed efficiency and carcass traits.
Calves from the low IGF-I selection line had similar DMI and ADG, but tended ($P = 0.06$) to have larger final BW compared to calves from the high IGF-I selection line. Although calves from low and high IGF-I selection lines had similar FCR, calves from the low IGF-I selection line tended ($P = 0.10$) to have lower NFI (more efficient) compared to calves from the high IGF-I selection line (Table 4), which supports previous research results demonstrating a positive genetic correlation between serum IGF-I and NFI (Johnston et al., 2001; Moore et al., 2005). Likewise, Moore et al. (2005) reported small negative genetic correlations between IGF-I and 200-d and 400-d BW, which also tends to support results from the current study.

Final ultrasound measurements of ribeye area and intramuscular fat were similar for calves from low and high IGF-I selection lines. Although not different statistically, there was a tendency (P = 0.14) for calves from the low IGF-I selection line to have less rib fat thickness compared to calves from the high IGF-I selection line. Davis et al. (2003) and Moore et al. (2005) reported small positive genetic correlations between serum IGF-I and ultrasound measurements of rib fat thickness. Collectively, results from this study support findings of Davis et al. (2003) and Moore et al. (2005), suggesting that selection for low serum IGF-I will result in cattle with lower NFI (improved feed efficiency), and with slight increases in lean growth rates.

Physiological indicator traits.
Postweaning and day 0 serum IGF-I concentrations were not correlated with initial BW, ADG or DMI (Table 5). Furthermore, neither of the IGF-I measurements was correlated with NFI or FCR, which is in contrast to Moore et al. (2005) who reported a significant genetic correlation between NFI and serum IGF-I. Calves from the low selection line had lower ($P < 0.01$) postweaning and day 0 serum IGF-I concentration than calves from the high selection line. In addition, heifers had lower ($P < 0.01$) serum IGF-I concentrations than bulls. However, postweaning and day 0 serum IGF-I concentrations were similar among NFI phenotype groups.

Full-feed heart rate was not significantly correlated with BW, ADG or DMI, but was positively correlated ($P < 0.05$) with NFI. Heart rate has been shown to be highly correlated ($r = 0.93$) to energy expenditures in cattle (Richards and Lawrence, 1984). Thus, these results suggest that calves with low NFI may have lower energy expenditures than calves with high NFI. In contrast, fasting heart rate was not correlated with any of the performance or feed efficiency traits. Heifers had greater full-feed heart rates, but similar fasting heart rates compared to bulls. This resulted in heifers having a greater ($P < 0.01$) change in heart rate from full-feed to fasting than bulls. Calves with low NFI tended to have lower ($P < 0.10$) full-feed heart rates, but similar fasting heart rates compared to calves with high NFI. Moreover, full-feed heart rates tended to be lower ($P < 0.10$) for calves from the low IGF-I selection line, but fasting heart rates were similar compared to calves from the high IGF-I selection line.

Implications

Compared to FCR, NFI was less affected by differences in initial BW, growth rate and carcass composition traits, suggesting that NFI may be a more robust trait to use in selection programs to improve feed efficiency. Despite the small magnitude of change in NFI between divergent IGF-I selection lines, serum IGF-I concentration may be a useful trait for use in selection programs designed to improve NFI. Lower heart rates in low NFI and low IGF-I phenotypes suggest that differences in energy expenditures may contribute to individual variation in feed efficiency of growing cattle.

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Table 1. Partial phenotypic correlations between feed efficiency, performance and ultrasound carcass traits in Angus bulls and heifers.

	Initial BW	ADG	DMI	NFI	FCR
Average daily gain (ADG)	0.05				
Dry matter intake (DMI)	0.49*	0.62*			
Net feed intake (NFI)	0.00	0.03	0.64*		
Feed conversion ratio (FCR)	0.41*	-0.60*	0.22	0.57*	
Final hip height	0.36*	0.31	0.36*	0.00	0.05
Final 12th rib fat thickness	0.49*	0.06	0.34*	0.13	0.30
Final ribeye area	0.62*	0.12	0.33*	-0.07	0.19
Final intramuscular fat	0.11	0.18	0.08	-0.09	-0.10

*Correlation coefficient is different from zero at $P < 0.05$.

Table 2. Effects of net feed intake classification on performance and feed efficiency in Angus bulls and heifers

	Low NFI	High NFI	SE	*P*-value
No. of animals	10	8	-	-
Performance traits				
Initial body weight, lb	708.6	718	21	0.73
Final body weight, lb	904.9	917.3	24.1	0.89
Final hip height, in	47.6	47.9	0.5	0.87
Average daily gain, lb/d	2.55	2.59	0.15	0.74
Dry matter intake, lb/d	23.33	29.07	0.95	0.01
Net feed intake, lb/d	-2.44	2.9	0.31	0.01
Feed conversion ratio, feed/gain	9.49	11.44	0.41	0.01
Final carcass composition traits				
12th rib fat thickness, in	0.33	0.36	0.03	0.68
Ribeye area, in^2	10.76	10.9	0.4	0.92
Intramuscular fat, %	4.46	4.12	0.2	0.42
Physiological indicator measurements				
Postweaning IGF-I, ng/mL	241.4	253.7	27.5	0.35
Day 0 IGF-I, ng/mL	181.2	191	9.14	0.37
Full-feed heart rate, beats/min	80.1	86.1	2.1	0.08
Fasting heart rate, beats/min	49.9	51	1.42	0.71
Change in heart rate, beats/min[a]	30.1	35	2.1	0.23

[a]Change in heart rate is full-feed heart rate minus fasting heart rate

Table 3: Effects of gender on performance and feed efficiency in Angus calves.

	Bulls	Heifers	SE	*P*-value
No. of animals	17	22	-	-
Performance traits				
Initial body weight, lb	808.7	633.9	13.9	0.01
Final body weight, lb	1033	797.4	15.5	0.01
Final hip height, in	48.3	47	0.3	0.01
Average daily gain, lb/d	2.91	2.12	0.1	0.01
Dry matter intake, lb/d	26.74	25.11	0.81	0.14
Net feed intake, lb/d	0.03	-0.1	0.48	0.84
Feed conversion ratio, feed/gain	9.29	11.99	0.32	0.01
Final carcass composition traits				
Final 12th rib fat thickness, in	0.3	0.39	0.02	0.01
Final ribeye area, in^2	11.57	10.2	0.27	0.01
Final intramuscular fat, %	4.04	4.65	0.14	0.01
Physiological indicator measurements				
Postweaning IGF-I, ng/mL	254.1	196.7	17.4	0.02
Day 0 IGF-I, ng/mL	214.4	142.4	5.3	0.01
Full-feed heart rate, beats/min	81	85.8	1.4	0.02
Fasting heart rate, beats/min	51.6	50	1	0.23
Change in heart rate, beats/min[a]	28.6	35.8	1.5	0.01

[a]Change in heart rate is full-feed heart rate minus fasting heart rate.

Table 4. Effects of IGF-I selection line on performance and feed efficiency in Angus bulls and heifers.

	High IGF-I Line	Low IGF-I Line	SE	*P*-value
No. of animals	18	21	-	-
Performance traits				
Initial body weight, lb	707.9	734.7	13.5	0.16
Final body weight, lb	895.6	934.8	15	0.06
Final hip height, in	47.4	47.9	0.3	0.21
Average daily gain, lb/d	2.44	2.6	0.09	0.22
Dry matter intake, lb/d	25.81	26.03	0.78	0.83
Net feed intake, lb/d	0.51	-0.58	0.47	0.1
Feed conversion ratio, feed/gain	10.9	10.39	0.31	0.24
Final carcass composition traits				
12th rib fat thickness, in	0.36	0.33	0.02	0.14
Ribeye area, in^2	10.82	10.95	0.26	0.71
Intramuscular fat, %	4.32	4.37	0.13	0.79
Physiological indicator measurements				
Postweaning IGF-I, ng/mL	256.3	194.5	16.9	0.01
Day 0 IGF-I, ng/mL	193.2	163.5	5.1	0.01
Full-feed heart rate, beats/min	85.2	81.5	1.4	0.06
Fasting heart rate, beats/min	51.3	50.3	1	0.43
Change in heart rate, beats/min[a]	33.8	30.5	1.4	0.09

[a]Change in heart rate is full-feed heart rate minus fasting heart rate.

Table 5. Partial phenotypic correlations between feed efficiency and performance traits, and physiological indicator measurements in Angus bulls and heifers

	Initial BW	ADG	DMI	NFI	FCR
Postweaning IGF-I	0.21	-0.19	-0.06	-0.01	0.17
Day 0 IGF-I	-0.3	0.2	0.03	0.1	-0.26
Full-feed heart rate	-0.12	0.12	0.3	0.38*	0.04
Fasting heart rate	-0.02	0.18	0.17	0.08	-0.05
Change in heart rate[a]	-0.1	-0.02	0.16	0.3	0.07

META ANALYSIS OF FEED INTAKE AND EFFICIENCY IN GROWING AND FINISHING CATTLE

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Summary

Data from eight studies were analyzed using meta-analysis techniques to characterize feed efficiency traits, and to examine correlations with performance and carcass traits in growing and finishing calves. The first database consisted of four studies of growing calves (n = 514) fed high-roughage diets. The second database contained four studies of finishing steers (n = 321) fed high-grain diets. Three feed efficiency traits were examined including net feed intake (**NFI**), partial efficiency of growth (**PEG**) and feed conversion ratio (**FCR**). In both growing and finishing studies, FCR was negatively correlated with ADG, but weakly correlated with feed intake, such that favorable FCR phenotypes grew substantially faster, and consumed slightly less feed. In contrast, NFI was strongly correlated with intake, but was not correlated with ADG in either growing or finishing calves. In both growing and finishing calves, PEG was weakly correlated with ADG, but strongly correlated with feed intake, demonstrating that favorable PEG phenotypes ate substantially less feed and had slightly higher ADG. In both growing and finishing studies, calves with low NFI consumed 18 to 20% less feed and had 18 to 21% lower FCR compared to calves with high NFI. Phenotypic correlations between all three of the feed efficiency traits and final rib fat thickness were weak for growing calves and moderate for finishing calves, such that the favorable phenotypes tended to be leaner. Correlations between feed efficiency traits and final ribeye area were either weak or not different from zero. Compared to other feed efficiency traits, NFI was the least influenced by rate and composition of growth in both growing and finishing calves.

Introduction

Currently, most breeding programs are focused on improving economically relevant output traits such as growth, carcass quality and fertility to enhance the economic viability of beef production systems. Generally absent from breeding programs today are avenues for exploiting genetic variation in feed efficiency, even though reductions in feed inputs would substantially improve profitability of beef operations. While the expense of measuring feed intake has curtailed the implementation of genetic strategies focused on feed efficiency, emerging commercialization of technologies to more cost effectively measure intake has helped to renew interest in this area. The objective of this study was to characterize various feed efficiency traits for post-weaning beef cattle, focusing on phenotypic relationships with performance and carcass traits in both growing and finishing calves.

Experimental Procedures

A Meta analysis of eight studies (Table 1) was conducted to characterize the feed efficiency traits, and to examine their correlations with performance and carcass traits in growing and finishing calves. Two databases were assembled and analyzed separately. The first database consisted of four studies that included growing steers and heifers (N = 514) fed high-roughage diets (0.94 to 0.97 Mcal ME/lb), with average initial body weights averaging 604 lb. The second database consisted of four studies that included finishing steers (N = 321) fed high-grain diets (1.24 to 1.36 Mcal ME/lb), with average initial body weights of 789 lb. Ultrasound estimates of 12th rib fat thickness and ribeye area measured at the end of the growing studies, and carcass cooler data collected at harvest of the finishing studies were used to assess carcass composition. Within studies cattle were individually fed and managed in a similar manner.

Three feed efficiency traits were derived from the growth and dry matter intake (**DMI**) measurements for each calf. 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*mid-test metabolic body weight ($BW^{0.75}$) ÷ NEm concentrations of the test diets. Net feed intake (**NFI**) was calculated as the difference between actual DMI and expected DMI from multiple linear regression of DMI on ADG and $BW^{0.75}$, assuming studies as random effects and variance components for the variance-(co)variance matrix.

The PROC MIXED (SAS Institute Inc., Cary, NC) procedure was used in the statistical analyses. All variables (Y_{ij}) were adjusted with a mixed model, assuming variance components for the variance-(co)variance matrix. Only the intercept was adjusted to account for study effect (a_i) using the statistical model described below. Phenotypic correlations between dependent variables were analyzed using the adjusted variables for the effects of study on the intercept only.

$$Y_{ij} = \mu_N + a_i + e_{ij}$$
$$where$$
$$a_i \sim iid\ N\left(0, \sigma_N^2\right); e_{ij} \sim iid\ N\left(0, \sigma_e^2\right)$$

Results and Discussion

The model R^2 of the multiple regression equations used to compute NFI were 0.68 and 0.67 for growing and finishing studies, respectively, indicating that about two thirds of the variation in feed intake was explained by variation in weight and ADG in both studies. In both growing and finishing studies, FCR was strongly correlated with ADG (-0.60 and -0.58) and initial weight (0.28 and 0.40), but weakly correlated with feed intake (0.12 and 0.25), demonstrating that favorable FCR phenotypes had substantially lighter initial weights and higher ADG, and consumed slightly less feed. In contrast, NFI was strongly correlated with intake (≈ 0.65) in growing and finishing calves, but as expected, NFI was not correlated phenotypically with initial weights or ADG. In both growing and finishing calves, PEG was weakly correlated with ADG (0.20 and 0.11) and initial weights (0.14 and 0.10), but strongly correlated with feed intake (-0.57 and -0.64), demonstrating that favorable PEG phenotypes ate substantially less feed and had slightly higher ADG and initial weights. The phenotypic correlations between these three feed efficiency traits and their component traits (growth and intake) were comparable to those reported in previous studies (Arthur et al., 2001a,b; Nkrumah et al., 2004; Lancaster et al., 2005).

All feed efficiency traits were strongly correlated to each other (> ± 0.50) in favorable directions. In general, phenotypic correlations between efficiency, intake and growth traits in growing calves were remarkably similar to those found in finishing calves. Phenotypic correlations between all three of the feed efficiency traits and final rib fat thickness were weak (± 0.11 to 0.15) for growing calves, such that the favorable phenotypes tended to be leaner. Rib fat thickness was also positively correlated with the three feed efficiency traits (± 0.21 to 0.38) in finishing calves. However, the magnitude of these correlations were higher in finishing compared to growing calves, suggesting that carcass fatness was more strongly correlated with feed efficiency when calves were fed high-energy diets. In general, phenotypic correlations between feed efficiency traits and final ribeye area were either weak or not different from zero in both growing and finishing calves.

To illustrate the phenotypic variation in NFI and relationships with other component traits, calves within growing and finishing studies were separated into low and high NFI groups (Table 3); low NFI calves being those that ranked less than 0.5 SD from the mean NFI of 0.0 ± 1.80 and 0.0 ± 1.96 lb/d for growing and finishing calves, respectively. For growing studies, calves with low NFI consumed 18% less feed and had 18% lower FCR and 44% higher PEG compared to calves with high NFI. In the finishing studies, low NFI calves consumed 20% less feed and had 21% lower FCR and 48% higher PEG than high NFI calves. Initial and final body weights and ADG were similar for low and high NFI phenotypes in both the growing and finishing calves. Thus, similar phenotypic variations in NFI were observed in growing and finishing calves. In economic terms, the difference in feed costs between finishing calves with low and high NFI equates to $0.32/day or $38.00 during a 120-day feeding period, assuming ration costs of $0.07/lb (dry matter basis).

There were no differences in ultrasound estimates of carcass composition (rib fat thickness or ribeye area) between calves with low and high NFI in the growing studies, however, in the finishing studies calves with low NFI had less carcass fat and larger REA than calves with high NFI. Clearly, there was larger differential in carcass fatness between low and high NFI phenotypes in finishing vs growing studies, which likely reflects greater expression of genetic potential for fat tissue deposition, due to the fact that these calves were fed a high-grain diet and were older during the NFI measurement period. These results suggests that selection for improved NFI may potentially impact carcass quality traits (e.g., marbling) in an antagonistic manner, especially if selection for NFI were applied to earlier maturing cattle on moderate- to high-energy diets. A number of studies have reported weak to moderate genetic correlations between NFI and carcass fat (Arthur et al., 2001a,b; Schenkel et al., 2004). The inclusion of carcass fat traits along with ADG and weight to compute NFI may be warranted to minimize unfavorable responses in carcass quality traits.

Implications

Considerable genetic variation exists in beef cattle for feed intake unaccounted for by differences in weight and growth rate, which is defined as net feed intake. Inclusion of NFI as part of a breeding program will provide opportunities to improve profitability of beef production systems through reductions in feed inputs, with minimal influences on growth or mature size.

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Table 1. Summary of studies involving growing and finishing calves used in the Meta analysis

	Finishing studies				*Growing studies*			
Study	King Ranch	McGregor	Cornell I	Cornell II	Spade Ranch	King Ranch	Camp Cooley I	Camp Cooley II
Number of calves	115	119	50	37	169	115	114	115
Diet ME, Mcal/lb	1.36	1.24	1.30	1.35	0.94	0.97	0.95	0.95
Sex	Steers	Steers	Steers	Steers	Steers	Steers	Heifers	Heifers
Breed	Santa Gertrudis	Red Angus	Angus/ Simmental	Angus	Braunvieh	Santa Gertrudis	Brangus	Brangus

Table 2. Pearson correlations among performance and feed efficiency traits for growing (above diagonal) and finishing (below diagonal) calves

		Growing studies							
	Trait	ADG	iBW	DMI	NFI	PEG	FCR	BF	REA
Finishing studies	Average daily gain	--	0.14	0.61	0.00	0.20	-0.60	0.06	0.08
	Initial BW	0.10	--	0.53	0.00	-0.25	0.28	0.28	0.45
	Dry matter intake	0.62	0.51	--	0.65	-0.57	0.12	0.24	0.25
	Net feed inake	0.03	0.06	0.67	--	-0.87	0.56	0.11	0.00
	Partial eff. of gain	0.11	-0.38	-0.64	-0.84	--	-0.77	-0.15	-0.10
	Feed conversion ratio	-0.58	0.40	0.25	0.63	-0.79	--	0.11	0.11
	12th rib fat thickness	0.20	0.22	0.44	0.33	-0.38	0.21	--	0.22
	Ribeye area	0.24	0.32	0.19	-0.14	0.02	-0.11	-0.20	--

[a]Correlations in bold are significantly greater then zero; $P < 0.05$.

Table 3. Characterization of performance, ultrasound, and feed efficiency traits in growing and finishing calves with low and high net feed intake (NFI)[a]

		Growing studies							
	Trait	ADG	iBW	DMI	NFI	PEG	FCR	BF	REA
Finishing studies	Average daily gain	--	**0.14**	**0.61**	0.00	**0.20**	**-0.60**	0.06	0.08
	Initial BW	0.10	--	**0.53**	0.00	**-0.25**	**0.28**	**0.28**	**0.45**
	Dry matter intake	**0.62**	**0.51**	--	**0.65**	**-0.57**	**0.12**	**0.24**	**0.25**
	Net feed inake	0.03	0.06	**0.67**	--	**-0.87**	**0.56**	**0.11**	0.00
	Partial eff. of gain	**0.11**	**-0.38**	**-0.64**	**-0.84**	--	**-0.77**	**-0.15**	-0.10
	Feed conversion ratio	**-0.58**	**0.40**	**0.25**	**0.63**	**-0.79**	--	**0.11**	**0.11**
	12^{th} rib fat thickness	**0.20**	**0.22**	**0.44**	**0.33**	**-0.38**	**0.21**	--	**0.22**
	Ribeye area	**0.24**	**0.32**	**0.19**	**-0.14**	0.02	**-0.11**	**-0.20**	--

[a]Animals with low and high NFI were < 0.50 and > 0.50 SD from average NFI, respectively (NFI SD was 1.80 and 1.96 lb/d for growing and finishing studies, respectively).
[b]ADG/DMI for growth.

EVALUATION OF FEED EFFICIENCY TRAITS AND THEIR RELATIOMSHIPS WITH CARCASS ULTRASOUND AND FEEDING BEHAVIOR TRAITS IN BRAHMAN HEIFERS

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Summary

Brahman heifers (n = 132) from two performance tests were used to characterize feed efficiency traits and examine phenotypic correlations with performance, carcass ultrasound, and feeding behavior traits. The heifers were fed a silage-based diet (ME = 2.78 Mcal/kg) and individual feed intake and feeding behavior traits measured with a Growsafe® feeding system. Net feed intake (NFI) was correlated with DMI (0.69), feed conversion ratio (**FCR**; 0.66) but not ADG or BW. Heifers with low NFI (< 0.5 SD; n = 37) consumed 25% less DMI and had 26% lower FCR than heifers with high NFI (> 0.5 SD; n = 44). Final UBF was not correlated with NFI, but was correlated ($P < 0.01$) with FCR (0.23). Initial age and BW were correlated with FCR (0.30, 0.40, respectively), but not with NFI, suggesting that younger and (or) lighter heifers at start of test had lower FCR, but similar NFI compared to older and (or) heavier heifers. Feeding duration was correlated ($P < 0.05$) with DMI (0.35), ADG (0.23) and NFI (0.32), but not with FCR. Meal frequency was not correlated with either of the feed efficiency traits, but was correlated ($P < 0.05$) with DMI (0.18). Eating rate (feed consumed/min) was correlated ($P < 0.05$) with DMI (0.65), ADG (0.21), FCR (0.44) and NFI (0.37). Heifers with low NFI (more efficient) spent less time ($P < 0.05$) at the feed bunk (155 vs. 174 ± 4 min/d) and consumed DMI at a slower rate ($P < 0.05$; 46.5 vs. 54.6 ± 1.6 g/min), but had similar meal frequencies compared to heifers with high NFI. Results from this study demonstrate that NFI was less influenced by rate and composition of growth, and age and body weight at the start of the test, compared to FCR.

Introduction

Feed cost is one of the major inputs in beef cattle production. Selection of animals that are more efficient can dramatically increase profit. The typical feed efficiency trait has been feed conversion ratio (FCR; amount of feed consumed per unit of weight gain) which is related to growth, body size and body composition. Net feed intake (the difference between actual feed intake and expected feed intake) is phenotypically unrelated to body size or growth rate. Thus selection for NFI instead of FCR would result in reductions in feed intake with little impact on growth or carcass traits. Net feed intake has been shown to be related to back fat thickness but not to ribeye area in steers and bulls. There is evidence that there is genetic variation in feed efficiency in beef cattle, which was reviewed by Archer et al. (1999). The genetic variation in NFI offers a potential for selection for low NFI (i. e. high efficiency) which will produce progeny that eat less, without decreasing growth (Herd et al., 2004). It has been reported that feeding behavior such as eating rate, bunk attendance and meal frequency is related to NFI (Lancaster et al., 2005). Taking into consideration that measuring feed efficiency is expensive, feeding behavior traits could be useful indicator traits.

Experimental Procedures

Two performance tests (test 1 n = 70; test 2 n = 62) were conducted at the Beef Development Center of Texas in Millican, TX with producer-owned Brahman heifers (Kallion Farms). Heifers 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 (2.78 Mcal/kg DM) consisted of 49% cracked corn, 30% corn silage, 7% cotton seed hulls, 5% cotton seed meal, 4.5% molasses and 4.5% supplement and was fed twice daily ad libitum.

Feed intake and feeding behavior traits were measured using a GrowSafe® system (GrowSafe systems Ltd., Airdrie, AB). GrowSafe Data Acquisition software was used to record feed intake data for 70 d. Daily feed intake was computed using GrowSafe Feed Intake Analysis software. Feeding behavior traits measured included feeding duration (min/d), meal frequency (meals/d) and eating rate (DMI/feeding duration).

Heifers were weighed at 14 d intervals, and ultrasound measurements of 12-13th rib backfat (**UBF**), 12-13th ribeye area (**UREA**), and percent intramuscular fat (**UIMF**) obtained on days 0 and 70 of the test by a Ultrasound Guidelines Council field certified technician using an Aloka 500-V instrument with a 17-cm 3.5 MHz transducer (Corometrics Medical Systems, Inc., Wallingford, CT, USA).

Images were collected and interpreted with Beef Image Analysis Pro software (Designer Genes Inc., Harrison, AR).

Growth rates of individual heifers were modeled by linear regression of BW against day on test using the PROC REG procedure of SAS (SAS Inst., Cary, NC), and the regression coefficients used to calculate ADG, initial and final BW. Metabolic body weight (**MBW**) was calculated as mid-test $BW^{0.75}$. Moisture analyses of weekly feed ingredient samples were used to determine dry matter intake (**DMI**).

Net feed intake was calculated as the residual from the linear regression of DMI on MBW and ADG, with test included as fixed effect. Heifers within test were ranked by RFI and separated into low (< 0.5 SD), medium (± 0.5 SD), and high (> 0.5 SD) groups. Data were analyzed using the PROC GLM of SAS that included fixed effects of RFI group and test.

Results and Discussion

Average (± SD) initial age and BW were 318 ± 25 d and 576 ± 83 lb for test 1 (N = 70) and 244 ± 26 d and 497± 79 lb for test 2 (N = 62). Overall mean (± SD) ADG, DMI and NFI were 2.12 ± 0.33, 18.5 ± 3.33, and 0.0 ± 2.31 lb/d, respectively. The partial correlations among growth, feed intake, ultrasound and feed efficiency traits are shown in Table 2. There was a strong correlation (0.66) between NFI and FCR. Lancaster et al. (2005), and Fox et al. (2004) reported similar correlations between NFI and FCR of 0.53 and 0.85, respectively. Strong correlations between FCR and ADG, BW and DMI were also found, which is in agreement with previous studies (Lancaster et al., 2005, Fox et al., 2004 and Arthur et al., 2001). In contrast, NFI was not correlated with any of the growth traits, which supports previous results that NFI is not related phenotypically to growth traits (Arthur et al., 2001).

Ultrasound traits were not correlated ($P > 0.05$) with NFI, however, FCR was positively correlated (0.23) with UBF (Table 2), which indicates that animals with lower FCR were leaner. Lancaster et al. (2005) reported correlations between NFI and UBF of 0.17 ($P < 0.05$) and no significant correlation between FCR and ultrasound traits. Ultrasound estimates of REA were positively correlated with growth traits and DMI, and UBF correlated with DMI, but not ADG. Lancaster et al. (2005) found both UREA and UBF were correlated to ADG. Characterization of performance, ultrasound traits and feed efficiency traits of heifers with low and high NFI are presented in Table 2. Heifers with low NFI consumed 25% less feed and had 26% lower FCR than heifers with high NFI even though ADG was similar. Ultrasound traits did not differ between NFI groups, which is in agreement with Lancaster et al. (2005). These results suggest that selection of animals based on NFI rather than FCR will facilitate improvements in feed efficiency with minimal responses in growth and composition traits.

Figure 1 show partial correlations between feeding behavior traits and ADG, FCR and NFI. Results indicate that ADG and NFI were correlated (0.23 and 0.32, respectively) with feeding duration but not with meal frequency. These results demonstrate that heifers with higher ADG and NFI spent more time at the bunk. In contrast, feeding duration was not correlated with FCR. Lancaster et al (2005) also reported that feeding behavior traits were not correlated to FCR. Both FCR and NFI were correlated with eating rate (range from 0.21 to 0.44). Heifers with high NFI spent 20 minutes longer at the feed bunk each day than heifers with low NFI. The results from this study were not in total agreement with Lancaster et al. (2005), which may be related to differences in breed and gender of calves used in the studies.

Age at the start of the test was not correlated to NFI, but was correlated to FCR and ADG (0.30 and 0.50, respectively). Likewise, initial body weight was correlated to FCR and ADG, but not to NFI. These results suggest that heifers that are lighter and younger at the start of the test will have lower FCR (improved efficiency) compared to heifers that are heavier and older at the start of the test . In contrast NFI was not correlated to initial age or body weight, suggesting that NFI as a measure of feed efficiency is less influenced by differences in age and previous management compared to FCR.

Implications

Of the two feed efficiency traits examined in this study, selection for low NFI will improve feed efficiency with minimal influences on body size, growth or age. Results from this study demonstrate that GrowSafe feed intake system can be successfully employed in a commercial performance test facility to measure feed efficiency in cattle.

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Table 1. Partial correlations[a] among growth, feed intake, ultrasound and feed efficiency traits in growing heifers

Trait	DMI	RFI	FCR	UREA[b]	UBF[b]	UIMF[b]
Mid-test body weight (MBW)	**0.62**	0.00	**0.33**	**0.61**	**0.48**	-0.04
Average daily gain (ADG)	**0.43**	0.00	**-0.44**	**0.22**	0.13	0.09
Dry matter intake (DMI)		**0.69**	**0.60**	**0.31**	**0.34**	0.10
Net feed intake (NFI)			**0.66**	-0.07	0.04	0.08
Feed conversion rate (FCR)				0.14	**0.23**	0.002

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

[b] Ultrasound traits, UREA (ribeye area), UBF (back fat thickness), UIMF (percentage intramuscular fat)

Table 2. Characterization of performance, ultrasound composition and feed efficiency traits in growing heifers with low, medium and high net feed intake (NFI)

	NFI Group[a]				
Trait[b]	Low	Med	High	SE	P-value
No. of Heifers	37	51	44		
Average daily gain, lb/d	2.14	2.07	2.09	0.53	0.65
Dry matter intake, lb/d	15.52x	18.47y	20.70z	0.32	<0.0001
Net feed intake, lb/d	-2.88x	-0.01y	2.44z	0.15	<0.0001
Feed conversion rate, DMI/ADG	7.36x	9.09y	9.90z	0.21	<0.0001
Final ribeye area, in^2 [c]	10.63	10.66	10.45	0.24	0.77
Final 12th rib fat thickness, in[c]	0.15	0.15	0.15	0.01	0.92
Final intramuscular fat, %[c]	2.73	2.93	2.80	0.11	0.34

[a] Low NFI (< 0.5 SD), medium (± 0.5 SD), high (> 0.5 SD) from tests mean NFI.

[b] Least square means within a row with different superscripts differ.

[c] Ultrasound traits measured at the end of each study.

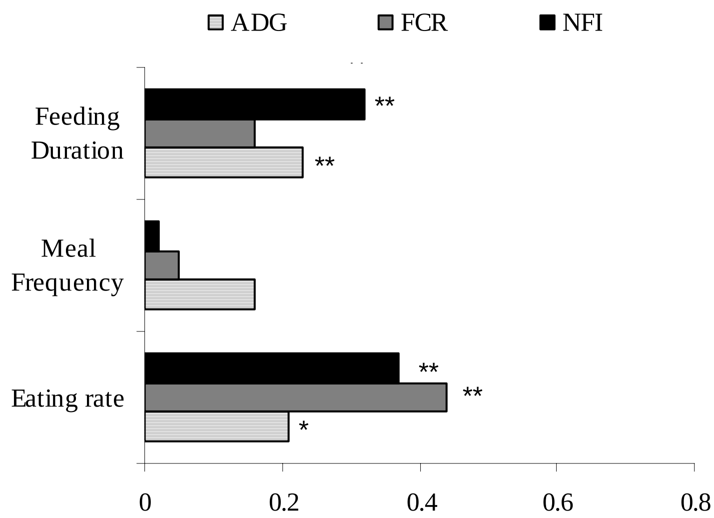

Figure 1. Partial correlations among feeding behavior traits and average daily gain, dry matter intake, and net feed intake (** P < 0.01 and * P < 0.05).

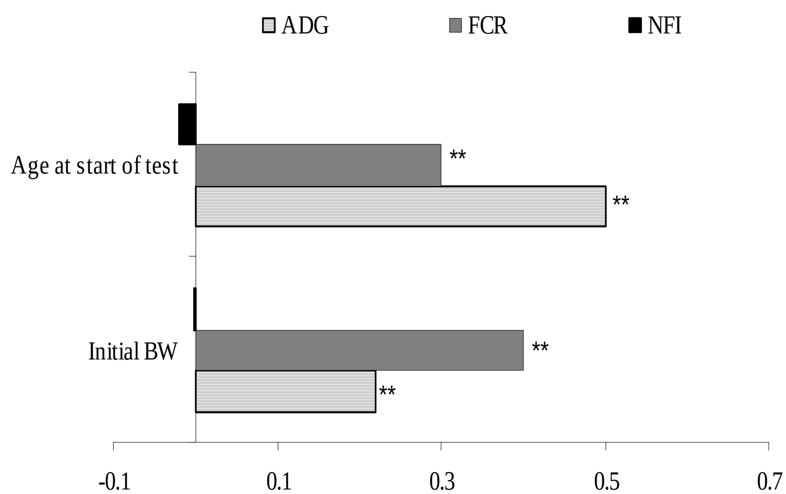

Figure 2. Partial correlations among feed efficiency traits and age and body weight at start of the tests (** P < 0.01).

USING MATHEMATICAL NUTRITION MODELS TO IMPROVE BEEF CATTLE EFFICIENCY

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Summary

Mathematical models integrate the scientific knowledge of energy and nutrients supply by the feedstuffs and requirements by the animals that have been accumulated over time and allow us to apply it in different production scenarios. Models have an important role in assisting the improvement of feeding systems and helping to understand the feedback structure that dictates the behavior of production systems. Thus, they can provide essential information to be used in the decision-making process of policy makers, producers, and consultants to maximize production while minimizing the environmental impacts through reduced nutrient excretion in an economically feasible fashion. Several mathematical nutrition models have been developed to account for more of the variation in ruminant production (Tedeschi et al., 2005b). This paper will discuss the usefulness of these models to predict beef production efficiency.

Introduction

The Cornell Net Carbohydrate and Protein System (**CNCPS**) model has been developed for more than 30 years (Fox et al., 2004) for use in ration balancing and performance prediction programs to account for factors that affect performance, feed efficiency and nutrient excretion in beef and dairy cattle in each unique production situation. Because of the wide variations in breed types and their crosses used for beef production around the world and environments in which they are fed prior to marketing as finished beef, the CNCPS model has focused on accounting for differences in maintenance requirement, mature body size and composition of gain, implant program, feed composition and feeding system. Evaluations of the CNCPS model have demonstrated the impact nutrition models can have on improving performance and reducing feed cost of production and nutrient excretion (Fox et al., 2004; Tedeschi et al., 2005a). The Beef NRC (1996; 2000) model was developed based on the CNCPS framework to specifically predict digestion, metabolism, and performance of beef cattle.

Growth models are being used in individual cattle management systems (**ICMS**) that are being developed for the beef industry to improve profitability, to minimize excess fat produced, to increase consistency of products, and to identify and reward individual owners for superior performance in the feedlot. To accomplish this, cattle are marketed as individuals when at their optimum carcass composition, which typically requires having cattle with different owners in the same pen (co-mingle). This requires allocating and billing feed fed to a pen to the individual animals in the pen. To make individual animal management work, the method used to allocate the feed consumed by animals from different owners that share the same pen must accurately determine cost of gain of each animal in a pen. A mathematical growth model (Cornell Value Discovery System, **CVDS**) was developed (Guiroy et al., 2001; Perry and Fox, 1997; Tedeschi et al., 2004) to address the following critical control points in launching a successful ICMS:

- Predicting optimum finished weight, incremental cost of gain and days to finish to optimize profits and marketing decisions while marketing within the window of acceptable carcass weights and composition,
- Predicting carcass composition and backfat deposition rate during growth to avoid discounts for under- or over-weight carcasses and excess backfat, and
- Allocating feed fed to pens to individual animals for the purpose of sorting of individuals into pens by days to reach a target body composition and maximum individual profitability.

Description of the CVDS Model to Predict Energy and Protein Requirements

Accounting for body composition at the marketing target end point. The first step for predicting feed required for the observed growth and incremental cost of gain and body composition as cattle grows is to identify the body composition at the marketing target end point. Carcass value in most markets and cost of gain can be related to proportion of protein and fat in the carcass. The single most recognizable quality grade in the world is USDA choice. Premium brand name products typically utilize the prime and upper 2/3 of the Choice grades and are increasing the value of U.S. beef products. Table 1 shows a summary of several experiments (Guiroy et al., 2001) that support the value of the Choice and prime grades level of fatness to minimize the percent of the beef that is unacceptable to consumers in the U.S.

These data show that EBF was significantly ($P < 0.05$) higher with each incremental increase in grade up to the mid Choice USDA grade. Taste panel scores and percent unacceptable followed the same trend. This data also indicate the correlation between USDA quality grades to changes in EBF as cattle grow. The most critical factor in this table for our model is the EBF at Standard (21.1%), Select (26.2%), and low Choice (28.6%) USDA grades because these are the body composition endpoints for different marketing targets used to identify feed requirements during growth.

The National Beef Quality Audit (Smith et al., 1995) reported the percent of steaks with low eating quality for the USDA Prime, Choice, Select, and Standard grades were 5.6, 10.8, 26,4, and 59.1 %, respectively, in data collected from typical feedlot cattle. The % unacceptable values were lower for the data analyzed by Guiroy et al. (2001) likely because they were uniform calves fed a 90% concentrate diet beginning at approximately 7 mo of age. The National Beef Quality Audit conducted by Smith et al. (1995) also reported that up to 20% of all beef does not meet North America consumer satisfaction in eating quality and recommends that the % of cattle grading low Choice and above be increased.

Based on a survey of retailers, purveyors, and exporters, the ideal mix would be 62% low Choice or better and 38% Select, with no Standard grade beef. This compares to the current 51% low Choice or better, 42% Select and 7% Standard grade and lower (McKenna et al., 2001). The 10% of the United States beef that is exported would have none below low Choice. The strong message from North America consumers is that the external fat must be removed from beef, but intramuscular fat (marbling) is required in the edible portion. This is likely due at least in part to the method of cookery commonly used compared to what is common in most other countries (Dikeman, 1987).

Accounting for differences in requirements for growth. It has been determined that cattle of different mature sizes have different fat and protein content of the weight gain at the same weight during growth (Fox and Black, 1984). Therefore, a size scaling procedure to account for differences in energy and protein requirements for growth among cattle of different frame sizes and genders has been developed (Fox and Black, 1984; Fox et al., 1988; Fox et al., 1992; Fox et al., 1999; Tylutki et al., 1994) and was adopted by the NRC Nutrient Requirements of Beef Cattle (NRC, 2000).

In this model, the animal BW at the target empty body fat % (**AFBW**) is divided into the weight of the standard reference weight (**SRW**) of an animal at that composition. This ratio is then multiplied by the animal's actual BW to adjust it to the standard reference animal for use in the energy requirement equation; this value is called the equivalent BW (Eq. [1]).

$$\text{Equivalent SBW}=\text{Current SBW}\text{x}\frac{\text{SRW}}{\text{SBW at Target \%EBF}} \quad [1]$$

The standard reference animal represents the cattle body size used to develop the equations to predict the net energy content of weight gain. Table 2 provides an example of the calculation of net energy required for growth (retained energy) computed with this model for three mature sizes (1102, 1212, and 1322 lb) of cattle. As mature size increases, weight at the same energy content of gain increases, because larger size animals are at an earlier stage of growth at the same weight and therefore have more protein and less fat in the gain. It also shows that energy requirements increase with increasing stage of growth and rate of gain because of more fat in the composition of the gain.

The following equations (Eq. [2] to [7]) from the NRC (2000) were used to compute the retained energy (Mcal/d) values shown in Table 2. Note that equivalent SBW (**EqSBW**) value is the same within the same stage of maturity regardless of the AFBW. This is because the equivalent BW is the degree of maturity (or stage of growth) multiplied by the SRW (1053 lb).

$$RE = 0.0635\times\left(EqEBW/2.204\right)^{0.75}\times\left(EWG/2.204\right)^{1.097} \quad [2]$$

$$EqEBW = 0.891\times EqSBW \quad [3]$$

$$EqSBW = SBW\times\frac{1053}{AFSBW} \quad [4]$$

$$SBW = 0.96\times BW \quad [5]$$

$$AFSBW = 0.96\times AFBW \quad [6]$$

$$EWG = 0.956\times ADG \quad [7]$$

Accounting for differences in requirements for maintenance. The model used for this purpose is described by Fox and Tylutki (1998). The effects of breed type are accounted for by adjusting the base NE_m requirement of 34.9 kcal/lb (77 kcal/kg) metabolic body weight (**MBW**) for *Bos indicus* and dairy types (-10 and +20% compared to *Bos taurus*). The effects of previous nutrition are accounted for by relating body condition score (**BCS**) to NE_m requirement. On a 1 to 9 scale, maintenance requirement is reduced by 5% for each BCS below 5 and is increased by 5% for each BCS above 5. The effects of acclimatization are accounted for by adjusting for previous month's average temperature (ranges from 31.8 to 47.6 kcal/lb MBW (70 to 105 kcal/kg MBW) at 30 and -20 ^{o}C, respectively). Environmental adjustments were developed based on the data reported by the NRC (1981).

Nonetheless, further examinations have to be conducted for different levels of production, animal type, environment (climate), and modeling approaches. The above adjustment should be used for static models, which are valuable for the mean of a period of growth but cannot be used consecutively in a dynamic model because of double accounting the previous climate effect over and over (Kebreab et al., 2004; Tedeschi et al., 2004). The effects of environment (climate) have an important effect on animal production and have to be accurately accounted for. Berman (2003; 2005) provided some information regarding heat stress for producing animals and such information could be adapted to current models.

Determining ration energy values. Predictions of dry matter intake (**DMI**) and net energy for growth (**NEg**) and maintenance (**NEm**) are highly dependent on having feed net energy values that accurately represent the feeds being fed. Tedeschi et al. (2005a) evaluated the accuracy of alternative methods for determining feed energy and protein values: the level 1 of the NRC (2000), which uses tabular values for feed composition and energy; the level 2 of the NRC (2000), which uses the CNCPS (Fox et al., 2004); and a summative equation commonly used by feed analysis laboratories to predict feed energy values from chemical composition (Weiss, 1993; , 1999; Weiss et al., 1992).

Metabolizable energy (**ME**) was predicted by the CNCPS to be first limiting in 19 treatment groups (Tedeschi et al., 2005a). Across these groups, the observed ADG varied from 1.76 to 3.17 lb/d (0.8 to 1.44 kg/d). When ME was first limiting, the ADG predicted by the CNCPS model accounted for more of the variation (80%) than did the summative equation or tabular (73 and 61%, respectively). Metabolizable energy allowable ADG predicted with the tabular system gave an overprediction bias of 11%, but the bias was less than 2% when predicted with the CNCPS or summative equation. The MSE were similar in all predictions, but the CNCPS model had the highest accuracy (lowest RMSPE). Metabolizable protein (**MP**) was predicted by the CNCPS to be first limiting in 28 treatment groups (Tedeschi et al., 2005a). Across these groups, the observed ADG ranged from 0.26 to 3 lb/d (0.12 to 1.36 kg/d). The ADG predicted by the CNCPS model accounted for more of the variation (92%) than did the summative equation or tabular (79 and 80%, respectively). Metabolizable protein-allowable ADG predicted with the tabular gave an overprediction bias of 4%, whereas the bias was less than 2% when predicted with the CNCPS or the summative equation. Similar to the ME first limiting analysis, the CNCPS model had the highest accuracy (lowest RMSPE: 0.11).

Predicting days to finish, carcass weight, body composition, quality and yield grade. Fox et al. (2002; 2001a) listed and exemplified the sequence of calculations of the growth model (Guiroy et al., 2001; Perry and Fox, 1997; Tedeschi et al., 2004) developed to account for individual animals when fed in groups. Previous evaluations of this model have indicated the CVDS model predicted DMR with an r^2 of 74% and mean bias of 2% (Tedeschi et al., 2004) and feed conversion ration (**FCR**) with and r^2 of 84% and a mean bias of 1.94% (Tedeschi et al., 2006) using the data of 362 individually fed steers. Guiroy et al. (2001) reported that the CVDS accurately allocated the feed fed to 12,105 steers and heifers in a commercial feedlot, with a bias of less than 1%. Recent evaluations with pen-fed Santa Gertrudis steers and heifers indicated the model was able to accurately predict the feed that was allocated to the pens with a bias of 2.43% (Bourg et al., 2006a).

Applications of the CVDS Model in Identifying Differences in Feed Efficiency

Selecting for Efficient Animals. Fox et al. (2001b) utilized an early version of the CVDS (Cornell Cattle Systems v. 5) to simulate the effect of growth rate and feed efficiency on cost to gain 595 lb (initial BW of 573 lb and final BW of 1168 kg). Based on their simulation (Table 3), an increase of 10% in ADG alone was predicted to increase DMI 7% and improve profits by 18%, probably due to fewer days on feed and thus less non-feed costs. The reduction in feed cost was due to a reduction in feed required for maintenance due to fewer days required to gain 595 lb. On the other hand, when intake was kept the same but efficiency of ME use by the animal was improved by an amount that resulted in a 10% improvement in feed efficiency, profits increased by 43%. The simulations of Fox et al. (2001b) clearly suggested that improving feed efficiency or feed conversion ratio may result in a higher benefit to the producer.

Okine et al. (2004) compared the profitability of animals with different efficiency traits. Animals started at 551 lb and were slaughtered at 1234 lb. Those with 5% increase in ADG saved US$ 2 per head versus US$ 18 per head for steers with a calculated increase of 5% in feed efficiency (Table 4).

Similar to Fox et al. (2001b), Okine et al (2004) also concluded that an increase in feed efficiency ratio (or a decrease in feed conversion ratio) leads to a higher profit. In part, this is because the same percentage change in DMI is numerically greater than that for ADG, which leads to a greater impact on the outcome; less days on feed. Thus, comparison should be made on a *ceteris paribus* condition in which all variables are kept constant and only one variable is varied at a time. Animals with higher ADG will always be more efficient as long as the maintenance requirement is constant. This happens because of the dilution of the amount of feed required for maintenance compared to the total amount of feed consumed, leading to a more efficient animal per unit of gain. Nonetheless, in practice this may not happen and maintenance requirement increases as ADG increases. Therefore, the most efficient animal will be that one that has a lower increase in maintenance per unit of ADG.

We performed a simulation slightly different than that shown by both Fox et al. (2001b) and Okine et al (2004).

In our simulation, the ADG (4 lb/d) was identical across the first three scenarios; therefore, we assumed that animals would change either DMI or maintenance requirements to obtain the same performance. In a fourth scenario, ADG was increased 10% for the same DMI. A 551-lb steer with AFBW of 1234 kg was fed a diet containing 1.32 Mcal/lb of ME and costing US$ 0.09/lb to set the conditions for the scenarios (Table 5). A purchase cost of US$ 0.88/lb BW and sale price of US$ 0.86/lb of BW were assumed.

When ADG was held constant, 185 days on feed were required to reach the low Choice USDA grade; a 10% increase in ADG reduced days on feed to 168 days. A decrease in efficiency by 10% (increased DMI by 10%) reduced profits by 42% and an increase in efficiency by 10% (decreased DMI by 10%) increased profits by 37%. The increase in efficiency is smaller than that reported by Fox et al. (2001b). Likely, because they changed ADG rather than DMI; increasing ADG by 10% and keeping DMI similar to the standard scenario, would have increased the profit by 44%, identical to the Fox et al. (2001b) finding. Selecting for animals with an increased ADG can improve feed efficiency so long as it does not change the mature size. If mature size is increased, the apparent increase in profit could be offset by the longer days on the feedyard to reach the USDA low Choice grade.

Performing a Risk Analysis. We performed risk analysis simulations using the CVDS model to evaluate the impact of initial BW (661 ± 44 lb), diet ME (1.27 ± 0.09 Mcal/lb), and a fixed feed cost of (US$ 0.02/lb) of a finishing steer fed for 120 days. The risk analysis was conducted with @Risk using 5,000 iterations and normal distribution was assumed for initial BW and diet ME (Figure 1). Our simulation indicated an expected ADG skewed to the right and was expected to be between 2.54 and 3.68 lb/d (90% confidence interval, **CI**), the DMR was expected to be between 18.3 and 20.7 lb/d (90% CI), and the FCR was predicted as 5.05 to 7.91 (90% CI).

The analysis of the FCR indicated a higher correlation between ADG and FCR (-0.971) than DMR and FCR (0.703). Figure 1 also indicated that variation in the standard deviation of mean SBW and initial SBW had the highest impact on the standard variation of the profit (0.524 and -0.512, respectively). Similarly, for each increase in the standard deviation of the mean ADG, profit would increase by 0.233 standard deviation units. A unitary change in the DMR standard deviation would decrease the profit by 0.048 standard deviation units. Therefore, for practical applications, the BW and consequently the cost associated with the purchase of each animal has the highest effect on profitability during the feedlot finishing period. The ADG would have a higher impact on the profit than the DMR, and because these two variables had inverse effects on profit, changing feed efficiency would have a higher impact on profit than a change in ADG or DMR alone. This result is in agreement with that shown in Tables 4, 5, and 6; ADG has a stronger impact on profit than intake, therefore, selecting for higher ADG than lower intake might be more profitable. Tedeschi et al. (2006) reported a phenotypic correlation between DMR and DMI, ADG, and Kleiber ratio of 0.75, 0.65, and 0.55, respectively. The DMR is the expected intake predicted by the model given the information on animal, diet and environment. This is similar to the expected intake predicted by the RFI using mean BW and ADG. Tedeschi et al. (2006) reported the correlation of the residual (observed minus expected intake) between these two approaches was 0.84. Similarly, Bourg et al. (2006b) reported a correlation of 0.80.

Using Mathematical Models for Genetic Selection. Additional evaluations of mathematical models have been conducted to assess heritability and genetic correlations. Williams et al. (2005) compared the Decision Evaluator for the Cattle Industry (**DECI**) and the CVDS models to predict DMR, using 504 steers and 52 sires. Heritability for DMR was around 0.33 for both models and genetic correlations between actual DMI and predicted DMR was greater than 0.95. Similarly, Kirschten et al. (2006) evaluated the genetic merits of the CVDS predictions and reported heritability of 0.35 and genetic correlations between DMI and DMR of 0.98, with low re-ranking of sires. These authors suggested that predicted DMR may be used in genetic evaluations with minimal genetic differences between DECI and CVDS models.

Implications

The CVDS model provides a method for predicting energy requirements, performance and feed required by individual cattle fed in a group with good accuracy by accounting for factors known to affect cattle requirements (e.g. breed type, body size, stage and rate of growth). Feed can be accurately allocated to individual steers, heifers or bulls fed in group pens, based on prediction of final EBF from carcass measures. This allows cattle from different owners to be fed in the same pen, allowing for more efficient marketing of feedlot cattle and collection of data in progeny test programs. Our preliminary analysis suggests this model also has the potential to be used in identifying differences in feed efficiency between individual animals fed in group pens. The predicted feed required for the observed performance appears to be strongly related to actual feed intake, and is moderately heritable. We are hopeful that research underway will provide additional information on the use of the CVDS in selection programs to improve feed efficiency of beef cattle.

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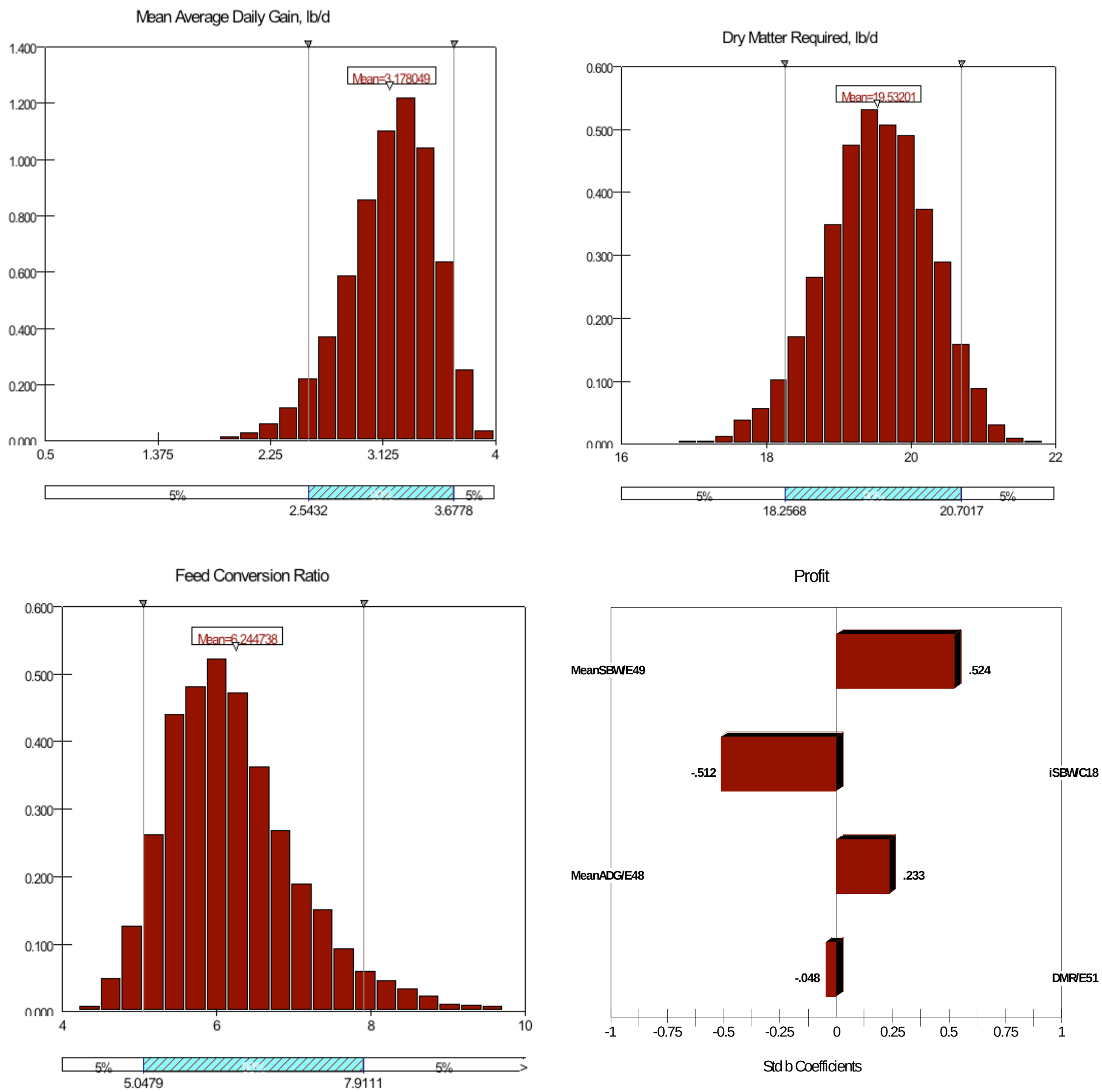

Figure 1. Simulation results of average daily gain, dry matter required, feed conversion ratio, and profit predicted by the CVDS model varying initial body weight and dietary metabolizable energy for a steer fed for 120 days.

Table 1. Relationship of carcass and empty body fat (EBF) to quality grade

N	USDA Quality Grade [a]	Carcass fat %	Mean EBF [b] %	EBF Std Error	Taste panel score [c]	Not acceptable [c] %
45	3.5	23.6	21.1 ^{u}	0.63	5.3	40
470	4.5	29.0	26.2 ^{v}	0.19	5.6	13
461	5.5	31.6	28.6 ^{w}	0.20	5.8	8
206	6.5	33.0	29.9 ^{x}	0.29	6.2	0
90	7.5	34.2	31.0 ^{xy}	0.44	-	-
51	8.5	35.2	31.9 ^{y}	0.59	-	-
32	9.5	35.8	32.5 ^{z}	0.74	-	-

[a] Standard = 3 to 4; Select = 4 to 5; low Choice = 5 to 6; mid Choice = 6 to 7; high Choice = 7 to 8; low Prime = 8 to 9; mid Prime = 9 to 10.
[b] Column means with different superscripts are significantly different at $P < 0.05$.
[c] Taste panel scores (1 to 8) and percent unacceptable values are from a subset of this data base.
Adapted from Guiroy et al. (2001).

Table 2. Relationship of stage of growth or maturity (u), body weight at 28% EBF (AFBW), and rate of gain (ADG) in computing retained energy

	AFBW, lb			Stage of maturity (u), %	
	50	60	70	80	90
1102	551	661	771	882	992
1212	606	727	849	970	1091
1322	661	793	926	1058	1190
Equivalent SBW, lb	527	632	737	843	948
	ADG, lb/d			Retained energy, Mcal/d	
2.20	3.37	3.86	4.34	4.79	5.24
2.64	4.12	4.72	5.30	5.85	6.40
3.31	5.26	6.03	6.77	7.48	8.17

Table 3. The effect of improvement in rate of gain and feed efficiency on profits [a]

Variables	Average steer	Effect of 10% higher ADG	Effect of 10% higher feed efficiency
DMI, lb/d	18.69	19.86	18.69
ADG, lb/d	3.22	3.53	3.61
Feed:gain ratio	5.82	5.67	5.18
Feed cost, $	176	172	157
Non feed cost, $	98	91	89
Total cost of gain, $	274	263	246
Profit, $	65	77	93

[a] Adapted from Fox et al. (2001b). Values were computed using Cornell Cattle System v. 5.0.

Table 4. Simulated cost and saving of steers with calculated 5% increase in feed efficiency or average daily gain compared to actual performance [a]

Variables	Actual data (200 d)	Calculated 5% increase in FER (200 d)	Calculated 5% increase in ADG (200 d)
DMI, lb/d	20.83	19.79	21.84
ADG, lb/d	3.42	3.42	3.59
Feed:gain ratio	6.08	5.78	6.08
Total cost of gain, $	424	406	422
Savings for 200 d, $/hd	---	18	2

[a] Adapted from Okine et al. (2004).

Table 5. The impact of changing feed efficiency, DMI, or ADG by 10% on profits [a]

Variables	Standard	Increased DMI 10%	Decreased DMI 10%	Increased ADG 10%
DMI, lb/day	20.61	22.68	18.51	20.61
ADG, lb/d	3.57	3.55	3.55	3.90
Feed:gain ratio	5.78	6.40	5.22	5.27
Feed cost, US$	326.98	361.86	295.43	298.37
Total cost, US$	935.71	971.92	903.96	898.10
Profit, US$	86.27	49.91	117.85	124.39
Total cost/gain, US$/lb/d	0.71	0.77	0.66	0.65
Purchase breakeven, $/lb BW	1.04	0.98	1.11	1.12
Annual margin for all costs, %	18.29	10.13	25.72	30.09

[a] Values were computed using the CVDS model version 1.0.18.

USING DECISION SUPPORT SYSTEMS TO EVALUATE THE EFFECTS OF CHANGING DIET CRUDE PROTEIN ON ANIMAL PERFORMANCE AND NITROGEN EXCRETION

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Summary

Feeding nutrients at concentrations that closely match animal requirements result in reduced excretion of N and P in concentrated animal feeding operations (**CAFO**). Data from an experiment conducted at the Texas A&M University Agricultural Experiment Station (Bushland, TX) were used to evaluate the predictions of animal performance by the Cornell Net Carbohydrate and Protein System (**CNCPS**) version 6.0. One hundred eight-four group-fed crossbred steers were previously fed a diet containing 13% CP (%DM) until reaching 1050 lb of BW (70 days on feed). Then, steers were allocated to three treatments formulated to have different levels of dietary CP (10.0, 11.5, and 13%), which were fed until animals reached 1250 lb of body weight (approximately 60 days on feed). Data from the second half of the experiment (different diets) were used for prediction of urinary, fecal, and total N excretion by the model. The CNCPS was able to explain 66% of the variation in animal performance with an average underprediction of 0.187 lb/d (mean bias of 5.9%). The model was also evaluated for predictions of N excretion (urine and feces). As dietary CP decreased from 13 to 11.5%, the model indicated a total N excretion of approximately 16%. An even greater reduction in total N excretion (26%) occurred when dietary CP was decreased from 11.5% to 10%. The overall decrease from 13 to 10% CP resulted in a reduction of total N excretion by 38%. Data suggest that decision support systems can be used to reduce total N excretion.

Introduction

Concentrated animal feeding operations (**CAFO**) concentrate N and P in the great plains of the United States, causing nutrient pollution of ground and surface water, and air quality issues. Precision feeding of nutrients based on animal requirements can prevent excess nutrients excretion (Vasconcelos et al., 2006). Precise diet formulation can potentially reduce purchased nutrients, manure nutrients, and volatilization losses of N (Fox et al., 2004). The objective of this study was to evaluate a decision support system (Cornell Net Carbohydrate and Protein System, **CNCPS,** version 6) as a tool to assist in formulating diets for feedlot cattle to minimize environmental pollution.

Experimental Procedures

The CNCPS was used to predict urinary, fecal, and total N excretion of 184 group-fed crossbred steers (N = 21 pens; data described by Vasconcelos et al., 2006). Steers were fed a high concentrate diet containing 13% CP (%DM) during the first half of the experiment, until animals reached 1050 lb of body weight (70 days on feed). Then, steers were assigned to one of three treatments with diets formulated to contain 10.0, 11.5, or 13% of dietary CP. Steers were harvested when reaching 1250 lb of body weight (approximately 60 days on feed). Animal, environment, and diet data from the second half of the experiment (different diets) were inputted in the model to predict animal used for prediction of animal performance for model evaluation as described by Tedeschi (2006). The CNCPS was also used to predict urinary and fecal N excretion for a hypothetical period of 150 days, which is approximately the common length of a feedlot. Model results were evaluated using a model evaluation system (**MES**, Tedeschi, 2006).

Results and Discussion

Model validation

The relationship between observed ADG and ADG predicted by the model is presented on Figure 1. The first limiting allowable ADG predicted by the model - either from metabolizable energy (**ME**) or metabolizable protein (**MP**) - was compared to the observed gain. The CNCPS system was able to explain 66% of the variation in animal performance with an average underprediction of 0.187 lb/d (mean bias of 5.9%). The intercept and the slope of the linear regression (Figure 1) were not different from zero and one respectively, which indicates good agreement. The accuracy of the model was higher (Cb = 0.94; Tedeschi, 2006) than the precision (r^2 = 0.66), suggesting that some variation was not accounted for by the model. The CNCPS accurately predicted the performance of these animals. Because of the high accuracy in predicting gain, we used the model to simulate the excretion of N (urine and feces) on different dietary CP diets.

Prediction of N excretion

The CNCPS predictions of urinary and fecal N excretion (150 days) are presented in Figure 2. As dietary CP decreased from 13 to 11.5%, the model indicated that the total N excretion was reduced by approximately 16%. A further reduction of dietary CP from 11.5% to 10% caused an even greater reduction in total N excretion (26%), resulting in a total reduction of N excretion by 38% when dietary protein was decreased from 13 to 10% of CP (% DM). Moreover, as dietary CP decreased, the ratio of urinary to fecal N decreased considerably (1:1 to 1:0.55). The reduction in the ratio of urinary N to fecal N is desirable because most of the volatilization of manure N to NH_3 is from the urinary N (Cole and Greene, 1998; Varel et al., 1999). The lower the volatilization of N, the higher will be the ratio of N to P, being more adequate for manure application as crop fertilizers (Cole and Greene, 1998).

Implications

These findings suggest that it is possible to use mathematical models to assist on precision feeding. The model can be used to predict total N excretion. Mathematical models can be a useful tool to assist in formulating and balancing animal diets to minimize environmental pollution.

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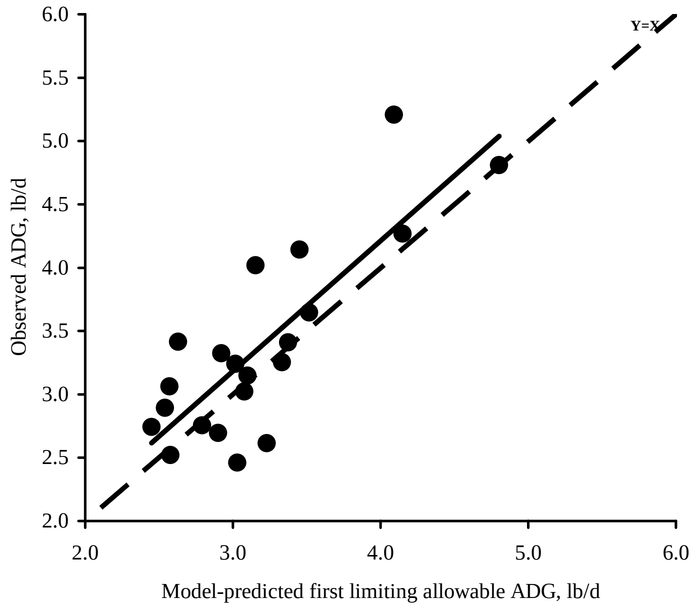

Figure 1. Relationship between observed average daily gain (ADG) and first limiting allowable ADG (ME or MP) predicted by the Cornell Net Carbohydrate and Protein System

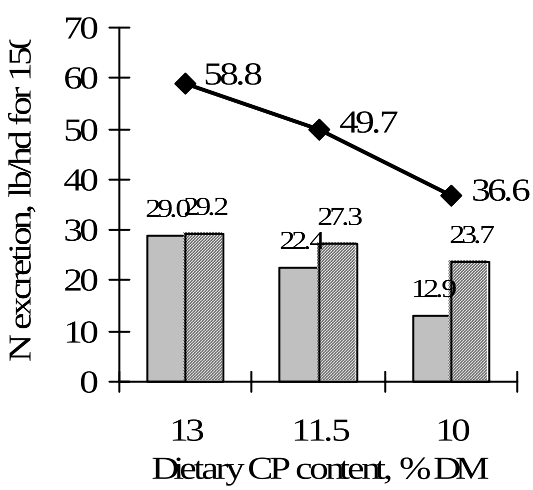

Figure 2. Urinary (solid bars), fecal (hash bars), and total N excretion (line) predictions for cattle fed different CP concentrations by the Cornell Net Carbohydrate and Protein System

Physiology

RELATIONSHIPS OF CATTLE TEMPERAMENT AND STRESS RESPONSES TO HANDLING DURING TYPICAL MANAGEMENT SITUATIONS

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Summary

The degree to which an animal reacts to novel or stressful situations is influenced by that individual's temperament. Stressful situations can often stem from human handling involved with common, seemingly harmless, management practices. Poor temperament has negative impacts on beef cattle production and may be an important trait to consider for a breeding herd. Exit velocity as a measure of animal temperament may be useful to beef producers as it is a quick, labor friendly, objective and simple assessment of cattle temperament. As stress responsiveness throughout the course of a typical beef production scheme was shown to be influenced by temperament, the benefits to a producer may far exceed the benefits of having a gentler herd.

Introduction

Temperament in cattle is commonly associated with a fear response to handling. Animals with a poor temperament will be easily excited and exhibit a greater fear response. Biologically, this response can be assessed by measuring the stress hormones cortisol (CORT) and epinephrine (EPI), both secreted from the adrenal glands. Poor temperament negatively impacts multiple facets of cattle production. Temperamental cattle exhibit lower weight gains (Burrow and Dillon, 1997; Voisinet et al., 1997b), produce tougher meat (Voisinet et al., 1997a), yield increased amounts of bruise trim (Fordyce et al., 1988), and have a compromised immune system (Fell et al., 1999). Differences in the stress response associated with animal temperament may be of value in understanding the link between animal behavior and economic endpoints within the beef industry. The objective of this study was to identify relationships between physiologic responses to handling, during typical management situations, and cattle temperament.

Experimental Procedures

At the conclusion of their time on pasture, three groups, each of 50 crossbred beef steers were transported to South Texas commercial feedlots. Prior to shipping, temperament was assessed by measuring exit velocity (EV), which is the rate at which the steers exited the squeeze chute and traversed a fixed distance (6.0 feet), as described by Burrow et al. (1988). Infrared sensors were used to remotely trigger the start and stop of the timing apparatus, (FarmTek Inc., North Wylie, TX). As exit velocity was the basis for categorizing cattle temperament, the slowest ten percent from each of the three groups were deemed calm (C; EV = 1.11 ± 0.2 m/sec) and the fastest ten percent from each group were deemed temperamental (T; EV = 3.37 ± 0.2 m/sec).

In order to measure endocrine parameters associated with a stress response, blood samples were obtained via tail-bleeding during management situations that are routine in a beef production scheme. These typical situations included prior to, and post-transportation (~ 650 miles) to the feedyard , during a routine weighing at d 70 of the feeding period, and on the day cattle were sent to slaughter. Plasma concentrations of cortisol and epinephrine were determined by RIA (Willard et al., 1995) and EIA (Alpco Diagnostics, Windham, NH, Cat. #17-EA613-192), respectively. The GLM procedure of SAS (Version 9, SAS Inst., Inc., Cary, NC), was utilized for ANOVA of hormone concentrations across the two temperament groups at each of the four data collections. Pearson correlation coefficients were calculated between EV, CORT and EPI both within and across each of the four points of data collection, using the CORR procedure of SAS.

Results and Discussion

Temperament influenced the steers' stress response to handling during all of the points of data collection. Prior to shipment to the feedyard, both concentrations of cortisol and epinephrine were greater in the temperamental steers than in the calm ones (Figure 1). Specifically, serum concentrations of cortisol differed ($P = 0.026$) between the two temperament groups (C = 9.87 ± 1.1, T = 13.97 ± 1.2 ng/mL), and plasma concentrations of epinephrine were influenced ($P = 0.017$) by temperament (C = 86.8 ± 24.9, T = 534.1 ± 202.6 pg/mL). Upon arrival to the feedyard, temperament continued to have an impact on the steers' adrenal responsiveness to being worked (Figure 2). Plasma concentration of epinephrine (C = 454.5 ± 136.1, T = 1845.9 ± 511.6 pg/mL) and serum concentrations of cortisol (C = 9.3 ± 1.7, T = 17.8 ± 3.1 ng/mL) were influenced ($P < 0.02$) by temperament. The marked increase in epinephrine concentration in both the calm and temperamental steers, following the transportation, highlights the physiological consequences of shipping stress. However, comparisons of pre-shipment versus post-shipment endocrine parameters has been left out of this analysis due to differing lengths of time that the cattle were held upon arrival to the feedlot, before initial processing.

Midway through the feeding period (d 70) temperament still influenced the stimulation of stress hormones induced by handling the steers (Figure 3). Mean concentration of cortisol differed ($P < 0.01$) with temperament group (C = 9.82 ± 1.6, T = 19.17 ± 1.7 ng/mL) as did plasma epinephrine concentration (C = 229.6 ± 55.9, T = 877.2 ± 220.0 pg/mL). Additionally, it is important to note that the original measure of exit velocity, taken prior to shipment to the feedlot, was still positively correlated with both serum concentration of cortisol (r = 0.62, $P < 0.001$) and plasma concentration of epinephrine (r = 0.79, $P < 0.001$). Such relationships , persisting seventy days into the feeding period, demonstrate the utility of exit velocity as an early objective method to identify temperamental calves.

By the end of the feeding period the influence of temperament on stress responsiveness had lessened but was still apparent (Figure 4). Prior to shipment to the packer serum concentration of cortisol differed ($P = 0.06$) with steer temperament (C = 11.77 ± 1.8, T = 16.67 ± 1.8 ng/mL). Plasma concentration of epinephrine at this time point was only numerically higher in the temperamental steers than in the calm ones ($P = 0.10$; C = 140.7 ± 42.7, T = 414.4 ± 154.9 pg/mL). Habituation to the management practices may explain why there is less of a difference in stress responsiveness between the two temperament groups by the end of the feeding period within a herd.

Implications

As animal temperament is linked with stress physiology the benefits from decreasing numbers of temperamental animals within a herd may extend beyond behavior. These data show that increased physiological stress responses associated with temperament persist throughout the course of typical beef steer's lifetime. With stress responsiveness having biological links to growth performance, immunological proficiency, and meat quality there may be financial gains to come from reducing the number of temperamental cattle within a herd.

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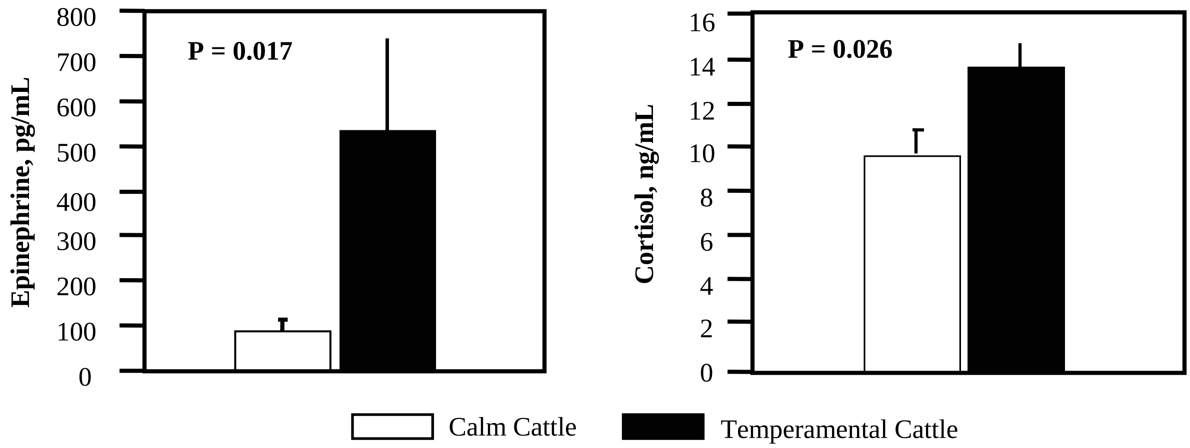

Figure 1. Mean concentrations of plasma epinephrine and serum cortisol for both the calm (open bars) and temperamental (solid bars) steers prior to transportation to the feedyard.

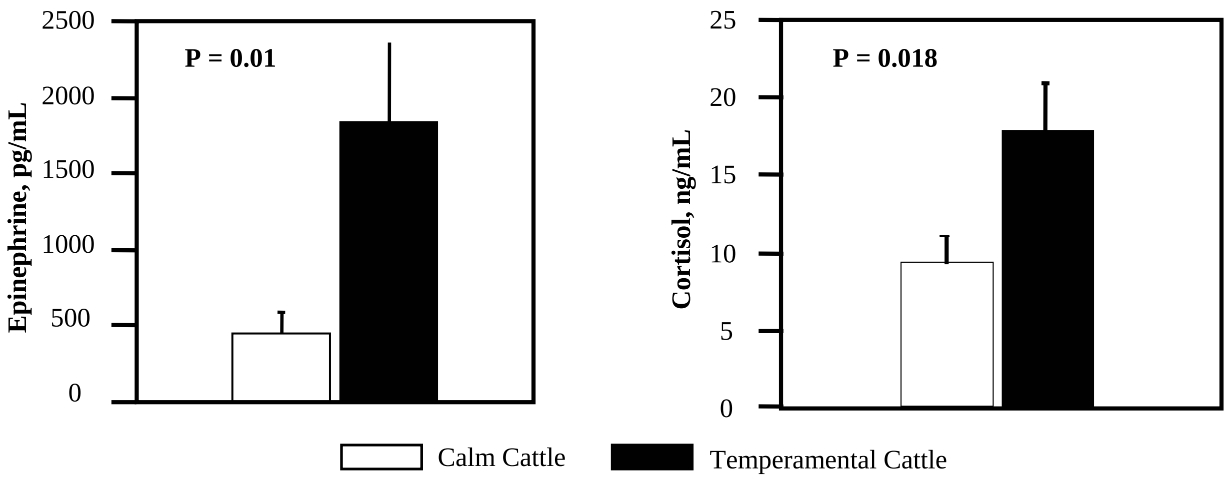

Figure 2. Mean concentrations of plasma epinephrine and serum cortisol for both the calm (open bars) and temperamental (solid bars) steers upon arrival (following transportation of ~ 650 miles) to the feedyard.

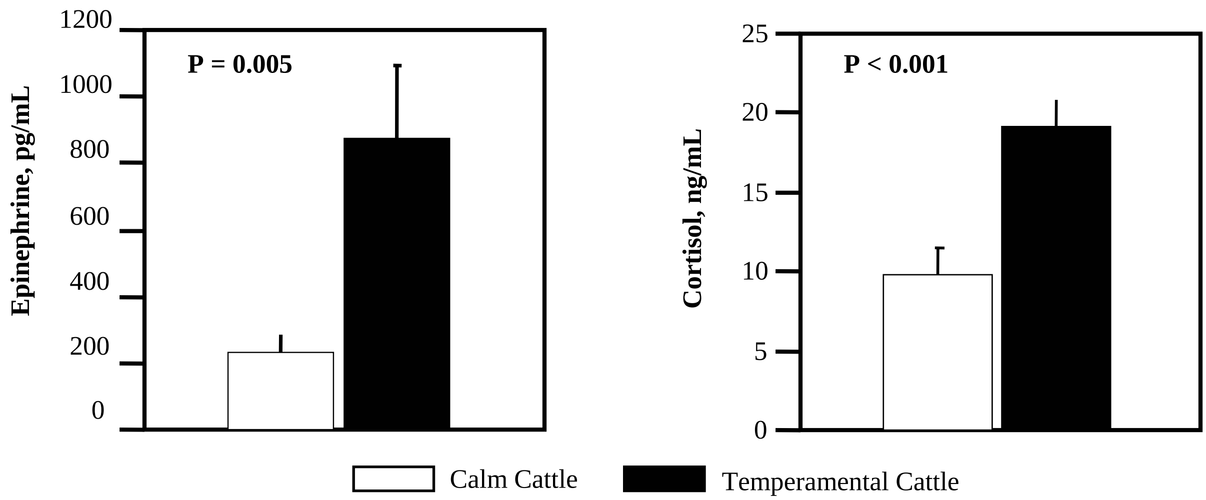

Figure 3. Mean concentrations of plasma epinephrine and serum cortisol for both the calm (open bars) and temperamental (solid bars) steers during a routine weighing at d 70 of the feeding period.

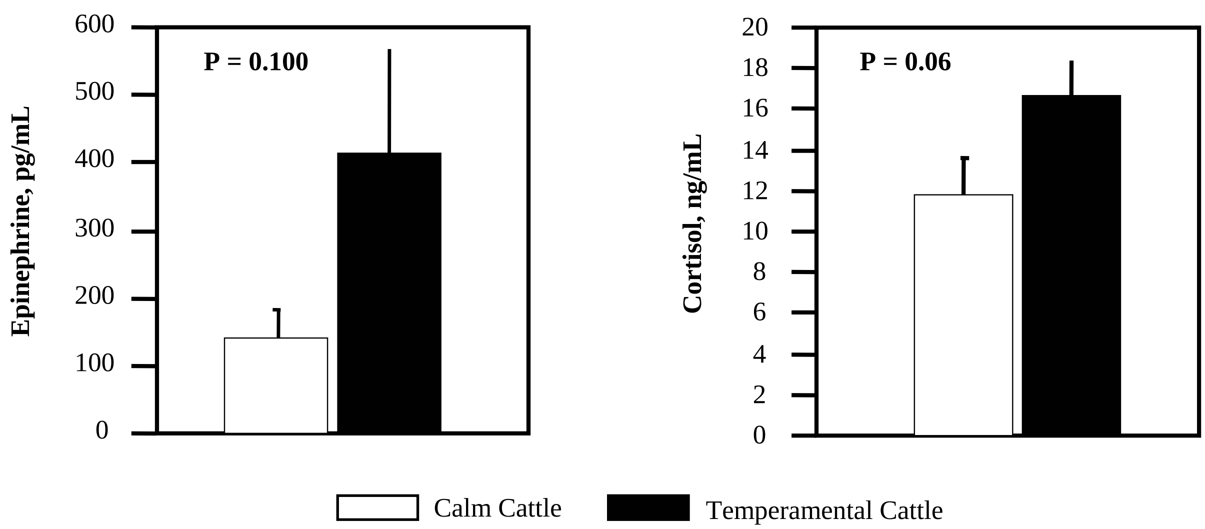

Figure 4. Mean concentrations of plasma epinephrine and serum cortisol for both the calm (open bars) and temperamental (solid bars) steers prior to shipment to the packing plant.

CALM CATTLE HAVE BETER RESPONSES TO WEANING VACCINATIONS

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Summary

Calf morbidity and mortality continue to plague the US beef industry. To combat this problem, pre-conditioning programs are beginning to be implemented in order to optimize immune function and nutritional status of cattle, while minimizing stress associated with the time of weaning. The goal of immunization is to confer the highest amount of protection against pathogens as possible. Cattle with poor temperaments may make it more difficult to optimize these events due to their higher level of stress responsiveness. Adverse effects of temperament on the health and performance of calves result in detrimental economic impacts making it important to understand their consequences. As profit potential for pre-conditioned calves is realized, more producers will more carefully examine their calf crop and their vaccination programs to increase the efficacy of weaning vaccinations.

Introduction

Animal temperament, in normal production situations, has been described as the degree of fearfulness and reactivity to humans, as well as to common handling procedures. Cattle with calm temperaments exhibit less of a fear response, whereas cattle with wild temperaments are more easily excited and have a greater response. This increased reactivity, or stress response, has been shown to have a significant negative impact on animal performance (Voisinet et al., 1997), beef quality (Lacourt and Tarrant, 1985), and beef tenderness (King et al., 2006). Not only has animal temperament been found to negatively affect growth and carcass performance, but it has been shown to negatively affect the immune system as well (Fell et al., 1999). Cattle with impaired immune responses, due to undesirable temperaments, may have a greater difficulty in providing a sufficient response when challenged with disease causing organisms in various production situations.

Experimental Procedures

A contemporary group of spring born (2004) Brahman bull calves (n = 45, weighing 419 ± 13 lbs at weaning) were pastured with dams until weaning (day 0) at the Texas Agricultural Experiment Station, Overton. Temperament was assessed to sort the calves into good and bad temperament groups. After weaning, calves were chosen for extremes in temperament based on exit velocity (EV) and penscore (calm n=10, EV=1.36 ± 0.20 m/s; temperamental n = 10, EV=2.90 ± 0.20 m/s). Weaning vaccinations of Fortress 8 (Pfizer, Exton, PA), Clostridial and Titanium 5 (Diamond Animal Health, Des Moines, IA) respiratory complex were given on days 0 and 42. Castration and dehorning were delayed until after the completion of collection of samples to assess immune function. The trial began at weaning (day 0) and continued for 11 weeks (Figure 1). At day 0, the calves had one 10 mL tube of blood taken to harvest serum for cortisol (CS) quantification and immunoglobulin (IgG) response to the Clostridial vaccine. Serial blood samples were taken for the duration of the trial with more frequent sampling one week following weaning (day 0) and revaccination (day 42) to get a clearer picture of primary and secondary responses to the vaccine. Serial serum samples were analyzed for vaccine specific IgG ELISA. Analysis of variance procedures for repeated measures were used (PROC MIXED of SAS) to determine differences in serum concentrations of cortisol, antibody profiles and temperament measures.

Results and Discussion

Average daily gain was higher ($P = 0.01$) in the calm (C) bull calves (0.54 ± 0.04 kg/day) than in the temperamental (T) bull calves (0.39 ± 0.03 kg/day). Serum cortisol (CS) concentrations (Figure 2) were significantly different ($P < 0.01$) throughout the study. Serum concentrations of cortisol for the calm bull calves averaged 5.32 ± 1.08 ng/mL vs. 10.20 ± 1.08 ng/mL for the T bulls. The interaction of treatment group and time tended to be significant ($P = 0.10$) showing differences in stress responsiveness over time between both groups. Put more clearly, all bulls were handled and managed in the same manner, allowing us to observe differences in the temperament groups CS profiles. Although there were differences in the CS profiles, similar, general trends can be seen between the two groups. Fell et al. (1999) reported similar results for nervous/temperamental cattle at weaning and at feedlot entry 6 months later. In the Fell et al. (1999) study, nervous cattle had significantly higher CS concentrations ($P < 0.01$) before and after weaning, and at feedlot entry ($P < 0.05$). The data collected supports this previous research, stating that temperamental cattle have significantly higher serum CS concentrations at early stages of the production cycle.

Serum concentrations of IgG (Figure 3), specific to the Clostridium vaccine used in this study, were significantly increased ($P < 0.01$) from day 0 across the length of the trial for both C and T bulls. There was no significant effect of temperament group ($P = 0.11$) with C bulls averaging a stimulation index (SI) of 7.12 ± 0.96 and 4.96 ± 1.01 for T bulls across the entire length of the study. There was no interaction of temperament and time ($P = 0.86$). Vaccine antibody (Ab) was first increased ($P < 0.01$) on day 6 post-vaccination for both the C and T bulls. Peak primary response was reached on day 13 with C bulls averaging a 6.61 ± 1.02 fold increase vs. a 4.53 ± 1.08 fold increase for the T bulls. By day 42, the primary responses tended to differ ($P < 0.10$) with the C bulls averaging a SI of 6.57 ± 1.13 vs. 3.76 ± 1.19 for the T bulls. On day 42, bulls were revaccinated. A significant ($P < 0.01$) secondary vaccination response was detected by day 49, where T bulls reached a peak response (SI = 9.43 ± 1.88 fold increase). By the end of the study, T bulls' antibody levels had decreased ($P < 0.05$) to 6.30 ± 1.34 fold. Secondary responses for C bulls peaked on day 54 with a 11.49 ± 1.58 fold increase. By the end of the study, C bulls had not significantly decreased ($P = 0.22$) vs. day 42 SI, averaging a 9.84 ± 1.27 fold increase.

Feng et al. (1991) reported that stress may not only affect antibody production, but also the seroconversion from IgM to other isotypes. Delayed seroconversion during pathogenic challenges may increase likelihood of morbidity, even in the presence of sufficient immune system activation. In addition to delayed seroconversion, stress may also have a direct effect on primary immune responses. These include T-lymphocyte clonal expansion and maturation, initial B-lymphocyte clonal expansion and IgM production and production of memory lymphocytes and plasma secreting B cells (Burns et al., 2003). Perhaps one of the most important implications is that stress may have its principal effects on the rate of antibody deterioration (Burns et al., 2002). The Burns et al. (2002) study reported that students experiencing high levels of life stress events were 2.5 times more likely to have inadequate antibody titers than students with high levels of life stress events who were recently vaccinated. This study provides a good model to test antibody deterioration in cattle with different levels of stress responsiveness.

Implications

If individuals or groups of cattle can be identified as having a higher risk of infection or suppressed immune responses to vaccines, management practices can be altered to reduce risk associated with cattle morbidity and mortality. Calm calves will have a better response to vaccination at weaning and should have reduced sickness and death loss as they move through the production system. Calm calves may have desirable physiological attributes, relative to the more temperamental calves, which may make them more profitable than temperamental calves for all segments of the beef industry.

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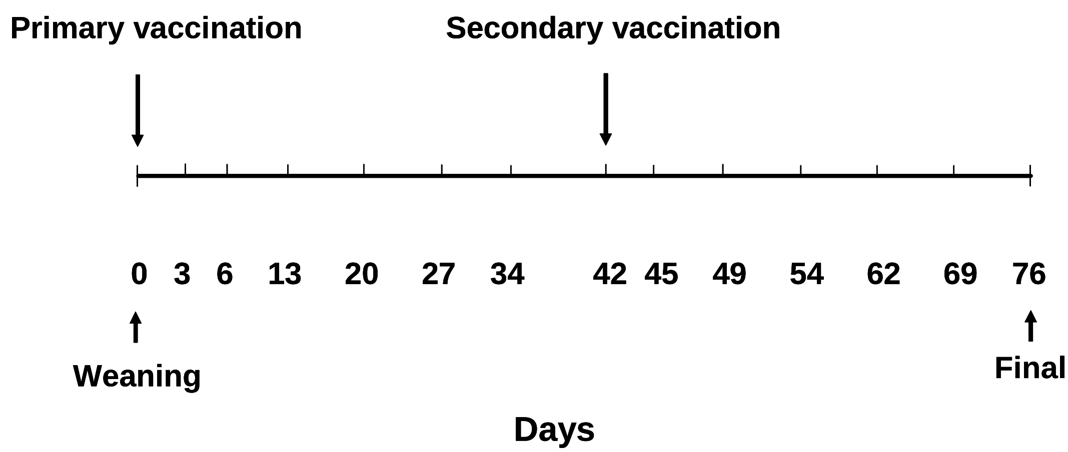

Figure 1. Vaccination and blood collection schedule for the Brahman bull calf immune trial (n = 20).

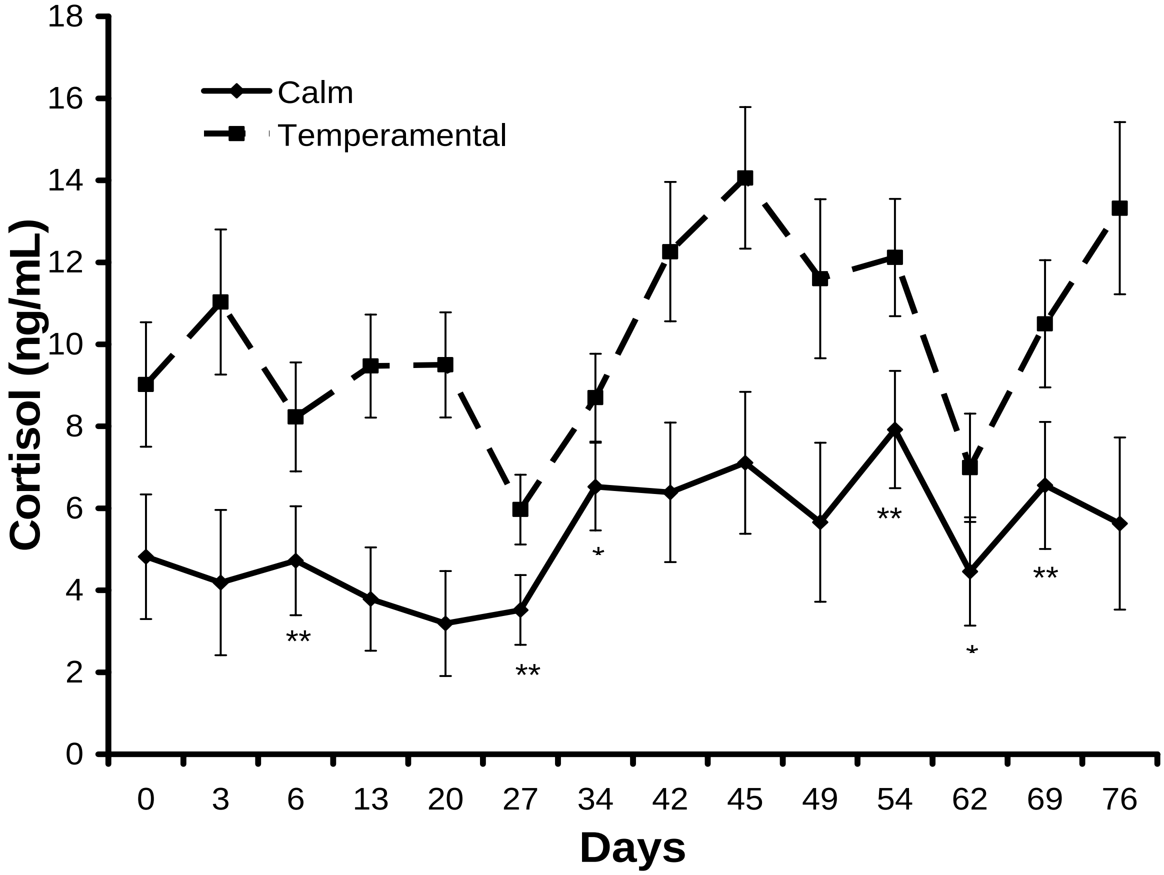

Figure 2. Least-squares means for cortisol concentrations for entire length of vaccination trial in calm (n = 10) and temperamental (n = 10) bull calves (Interaction P = 0.10). Values within day differ (P < 0.05) unless noted by symbols of * (P < 0.10) or ** (P > .10).

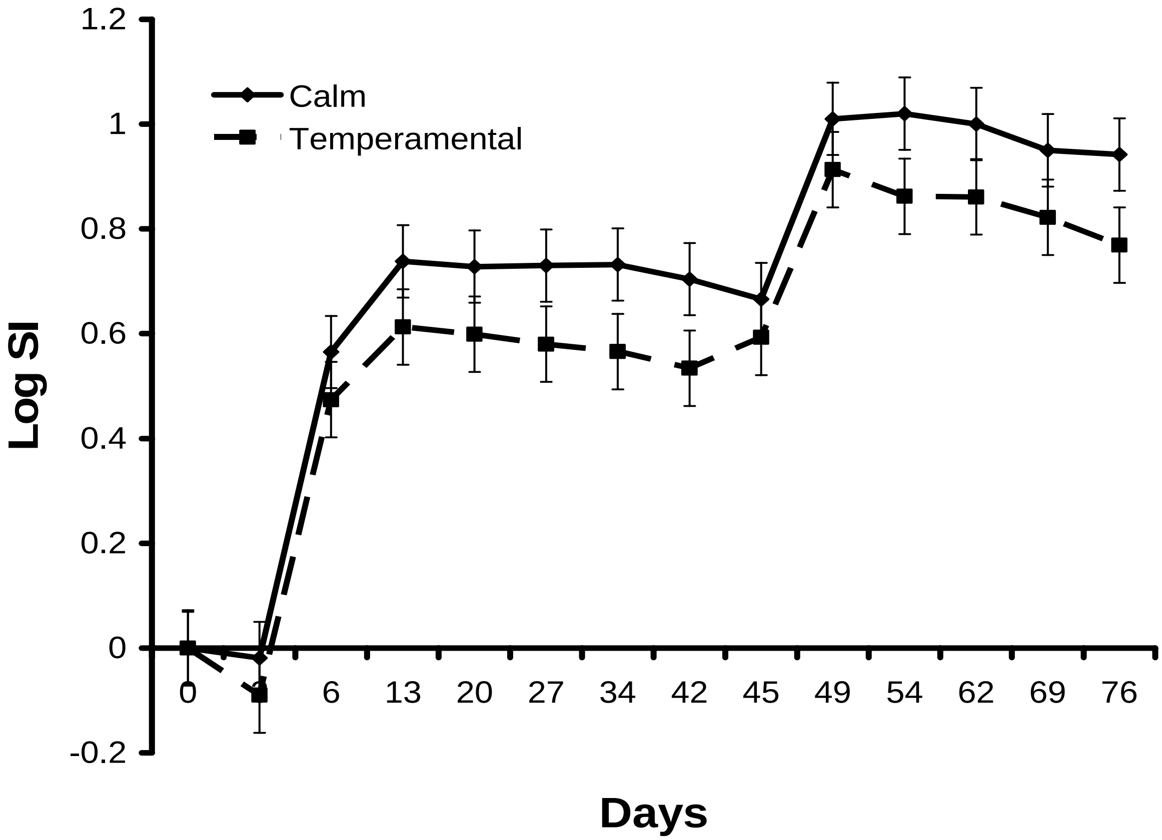

Figure 3. Log transformed values of serum IgG concentrations after primary and secondary vaccinations in calm (n = 10) and temperamental (n = 9) bull calves (Interaction P = 0.86). Vaccinations were given at day 0 and 42. Actual stimulation indices reported in text.

Range and Pasture

NUTRITIONAL AND RANGE HEALTH IMPLICATIONS OF SOUTH TEXAS BROWSE-USE BY CATTLE

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Summary

Field data collected with beef steers to measure diet quality in terms of crude protein and digestibility, dietary grass, forb and browse content, and fecal output in relation to declining grass availability were used to conduct analyses to determine the ability of browse to meet cattle nutritional requirements. Energy intake was the first limiting nutrient for beef steers and dry and lactating cows. Thresholds at which energy became limiting for 1 lb/day gain in steers varied among trials from about 5 to 30% dietary browse. Energy became limiting for dry cow maintenance between 2 to 15% dietary browse and at 2% for lactating cows. Most instances of dietary browse above 20% occurred at grass standing crop levels below 500 lbs/acre, which is below recommended minimum levels for midgrasses.

Introduction

Woody plants make up a significant portion of the vegetation in South Texas. As a result, these plants provide large amounts of potential browse. Some South Texas ranchers believe that this browse is a valuable forage resource for cattle. However, it is doubtful that cattle are suited to eating many South Texas browse species which often have small leaves and large thorns.

Cattle are classified as grazers (Hoffmann, 1988) with a mouth anatomy best suited to eating grasses. Cattle have an inflexible upper lip and use their tongues to grasp and pull forage into their mouths, giving their heads a jerk to break off forage. Annual cattle diets in Texas typically contain less than 7 to 10% browse. A seasonal cattle diet study on a South Texas ranch reported that browse made up mostly 2 to 3% of the diet and was highest (12%) in winter (Everitt et al., 1981).

The purpose of this study was to determine 1) the ability of South Texas browse to meet nutritional requirements of growing beef steers and mature dry and lactating beef cows and 2) grass standing crop levels at which cattle shifted to browse.

Experimental Procedures

Data for the nutritional analyses presented in this paper were generated from a diet study conducted about 40 miles west of Corpus Christi, Texas. Experimental procedures were reported in detail by Stuth and Lyons (1999). The study site was a gray sandy loam range site. Seven years before the diet study, brush was chained on four pastures. Brush on two of the chained pastures was sprayed with herbicide 3 years before the diet study. Four, 21-day grazing trials were conducted in one chained and one chained and sprayed pasture per trial. In each grazing trial, six, 530-750 lb steers were grazed per pasture. Grass standing crop was grazed to a 90% utilization level. Diet, fecal, and vegetation sampling was conducted during 4 to 5 sampling periods per trial.

Diet samples were collected with esophageal fistulated steers. Diet composition in terms of percent grass, forbs, and browse was determined using macrohistological analysis. Crude protein (CP) was estimated using micro-Kjeldahl analysis. Digestibility was estimated as digestible organic matter (DOM) and corrected to *in vivo* using standards. Fecal output was estimated with a ytterbium acetate marker.

For the nutritional analyses, diet digestibility and fecal output estimates were used to estimate dry matter intake for 640 lb steers and 1140 lb dry and lactating cows. Using dry matter intake, CP and DOM values, CP and energy intake were estimated during each sampling period and within each trial. From these nutrient intake values, potential CP and energy gain were calculated for the steers, and CP and energy maintenance were calculated for the cows. These gain and maintenance estimates were used as dependent variables with log of percent dietary browse as the independent variable to develop regression equations to illustrate gain and maintenance thresholds for steers and cows, respectively.

Results and Discussion

In the March trial, crude protein declined fairly steadily across sampling periods. In contrast, after initial declines, CP in May, August, and January tended to level off or increase toward the end of the trial (Figure 1). Digestibility in March declined markedly after the first sampling period and then leveled off. In May, August, and January, digestibility declined steadily across sampling periods (Figure 2).

Digestible organic matter was negatively correlated ($r = -0.64$) with percent dietary browse. However, there was no correlation between crude protein and percent dietary browse across all trials and only a slight correlation without the March trial ($r = 0.30$).

Pasture treatments (chaining and chaining + spraying) created differences in initial grass standing crops within pastures. Average initial grass standing crop was higher ($P < 0.05$) in chained and sprayed pastures (0 = 2052 lbs/acre) than in chained pastures (0 = 1018 lbs/acre). Likewise, average initial browse level was higher ($P < 0.05$) in chained pastures (0 = 1780 lbs/acre) than in chained and sprayed pastures (0 = 1004 lbs/acre).

Beginning dietary browse levels ranged from 1 to 5% across trials. Ending dietary browse was above 50% in chained pastures and around 20% in chained and sprayed pastures.

Grass standing crop and fecal output were positively correlated across trials (Table 1). However, grass standing crop and dietary browse were negatively correlated across all trials suggesting that steers shifted to browse when the grass became less available. Fecal output and dietary browse were also negatively correlated, suggesting that forage intake could not be maintained as browse consumption increased.

South Texas browse species have several defenses that make it difficult for cattle to utilize them. For example, blackbrush, a common South Texas browse plant, has small compound leaves and large thorns, up to 2.5 inches long. In an African study, Cooper and Owen-Smith (1986) reported that large ruminants reduced bite counts and bite size when they encountered plant spines and thorns and could not make up for these reductions by increasing grazing time. Spiny hackberry is considered a valuable browse plant for deer. However, it has small leaves and thorns associated with the stems. Whitebrush has very small leaves which would make harvest efficiency difficult for cattle. Although coyotillo has large leaves which are not physically protected from browsing animals, the leaves are unpalatable and toxic.

Graphs in Figure 3 compare potential gain for growing steers calculated from crude protein intake using NRC (1996) Beef Cattle Requirements. Crude protein intake was derived from estimated forage intake and diet crude protein levels for each sampling period. In all trials, there was a negative logarithmic relationship, although weak in August, between dietary browse and potential CP gain. In March, August, and January, potential gain fell below a 1 lb/day gain threshold between 2 and 25% dietary browse and then approached zero. In May, potential gain remained above 1 lb/day across the entire trial.

Energy tended to be the first limiting nutrient. Potential energy gain also had a negative logarithmic relationship with dietary browse across all trials (Figure 4). In March, August, and January, potential gain fell below 1 lb/day below 10% dietary browse and then approached zero. In May, potential gain fell below the 1 lb/day threshold at about 30% dietary browse.

For mature, dry cows, crude protein intake (Figure 5) remained at or above requirements across the range of dietary browse. However, for mature lactating cows, crude protein intake fell below requirements between 2 and 15% dietary browse, depending upon the trial.

As with steers, energy was the first limiting nutrient for mature cows. For dry cows, net energy of maintenance intake (Figure 6) fell below requirements between 2 (August and January) to 15% (March and May) dietary browse depending upon the trial. For lactating cows, intake fell below requirements above about 2% dietary browse.

Guajillo, another common South Texas woody plant, is not physically protected from browsing and has large amounts of readily accessible leaf material. On the surface, guajillo appears to have nutritional value. For example, in the growing season, it may test 20% crude protein. However, Barnes et al. (1991) reported digestible protein levels of around 10% when crude protein levels were at 20%. This discrepancy between crude and digestible protein is a result of nonprotein nitrogenous compounds in guajillo. Nantoumé et al. (2002) reported that while guajillo has a high nitrogen content, it has a low true protein content. Guajillo also tends to be low in digestibility. In a white-tailed deer study, Campbell and Hewitt (2005) reported that nitrogen requirements for growth and antler development were met by diets with less than 60% guajillo. However, energy requirements for maintenance and antler growth were met with diets by diets with less than 20% guajillo.

Cattle in the study did not shift to high levels of dietary browse until the grass standing crop was below 500 lbs/acre. All but one data point above 20% dietary browse occurred when grass standing crops were below 500 lbs/acre (Figure 7). The majority of the more desirable and productive grasses found in South Texas are midgrasses. Forage residue levels below 500 lbs/acre are below the minimum recommended levels (750-1000 lbs/acre) for midgrasses (Hanselka et al. 2001). Residual herbaceous vegetation on rangelands adds organic matter to soil, holds water for infiltration into soil, reduces evaporation, keeps soil cooler, and reduces erosion (Hanselka et al. 2001).

Implications

As browse increased in cattle diets, both digestibility of the diet and forage intake decreased resulting in reduced nutrient intake. Nutritional analyses indicated that energy will be the first limiting nutrient for growing steers or dry and lactating cows as browse increases in the diet. Estimates for potential crude protein gain may be overestimated because tannins and non-protein nitrogenous compounds were not measured, and therefore, crude protein values reported here may be greater than digestible protein values. The point at which cattle consumed more than 20% browse corresponded to a forage residue level that is detrimental to range health in midgrass and tallgrass plant communities.

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Table 1. Correlations of grass standing crop (GSC) and percent fecal output of body weight (FO), or percent dietary browse (DB) for each trial.

	Mar	May	Aug	Jan
GSC vs. FO	0.91	0.81	0.79	0.84
GSC vs. DB	-0.71	-0.76	-0.50	-0.51
FO vs. DB	-0.70	-0.92	-0.75	-0.43

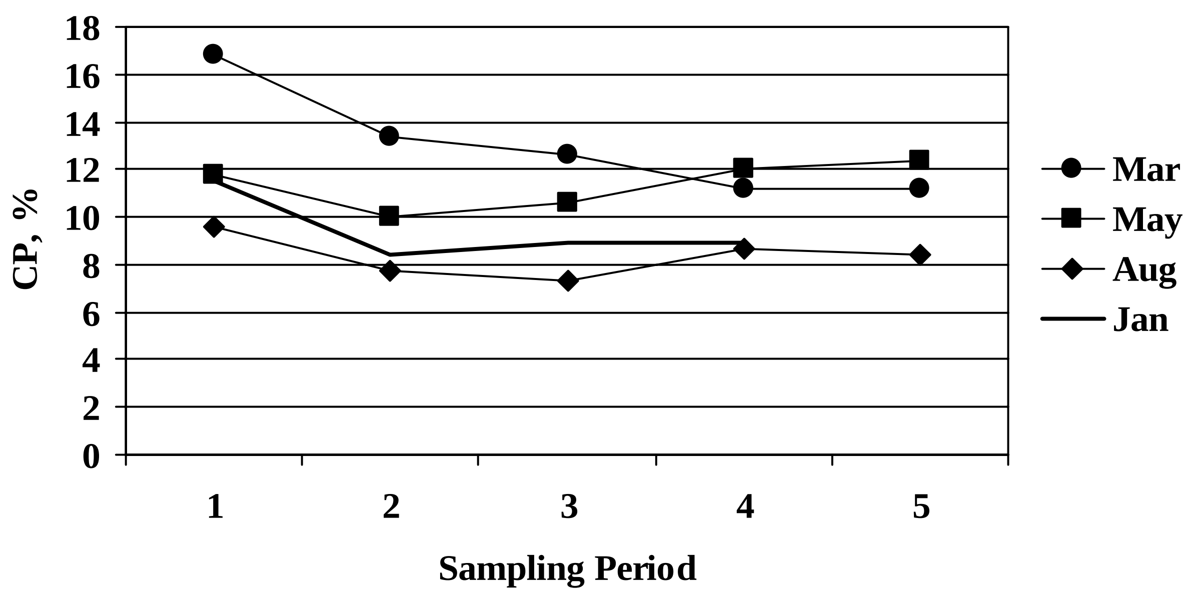

Figure 1. Diet crude protein (CP) trends across sampling periods during four field trials.

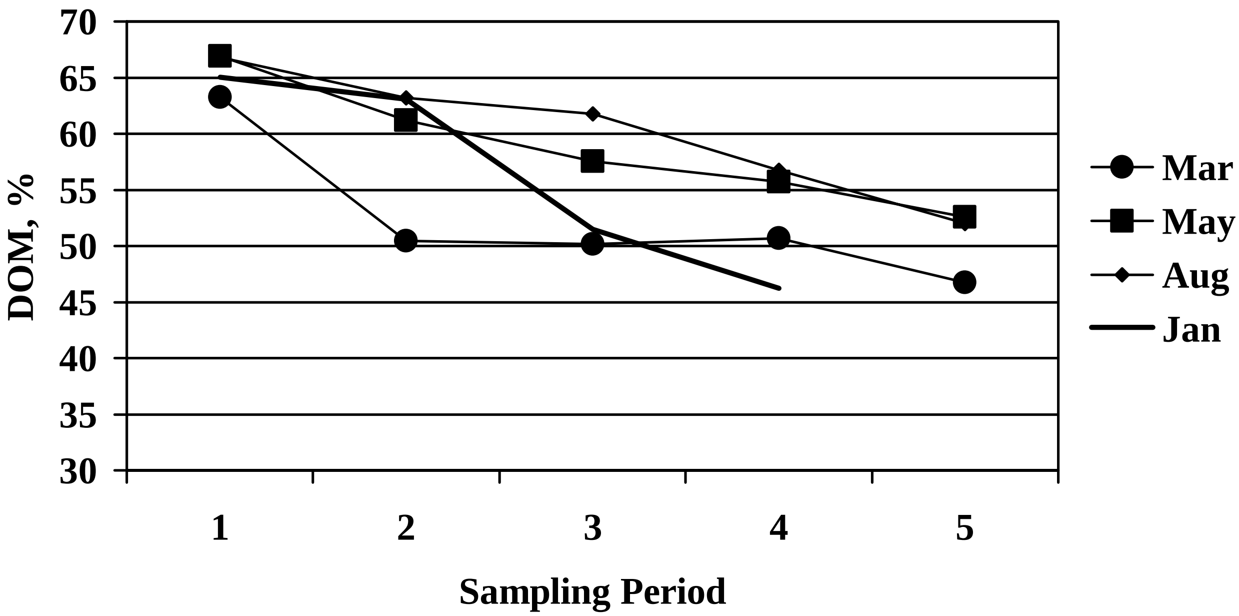

Figure 2. Diet *in vivo* corrected digestible organic matter (DOM) trends across sampling periods during four field trials.

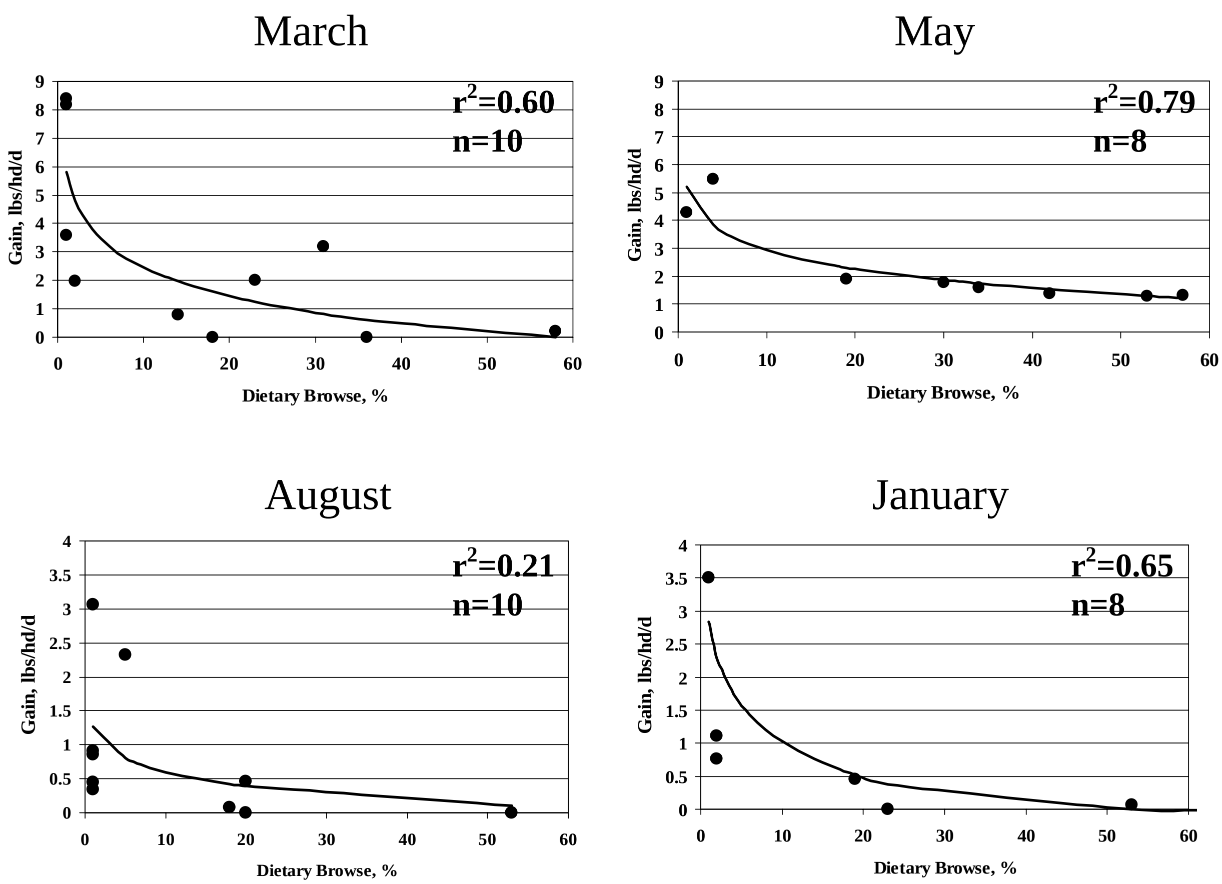

Figure 3. Potential gain for steers based on crude protein intake for each of the four field trials. Dots represent data points. Curved lines represent regressions of percent dietary browse and potential gain.

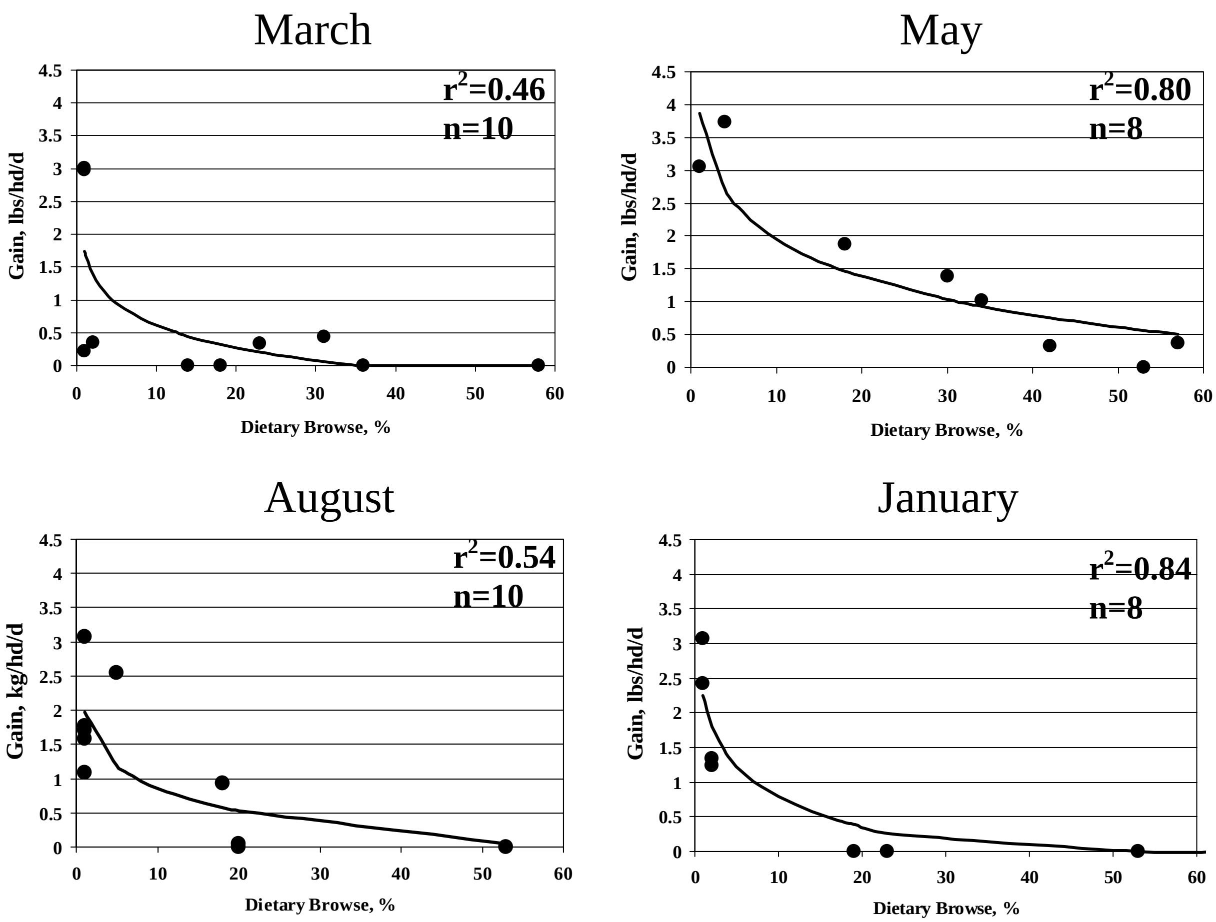

Figure 4. Potential gain for steers based on energy intake for each of the four field trials. Dots represent data points. Curved lines represent regressions of percent dietary browse and potential gain.

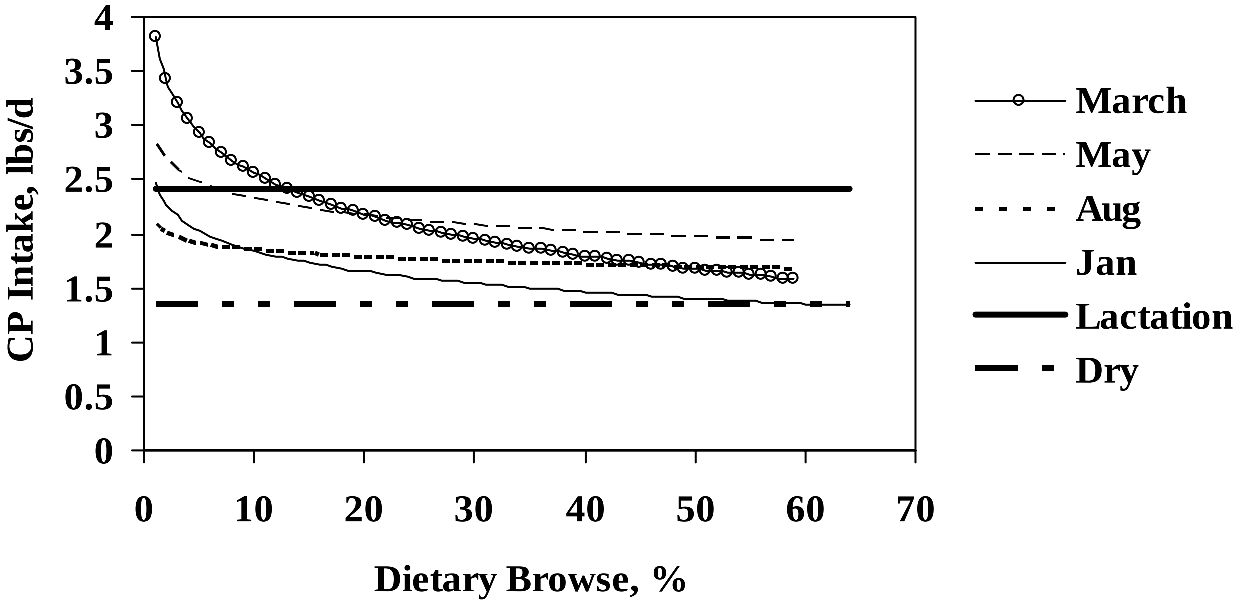

Figure 5. Curved lines represent regressions of dietary browse versus potential crude protein (CP) intake during each of the four trials. Horizontal lines represent crude protein intake requirements for 1140 lb lactating (75 days) and dry cows. For dry cows, crude protein intake was at or above requirements during all trials. However, for lactating cows, intake fell below requirements between 2 and 15% dietary browse.

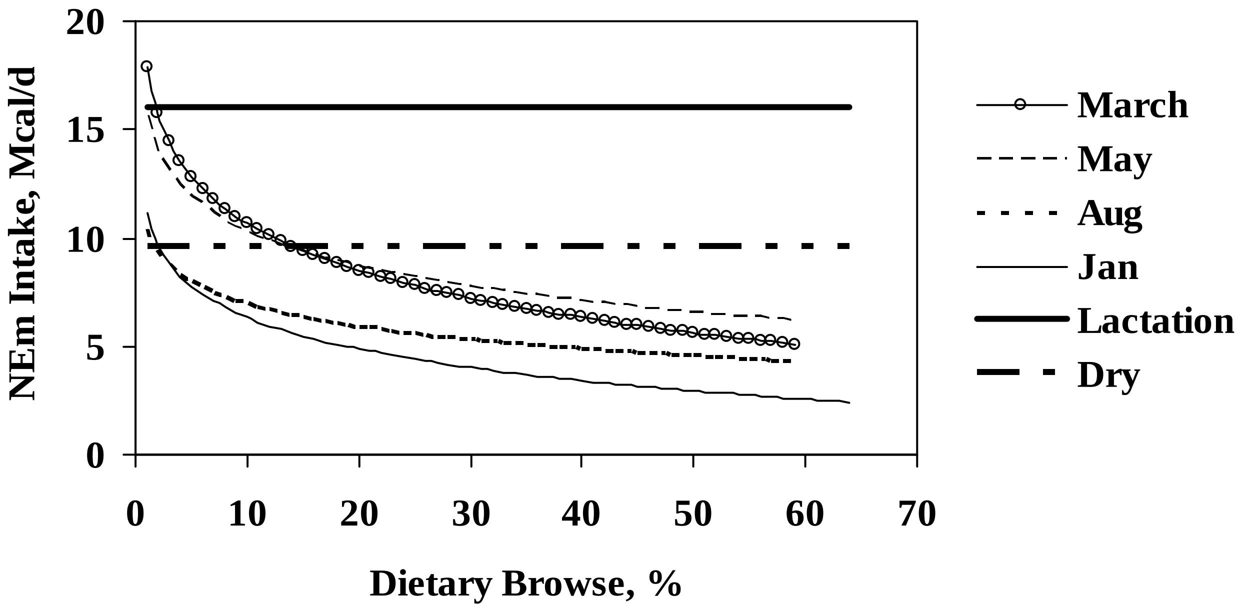

Figure 6. Curved lines represent regressions of dietary browse versus potential net energy of maintenance (NEm) intake during each of the four trials. Horizontal lines represent NEm intake requirements for 1140-lb lactating (75 days) and dry cows. Energy intake fell below dry cow requirements between about 2 and 15% dietary browse and below requirements for lactating cows at about 2% dietary browse.

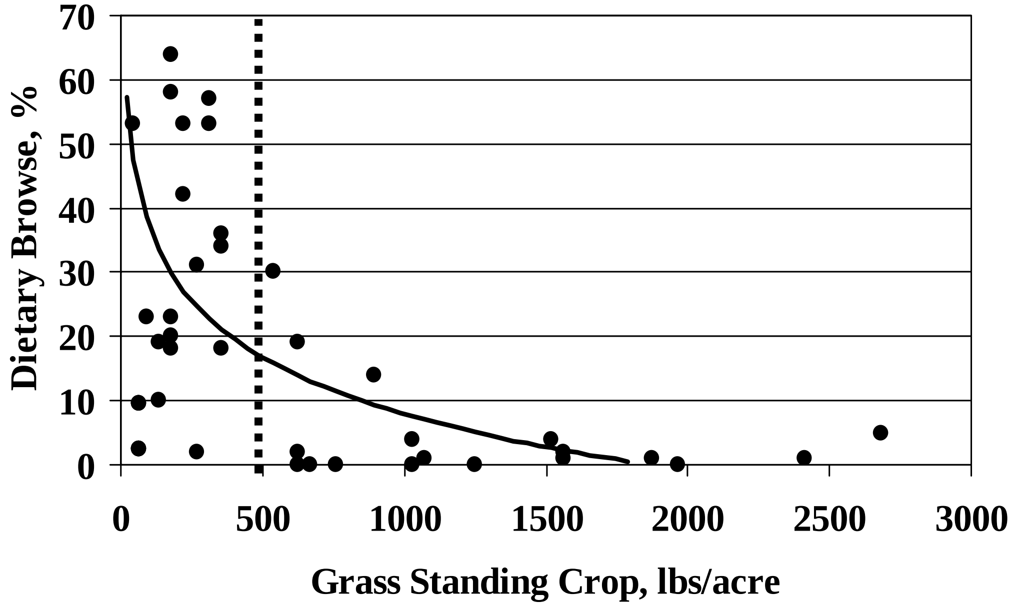

Figure 7. Relationship between grass standing crop and dietary browse. Dots represent actual data points. The curved line represents the regression of grass standing crop and percent dietary browse. Most data points for dietary browse levels above 20% occur below grass standing crop levels of 500 lbs/acre. These grass levels are below minimum recommended levels to maintain midgrasses such as the more desirable and productive grasses in South Texas.

INTRA AND INTER-LABORARTORY VARIATION IN FORAGE QUALITY ANALYSIS: EFFECT ON NUTRITIONAL MANAGEMENT OF BEEF CATTLE

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Summary

The effects of intra and inter-laboratory variation on forage quality analysis and the magnitude of difference required to impact nutritional management decisions for beef cattle has not been reported. A study was conducted to determine the effect of forage analysis results obtained from four different commercial laboratory facilities on predicted animal performance and subsequent supplemental feeding management decisions in beef cattle production. Each laboratory reported CP, ADF, and TDN for wheat (Triticum aestivum) straw, kleingrass (Panicum coloratum) hay and alfalfa (Medicago sativa) hay on three dates. Intra-laboratory variation was minimal. Average coefficients of variation were 5.17 ± 2.26, 3.55 ± 0.63, and 2.85 ± 0.55 % for CP, ADF, and TDN, respectively. Similarly, coefficient of variation values were 4.50 ± 1.18, 3.65 ± 0.86, 4.51 ± 1.96, and 2.76 ± 0.59 % for laboratories 1, 2, 3, and 4 respectively. Inter-laboratory variation was relatively small for CP, intermediate for ADF, and substantial for TDN. The effect of laboratory on reported TDN was significant ($P < 0.04$) for all forages. Inter-laboratory variation in TDN resulted in potentially large differences in costs to supplement beef cattle, especially on low quality forages.

Introduction

Efficient use of forage is vital to the economic sustainability of beef production. Standardized Performance Analysis data indicate that of the $407 per yr average cost of production per cow exposed to breeding, $162 is attributed to grazing and feed (McGrann, 2000). Proper stocking rate is the most important factor in supplying an adequate quantity of forage to grazing cattle (Holechek et al., 2000). Forage quality must also be considered, for if either are insufficient the diet will require supplementation. Feeding decisions are thus among the most difficult faced by cattle producers.

Since forage quantity and quality determine the nutritional environment for grazing cattle, both should be monitored. Of these two, quantity estimates are the more easily obtained and can be accomplished by weighing hand-clipped plots for example (Holechek et al., 2000). Difficulty in determination of forage quantity is of course affected by spatial scale and other factors. Monitoring forage quality is a multi-step process requiring some type of laboratory analysis; the end result can be affected by: 1) heterogeneity of the forage, 2) sampling technique, 3) error in laboratory method for specific measured constituents, and 4) variation due to differences in calculated energy values.

The effects of intra and inter-laboratory variation on forage quality analysis and the magnitude of difference required to impact nutritional management decisions for beef cattle has not been reported. We hypothesized that: 1) intra-laboratory variation would be small for CP, ADF, and TDN, 2) inter-laboratory variation would be small for CP and ADF, and 3) inter-laboratory variation for TDN would be large enough to have an economic effect. The objective of this study was to determine the effect of forage analysis results obtained from different commercial laboratories on predicted animal performance and subsequent supplemental feeding management decisions in beef cattle production.

Experimental Procedures

Experimental Design and Statistical Analysis

Three forage stocks of known *in vivo* digestibility (Hunt et al., 1995) which are employed in our laboratory as standards for determination of *in vitro* digestible organic matter (Li et al., 2006) were used in this study. On three separate occasions, approximately 30 d apart, two samples (~10 g) each of wheat (*Triticum aestivum*) straw, kleingrass (*Panicum coloratum*) hay, and alfalfa (*Medicago sativa*) hay, were sent to four well established commercial forage testing laboratories in the U.S. The same four laboratories were used each time. The forage stocks were milled to a 2-mm particle size and stored at - 20^{o} C in plastic tubs. Prior to removing aliquots, each stock was thoroughly mixed. Each laboratory reported CP, ADF, and TDN for each sample. Within each forage, differences in reported values for CP, ADF, and TDN were determined by analysis of variance procedures (Snedecor and Cochran, 1989) for a randomized complete block (with sub–sampling) design.

Nutritional Management Scenarios

To determine the effects of reported CP, ADF and TDN values on nutritional management of beef cattle, these values were entered in the NRC (1996) beef cattle model. Additional values needed to populate the feedstuff characteristics for each forage were obtained from NRC feed composition tables. Three age/class/production goal scenarios were utilized: 1) body condition maintenance in a non-lactating mid-gestation cow, 2) less than 0.5 body condition score (BCS) mo^{-1} loss in a lactating non-pregnant cow, and 3) 0.91 kg per day body weight (BW) gain in a growing steer. Specific animal, environmental, and management criteria are listed in Table 1. Relative forage quality (i.e. nutrient density) and animal nutritional needs were matched, thus values reported for wheat straw were considered the forage for scenario 1, values for kleingrass hay were applied in scenario 2, and similarly alfalfa hay was used in scenario 3. In the event a stated production goal could not be met with forage alone, cracked corn and or cottonseed meal were supplied as supplements. NRC (1996) tabular values for these respective supplements were used. To evaluate the potential economic impact of inter-laboratory variation on nutritional management decisions, the cost of each diet, including any supplements, was calculated using prices obtained in the College Station, Texas area during the summer of 2004 (Table 1).

Results and Discussion

Intra-laboratory variation was minimal for all three variables. Average coefficient of variation (CV) was 5.17 ± 2.26, 3.55 ± 0.63, and 2.85 ± 0.55 % for CP, ADF, and TDN, respectively. Similarly, CV values were 4.50 ± 1.18, 3.65 ± 0.86, 4.51 ± 1.96, and 2.76 ± 0.59 % for laboratories 1, 2, 3, and 4, respectively. Difference between duplicates within laboratory averaged less than 1.3 ± 0.5 units across all three constituents. Maximum differences observed were 1.2, 3.8, and 4.3 units for CP, ADF, and TDN, respectively. The effect of these extremes in intra-laboratory variation on projected animal performance was determined by using the NRC beef cattle model for the growing steer described in scenario 3. Cases were set up in which one constituent was held constant and the other varied by the approximate maximum difference observed (Table 2). The effect of intra-laboratory variation due to CP yielded no difference in predicted daily gain. The difference in predicted daily gain due to high and low values for TDN was 0.2 kg per day. In recent studies conducted by our laboratory, forty eight Angus cross steers (225 ± 5.0 kg BW) consuming a similar quality diet (12 % CP, 60 % TDN) gained an average of 1.25 kg per day with a SD of 0.15 "Stuth, Texas A&M University, College Station, TX, personal communication". Thus while a potential inter-laboratory difference of 4 units in TDN is intuitively large, the subsequent effect on predicted animal performance would be no greater than that one might expect to occur from individual animal variation.

Inter-laboratory variation was relatively small for CP, intermediate for ADF, and substantial for TDN (Figure 1, Table 3). The effect of laboratory on reported TDN was significant ($P < 0.04$) for all forages, and in wheat straw was significant ($P < 0.02$) for all constituents. Laboratory also affected ($P = 0.05$) reported CP values in alfalfa. There were no significant effects ($P > 0.1$) due to date for any forage or constituent. The range in reported values between laboratories for each constituent varied from 1.1 ± 0.1 units for CP, to 3.1 ± 0.6 and 10.9 ± 3.7 units for ADF and TDN, respectively.

The results support the findings of Putnam (1996), and illustrate some of the problems associated with forage quality monitoring. Split samples (n = 35) from three subjective quality levels (low, moderate, high) of alfalfa sent to 19 different laboratories yielded mean percentage point ranges of 5.4 ± 0.8 for ADF and 4.7 ± 0.2 for TDN. To carry this exercise further and illustrate the effect of equation used on reported TDN values, Putnam applied four different equations based on ADF, to a single ADF value and obtained a range of 12.0 percentage points (45.4 to 57.4 % TDN). Inter-laboratory variation, though independent of forage characteristics, is exacerbated by sampling error and forage heterogeneity. In the same report, 20 core samples taken from one "seemingly uniform stack" of pure alfalfa hay (analyzed by one laboratory, using one TDN equation) varied from 54.5 to 59.2 % TDN, a 4.7 percentage point range. Similar observations have been made with stockpiled bermudagrass (*Cynodon dactylon*) in East Texas (Cleere et al. unpublished report). Seven samples clipped from a single pasture on one date and analyzed by one laboratory yielded a CP value of 11.2 ± 0.89 % with a range of 7.2 percentage points. Corresponding values were 32.5 ± 2.55 and 19.5 for percent ADF, and 57.3 ± 1.66 and 11.6 for percent TDN, respectively.

Protein and energy content are the two major determinants of forage quality. Crude protein (% N x 6.25) is a chemical property of forage and can be measured directly. Energy content is not a single chemical property but rather a feedstuff characteristic affected by physico-chemical properties of the forage. Percent TDN is a widely used method to determine an energy value for animal feeds. While this value was obtained via proximate analysis (TDN = digestible CP + digestible nitrogen free extract + digestible crude fiber + digestible ether extract X 2.25, Morrison, 1959) in times past, one need only scan the literature or internet to discover that many different equations for calculating TDN are in current use. Some of these equations are feedstuff specific, some based on multiple regression using factors such as CP, ash, or lignin. Others utilize simple regression based on ADF or NDF. The result of there being many different TDN equations is probably two-fold: 1) more useful determinations of energy value for specific feeds and forages than that obtained with a "one-size fits all" equation, and 2) confusion on the part of producers when having their forages analyzed, as the results obtained from different laboratories for the same forage can be very different. While some variation both within and between laboratories is to be expected, these potential differences, especially in energy values, can create difficulty in planning for and managing the nutrition of grazing or forage-fed cattle.

Even though there were significant differences in reported forage quality parameters between laboratories in the current study (Figure 1), the important question is: what do these results mean to producers or nutritionists in practical management situations? We have discussed the impact of a 1.0 percentage point difference in CP or a 4 point difference in TDN on projected gain; but at what level of variation do these differences begin to affect nutritional balance or supplementation decisions? For instance, what effect does a 10.0 unit differential in TDN have on nutritional management? Table 4 contains nutritional balance results, and Table 5, the amounts of forage and supplements fed along with costs incurred in each production scenario. In scenario 1, projected days for a non-lactating mid-gestation cow to lose 1 BCS ranged from 17 to 90 days. Dry matter intake was set at 2.0 ± 0.1 % BW and corn was fed at no more than 0.5 % BW. Using these inputs and the range of nutritional balance values obtained to plan a maintenance feeding regimen resulted in a \$0.45 cow $^{-1}$ d $^{-1}$ (per cow per day) cost differential, or \$22.50 for a herd of 50 animals d $^{-1}$ and \$675.00 for this herd to be fed for 30 days. Additionally, the amount of forage required ranged from 5.45 to 7.72 kg cow $^{-1}$ d $^{-1}$, a potential difference of 113.50 kg d $^{-1}$ for the herd, and 3405.00 kg (i.e. 5 - 6 round bales) for 30 d. The amount of corn fed varied from 0.68 to 3.29 kg cow $^{-1}$ d $^{-1}$, a 130.53 kg d $^{-1}$ difference for the herd, and a 3915.75 kg difference over 30 days. Similarly, values are: 1.59 to 1.82, 11.35, and 340.50 for cottonseed meal. The differences in quantity of forage and supplements would also be expressed in such items as storage, labor, or fuel in a pen-feeding situation. Inefficient use of current pasture and a perceived need for higher subsequent input costs for fertilizer or weed control could also be expected in a grazing system. These costs are not reflected in the data presented here.

In scenario 2, projected days for a non-pregnant cow at 60 days of lactation to lose 1 BCS ranged from 18 to 25 days. Dry matter intake was set at 2.5 ± 0.1 % BW and again the amount of corn was set at less than or equal to 0.5 % BW. When fed to lose no more than 0.5 BCS in one month, the daily amounts of forage and corn differed by a span of 0.91 kg cow $^{-1}$ d $^{-1}$; subsequently 45.40 kg d $^{-1}$ for the same 50 cow herd and 1362.00 kg for the herd over a one month period. The net difference in cost was minimal (\$0.12 cow $^{-1}$ d $^{-1}$) however, when compared to the previous example, the herd per day, and per 30 days expenditures were \$6.00 and \$180.00 respectively.

In scenario 3, for a growing steer, range of BW gain was 0.45 kg (0.21 to 0.66 kg d $^{-1}$). The stated production goal in this feeding scenario was 0.91 kg d $^{-1}$ BW gain. We were not able to achieve this goal with the forage values from laboratory 2, considering the additional restrictions of total dry matter intake at no more than 2.7 ± 0.1 % BW and corn feeding at 0.5 % BW. Slight modification to 1.5 kg corn (~ 0.66 % BW) achieved the desired gain. Feedstuff quantities and subsequent cash outlay varied comparatively little in this scenario; corn only ranged from 0.68 to 1.14 kg d $^{-1}$, alfalfa from 4.99 to 5.22. Cost differential in dollars spent per day, herd, and month were \$0.10, \$5.00, and \$150.00 respectively.

Reported nutritional values from all four laboratories were repeatable and within acceptable levels of error. There was however, considerable variation between laboratories, and, unfortunately the greatest difference was observed in the low quality forage. This would have the highest impact in winter or drought feeding situations when monitoring forage conditions is most critical. Choice of laboratory and or TDN calculation can thus be an important decision. Which of these values are most correct can not be determined without conducting animal feeding trials. It should be noted though, that all laboratories reported values similar to previously published *in vivo* values for CP, but in general TDN was numerically below that previously reported for organic matter digestibility (Hunt et al., 1995).

As alluded to earlier, several factors affect forage quality determinations. Heterogeneity of the resource will always be a function of such variables as species, topography, hydrology, or fertilization pattern. Proper sampling technique with an adequate number of samples will help minimize the effect of this factor. Laboratory method error should be negligible if a reputable facility is utilized. Producers and nutritionists alike should be aware of the potential for variation between laboratories and should evaluate several before choosing one whose protein and energy values result in acceptable animal performance and that best fits their particular production situation.

Implications

Inter-laboratory differences in energy value of forage may be inconsequential to the scientist doing his or her own chemistry, or to a producer or nutritionist working with a single laboratory. If however, forage is purchased from several sources, or if a consultant is working with numerous clients in various locations using different laboratories, the differences could be costly. Any attempt to develop state, regional, or national forage, pasture, or animal diet quality monitoring programs will require some standardization in sampling, chemistry, and energy calculation.

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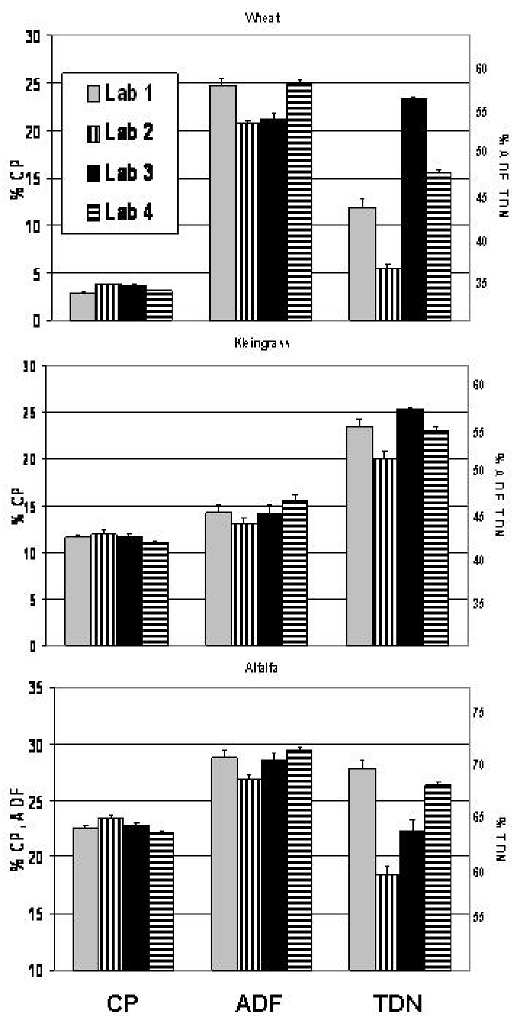

Figure 1. Nutritional quality attributes by forage type and laboratory. Mean ± SEM, n = 6.

Table 1. Animal, environmental, and production inputs for nutritional balance and supplementation scenarios

Input	Scenario 1	Scenario 2	Scenario 3
Class	Cow	Cow	Steer
Age (mo)	60	60	8
Breed	Angus	Angus	Angus
Body Weight (kg)	500	500	227
Body Condition Score	5	5	5
Mature Weight (kg)	NA	NA	545
Pregnancy (d)	180	0	NA
Lactation (d)	0	60	NA
Temperature (^{o}C)	21	21	21
Windspeed (km/h)	8	8	8
Forage	Wheat	Kleingrass	Alfalfa
Feeds	Cracked Corn Cottonseed Meal	Cracked Corn	Cracked Corn
Production Goal	± < 0.2 BCS mo^{-1}	Lose < 0.5 BCS mo^{-1}	Gain 0.91 kg d^{-1}
Management Restrictions	DMI = 2.0 ± 0.1 % BW	DMI = 2.5 ± 0.1 % BW	DMI = 2.75 ± 0.15 % BW
	Corn < 0.5 % BW	Corn < 0.5 % BW	Corn < 0.5 % BW

Table 2. Effects of maximum intra-laboratory variation for reported CP and TDN on predicted gain in a growing steer (227 kg)

% CP	% TDN	DMI (kg d^{-1})	ADG (kg d^{-1})
12.0	58.0	5.22	0.19
12.0	62.0	5.36	0.39
11.5	60.0	5.31	0.29
12.5	60.0	5.31	0.29

Table 3. Effects of date of analysis and laboratory on reported forage quality attributes

		CP		ADF		TDN	
Forage	Effect	F statistic	P value	F statistic	P value	F statistic	P value
Wheat	Lab	10.92	0.0076	7.75	0.0174	90.73	0.0001
	Date	1.77	0.2492	0.35	0.7184	0.02	0.9777
Kleingrass	Lab	1.18	0.3923	0.94	0.4796	5.55	0.0365
	Date	0.88	0.4617	0.86	0.4680	0.26	0.7821
Alfalfa	Lab	4.74	0.0504	2.01	0.2138	14.09	0.0040
	Date	1.52	0.2929	0.92	0.4484	1.18	0.3687

Table 4. Effects of forage quality attributes as reported by four different laboratories on nutritional balance estimates for each forage type:animal scenario

Forage: Animal	Lab	CP	TDN	DMI kg/d^{-1}	NEm diet (Mcal)	NEm req (Mcal)	NEm bal (Mcal)	NEg diet (Mcal)	NEg req (Mcal)	MP diet (g d^{-1})	MP req (g d^{-1})	MP bal (g d^{-1})	BW gain kg/d^{-1}	d to lose 1 BCS
Wheat: NLC[1]	1	2.80	41.85	7.67	5.2	12.9	-7.7	NA	NA	317.0	439.0	-122.0	NA	22
	2	3.80	35.47	6.17	2.7	12.6	-10.0	NA	NA	262.0	439.0	-177.0	NA	17
	3	3.62	53.33	10.22	11.1	12.9	-1.8	NA	NA	541.0	439.0	102.0	NA	90
	4	3.10	45.49	8.76	7.1	13.0	-6.0	NA	NA	396.0	439.0	-43.0	NA	28
Kleingrass: LC[2]	1	11.55	53.39	11.08	12.0	19.6	-7.6	NA	NA	850.0	819.0	31.0	NA	22
	2	11.90	49.98	11.08	10.7	19.6	-9.1	NA	NA	829.0	819.0	10.0	NA	18
	3	11.70	55.33	11.21	12.9	19.6	-6.5	NA	NA	883.0	819.0	64.0	NA	25
	4	10.94	52.92	11.03	11.8	19.6	-7.8	NA	NA	823.0	819.0	4.0	NA	21
Alfalfa: GS[3]	1	22.60	67.88	5.40	8.5	5.4	1.9	1.9	3.1	549.0	423.0	126.0	0.66	NA
	2	23.40	58.38	5.22	6.6	5.6	0.5	0.5	1.0	498.0	289.0	208.0	0.21	NA
	3	22.80	62.33	5.36	7.4	5.5	1.1	1.1	1.9	522.0	349.0	173.0	0.41	NA
	4	22.20	66.35	5.40	8.2	5.5	1.7	1.7	2.7	538.0	404.0	134.0	0.59	NA

[1]non lactating cow, [2]lactating cow, [3]growing steer

Table 5. Effects of forage quality attributes as reported by four different laboratories on cost of supplemental feeding strategies for each forage type: animal scenario

Forage: Animal	Lab	kg forage	kg corn	kg CSM	NEm bal (Mcal)	MP bal g /d$^{-)}$	DIP bal g /d^{-1}	Tot kg fed	d lose 1 BCS	ADG kg/d	$ Forage d^{-1}	$ Corn d^{-1}	$ CSM d^{-1}	$ Suppl d^{-1}	$ Total d^{-1}
Wheat: NLC[1]	1	6.36	2.27	1.82	0.00	445.0	61.0	10.0	NA	NA	0.42	0.50	0.40	0.90	1.32
	2	5.45	3.29	1.70	0.09	473.0	84.0	10.0	NA	NA	0.36	0.73	0.38	1.10	1.46
	3	7.72	0.68	1.59	0.18	381.0	-22.0	10.0	NA	NA	0.51	0.15	0.35	0.50	1.01
	4	6.36	2.04	1.59	0.00	398.0	9.0	10.0	NA	NA	0.42	0.45	0.35	0.80	1.22
Kleingrass: LC[2]	1	9.53	2.72	NA	-2.63	234.0	-145.0	12.3	63.0	NA	0.84	0.60	NA	NA	1.44
	2	9.08	3.18	NA	-3.25	236.0	-120.0	12.3	51.0	NA	0.80	0.70	NA	NA	1.50
	3	9.99	2.27	NA	-2.47	236.0	-125.0	12.3	67.0	NA	0.88	0.50	NA	NA	1.38
	4	9.53	2.72	NA	-2.80	214.0	-177.0	12.3	59.0	NA	0.84	0.60	NA	NA	1.44
Alfalfa: GS[3]	1	5.22	0.68	NA	4.30	111.0	374.0	5.9	NA	0.93	0.69	0.15	NA	NA	0.84
	2	5.22	1.14	NA	3.80	176.0	397.0	6.4	NA	0.79	0.69	0.25	NA	NA	0.94
	3	5.22	1.14	NA	4.30	149.0	386.0	6.4	NA	0.90	0.69	0.25	NA	NA	0.94
	4	4.99	0.91	N+A	4.20	111.0	334.0	5.9	NA	0.90	0.66	0.20	NA	NA	0.86

[1]non lactating cow, [2]lactating cow, [3]growing steer

Reproduction

EFFECTS OF ONCE DAILY SUCKLING AND PARITY ON FOLLICULAR DYNAMICS IN POSTPARTUM BRAHMAN COWS

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Summary

Changes in follicular dynamics were monitored in 44 Brahman multiparous (n = 30) and primiparous (n = 14) cows randomly assigned to act as controls (n = 22) or to be once-daily suckled (n = 22). Primiparous cows had 34% more follicular waves ($P < 0.05$) prior to first ovulation (FO). Once-daily suckled multiparous cows had 37% less follicular waves ($P < 0.05$) prior to FO. Interval from calving to FO was reduced by an average of 12 days ($P < 0.05$) by once-daily suckling in multiparous cows. Ovulation before day 88 occurred in 42/44 (95%) cows. Behavioral estrus was not detected in 40/42 (95%) cows at FO. The length of the subsequent estrous cycle was short (<17 days) in 39/42 (93%) cows. We conclude that parity and suckling influence postpartum interval. It seems obligatory that postpartum Brahman cows experience a silent ovulation and CL formation prior to resumption of normal estrous cyclicity.

Introduction

Beef cows must maintain a yearly calving interval in order to sustain economic viability. Length of the postpartum interval determines attainment of a yearly calving schedule. Primiparous cows have a longer interval from calving to estrus compared to multiparous cows (Wiltbank, 1970). Suckling by the newborn calf suppresses return to estrous cyclicity which reduces opportunity for conception to occur earlier in the postpartum period (Margerison et al., 2002). Once-daily suckling shortens the postpartum interval in first calf beef heifers (Randel, 1981). Despite the fact that suckling and parity affect postpartum reproductive processes, the effect on follicular dynamics requires further clarification. Ultrasonography is a reliable for monitoring follicular development (Pierson and Ginther, 1988). The "nonidentity" method is appropriate for profiling waves, detecting ovulation, and corpus luteum formation (Ginther, 1993). Before we can devise treatments or systems to shorten the postpartum interval in Brahman cattle it is important to know if the cause for postpartum anestrus is due to lack of development of a dominant follicle or to failure to ovulate a dominant follicle.

Experimental Procedures

Forty-four Brahman multiparous (n = 30) and primiparous (n = 14) cows were randomly assigned within parity, calving order, and sex of calf to either control (n = 22) or once-daily suckled (n = 22) treatments. Cows were weighed and assigned a body condition score, and calves identified by ear tag and weighed within 24 h of parturition.

A Sonovet 600 (Universal Medical Systems) ultrasound equipped with a 7.5-MHz rectal probe was used to observe follicular size, ovulation, corpus luteum (CL) formation, and pregnancy. Follicular development on each ovary was monitored daily by transrectal ultrasonography from d 21 post-calving and continued through estrus detection or d 88 after calving. Two subsequent observations were made at d 7 and d 10 post-estrus for CL identification.

Cows and calves were weighed and cow body condition score recorded weekly beginning at d 21 post-calving and continued through d 10 post-estrus. Further weight and BCS observations were recorded at 28 d intervals through weaning. Weaning weights were adjusted to 205 d for statistical analysis. Blood samples were collected from cows by venipuncture of a tail vessel at weekly intervals to determine serum progesterone concentration (d 21 through detection of estrus). Blood samples were also taken on d 7 and 10 post-estrus for corpus luteum confirmation. Samples were refrigerated (4°C) for 24 h followed by centrifugation. The collected serum was then stored at -20°C until hormone analysis. An RIA procedure was utilized to determine blood progesterone content (Williams, 1989).

Suckling treatments commenced on d 28 post-calving and continued through detection of estrus. Cows assigned to the control group were exposed to *ad libitum* suckling. Once-daily suckled cows were limited to a suckling period of 45 to 60 min daily.

Cows were artificially inseminated (AI) 12 h after detection of standing estrus. Semen from one bull and one single ejaculate was utilized for all cows. Vasectomized bulls equipped with chin ball markers were introduced on d 1 post-calving for estrus detection. The cows were visually observed for estrus twice daily. After first AI, cows were exposed to a fertile bull for the remainder of the breeding season. Pregnancy was determined by uterine palpation and ultrasonography 42 d after AI to determine first service conception rate.

The effect of once-daily suckling, parity, and sex of calf on follicular dynamics, return to estrus, calf weight gains, cow weight and body condition score change, and progesterone concentrations were analyzed utilizing the general linear model (GLM) procedure of SAS with the cow as the experimental unit. Progesterone concentrations were also analyzed using the GLM repeated measure procedures of SAS. The calf served as the experimental unit for the calf weight analysis. Least square means (± standard error) are reported for all variables within main effect treatments. First service conception rates were analyzed by using the Chi Square procedures of SAS. All possible interactions were analyzed within the statistical model including 1) calf sex × parity, 2) calf sex × treatment, 3) parity × treatment, and 4) calf sex × parity × treatment.

Results and Discussion

Effects of Parity

At the start of the suckling treatment (d 21), multiparous cows weighed more ($P < 0.02$) than primiparous cows. Cow weights did not differ ($P > 0.10$) at the end of the suckling treatment. Cow body weights differed at weaning ($P < 0.02$) with primiparous weighing less than multiparous cows. Cow body condition scores did not differ ($P > 0.10$) early in the postpartum period, but were significantly different ($P < 0.001$) at weaning where primiparous cows had a lower BCS. Calf body weight was not influenced ($P > 0.10$) by parity at the start of the suckling treatment. However, primiparous cows had heavier ($P < 0.03$) calves than did the multiparous cows at the end of the suckling treatment. There was no influence of parity on weaning weights. Moreover, there was no difference ($P > 0.10$) in calf growth rates from birth to weaning or during the suckling treatment due to parity.

Primiparous cows experienced more ($P < 0.04$) follicular waves from d 21 through first ovulation than multiparous cows. The number of follicular waves after first ovulation, preceding second ovulation did not differ ($P > 0.10$) between the two groups. The length of the follicular wave associated with first ovulation was not influenced by parity ($P > 0.10$), but wave length associated with second ovulation was longer ($P < 0.04$) in multiparous cows. Multiparous cows had a shorter interval from calving to first ($P < 0.07$) and second ($P < 0.05$) ovulations compared to primiparous cows. More dominant follicles were developed ($P < 0.02$) by primiparous cows than multiparous cows. The second ovulatory follicle, which was associated with behavioral estrus in all but one cow, was significantly larger ($P < 0.002$) in multiparous cows than in primiparous cows. Progesterone concentrations associated with first and second luteal tissue did not differ ($P > 0.10$) within parity. Multiparous and primiparous cows showed a higher ($P<0.001$) serum progesterone concentration associated with the second luteal phase than with the first luteal phase.

Effects of Once-Daily Suckling

Cow body weights and body condition scores at the start and end of the suckling treatment, and at weaning were not statistically different between treatment groups ($P > 0.10$) regardless of parity. Calves out of primiparous and multiparous cows had similar body weights ($P > 0.10$) at the start of the suckling treatment. Calves of once-daily suckled multiparous cows weighed less ($P < 0.03$) at the end of the suckling treatment than their control counterparts. Suckling treatment did not affect ($P > 0.10$) calf weight at the end of the treatment period in primiparous cows. Weaning weights were influenced by once-daily suckling ($P < 0.01$) in calves out of multiparous cows. Once-daily suckled calves weighed less compared to control calves. Weaning weights of calves out of primiparous cows were also affected ($P < 0.04$) by suckling treatment. Control calves weighed an average of 20 kg more than the once-daily suckled calves. Average daily gain from birth to weaning and during the suckling treatment was affected ($P < 0.02$) by suckling treatment in calves out of primiparous cows. Control calves had the higher rate of gain at both measurement points. Once-daily suckling reduced calf average daily gain from birth to weaning ($P < 0.001$) and during the suckling treatment ($P < 0.04$) in multiparous cows.

Once-daily suckled multiparous cows had fewer follicular waves ($P < 0.03$) from d 21 through first ovulation than control cows. The number of follicular waves prior to or after first ovulation were not affected ($P > 0.10$) by suckling treatment in primiparous cows. Suckling treatment had no influence ($P > 0.10$) on length of follicular waves associated with first or second ovulation regardless of parity. Interval from calving to first ovulation was decreased ($P < 0.03$) in multiparous cows by once-daily suckling. Those intervals did not differ in primiparous cows. There was no effect of suckling treatment ($P > 0.10$) on interval from first ovulation to second ovulation or on number of dominant follicles developed from d 21 to estrus in both primiparous and multiparous cows. Statistical differences were not seen ($P > 0.10$) in size of first and second follicle detected, or on size of first or second ovulatory follicle in any treatment group. Once-daily suckled, multiparous cows tended ($P < 0.06$) to have higher concentrations of progesterone associated with the first luteal tissue developed than controls, but not with the second luteal phase. Differences within primiparous cow treatment groups were not significant ($P > 0.10$). Sex of calf itself had no effect ($P > 0.10$) on any variable regardless of suckling treatment or parity. However, there was a tendency ($P < 0.06$) of a three-way interaction between sex of calf, parity, and treatment on interval from calving to first ovulation and interval from calving to second ovulation. Data collected in the current research show that multiparous cows which gave birth to female calves and were once-daily suckled had the shortest intervals to first and second ovulation. This interaction also affected (P <

0.03) the number of dominant follicles that developed from d 21 through estrus.

Ovulation

Ovulation before d 88 occurred in 42 of 44 (95%) cows overall. Murphy et al. (1990) noted that first ovulation is rarely associated with estrus in *Bos taurus* cows. Similar events were seen here with 40 of 42 (95%) first ovulations not being accompanied by behavioral estrus. Furthermore, 39 of 42 (93%) first ovulations were followed by a subsequent short estrous cycle (≤17 d). Mean estrous cycle length was 9.4 ± .9 d for multiparous cows and 10.4 ± 1.4 d for primiparous cows. The two cows that did not ovulate before d 88 were primiparous, and one was once-daily suckled and the other was a control. One multiparous and primiparous cow showed estrus behavior at first ovulation, but the subsequent estrous cycle was short. One multiparous cow experienced two silent ovulations.

Conception

First service conception rates were not influenced ($P > 0.10$) by parity. Primiparous and multiparous cows achieved 41.7% (5/12) and 60% (18/30) first service conception rates, respectively. Once-daily suckling showed no statistically significant ($P > 0.10$) effect on first service conception rate. Primiparous once-daily suckled cows had a 33% (2/6) first service conception rate, while control cows showed a rate of 50% (3/6). Multiparous cows did not ($P = 1.0$) show any influence of suckling on first service conception rates, with once-daily suckled and control cows having a first service conception rate of 60% (9/15) each. Overall pregnancy rate at weaning for multiparous cows was 97% (29/30). Once-daily suckled multiparous cows had a 100% pregnancy rate. Primiparous cows attained a 79% (11/14) pregnancy rate with the once-daily suckled cows showing the numerically higher pregnancy rate of 86% (6/7).

Implications

These data show that ovarian function is resumed shortly after parturition and ovulation of a dominant follicle ends postpartum anestrous. Primiparous cows experienced more follicular waves and grew more dominant follicles prior to first estrus. Once-daily suckling hastened return to estrus and reduced the number of follicular waves prior to first post-partum estrus in multiparous cows without affecting fertility. The incidence of first ovulation being associated with behavioral estrus was low. Short estrous cycles followed first ovulation. It appears obligatory that postpartum Brahman cows experience a silent ovulation with formation of functional luteal tissue prior to resumption of normal estrous cyclicity.

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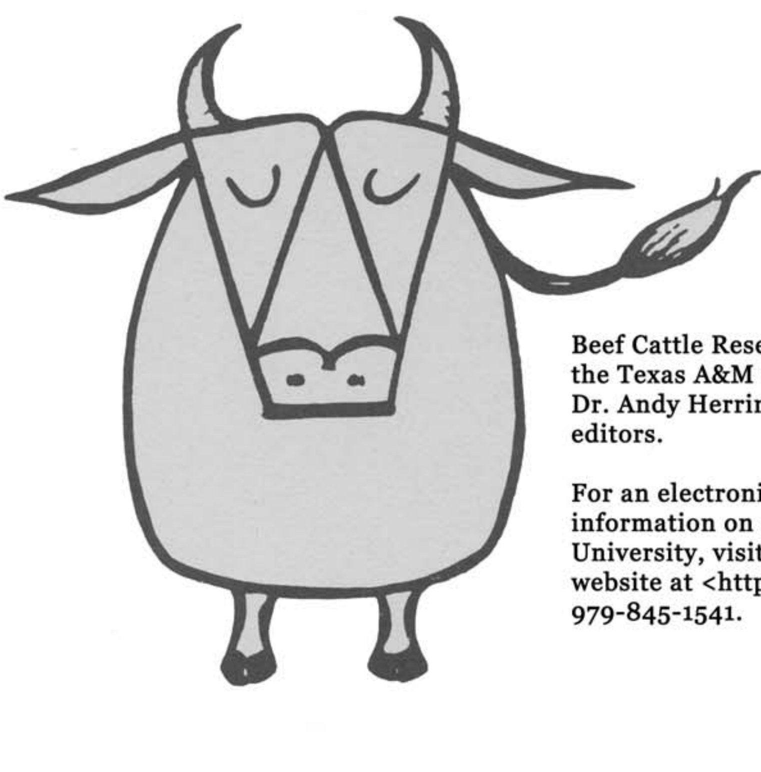

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