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2009-2010
BEEF CATTLE RESEARCH IN TEXAS

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AgriLIFE RESEARCH & EXTENSION
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TEXAS A&M UNIVERSITY

COLLEGE OF AGRICULTURE AND LIFE SCIENCES

Department of Animal Science

Beef Cattle Research in Texas 2009-2010

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, 2010 there were 13.3 million cattle in Texas. There were approximately 145,000 Texas cattle producers accounting for 5.1 million beef cows and over 6 million stocker calves operating under widely varying environments and production systems across the state. There were close to 3 million cattle on feed in Texas feedlots on any given day, and packing plants in Texas with processing capacity of 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 cattle and calves in Texas for 2010 were $7.4 billion.

Many state organizations 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 are dedicated to helping Texas cattle producers deal with emerging production and policy issues, improve profitability and sustainability, and satisfy demands of beef consumers. We in academia as well as industry are fortunate and grateful for their support.

The publication highlights some of the recent projects conducted through Texas A&M AgriLife 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 continued success and sustainability of the Texas and United States beef cattle industries.

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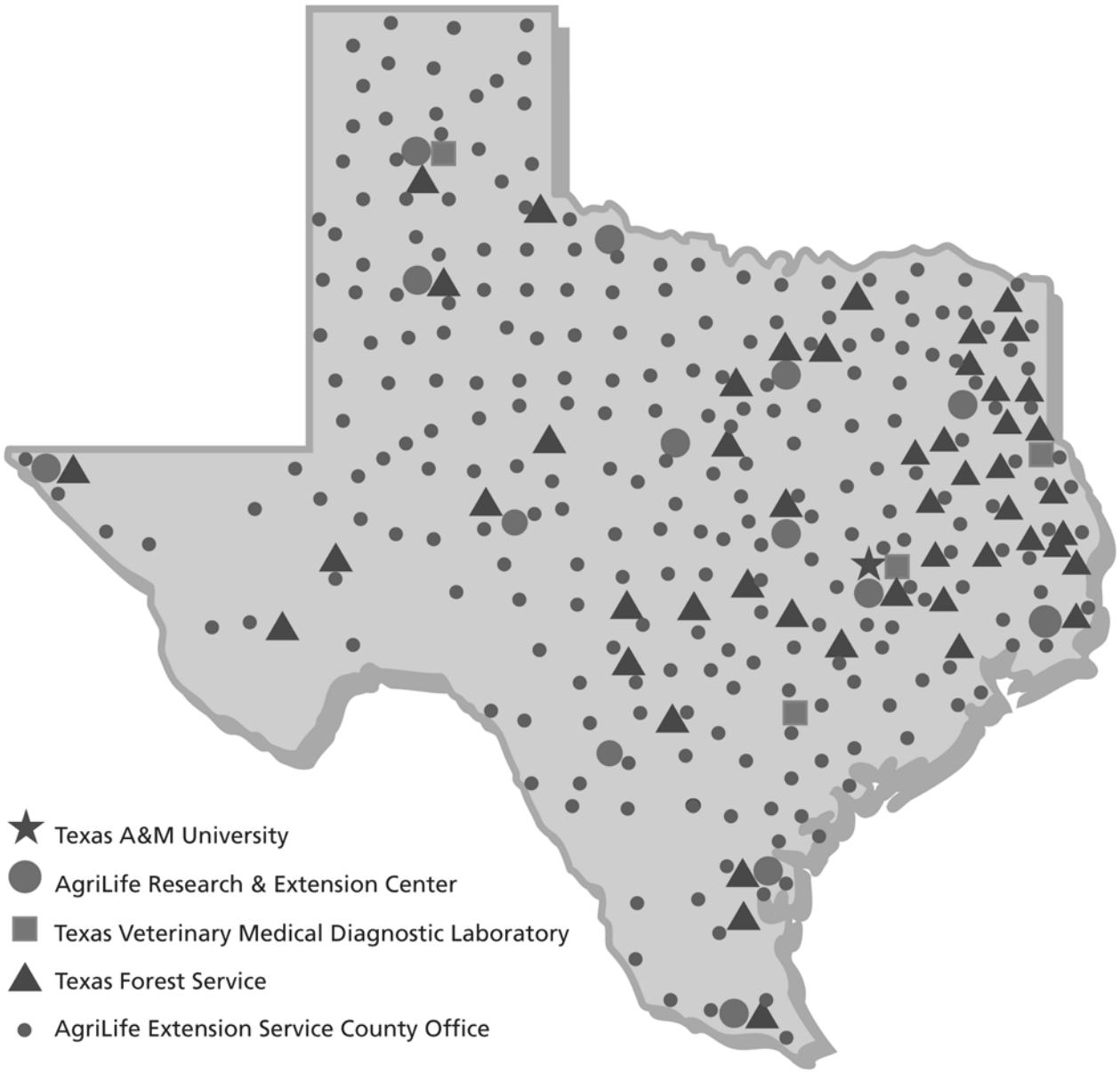

Texas A&M University has been a recognized leader in agriculture, natural resources and life Sciences since Texas A&M became a land-grant institution in 1876. Texas A&M AgriLife encompasses five main components of The Texas A&M University System: College of Agriculture and Life Sciences at Texas A&M University, Texas AgriLife Research, Texas AgriLife Extension Service, Texas Forest Service, and Texas Veterinary Medical Diagnostic Laboratory. With teaching, research, extension and laboratory facilities throughout Texas, Texas A&M AgriLife serves people of all ages and backgrounds and is a cornerstone of one of the state's premier institutions of higher education.

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CHARACTERIZATION OF POPULATION DIFFERENTATION AMONG *BOS TAURUS* BEEF AND DAIRY BREEDS

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Summary

Selection for specific phenotypes leaves a genetic signature in the underlying DNA that can be detected by various analysis methods. In this study, we measured the amount of population differentiation among 12 *Bos taurus* breeds of cattle using Wright's F_{ST} index to reveal signatures of divergent selection. To begin characterization of clusters of SNP with high F_{ST} values (>0.25), we chose to focus on BTA2 near the gene encoding myostatin and on BTA14 near the gene for diacylglycerol O-acyltransferase 1, which are known to be under positive selection. There was evidence of divergent selection in these regions but the density of SNP is currently insufficient to determine whether the signatures were due to these genes or other nearby genes. Our data suggest that the genes encoding thyroglobulin, eukaryotic translation initiation factor 2C, 2 and collagen, type XXII, alpha 1 on BTA14 may be undergoing divergent selection as well.

Introduction

In the last 100 years, selection has contributed to substantial genetic progress in beef and dairy cattle that has resulted in considerable increases in productivity. For example, genetic merit for milk yield in Holstein cows is improving at a rate of 21 gallons (~1%) per year. In the United States, pounds of beef per animal harvested have increased by over 80% in 50 years (2004). These improvements in phenotypes are partially due to positive selection of underlying genotypes. Wright's F_{ST} index (Wright, 1943b; Wright, 1943a), which is based on allele frequency differences among populations as a measure of divergence, has been widely used in other species to identify regions under selection (e.g. Akey et al., 2002). The objective of this study was to use the single nucleotide polymorphisms (SNP) and *Bos taurus* populations from the HapMap project to investigate genome-wide population differentiation to reveal signatures of divergent selection.

Experimental Procedures

Genotypes for 34,886 SNP for 331 animals representing 7 beef (Angus, Hereford, Red Angus, Charolais, Limousin, Romagnola, and Piedmontese) and 5 dairy (Norwegian Red, Brown Swiss, Guernsey, Jersey, and Holstein) breeds were obtained from the bovine HapMap database (http://bfgl.anri.barc.usda.gov). These data (~11.2 million genotypes) were filtered to remove any monomorphic markers, markers or animals with poor completion rates (>10%), and markers that were discordant in multiple trios. Furthermore, markers that violated Hardy Weinberg equilibrium proportions ($P < 0.05$) in multiple breeds, indicative of genotyping errors, were removed. For F_{ST} analyses, the offspring of trios (n = 34) were also removed. Finally, markers assigned to the X chromosome or to unassigned scaffolds (Chr. Un) were filtered. In the final dataset of 29,131 SNP and 290 animals, Wright's F_{ST} (Wright 1943a,b) was calculated for each SNP. These values were plotted by SNP coordinate on build Btau4.0 of the bovine genome sequence.

Results and Discussion

Genotypes analyzed in this study correspond to 25,332 SNP from a genome-wide assay (HapMap 25K chip) and 3,799 SNP from densely sampled regions of BTA 6, 14, and 25 (HapMap 4.5K chip). Approximately 2.5 Gb of the genome was represented in this dataset with an average intermarker spacing of ~100 kb based on markers from the 25K dataset (Table 1). Wright's F_{ST} (Wright 1943a, b) was calculated for every marker with MAF > 0.05 in at least one breed. This is similar to the approach of Akey et al. (2002) for human SNP data. The average value of F_{ST} was 0.131 across the autosomes (Table 1) and these data approximated a χ^2 distribution (Figure 1). Large standard deviations were associated with the mean value of F_{ST} for each chromosome because there is substantial variation in F_{ST} values throughout the genome, even for closely associated markers (Weir et al., 2005). Similar variability was observed in human data when F_{ST} was determined for individual SNP (Weir et al., 2005; Akey et al., 2002). As in Weir et al. (2005), a normal distribution was obtained by averaging values of F_{ST} for adjacent markers (e.g. in 5 Mb windows; data not shown).

We identified 1,656 markers across the genome with extremely high values of F_{ST} (>0.25) suggestive of divergent selection (Figure 2). Conversely, we identified 1,648 markers across the genome with extremely low values of F_{ST} (<0.05) suggestive of balancing selection. Clusters of markers with high F_{ST} may allow genes under directional selection to be identified. We exemplify this for SNP in the vicinity of myostatin (*MSTN*) and diacylglycerol O-acyltransferase 1 (*DGAT1)* that are known to be under positive selection in some beef (Bellinge et al., 2005) and dairy breeds (Grisart et al., 2004), respectively.

Mutations that inactivate *MSTN* cause muscular hypertrophy, also known as double muscling (McPherron and Lee, 1997). The phenotype was first documented in 1807 and has become increasingly widespread in European cattle (Culley, 1807 cited by (Bellinge et al., 2005). The double muscling phenotype is observed at moderate to high frequencies in the Piedmontese, Limousin and Charolais breeds (Grobet et al., 1998), but at low frequencies in the other breeds that were sampled for the HapMap study. In the vicinity of *MSTN* at ~6.53 Mbp on BTA2 there is a cluster of 8 markers with F_{ST} > 0.25 (Figure 3a). Although these SNP with extreme F_{ST} values are not in the *MSTN* gene, it is likely that haplotypes for these SNP have hitchhiked with the *MSTN* mutation and thus mark this as a region under positive selection for the double muscling phenotype.

A mutation (K232A) in *DGAT1* has been shown to influence milk percentage, milk yield, and intramuscular fat content in cattle (Grisart et al., 2002; 2004). The K allele increases fat percentage, which has been a major breeding objective of the dairy industry and therefore this mutation has been under strong positive selection (Grisart et al., 2004). Grisart et al. (2004) suggested that because a limited number of K-carrying chromosomes would have initially existed, there would be considerable linkage disequilibrium with surrounding markers due to the selective sweep for the K allele. However, in the current study, when average F_{ST} for the 12 *Bos taurus* breeds was used as a measure of population differentiation, there was limited evidence of this sweep (Figure 3b). Few of the markers adjacent to *DGAT1* had high values (>0.15) for F_{ST}. However, it should be noted that no markers in this region from 0 to ~1.5 Mb had very low F_{ST} (<0.05). We expect that population specific F_{ST} values (Weir and Hill, 2002) for the dairy breeds would be more indicative of selection in this region.

In both dairy and beef cattle, the confidence interval for the QTL containing *DGAT1* extends for 10 to 20 cM. Thus, other genes underlying this QTL may also contribute to the variation in fat composition attributed to *DGAT1*. For example, thyroglobulin (*TG*) at ~7.7 Mb (Figure 3b) is associated with marbling and quality grade in beef cattle and SNP in *TG* are part of the GeneStar Quality Grade marker panel (Barendse, 1999; Van Eenennaam et al., 2007). For the SNP tested in this study, several that flanked *TG* had extreme values of F_{ST} and very few markers had very low F_{ST} values, suggesting strong population differentiation in the vicinity of *TG*.

One of the long-term goals of this study is to identify novel genes that exhibit signatures of recent positive selection. However, this remains challenging because of the relatively low density of SNP markers currently available and the relatively poor annotation of the bovine genome. Often, SNP with extreme values of F_{ST} lie several kilobases from the nearest known gene. In such cases, the question remains whether the SNP are in linkage disequilibrium with other gene-associated SNP or whether they mark as yet undetermined DNA regulatory regions, such as transcription factor binding sites, enhancers or silencers. As shown in Figure 3b, we were able to identify SNP associated with eukaryotic translation initiation factor 2C, 2 (*EIF2C2*), that is responsible for microRNA cleavage in RNA interference (Morita et al., 2007). In mice, knockout of *EIF2C2* causes embryonic lethality early in development. In cattle, it is therefore possible that *EIF2C2* contributes to variation in fertility associated with early embryo losses.

In Figure 3b, it was also observed that there were many SNP in the vicinity of the collagen, type XXII, alpha 1 (*COL22A1*) gene (Koch et al., 2004), which encodes a component of collagen XXII. This protein interacts with components of microfibrils (Koch et al., 2004) and therefore it is possible that *COL22A1* contributes to variation in meat quality in beef cattle.

In future work, we will characterize all clusters of SNP with extreme values of F_{ST}, determine whether they coincide with beef or dairy QTL and then identify the nearest genes associated with those clusters to better understand genetic factors that contribute to population differentiation among *Bos taurus* cattle breeds. The challenge with analysis of signatures of selection in cattle is that marker density is still insufficient and prevents the immediate determination of causative genes. As proposed by Villa-Angulo et al. (2008) at least 574,000 markers are needed to capture all of the haplotype block structures in cattle. Once a resource of this density becomes available it will be easier to determine which loci are at the core of these signatures of selection.

Implications

Selection for specific phenotypes leaves signatures in the DNA. We demonstrated that Wright's F_{ST} can detect some of these regions of the genome that are under divergent selection. A few genes, such as *DGAT1* and *MSTN,* are already being used by producers in advanced breeding programs and the expectation was that they would show a strong signature of selection. However, the amount of divergence among populations for these genes was not as strong as expected. Identifying the specific loci that are under selection will require assays of much higher density than are currently available for cattle.

Acknowledgments

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Table 1. Summary statistics for F_{ST} by chromosome for the Hapmap 25K SNP set

BTA	Length (bp)	# SNP	Avg. F_{ST}	Std. Dev.	No. Markers[1]			
					Very Great	Great	Mod.	Little
1	160907802	1555	0.133	0.068	91	428	951	85
2	140356784	1446	0.130	0.067	76	376	905	89
3	127652798	1279	0.134	0.070	78	365	763	73
4	124039900	1215	0.136	0.068	64	356	732	63
5	125784649	1214	0.148	0.077	105	410	638	61
6	122295181	1199	0.143	0.075	111	349	686	53
7	111450679	1034	0.139	0.070	73	320	582	59
8	116646425	1154	0.125	0.060	50	283	744	77
9	107350408	963	0.134	0.070	58	263	603	39
10	106098797	1046	0.125	0.059	40	270	673	63
11	110099902	1159	0.144	0.069	83	394	624	58
12	85206304	837	0.126	0.066	33	210	535	59
13	84107162	924	0.149	0.075	91	292	498	43
14	81080327	837	0.137	0.069	54	237	499	47
15	84423077	770	0.122	0.056	20	199	500	51
16	77570437	793	0.127	0.062	28	202	516	47
17	76127165	795	0.134	0.072	52	217	481	45
18	65707717	653	0.135	0.068	43	186	390	34
19	65063234	683	0.132	0.071	36	173	436	38
20	75458338	807	0.133	0.069	49	227	479	52
21	68877573	662	0.118	0.058	19	141	456	46
22	61746535	643	0.126	0.058	19	169	422	33
23	53228442	592	0.122	0.064	30	128	383	51
24	64932885	679	0.133	0.066	34	196	416	33
25	43444595	427	0.120	0.055	14	103	276	34
26	51000868	532	0.131	0.069	30	141	332	29
27	48747412	457	0.110	0.052	6	79	330	42
28	46014400	486	0.115	0.052	11	105	338	32
29	51649444	491	0.124	0.060	17	129	304	41
All	**2537069240**	**25332**	**0.131**	**0.065**	**1415**	**6948**	**15492**	**1477**

[1]Number of markers in each category based on the qualitative guidelines for interpretation of F_{ST} (Wright, 1978 cited by Hartl and Clark, 1997); very great differentiation ($F_{ST} > 0.25$), great differentiation (0.15 to 0.25), moderate differentiation (0.05 to 0.15) and little differentiation ($F_{ST} < 0.05$).

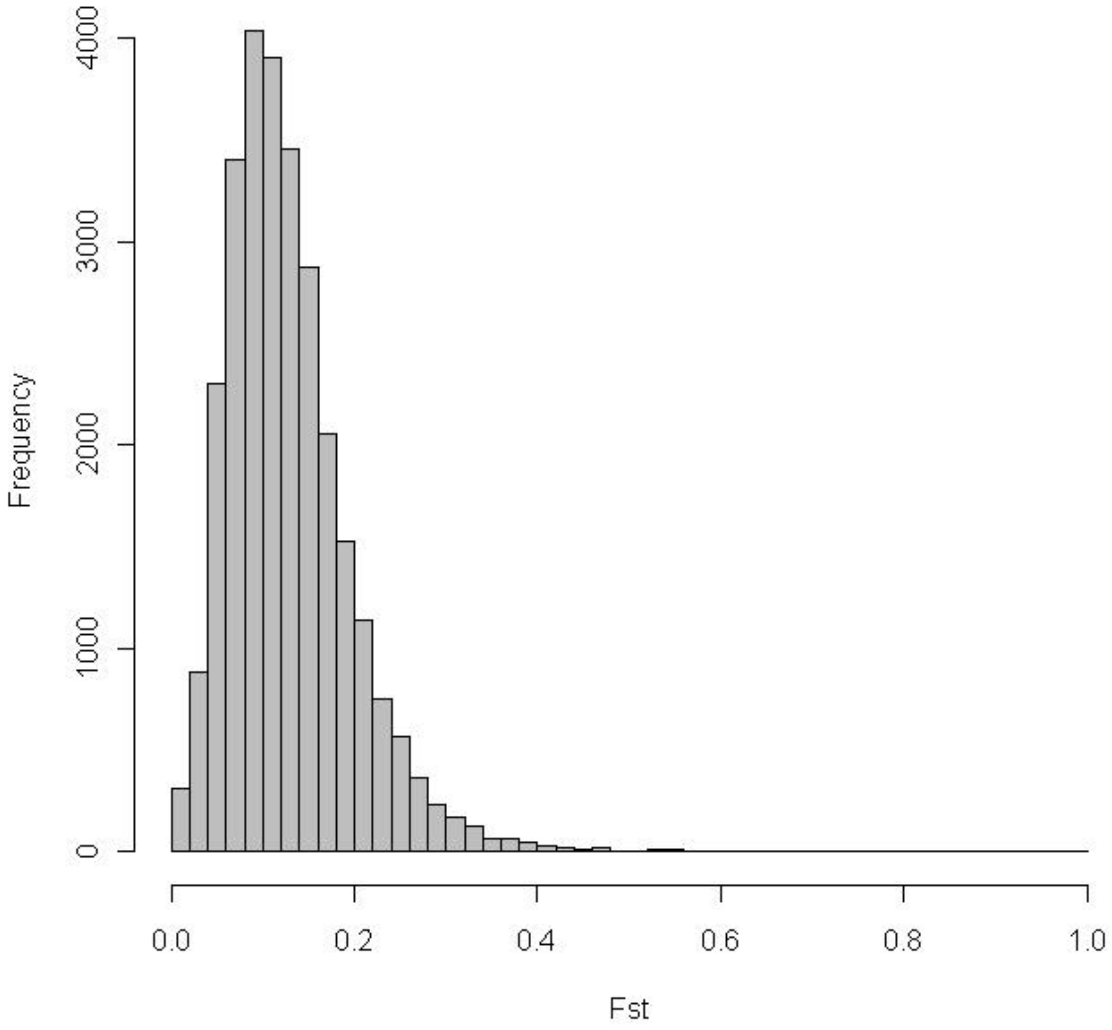

Figure 1. Histogram of the observed values of F_{ST} for 29,131 autosomal SNP.

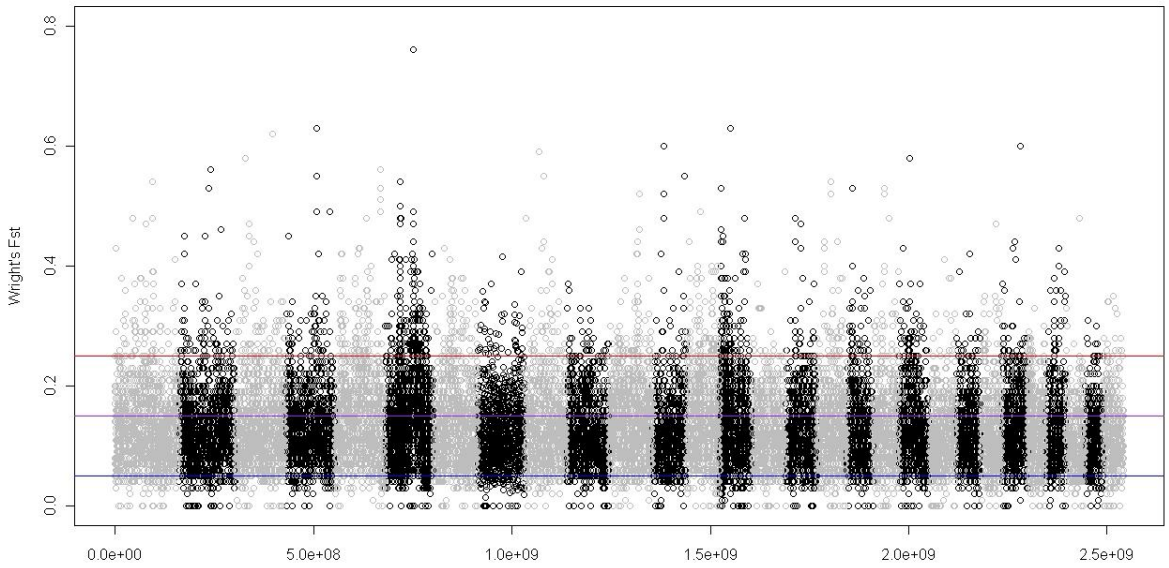

Figure 2. Distribution of F_{ST} values across 29 bovine autosomes. Values for each marker were plotted against the coordinates in Mb from build Btau 4.0 of the bovine genome sequence. Odd numbered chromosomes are presented in gray and even numbered chromosomes are black. Horizontal lines indicate F_{ST} thresholds of 0.05, 0.15 and 0.25 that are commonly used for qualitative interpretation of Wright's fixation index. Very high values of F_{ST} are suggestive of divergent selection and very low values are suggestive of balancing selection.

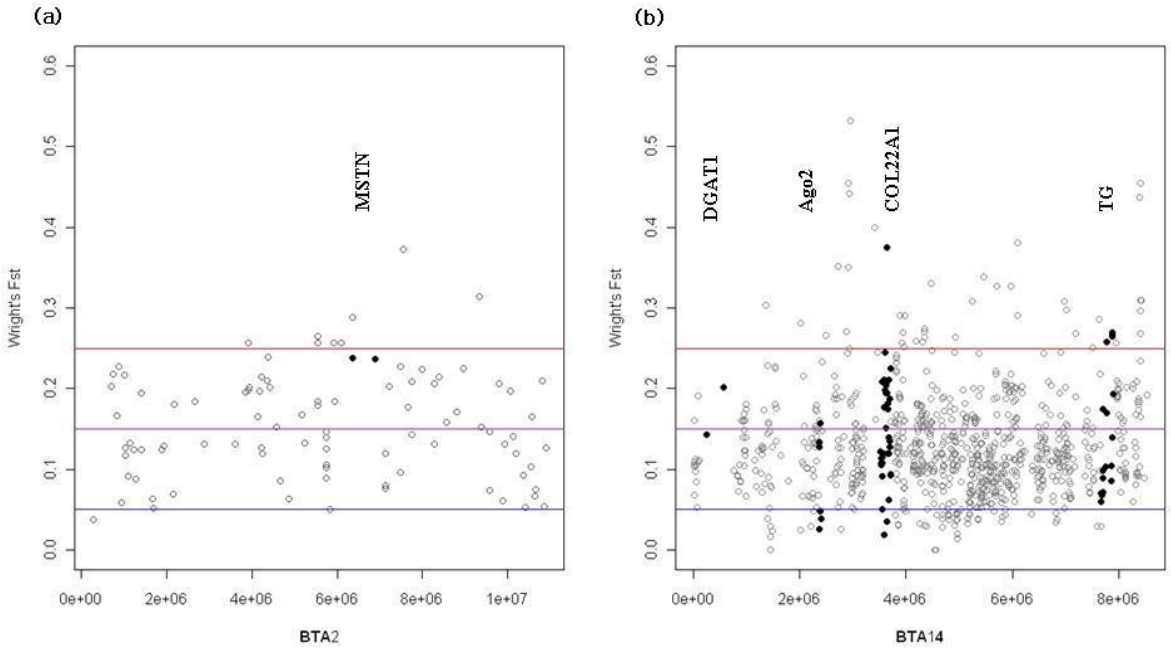

Figure 3. Distribution of F_{ST} values in regions known to be under positive selection. (a) Proximal region of BTA2 that includes the gene for myostatin. (b) Proximal region of BTA14 that includes the genes encoding diacylglycerol O-acyltransferase 1, thyroglobulin, eukaryotic translation initiation factor 2C, 2 and collagen, type XXII, alpha 1. Single nucleotide polymorphisms that flank or fall within the named genes are shown in black.

ECONOMICS

ECONOMICS OF OPERATING A WATER TRUCK SYSTEM IN A CATTLE FEEDLOT

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Summary

Concentrated cattle feeding operations in the Texas Panhandle generate dust emissions due to the region's semi-arid conditions. An economic analysis was conducted on the use of a water truck system(s) to control dust. Investment costs were $171,656 for a 10,000-head feedlot operating one truck, $343,312 for a 30,000-head lot with two trucks, and $514,968 for a 50,000-head feedlot with three trucks. Annualized fixed costs were $22,173 or $2.22 per head capacity, $44,346 or $1.48 per head capacity, and $66,519 or $1.33 per head capacity for the three-sized feedlots, respectively. Operational costs were $16,813 or $1.68 per head capacity, $47,938 or $1.60 per head capacity, and $79,063 or $1.58 per head capacity for the feedlots, respectively. A sensitivity analysis of diesel fuel prices was conducted varying prices from $1.50 to $4.50 per gallon. Each $0.50 increase in diesel fuel price added $0.14 per head operational cost in the three-sized feedlots.

Introduction

An integrated approach to feedlot pen maintenance and manure management is necessary for effective dust suppression. Routine manure harvesting/collecting methods, vegetative barriers, increasing stocking rates and water application to pen surfaces, roads and service areas are methods commonly practiced. Water application is typically done using a traveling gun, solid-set sprinkler and water-truck system(s).

This study focused on maintaining pen surface moisture for dust control between 25% and 40% with a water truck system(s). The investment of a water truck was previously investigated in 2007 (Amosson et al, 2007); however, over the past two years, new governmental air emission regulations required equipment modifications and have resulted in at least a 10% increase in the water truck system(s) cost. Thus, it was necessary to revisit this control method to determine its current economic viability. Some costs decreased while others increased during this time.

Experimental Procedures

Fixed, operational and total costs were projected for a year 2010 model truck equipped with a 4,000-gallon tank capable of transporting and applying one-eighth inch of water depth to the pen surface to suppress dust for the 10,000, 30,000 and 50,000-head feedlots. Fixed costs were comprised of a one-water truck system in a 10,000-head feedlot, two trucks with a 30,000-head lot and three trucks for a 50,000-head feedlot.

The straight-line method of depreciation was used assuming a 25-year useful life for the truck with a salvage value of $10,000, and a 15-year useful life for the water tank with no assumed salvage value. Capital expenditure projections were provided by industry personnel with a six percent discount rate used to estimate cost streams in current dollars. Using industry averages, the insurance premium increased three-fold to $478 per year, as compared to the prior evaluation. Truck tax, title and license were not charged because this equipment is not typically operated on public highways; however, a one-time $29 registration fee was assessed (Bledsoe, 2009).

Components of operational costs included maintenance and repairs, labor, truck fuel cost and pumping cost. Maintenance and repairs using industry averages were estimated at $2,500 per truck. In the Texas Panhandle, a water truck system(s) is typically operated six months of the year to control emissions, April 15 to October 15, or 184 days (Auvermann, 2009). Labor costs were assumed at $10.70 per hour based on the U.S. Farm Wage Rate: Quarterly Data (NASS, 2009). A diesel fuel rate of $1.98 per gallon was used for operating the water truck system(s). Energy costs were the expenditures required to pump the water and were determined utilizing the following formulas:

KW = (.746 * Motor Horsepower)/90% motor efficiency

Where: KW = # of kilowatt. Hours per hour

Total Energy Cost = KW * electricity cost * hours per year operated

Electricity costs in 2009 were $0.08 per Kwh, based on industry input.

It was assumed an irrigation well was available with a sufficient capacity to fill the 4,000-gallon water tank; therefore, expenditures do not include the installation or depreciation of a new well to pump groundwater. Also,

there were no costs included for the installation of an irrigation reservoir.

Cost estimates were calculated on a per head capacity and a per head marketed basis. This action was accomplished by utilizing the 1996 – 2000 Southwestern Public Service Company Fed Cattle Survey to determine the five-year average cattle turnover rate for the three-sized feedlots. A sensitivity analysis was conducted using three annual turnover rates (1.75, 2.00 and 2.25) to enhance the applicability of results to feedlots.

Following labor costs, diesel fuel price was the second most costly operational cost variable. A sensitivity analysis was conducted on diesel fuel prices to determine the effect changing prices had on feedlot operational costs in dollars per head for the three-capacity feedlots. Seven diesel fuel prices were used that varied from $1.50 to $4.50 per gallon.

Results and Discussion

The purpose of this study was to determine the initial investment, fixed, operational and total costs of a water truck system(s). The findings are discussed in the following section.

Investment Costs

Updated total cost of a 4,000-gallon water truck dust control system was $171,656. Of that amount, $137,189 was for the truck (2010 price) and $34,467 was for the water tank. Investment costs were $17.17 (one truck) per head capacity for a 10,000-head feedlot. Two trucks utilized in a 30,000-head lot cost $343,312, or $11.44 per head capacity. Three trucks operated in a 50,000-head feedlot cost $514,968, or $10.30 per head capacity (Table 1).

Fixed Costs

Annualized investment cost, depreciation, interest, insurance and registration fee constituted the total fixed costs. In a 10,000-head feedlot, annualized fixed costs totaled $22,173, or $2.22 on a per head capacity basis. A 30,000-head feedlot's annualized fixed costs were projected at $44,346, or $1.48 per head capacity. Total annualized fixed costs of a 50,000-head feedlot were estimated at $66,519, or $1.33 per head capacity. The straight-line depreciation method was utilized using 25-years useful truck(s) life with an assumed salvage value of $10,000. The useful life for the water tank(s) was 15-years, with no assumed salvage value. Insurance rates for a 2010 water truck system(s) increased three-fold to $478, as compared for the prior analysis. A one-time truck registration fee of $29 was also included (Table 2).

Operational Costs

Operational costs were comprised of the pumping cost to fill the water tank, maintenance and repairs, labor and truck fuel cost. Pumping cost ($0.08 per Kwh) ranged from $1,241 for a 10,000-head lot to $6,207 for a 50,000-head feedlot. Annual maintenance and repairs were projected at $2,500 per truck. Labor cost was the single largest operational expenditure at $7,511, $22,534 and $37,557 for 10,000, 30,000 and 50,000-head capacity feedlots, respectively. At a rate of $1.98 per gallon, one water truck for a 10,000-head lot had annual diesel fuel costs of $5,560, whereas, $27,799 were estimated to operate three trucks in a 50,000-head feedlot (Table 3).

Incorporating all the operating variables resulted in total operational costs of $16,813, or $1.68 per head capacity, utilizing one water truck. Operating two trucks in a 30,000-head lot cost $47,938 or $1.60 per head capacity, a decrease of $0.08 per head. Using three water trucks in a 50,000-head lot, operating costs totaled $79,063, or $1.58 per head capacity, a decrease of $0.10 from a 10,000-head lot. Applying one-eighth inch of water in depth in a 10,000-head feedlot required 54 truck tanks of water and 3.38 eight-hour days. Similarly, a 30,000-head lot required 162 loads and 5.06 days using two trucks. Using three trucks in a 50,000-head lot resulted in 270 loads of water and 5.63 eight hour days to apply one-eighth inch of moisture (Table 3).

Total Costs

To establish total annual cost to operate the water truck system(s) in the three-sized feedlots, projected fixed and operational costs were combined. Annualized fixed costs were $2.22 per head capacity for a 10,000-head feedlot, $1.48 for a 30,000-head lot and $1.33 for a 50,000-head lot. Operational costs varied from $1.68 in a 10,000-head feedlot to $1.58 in a 50,000-head capacity lot. Total costs per head of capacity were $3.90 in a 10,000-head lot, $3.08 in a 30,000-head lot and $2.91 in a 50,000-head lot (Table 4).

Turnover Rates

Three annual turnover rates of 1.75, 2.00, and 2.25 were used to adjust dollars per head capacity to dollars per head marketed. At a turnover rate of 2.25 in a 10,000-head lot, annual fixed costs were $0.99; operational costs were $0.75 and total costs totaled $1.74 per head marketed to operate one water truck system. With a 1.75 turnover rate, total cost per head marketed in a 10,000-head lot was $2.23, a 29% increase. A turnover rate of 2.00 compared to 2.25 in a 30,000-head feedlot changed total costs from $1.54 to $1.37 per head marketed, an 11% decrease. A 2.25 turnover rate resulted in annual fixed costs of $0.59, operational costs of $0.70 and total costs of $1.29 per head marketed to operate three water trucks required in a 50,000-head feedlot (Table 5).

Diesel Fuel Price Variations

A sensitivity analysis was done on diesel fuel prices to determine the effects of changing prices on feedlot operational costs in dollars per head for the three-capacity feedlots. Seven diesel fuel prices varied from $1.50 to $4.50 per gallon. Each $0.50 per gallon increase in diesel fuel price created an additional $0.14 per head operational

cost in all three-sized feedlots. A diesel fuel price of $2.50 per gallon in a 10,000-head capacity feedlot resulted in a cost of $1.78 per head; while, at $3.00 per gallon the cost was $1.92 per head, a difference of $0.14. Operational costs for a 30,000-head feedlot were $1.99 per head at a $3.50 per gallon diesel fuel price and $1.85 for a $3.00 diesel fuel per gallon, the same difference of $0.14 per head (Table 6).

Environmental Quality Incentives Program (EQIP)

The Environmental Quality Incentives Program (EQIP) provides designated cost-share EQIP monies for feedlots to address environmental issues (Sokora, 2009). Guidelines administered by the USDA Natural Resources Conservation Service (NRCS) allow EQIP monies for a solid-set sprinkler, but a water truck system(s) does not quality (Auvermann and Sweeten, 2005).

Implications

An economic analysis was conducted to examine the investment, fixed, and operational costs associated with using a water truck system(s). Investment costs were $171,656, $343,312 and $514,968 for a 10,000, 30,000 and 50,000-head feedlot, respectively. On a per head capacity basis, total annualized fixed costs were $2.22, $1.48, and $1.33, and operational costs were $1.68, $1.60 and $1.58 for the three-sized feedlots. A sensitivity analysis revealed each increase of $0.50 per gallon in diesel fuel price resulted in an additional operational cost of $0.14 per head.

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Table 1. Projected investment costs for a water truck system(s) for 10,000, 30,000 and 50,000-head capacity feedlots.

Cattle Feedlot Capacity, Head	Water Truck, each	Water Tank, each	Number of Water Truck System(s)	Total Water Truck System(s) Cost	Total Water Truck System(s) $/hd Capacity
10,000	$137,189	$34,467	1	$171,656	$17.17
30,000	$137,189	$34,467	2	$343,312	$11.44
50,000	$137,189	$34,467	3	$514,968	$10.30

Table 2. Projected annualized fixed costs for a water truck system(s) using a 25-year useful life for the truck(s) and a 15-year useful life for the water tank(s) in three-sized feedlots.

Cattle Feedlot Capacity, Head	Total Water Truck System(s) Cost	Annualized Fixed Cost	Annual Depreciation	Insurance & Registration	Total Annualized Fixed Cost	Total Annualized Cost $/Hd Capacity
10,000	$171,656	$1 4,281	$7,385	$507	$22,173	$2.22
30,000	$343,312	$28,561	$14,771	$1,014	$44,346	$1.48
50,000	$514,968	$42,842	$22,156	$1,512	$66,519	$1.33

Table 3. Projected annual operational costs for a water truck system(s) in three-sized feedlots.

Cattle Feedlot Capacity, Head	Pumping Cost	Maintenance & Repairs	Labor Cost	Truck Fuel Cost	Total Operational Cost	Total Operational Cost $/Hd Capacity
10,000	$1,241	$2,500	$7,511	$5,560	$16,813	$1.68
30,000	$3,724	$5,000	$22,534	$16,680	$47,938	$1.60
50,000	$6,207	$7,500	$37,557	$27,799	$79,063	$1.58

Table 4. Estimated fixed, operational, and total annual costs for a water truck system(s) in three-sized feedlots.

Cattle Feedlot Capacity, Head	Total Fixed Costs $/Hd Capacity	Total Operational Costs $/Hd Capacity	Total Costs $/Hd Capacity
10,000	$2.22	$1.68	$3.90
30,000	$1.48	$1.60	$3.08
50,000	$1.33	$1.58	$2.91

Table 5. Total annual cost including fixed and operational costs ($/head marketed) for a water truck system(s) based on a 25-year useful life for three-feedlot capacities and turnover rates.

Cattle Feedlot Capacity, Head	Turnover Rate (Hd Marketed/ Hd Capacity)	Total Fixed Cost $/Hd Marketed	Total Operational Cost $/Hd Marketed	Total Cost $/Hd Marketed
10,000	1.75	$1.27	$0.96	$2.23
	2.00	$1.11	$0.84	$1.95
	2.25	$0.99	$0.75	$1.74
30,000	1.75	$0.84	$0.91	$1.75
	2.00	$0.74	$0.80	$1.54
	2.25	$0.66	$0.71	$1.37
50,000	1.75	$0.76	$0.90	$1.66
	2.00	$0.67	$0.79	$1.46
	2.25	$0.59	$0.70	$1.29

Table 6. Feedlot operational costs in dollars per head capacity at seven different diesel fuel prices varying from $1.50 to $4.50 per gallon.

Cattle Feedlot Capacity, Head	Price per gallon						
	$1.50	$2.00	$2.50	$3.00	$3.50	$4.00	$4.50
10,000	$1.68	$1.64	$1.78	$1.92	$2.06	$2.20	$2.34
30,000	$1.60	$1.57	$1.71	$1.85	$1.99	$2.13	$2.27
50,000	$1.58	$1.56	$1.70	$1.84	$1.98	$2.12	$2.26

A COMPARISON OF HISTORIC KING RANCH CATTLE MARKETING METHODS TO RETAINED OWNERSHIP

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Summary

For many years, King Ranch, Kingsville, Texas, has used a production and marketing plan consisting of selling their raised calves, stockering purchased cattle as pasture conditions permitted, and using their feedlot to primarily finish purchased cattle. This plan is based upon advantages gained from two distinct business principles; arbitrage and asset turnover ratio. Historic production and financial records of the cow-calf, stocker, and feedlot enterprises of King Ranch, for the years 2001through 2008, were analyzed. Annual and cumulative profit and loss on a per head basis were calculated. For comparisons sake, a retained ownership scenario was mimicked using the accumulated costs and returns from representative cattle of ranch origin retained through the stocker and finishing phase. When compared to retained ownership, the historic production and marketing plan resulted in greater ($P < 0.01$) per head annual ($300 versus $8) and cumulative ($2400 versus $62) net income.

Introduction

Retained ownership of calves through the beef supply chain has been widely promoted as an alternative marketing plan. Advantages include the ability to capture the investment in breeding, genetics, herd health, and nutrition (Gebremeskel and Shumway, 1979; Lambert, 1989; Schroeder and Featherstone, 1990; Busby and Kuhl, 2000; White et al, 2007). However, other alternative production and marketing opportunities exist. The use of arbitrage, the simultaneous buying and selling of the same commodity in different markets in order to profit from price discrepancies is one (Merriam-Webster, 2007). A second is increased asset turnover ratio, which is defined as the amount of sales generated for every dollar's worth of assets and is calculated by dividing sales in dollars by assets in dollars (Farm Financial Standards Council, 2008). King Ranch has successfully used these two business principles in combination for the past eight years in the production and marketing of their cow-calf, stocker, and feedlot enterprises. The objective of this study was to compare and contrast the historic annual and overall profitability of King Ranch's current production and marketing plan to retained ownership.

Experimental Procedures

King Ranch Production and Marketing

King Ranch operates an 825,000 acre ranch in South Texas with three distinct cattle enterprises; cow-calf, stocker, and a feedlot. It is the third largest cow-calf operation in the United States (NCBA, 2009) calving approximately 25,000 head of mother cows in two calving seasons (Payne et al., 2009). The number of stocker cattle the ranch runs in any given year varies greatly with price and pasture condition. During the eight years of this study, the number of stockers ranged from zero in 2002, to 14,250 in 2003. The King Ranch feedlot has a onetime capacity of 16,000 head. A normal mix of cattle in the feedlot consists of approximately 65% purchased feeders, 20% custom fed cattle, and 15% home raised cattle.

Most of the ranch raised calves are sold in large lots following a backgrounding period. The dual calving season employed allows calves to be marketed seasonally each year. Because of the overall uniformity of the ranch raised calves, large number available, and process verification, prices received are above market averages. The stockers are sourced from Texas and the Gulf Coast region and purchased in small lots for prices substantially below the market. They are both steers and bulls, typically a variety of colors and breeds, and range in weight from 450 to 550 pounds. Upon arrival, these cattle are vaccinated, and dehorned and castrated if necessary. Before summer of the following year, the stockers are sorted for size and type into large drafts and sold at approximately 750 pounds at prices par with market. Because of their heat tolerance, the feedlot purchases cattle of primarily Brahman influence at prices below the market; however, approximately 15% of ranch raised calves are also retained and fed for data collection purposes. Fed cattle are sold weighing 1,100 to 1,200 pounds. The feedlot cattle are contracted in the beef at approximately $1.00 per cwt. less than the prices received for fed cattle in the Texas Panhandle.

Data Collection and Analysis

King Ranch annual financial statements and production records for the years 2001 to 2008 were analyzed. Records from each enterprise on a per head basis included; production costs, revenue received for ranch raised fed cattle, and profit or loss. All figures in the financial statements were calculated and reported according to Generally Accepted Accounting Principles.

Two marketing strategies were compared using three enterprises for the years 2001 through 2008. In this study, *Status Quo* refers to the primary marketing method King Ranch used during this time period. *Retained Ownership* refers to an alternative scenario of retaining

ranch raised weaned calves through a stocker and feedlot finishing period.

Pre-tax profit or loss during each fiscal year for *Status Quo* was calculated by summing the average profit or loss from selling a single weaned calf, stocker, and finished animal during the period. Pre-tax annual profit or loss for each fiscal year for *Retained Ownership* was calculated by summing the average costs for the period of weaning a calf, running a stocker, and finishing an animal in the feedlot; then subtracting that total from the average revenue for a ranch raised fed animal during the same fiscal year. Gains or losses from risk management strategies employed during these years were not included in the determination of profit or loss. A mean comparison was conducted using a paired student ***t***-Test.

Results and Discussion

Results of these analysis show that King Ranch had greater average annual and cumulative profits ($P < 0.01$) using the production and marketing program that they have had in place for the last eight years, than if it had retained ownership of their raised calves through the stocker and feedlot phase (Table 1).

Creating, Finding, and Taking Advantage of Value Discrepancies

The historic development of the cattle industry included individuals and businesses who strategically took advantage of price discrepancies due to differences in cattle quality and quantity, location, demand, and timing (Ball, 1998). Price discrepancies due to these factors are evident in all commodity markets. By utilizing its three cattle enterprises, King Ranch has flexibility in both the production and marketing aspects of its business to create, find, and take advantage of value discrepancies in the cattle market in order to increase their overall profitability. In other words, they actively use the principles of arbitrage. Their system also allows them to take advantage of additional opportunities found in areas such as: compensatory gain, environmentally adapted cattle, multiple calving seasons, their management expertise, economies of scale, forage availability, and perhaps most importantly, their brand name and associated reputation.

King Ranch's choice to calve twice a year allows them to sell their raised calves into two different markets. These calves are sold in large numbers, and are uniform in multiple ways. These include: genetically, color, size and weight, health status, and process. As a result, cattle feeders have been willing to pay market premiums for the King Ranch calves.

When King Ranch buys stocker cattle, it does so only when both the market and pasture conditions on the ranch are favorable. They buy large volumes of calves that are from a similar region, mixed color and breed, of uncertain health and vaccination status, may be bulls, may have horns, and are in small lots. These types of cattle are discounted heavily in the marketplace, which puts King Ranch in a position to take advantage of value discrepancies. Another discount faced by the sellers of these calves is the basis difference due to geographical location with respect to central markets, which in south Texas, runs between $5.00 and $10.00 per cwt for 500 pound calves. Using their production expertise and facilities, King Ranch is able to create value by improving the status of the cattle's health and nutrition. These cattle also provide King Ranch an excellent opportunity to garner the benefits of compensatory gain. At time of sale, cattle are sold in large, uniform lots, which increases their value in the marketplace. In addition, basis differences narrow to between $3.00 and $5.00 per cwt., allowing King Ranch to harvest the accumulated value they have created and capture the discrepancy between the original discounted purchase price and average market price on the original weight of the animal. In summary, for a variety of reasons, stockers can be purchased at relatively low prices, have the potential for inexpensive gains, and can be sold at prices par with the market.

The King Ranch feedlot is also positioned to take advantage of comparable scenarios. They are able to fill their yard with cattle at prices well below the market, increase the cattle's value through management, capture production variables like compensatory gain, and sell them in the beef for $1.00 less than prices received in the Texas Panhandle. At time of purchase, these cattle consistently grade a #2 on the USDA Feeder Cattle Grading System (USDA, 2000), but when finished, sell par with the market. Selling the cattle in the beef also narrows the basis penalty to zero.

Asset Turnover Ratio

Generally speaking, businesses with low profit margins tend to have high asset turnover ratios and businesses with high profit margins have low asset turnover ratios. In contrast, many cattle businesses have both low profit margins and low asset turnover ratios. This is due to their relatively high levels of investment, low prices for their commodities, and long production cycles. Since profit margins in commodity businesses can be difficult to change, one strategy to increase total profits is to increase the asset turnover ratio of an agricultural business (Hoekema, 1999). For example, if a business has a 3% profit margin and sells once a year, it will make $0.03 on every dollar it has invested in its business. However, if it is able to maintain that same margin and sell three times each year, it will accumulate $0.09 on every dollar it has invested in its business. King Ranch has utilized this principle by having multiple enterprises and calving seasons, which increase the frequency of its sales into more markets, while leaving its asset base unchanged. The result is that they have an increased asset turnover ratio compared to a production or marketing programs with fewer enterprises that sell less frequently.

Retained Ownership

While retaining ownership of a calf crop through the finishing phase has well documented advantages (Gebremeskel and Shumway, 1979; Lambert, 1989; Schroeder and Featherstone, 1990; Busby and Kuhl, 2000; White et al, 2007), it also has hidden opportunity costs. By choosing to retain ownership of its calf crop, a cattle business is basically choosing to interact with the market a single time at commodity prices for each calf crop. While this decision has the potential to take advantage of investments in genetics and herd health through performance and carcass traits, when compared to the choice to have separate enterprises of cow-calf, stocker, and finishing, it results in forgoing many opportunities. These may include: selling calves at premium prices, buying replacement cattle at prices below the market, taking advantage of compensatory gain, and fully utilizing facilities and skills. Also, by comparison, it would have a lower asset turnover ratio. Retained ownership may carry additional risk, as it decreases flexibility in the marketplace.

Summary

Strategically using arbitrage and increasing asset turnover ratio, King Ranch has been able to improve its profitability when compared to retaining ownership of its calf crop through the finishing phase. Arbitrage allows the King Ranch to fully utilize all of the value nuances in the cattle market to its advantage. In addition, increasing asset turnover ratio is a way for King Ranch to take a relatively low profit margin and create additional wealth by cycling it more frequently.

Implications

Alternative production and marketing opportunities exist for cattlemen. Arbitrage occurs throughout all segments of the modern cattle industry, but is not commonly discussed as a marketing alternative. However, its use has potential to increase profitability for cattle businesses which historically have high levels of investment and receive relatively low prices for their commodities. As a result, and in combination with their relatively long production schedules, many cattle businesses have low profit margins and low asset turnover ratios. Increased asset turnover ratio can be achieved by including multiple enterprises in a business model and by choosing enterprises that accelerate rather than slow asset turnover. Strategically using these business principles in combination can improve profitability.

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Table 1. Annual profit or loss per head for King Ranch status quo production and marketing system and a retained ownership scenario using historic data.

	Profit or Loss ($/head)	
Year	Status Quo	Retained Ownership
2001	311	33
2002	147	79
2003	424	32
2004	487	96
2005	340	22
2006	172	-34
2007	360	-12
2008	156	-154
Summary Statistics		
Mean Profit	300[a]	8[b]
Range	147-487	-154-96
Std Dev	129	78
Cumulative Profit	2397[a]	62[b]

[a,b] Means within the same row with different superscripts differ ($P < 0.01$).

ECONOMIC ANALYSIS OF MANURE HARVESTING EQUIPMENT IN FEEDYARDS FOR DUST CONTROL

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Summary

Feeding such large quantities of cattle produces large amount of manure. One of the purposes of manure management is dust suppression which becomes a greater issue. Texas AgriLIFE Research and Texas AgriLIFE Extension personnel developed, compiled and analyzed a two-page written survey that was reviewed by agricultural engineers. Survey data were utilized to determine the most frequently used manure harvesting equipment. Results showed that larger yards tended to own and operate the manure harvesting equipment themselves. Only 23% and 21% of medium and large capacity feedyards, respectively, owned and operated an elevating scraper possibly due to its high cost. Larger feedyards tended to hire contractors more frequently, and did so, 71% of the time. Medium-sized feedyards used manure contractors, 39% of the time, and smaller yards, 36%.

Introduction

Intensive cattle feeding operations are a major economic simulator in much of the United States. In fact, Texas Cattle Feeders Association (TCFA) member feedyards in Texas, Oklahoma and New Mexico produce 7 million fed cattle in 2007, or 30 % of the nation's fed cattle production. However, feeding such large quantities of cattle produces large amount of manure. Manure contributes to atmospheric emissions, such as dust (particulate matter), hydrogen sulfide, ammonia and volatile organic compounds. One of the purposes of manure management is dust suppression which becomes a greater issue as manure depth increase (Auvermann, 2006). This study concentrated on one method of dust control which is manure harvesting equipment. Examples of implements included: tractor-pulled box scraper, front-end loader, dump truck, spreader truck, elevating scraper and tractor-pulled end-dump.

Experimental Procedures

Texas AgriLIFE Research and Texas AgriLIFE Extension personnel developed, compiled and analyzed a two-page written survey that was reviewed by agricultural engineers. The survey was administered by TCFA personnel to 41 member feedyards during the first quarter of 2008. Major components of the survey focused on the manure harvesting equipment owned/operated by the feedyard and those manure collecting operations that were done by manure contractors. To determine similarities and differences between operations, categorization of feedyards was based on the number of head fed as follows: 1) less than 10,000 head capacity, 2) 10,001 to 39,999 head capacity, and 3) 40,000 or more head capacity. Survey data were utilized to determine the most frequently used manure harvesting equipment including: front-end loader, dump truck, spreader truck, elevating scraper and tractor trailer end-dump. After the most commonly used implements were identified, an economic analysis on an hourly basis was performed (see Table 1).

Six representative manufacturers in the Texas High Plains, South Plains, Dallas/Fort Worth, New Mexico and Oklahoma regions provided purchase price, salvage value, remaining value, useful life in years and normal life in hours of operation for 2010 implement models. Hourly fixed costs for interest, depreciation, insurance, registration and taxes were established. A six percent discount rate was used to estimate cost streams in current dollars. Depreciation was determined using the straight line-method with differing salvage values, dependent on the equipment. Insurance, registration and taxes were calculated at one percent of the purchase price.

Hourly components of operational costs include labor, fuel, maintenance and repairs (M&R) and lubrication. Operator labor costs were assumed to be $10.70 per hour, based on the U.S. Farm Wage Rate: Quarterly Data (NASS, 2009). Actual hours of labor exceeded machine time by 10%, because it included travel and time required to lubricate and service the equipment. Consequently, labor costs were estimated by multiplying the labor wage rate of $10.70 times 1.10, to establish $11.77 for the hourly labor cost. Current diesel fuel price was averaged at $1.98 per gallon based on information collected from three distributors. Average fuel consumption (in gallons per hour) was provided by industry representatives and differed by equipment. Several manufacturers described M&R and lubrication as important expenditures because these help to prevent wear and tear and possibly extend the useful life of the equipment. Annual M&R costs were provided by manufacturers and varied by equipment. Lubrication expenditures were estimated at 15% of the diesel fuel cost. Tire replacement was a large expenditure, dependent on individual machinery, and was not included in this analysis because it varied widely by source.

Total hourly fixed and operational data were combined to arrive at a total hourly cost for each implement including:

the tractor-pulled box scraper, front-end loader, dump truck, spreader truck, elevating scraper and tractor trailer end-dump for feedyard dust control. The results of the feedyard manager surveys were compared with the calculated total hourly cost of the most frequently operated manure harvesting equipment to determine if a correlation existed between equipment operations.

Results and Discussion

The tractor-pulled box scraper was used 50%, 69% and 93% of the time by small, medium and large feedyard sizes, respectively. Larger yards tended to own and operate the manure harvesting equipment themselves. For example, 100% of the large feedyards surveyed owned a front-end loader and 93% operated their own tractor-pulled box scraper. Medium-size yards were also inclined to own manure harvesting equipment, but not to the degree of the larger feedyards. Only 23% and 21% of medium and large capacity feedyards, respectively, owned and operated an elevating scraper possibly due to its high cost. Across all 41 feedyards surveyed, the prominent implements owned by feedyards were the tractor-pulled box scraper, front-end loader and dump truck at 71%, 68% and 61%, respectively.

Manure harvesting from pens was done either by a contractor, or a feedyard, or by a combination of both. Larger feedyards tended to hire contractors more frequently, and did so, 71% of the time. Medium-sized feedyards used manure contractors, 39% of the time, and smaller yards, 36%. Of the 41feedyards surveyed, less than 10% harvested manure by a combination of feedyard personnel and manure contractors. The percentage of manure harvesting done by feedyards themselves, by hired contractor, or by feedyard/contractor combination for the three feedyard size categories is located in Table 2.

The elevating scraper was by far the most costly implement at $311,000. The least costly machinery was the box scraper alone at $7,000 with no salvage value at the end of seven years of useful life due to wear and tear. The tractor to pull the box scraper was $70,000 with $10,000 of salvage value after a useful life of ten years. The purchase price of the front-end loader and spreader truck were projected at $170,000 each. Purchase price, salvage value, projected useful life and normal life of each equipment item are found in Table 3.

Interest, depreciation, insurance, registration and taxes constituted the total hourly fixed costs for 2010 model manure harvesting equipment and are located in Table 4. Because of the initial capital expenditure for the elevating scraper, this implement had the largest hourly fixed costs of $2.26 of all equipment. Combining the hourly fixed cost of the box scraper at $0.45 and the tractor at $0.82, established a total hourly fixed cost of $1.27 for the unit. Even though the purchase price of the front-end loader and spreader truck were the same at $170,000, their hourly fixed costs were $1.49 and $1.97, respectively. This difference is due to the useful life of 15 years for the front-end loader and 10 years for the spreader truck.

Operator labor, fuel, maintenance and repairs, and lubrication comprised the hourly operational costs for the manure harvesting equipment. Hourly diesel fuel ($1.98 per gallon) consumption costs ranged from $3.76 for the tractor-pulled box scraper unit to $29.70 for the tractor-trailer end dump. The tractor-trailer end dump had the highest fuel consumption rate at 15 gallons per hour, causing the hourly fuel costs to be $29.70, compared to $19.80 for the dump truck and $6.14 for the front-end loader. Hourly fuel cost for the spreader truck was $15.84 (Table 5).

Hourly labor cost was $11.77, and was the same for all implements. Annual M&R costs were provided by manufacturers and varied by equipment, and ranged from $1.05 per hour for the box scraper alone to $5.00 per hour for the elevating scraper and tractor-trailer end-dump. Lubrication expenditures were derived at 15% of the fuel cost and ranged from $0.66 per hour for the tractor pulled box scraper as a unit to $4.46 per hour operating the tractor-trailer end dump. The tractor trailer end-dump had the highest lubrication expense because this implement travels predominately on public roads at 15 per gallons per hour and had the longest normal life at 30,000 hours. Even though the box scraper does not have an hourly fuel rate, the equipment still requires lubrication and was estimated at $0.10 per hour, according to industry standards. Combined hourly operational costs for the tractor-pulled box scraper were $30.26, since the two are considered one unit. Total hourly operational costs ranged from $20.71 for the front-end loader to $50.93 for the tractor-trailer end dump (Table 6).

Fixed and operational costs were combined to establish total costs per hour to own and operate the manure harvesting equipment. Total operating costs were greater than the fixed costs due to two factors: 1) operating labor at $11.77 per hour, and 2) fuel cost at $1.98 per gallon in association with the hourly fuel consumption of individual equipment. The most frequently utilized manure harvesting implements identified in the feedyard manager survey (see Table 1) operating simultaneously, tractor-pulled box scraper, front-end loader and dump truck, had a combined hourly cost of $89.89 (see Table 7). Across the 41 feedyards surveyed, 71%, 68% and 41% of the feedyards surveyed owned/operated a tractor-pulled box scraper, a front-end loader and a dump truck, respectively. 41% owned a tractor-trailer end dump for which fixed and operating costs totaled $51.54 per hour over the 41 feedyards. At a total hourly cost of $31.32, only 15% owned/operated an elevating scraper.

Government Assistance Program

The Environmental Quality Incentive Program (EQIP) provides financial and technical assistance to agricultural producers who apply conservation practices on their land.

There are three major Atmospheric Resource Quality Management (ARQM) Schedules within EQIP which a feedyard may participate. Schedule 1 requires one manure harvesting and one manure cleanout per year. When satisfactorily accomplished, the feedyard will receive government cost share payments of $165 to $330 per pen acre per year for a maximum of three years (Table 8). Schedules 1 and 2 were implemented with different manure harvesting dates to provide flexibility because some yards collect manure before or during the summer months (Schedule 1), while others, clean pens before the fall (Schedule 2). EQIP is a viable method to supplement manure harvesting costs if the feedyard is willing to adhere to the guidelines set forth in the Manure Harvesting (Sokora, 2009).

Implication

The tractor-pulled box scraper was used 50%, 69% and 93% of the time by small, medium and large feedyard sizes, respectively. Larger yards tended to own and operate the manure harvesting equipment themselves. Only 23% and 21% of medium and large capacity feedyards, respectively, owned and operated an elevating scraper possibly due to its high cost. Larger feedyards tended to hire contractors more frequently, and did so, 71% of the time. Medium-sized feedyards used manure contractors, 39% of the time, and smaller yards, 36%. Participating in EQIP can help in defraying some of these expenses.

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Table 1. Percentage of manure harvesting equipment owned/operated by the 41 feedyard managers surveyed for three sizes of feedyards - June 2008

Equipment Item	Less than 10,000 Head Capacity	10,001 to 39,999 Head Capacity	40,000 or More Head Capacity	Across 41 Feedyards Surveyed
	Percent of feedyards using manure harvesting equipment			
Tractor-pulled box scraper	50	69	93	71
Front-end loader	50	54	100	68
Dump truck	50	85	50	61
Spreader truck	35	39	64	46
Elevating scraper	0	23	21	15
Tractor-trailer end dump truck	14	39	64	41

Table 2. Percentage of feedyard manure harvesting done by the feedyard, contractor or combination of a feedyard/contractor in three sizes of feedyards - June 2008.

Manure Harvested By:	Less than 10,000 Head Capacity	10,001 to 39,999 Head Capacity	40,000 or More Head Capacity	Across 41 Feedyards Surveyed
	Percent of feedyards hiring a manure contractor			
Feedyard	58	54	29	46
Contractor	36	39	71	49
Combination Feedyard/Contractor	7	8	0	5

Table 3. Purchase price, salvage value, remaining value, projected useful life in years and normal life in hours for manure harvesting equipment - June 2008.

Equipment Item	Purchase Price	Salvage Value	Remaining Value	Projected Useful Life (years)	Normal Life (hours)
Box scraper	$7,000	$0.00	$0.00	7	5,000
Tractor	$70,000	$10,000	$60,000	10	20,000
Front-end loader	$170,000	$15,000	$155,000	15	20,000
Dump truck	$75,000	$1,500	$73,500	25	20,000
Spreader truck	$170,000	$25,000	$145,000	10	20,000
Elevating Scraper	$311,000	$15,000	$296,000	20	20,000
Tractor-trailer end dump	$145,000	$13,500	$131,500	25	30,000

Table 4. Purchase price, hourly annualized fixed cost, depreciation, insurance, registration and taxes, where applicable, for manure harvesting equipment - June 2008.

Equipment Item	Purchase Price	Hourly Annualized Fixed Cost	Hourly Depreciation	Hourly Insurance, Registration and Taxes	Total Hourly Fixed Cost
Box scraper	$7,000 $	0.25	$0.19	$0.01	$0.45
Tractor	$70,000	$0.48	$0.30	$0.04	$0.82
Front-end loader	$170,000	$0.88	$0.52	$0.09	$1.49
Dump truck	$75,000	$0.29	$0.15	$0.04	$0.48
Spreader truck	$170,000	$1.15	$0.73	$0.09	$1.97
Elevating scraper	$311,000	$1.36	$0.74	$0.16	$2.26
Tractor-trailer end dump	$145,000	$0.38	$0.18	$0.05	$0.61

Table 5. Diesel fuel consumption and hourly diesel fuel cost for manure harvesting equipment - June 2008.

Equipment Item	Diesel Fuel Consumption per Hour	Diesel Fuel Cost per Gallon	Total Hourly Diesel Fuel Cost
Box scraper	0.00	$1.98 $	0.00
Tractor	1. 90	$1.98	$3.76
Front-end loader	3.10	$1.98	$6.14
Dump truck	10.00	$1.98	$19.80
Spreader truck	8.00	$1.98	$15.84
Elevating scraper	5.40	$1.98	$10.69
Tractor-trailer end dump	15.00	$1.98	$29.70

Table 6. Hourly operational costs for labor, fuel, maintenance and repairs, and lubrication for manure harvesting equipment - June 2008.

Equipment Type	Hourly Labor Cost	Hourly Fuel Cost (gal/hr)	Hourly Maintenance and Repairs Cost	Hourly Lubrication Cost	Total Hourly Operational Cost
Box scraper	$11.77	$0.00	$1.05	$0.10	$12.92
Tractor	$11.77	$3.76	$1.25	$0.56	$17.34
Front-end loader	$11.77	$6.14	$1.88	$0.92	$20.71
Dump truck	$11.77	$19.80	$4.38	$2.97	$38.92
Spreader truck	$11.77	$15.84	$2.00	$2.38	$31.99
Elevating scraper	$11.77	$10.69	$5.00	$1.60	$29.06
Tractor-trailer end dump	$11.77	$29.70	$5.00	$4.46	$50.93

Table 7. Hourly fixed, operational and total costs for manure harvesting equipment – June 2008.

Equipment Item	Total Hourly Fixed Cost	Total Hourly Operational Cost	Total Hourly Cost
Box scraper	$0.45	$12.92	$13.37
Tractor	$0.82	$17.34	$18.16
Front-end loader	$1.49	$20.71	$22.20
Dump truck	$0.48	$38.92	$39.40
Spreader truck	$1.97	$31.99	$33.96
Elevating scraper	$2.26	$29.06	$31.32
Tractor-trailer end dump	$0.61	$50.93	$51.54

Table 8. Texas natural resources conservation service (NRCS) 2009 environmental quality incentive program (EQIP) and atmospheric resource quality management (ARQM) schedules for manure harvesting and manure cleanout and corresponding cost-share payments- June 2009

ARQM* Schedule	Manure Harvest	Manure Cleanout	Payment Received
ARQM Manure Harvest Schedule 1	1 manure harvest of all pens between March 1 to May 31 time period	1 manure cleanout between November to February time frame	$165 per pen acre (maximum 3 yrs)
ARQM Manure Harvest Schedule 2	1 manure harvest of all pens between June 1 to September 30 time period	1 manure cleanout between November to February time frame	$165 per pen acre (maximum 3 yrs)
ARQM Manure Harvest Schedule 3	2 manure harvests of all pens between March 1 to May 31 & June 1 to September 31 time period	1 manure cleanout between November to February time frame	$330 per pen acre (maximum 3 yrs)

HEALTH

PRELIMINARY INVESTIGATION OF THE ASSOCIATION BETWEEN FEEDING ETHANOL CO-PRODUCTS AND PREVALENCE OF *SALMONELLA ENTERICA* IN COMMERCIAL FEEDLOTS

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Summary

Prevalence of *Salmonella enterica* in feedlot cattle varies and may be influenced by factors affecting hindgut and environmental ecology. The objective of this study was to estimate the association between feeding wet corn distillers grains (WDG) and fecal shedding of *Salmonella enterica* in feedlot cattle. Six feedlots were selected for sampling and feces was collected from 10 fecal pats within each of 6 pens in each feedlot. Samples were evaluated for *Salmonella enterica* using routine microbiological methods. Feedlots with WDG in the ration had a prevalence of 15% and feedlots not using WDG had a prevalence of 51%. The odds of identifying *Salmonella enterica* in feedlots not feeding WDG were not significantly different (P = 0.21) than feedlots with WDG in the ration. The results of this preliminary investigation indicate that feeding WDG does not have a significant effect on *Salmonella enterica* shedding in feedlot cattle.

Introduction

The feeding of ethanol co-products including wet corn distillers grains (WDG) may affect the prevalence of food safety pathogens in the feces of feedlot cattle due to differences in composition relative to conventional diets. Varying nutrient constituents may alter microbial ecology in the hindgut favoring persistence of specific microbes. There is limited evidence suggesting that the prevalence of some food safety pathogens may be affected by feeding distillers grains under experimental conditions (Jacob et al., 2008a; Jacob et al., 2008b; Jacob et al., 2008c; Jacob et al., 2009). Fecal shedding of *Salmonella enterica* and other food safety pathogens prior to harvest increases the risk of contamination of beef products (Dewell et al., 2008). The organism can be cultured from 4 to 6% of fecal samples collected from U.S. feedlots, but substantial correlation exists within pen and within feedlot (Callaway et al., 2006; Dargatz et al., 2003). The objective of this study was to estimate the association between feeding WDG and fecal shedding of *Salmonella enterica* in commercial feedlots.

Experimental Procedures

Six feedlots in the Texas Panhandle were selected for sampling based on the presence of WDG in the ration at the time of collection (n=3 with WDG; n=3 without WDG). Within each feedlot, 10 freshly voided fecal samples were collected from the pen surface in each of 6 randomly selected pens. Within pens, fecal pats were not randomly selected for sampling, but effort was made to sample throughout the pen and avoid sampling of adjacent fecal pats. Samples were placed on ice and shipped to College Station, TX for processing. One g of feces was inoculated into separate tubes of buffered peptone water and tetrathionate broth and swabbed onto XLT4 and MacConkey's agar plates. One mL of the buffered peptone water was transferred to Rappaport-Vassiliadis (RV) broth and the buffered peptone water was held overnight at 4° C for subsequent determination of the Most Probable Number (MPN) of organisms present in positive samples; the tetrathionate and RV broths were incubated 24 hr at 37° C. After incubation, the tetrathionate and RV broths were swabbed onto XLT4 and MacConkey agar plates which were incubated an additional 24 hr at 37° C. Characteristic colonies from any of the 4 plates were subjected to biochemical testing to confirm the isolate as *Salmonella* spp. Isolates confirmed as *Salmonella* spp. were submitted to the National Veterinary Services Laboratory (NVSL) in Ames, IA for serotyping. Descriptive statistics were generated for the proportion of samples from which *Salmonella enterica* was isolated, adjusted for correlation within feedlots. The odds of identifying *Salmonella enterica* in cattle receiving WDG were estimated using mixed-effects logistic regression with feedlot and pen modeled as nested random effects and inclusion of WDG modeled as a fixed effect. Month of sample collection was assessed for inclusion in the model as a fixed effect. Model fit was compared between nested models using Akaike's Information Criterion. The association between MPN and feeding WDG was assessed using linear mixed-effects models with similar construct. The distribution of *Salmonella enterica* serotypes recovered was evaluated graphically and by comparing the proportion of isolates assigned to the respective serotypes using a test for equality of proportions. Statistical significance for all comparisons was determined at the $P < 0.05$ level.

Results and Discussion

Fecal samples were collected from the pen surface of 6 pens in each of 6 feedlots. Three feedlots fed 0% WDG, 2 feedlots fed 15% WDG, and 1 feedlot fed 24% WDG on a dry matter basis. All feedlots used steam-flaked corn based rations. *Salmonella enterica* was recovered from

32.7% of all fecal pats sampled. Prevalence of *Salmonella enterica* in fecal pats varied from 0% to 90% among pens and 0% to 85% among feedlots (Figure 1). Feedlots with WDG in the ration had a *Salmonella enterica* prevalence of 15% (S.D. 0.36) and feedlots not using WDG had a prevalence of 51% (S.D. 0.50) (Figure 2). The odds of culturing *Salmonella enterica* from fecal pats in feedlots not feeding WDG were not significantly different (P = 0.21) relative to feedlots with WDG in the ration (Figure 3). Feedlot and pen accounted for 57.2% and 20.1% of the variability in the model, respectively. The MPN parameter was transformed by taking the logarithm of (MPN + 0.01) which yielded normally distributed residuals from the linear mixed-effects model. The association between the transformed MPN and WDG feeding was not significant (P = 0.13) and feedlot and pen accounted for 39.7% and 22.1% of variability in this model, respectively.

Several *Salmonella enterica* serotypes were only observed in samples from feedlots without WDG in the ration including Lille, Minnesota, Agona, and Oranienburg (Figure 4). Serotype Muenster was identified in 3 samples all from feedlots with WDG in the ration. Differences in the proportion of isolates assigned to each serotype, when limited to serotypes found in both cohorts, were observed for Anatum (30.4% in feedlots not feeding WDG compared to 18.5% in feedlots with WDG in the ration) and Montivedeo (25.0% in feedlots not feeding WDG compared to 18.5% in feedlots with WDG in the ration), but these differences were not significant (P = 0.22 and 0.49, respectively) (Figure 5). The distribution of *Salmonella enterica* serotypes was similar to previous reports in feedlot cattle from the same geographic region (Kunze et al., 2008).

Generally, there appeared to be decreased odds of identifying *Salmonella enterica* in samples from cattle in feedlots utilizing WDG as a component of the ration and decreased concentrations of *Salmonella enterica* in positive samples from feedlots utilizing WDG based on MPN data. However, the study did not have sufficient statistical power to resolve these differences. This is due to the relatively small number of samples evaluated and the high degree of correlation associated with the dependence of observations clustered within feedlot and within pen. It is likely that the prevalence of *Salmonella enterica* in the feces of feedlot cattle is not significantly different in cattle fed WDG. This is consistent with previous studies performed using distillers grains in dry-rolled and steam-flaked corn diets under experimental conditions (Jacob et al., 2008b; Jacob et al., 2009). Inconsistent results have been obtained with regard to the effect of feeding distillers grains on shedding of *E. coli* O157:H7 (Jacob et al., 2008a; Jacob et al., 2008b; Jacob et al., 2008c; Jacob et al., 2009). Previous reports have observed opposing patterns in prevalence of *Salmonella enterica* and *E. coli* O157:H7 indicating that some degree of antagonism may exist in the establishment of their respective niches in the lower digestive tract (Smith et al., 2005).

Implications

Although dietary factors may have a substantial role in the ecology of microbes in the lower digestive tract in cattle, there does not appear to be an association between feeding WDG and the prevalence of *Salmonella enterica* in feces of feedlot cattle in commercial settings. However, the present study did not have sufficient power to definitively resolve this issue, thus additional research will be necessary to confirm the results of this work.

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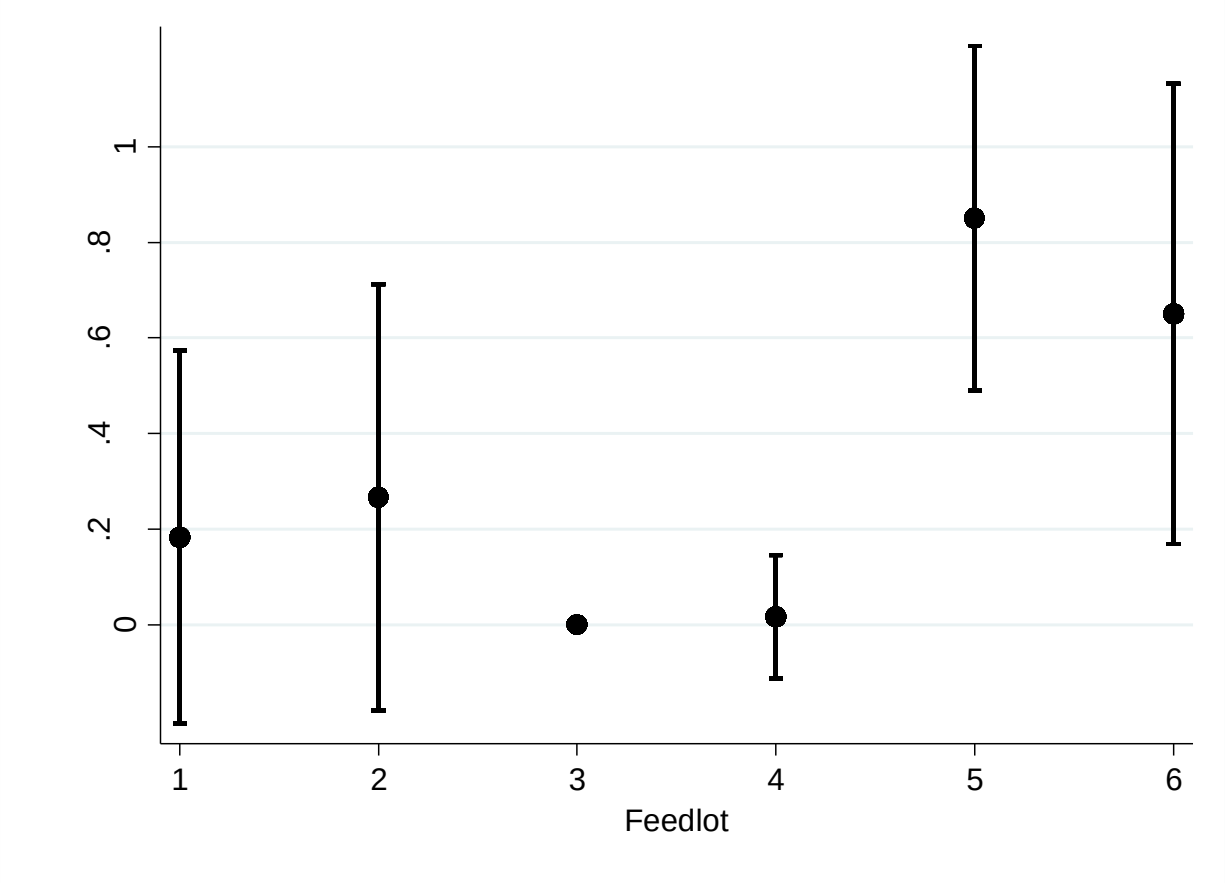

Figure 1: Prevalence and standard deviation (bars) of *Salmonella enterica* in feces of cattle from 6 commercial feedlots in the Texas Panhandle. Standard deviation is adjusted for dependence at feedlot level.

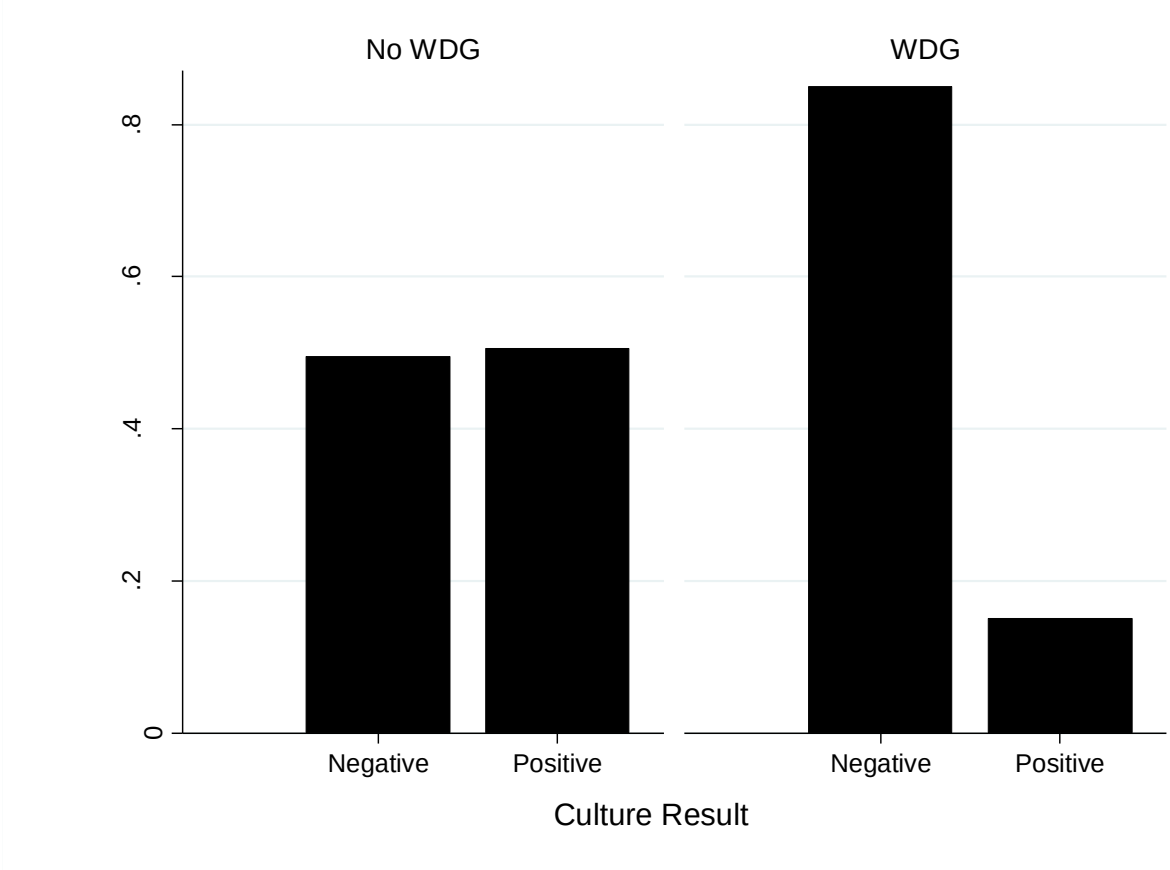

Figure 2: Prevalence of *Salmonella enterica* in fecal pats from commercial feedlots in the Texas Panhandle with wet corn distillers grains (WDG) in the ration and feedlots not feeding WDG.

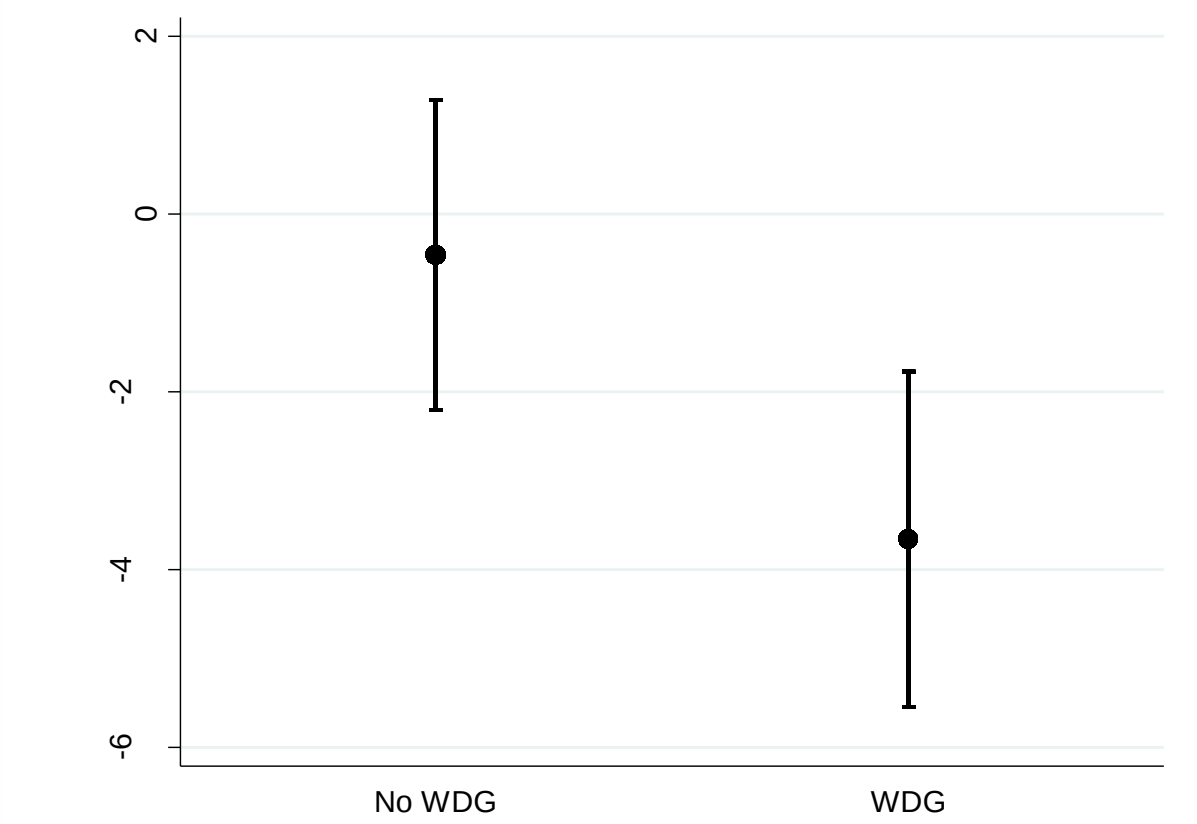

Figure 3: Predicted mean log odds and standard error (bars) of recovering *Salmonella enterica* associated with feeding wet corn distillers grains (WDG) in feedlot rations in the Texas Panhandle. Nested random effects were included to account for dependence of observations within pen and feedlot.

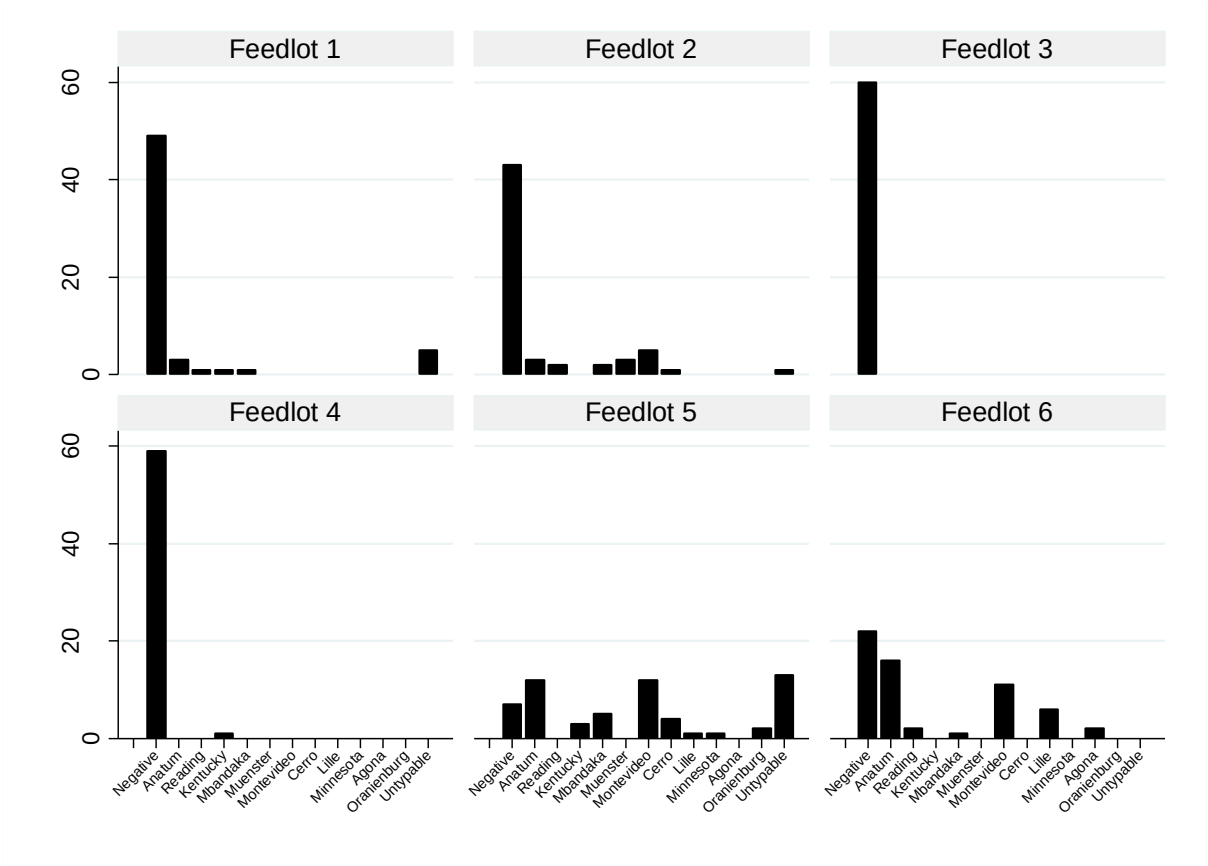

Figure 4: Distribution of serotypes of *Salmonella enterica* in feces from cattle in commercial feedlots of the Texas Panhandle.

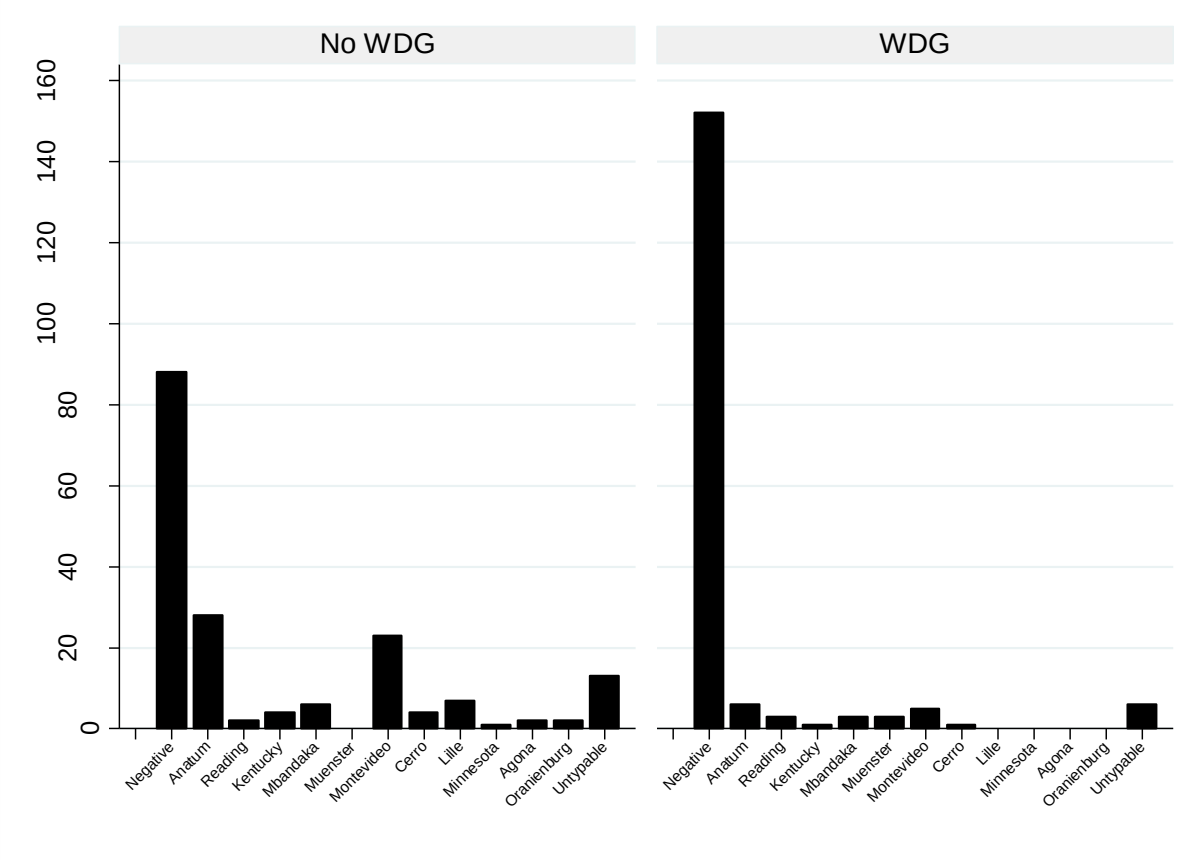

Figure 5: Distribution of *Salmonella enterica* serotypes in feces of cattle from commercial feedlots in the Texas Panhandle associated with use of wet corn distillers grains (WDG) in the ration.

EVALUATION OF IMMUNE RESPONSE AND PERFORMANCE OF STEERS CHALLENGED WITH BVD VIRUS

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Summary

In 2008, 2009 and 2010, steers from the McGregor Genomics project have been evaluated for health and immune responses following a BVDV challenge where sires/families have been stratified across vaccine treatments (killed, modified-live, or non-vaccinated). In 2008, 73 Angus-sired steers were utilized, and only 8 animals were not vaccinated. In 2009, 93 Angus-sired steers were used, but vaccination treatments were equally represented. In 2010, 78 half Bos indicus, half Angus steers were used. Large individual animal differences have been observed in both years for IgG titers with similar trends in 2008 and 2009. There has also been large variability in rectal temperature response across years. The protocol for treating cattle has been rectal temperature over 104.0° F or other obvious signs of BVD/BRD. This report describes health and feed intake results from the 2009 trial.

Introduction

It is widely recognized that bovine respiratory disease (BRD) is responsible for large economic losses in cattle feedlots, and is viewed by many in the industry as the single greatest economical production threat to feeding cattle. Results from the Texas Ranch to Rail Program have shown that cattle that are treated for BRD lost $93 per animal as compared to those that were not treated (McNeill, 1999). However, despite improved vaccines and beef quality assurance programs, BRD is still a continual and widespread health problem in U.S. feedlot cattle.

Bovine viral diarrhea (BVD) is one disease that is a component of BRD complex, and is a serious economic threat to not only the U.S. beef cattle industry, but to production worldwide (Peterhans et al., 2003). Acute BVDV infections vary in clinical signs, and, non-cytopathic, acute BVDV infections are most common and are characterized by high morbidity, low mortality, normal host immune response and minimal mucosal lesions (Kelling, 2004). In the cow-calf sector, BVD can be responsible for abortion at all stages of gestation, and, exposure to non-cytopathic BVDV strains in mid gestation (day 40 to 125) typically results in calves born that are persistently infected (PI) yet exhibit no clinical signs of illness, and do not have serum titers. Recurrence of transient infection with BVDV in feedlots is thought to perpetuate through exposure to PI animals at levels that overwhelm the immune system of vaccinated animals. In the United States BVD virus can be isolated into 2 genotypes (type 1 and type 2), with several possible subtypes (BVD1a, BVD1b, etc.); BVD1b is the most prevalent subtype in U.S. feedlots (Fulton et al., 2003; Fulton et al., 2009). Educational efforts based on clinical research over the past 15 years have raised the awareness of BVD and the PI possibility among feedlot managers and cow-calf producers, and several tests for BVDV and PI status are commercially available. However, much remains to be determined about this disease because it is immunosuppressive and causes such a wide array of symptoms and secondary health issues, and, questions also remain about vaccine types.

The objectives of this research are to evaluate genetic variability in immune response, health status and cattle performance when different BRD vaccination strategies are used and animals are administered a known BVDV challenge.

Experimental Procedures

Animal background

Yearling, Angus-sired steers (n = 93) produced from the Texas A&M University McGregor Genomics Project cows, born in the spring of 2008 were used to conduct this trial in the Spring of 2009. Steers were stratified by sire and genomics cow family and assigned to 1 of 3 vaccine treatment groups of killed BRD vaccine (KV group, n = 28), a modified-live BRD vaccine (MLV group, n = 34,) or a non-vaccinated (NON, n = 31) group. The KV steers received a primary injection of a commercially available killed BRD vaccine on day -56 and a booster on day -35. The MLV steers received a single injection of a commercially available MLV vaccine on day -35 and were isolated from the KV and NON steers for 7 days. The NON steers received no BRD vaccine injections. All steers were confirmed to be free of persistent infection (PI) prior to vaccination through ear notch sample by antigen capture ELISA at the Texas Veterinary medical Diagnostic Laboratory (TVMDL, Amarillo, TX) and were seronegative for BVD and infectious bovine rhinotracheitis (IBR) prior to vaccination.

BVDV challenge and data collection

On day 0, all steers were administered an intranasal BVD viral challenge with strain CA0401186a from the USDA-

ARS National Animal Disease Center; this strain is a type 1b, non-cytopathic strain isolated from a persistently infected calf submitted to the National Animal Disease Center (NADC) from Tulare laboratory of the California Animal Health and Food Safety Laboratory (Ridpath et al., 2007).

Clinical evaluations were conducted twice daily for 14 days following challenge to assess apparent health with a score of 0 (no symptom), or 1-5 (least severe-most severe) for 6 symptoms commonly associated with BVD (coughing, ocular secretions, nasal secretions, depression, diarrhea, and gauntness/shrink). From days 15 to 42 observations were performed once daily.

Serum neutralizing IgG titers for IBR, BVD Type1 (BVD1) and BVD Type2 (BVD2) were evaluated on days -56, -35, 0, 14, 28, and 42. Weights and rectal temps were collected on these days as well as days 1, 3, 7, and 10. Cattle were fed by hand daily in 4 pens equipped with GrowSafe feed bunks to evaluate individual feed intake. Rectal temperature was used to evaluate health status in addition to physical symptoms, and steers over 40.0° C (104.0° F) were treated with a commercially available antimicrobial.

Statistical Analyses

Rectal temperature and IgG titers (log base 2 transformed) were analyzed through mixed model procedures as repeated measures with vaccine treatment, day, vaccine treatment × day, sire, and vaccine treatment × sire in the models.

Daily feed intake was analyzed (as fed) through mixed model repeated measures with a model that included vaccine treatment, day, vaccine treatment x day, pen, maternal grandsire and vaccine treatment x maternal grandsire.

Sire accounted for more of the genetic differences in rectal temperature and titer values, whereas maternal grandsire accounted for more differences in feed intake. Least squares means were evaluated for effects significant ($P < 0.05$) in the statistical models.

Results and Discussion

Differences in rectal temperature were observed ($P < 0.05$) due to vaccine treatment, day, vaccine treatment × day, and sire. Peak mean rectal temperature was observed on d 7 (103.3° F). At d 7 MLV steers had lower ($P < 0.05$) rectal temperature (102.6) than KV or NON steers (both 103.6). During the 14 days following challenge, 50% (14 of 28) of the KV steers and 45% (14 of 31) of the NON steers had rectal temperature over 104.0° F and were treated for BRD; however none of the 34 MLV steers had rectal temperature over 104.0° F. Differences in BVD1 and BVD2 titers showed similar patterns with vaccine treatment, day, vaccine treatment × day, and sire accounting for variation; a vaccine treatment × sire interaction was present for BVD1 ($P = 0.08$) that was not present for BVD2 ($P = 0.50$). Figure 1 shows BVD1a titers for the vaccine treatments across the 6 evaluation days. IBR titers showed large differences due to vaccine treatment, day and vaccine treatment × day, but not sire or vaccine treatment × sire. Figure 2 shows IBR titers for the vaccine treatments across sampling days. KV steers had higher ($P < 0.05$) titers for IBR, BVD1, and BVD2 than MLV steers, which in turn were higher ($P < 0.05$) than titers of NON steers. On day 0, KV and MLV steers had equal BVD1 titers, but KV steers had higher BVD2 than MLV steers. Figure 3 shows the titers of the 3 vaccine treatments across sire groups. There were large titer differences among individuals in all vaccine treatment, and it appears substantial genetic variation exists in response to BRD vaccines; however, there was no clear relationship of BVD titers to rectal temperature. No major physical symptoms associated with severe BVD illness were observed.

Large differences were observed in daily feed intake due to vaccine treatment, day, and vaccine treatment x day. MLV steers consumed approximately 1.1 lb/day more than KV and NON steers. The most substantial differences in daily feed intake across vaccine treatment appeared to occur from day 7 to 10 following challenge with NON steers consuming 1.8 to 6.8 lb/day less that vaccinated steers. Daily feed intake and rectal temperature across the three vaccine treatments for the entire 42-day trial are shown in Figure 5. Differences in daily feed intake were also seen due to maternal grandsire with a difference of 3.1 lb across maternal grandsire means (25.1 to 28.2 lb) and vaccine treatment x maternal grandsire with a range of 0.9 to 2.2 lb across vaccine treatment within maternal grandsire groups. Maternal grandsire groups accounted for more differences in feed intake than did sire groups. Figure 4 shows daily feed intake for the 3 vaccine treatments across maternal grandsires. Daily feed intake was also compared between steers with > 104.0° F rectal temperature within 14 d following challenge and those ≤ 104.0° F; steers > 104.0° F rectal temperature consumed 0.9 to 8.6 lb less daily feed intake during days 7 to 10. Steers in the NON group that were not treated for high rectal temperature also showed a depressed feed intake pattern during days 7 to 10 that was similar to the decreased feed intake of steers with > 104.0° F. ADG was also evaluated for the 3 14-d periods due to vaccine treatment, pen, maternal grandsire, vaccine treatment × maternal grandsire and day-0 weight as a covariate, but no differences existed due to vaccine treatment or maternal grandsire in any period.

Implications

There were large differences observed in rectal temperature and serum IgG titers due to vaccine treatments. There were also large differences among sires for both rectal temperature and IgG titers. There were no obvious relationships among IgG titers and rectal

temperature. Peak rectal temperature was observed around days 7 and 10 following challenge, and a reduced feed intake pattern during this time was also observed. Steers in the KV and MLV groups that were not treated for high rectal temperature did not show decreased feed intake following challenge, but non vaccinated steers did. It appears that substantial genetic variation exists in immune and health responses to BVDV challenge that could lead to identification of genetic markers for health and eventually selection for vaccination response. However, the unclear relationships between increased rectal temperature with physical symptoms and titer response, as well as the interactions of family lines with vaccination strategies illustrate the complexity of animal health management.

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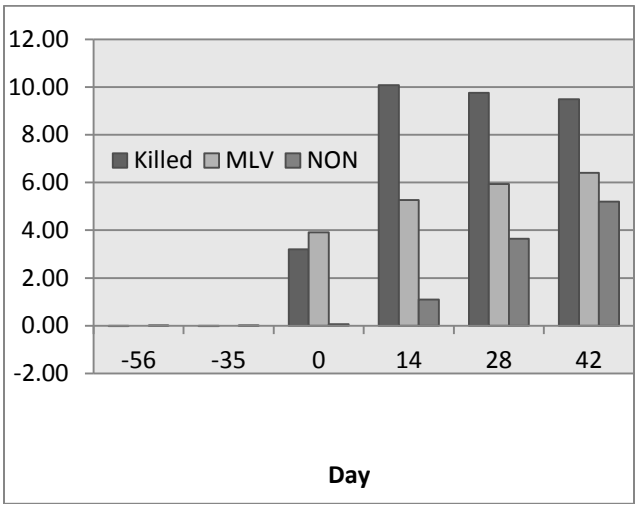

Figure 1. Titers (log base 2) for BVD1a across vaccine treatment and day from 2009 BVDV challenge

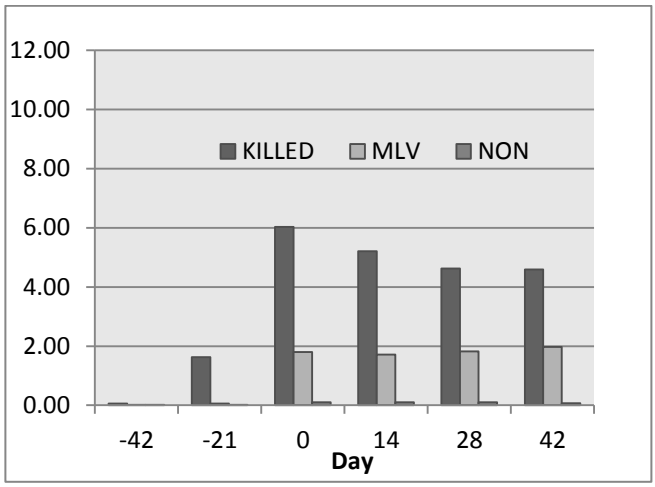

Figure 2. Titers (log base 2) for IBR across vaccine treatment and day from 2009 BVDV challenge

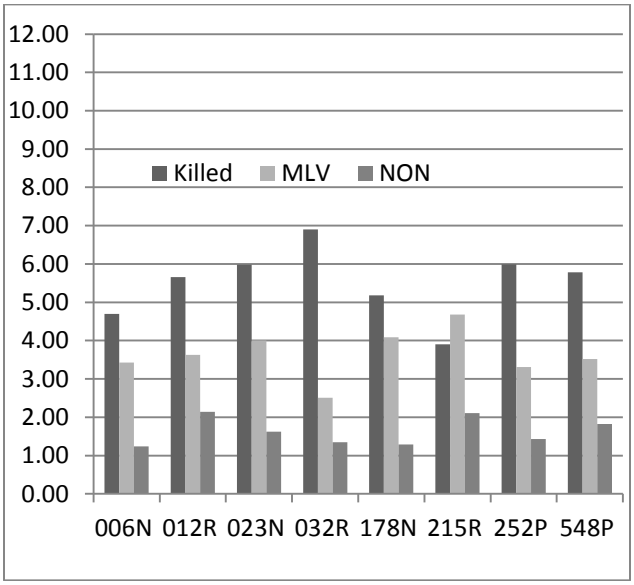

Figure 3. Titer means (log base 2) of BVD1a across sires and vaccine treatments

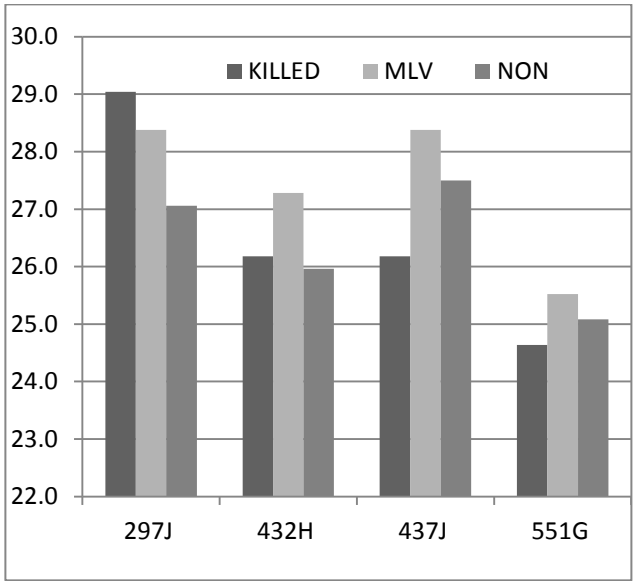

Figure 4. Average daily feed intake (lb) across vaccine treatments and maternal grandsires

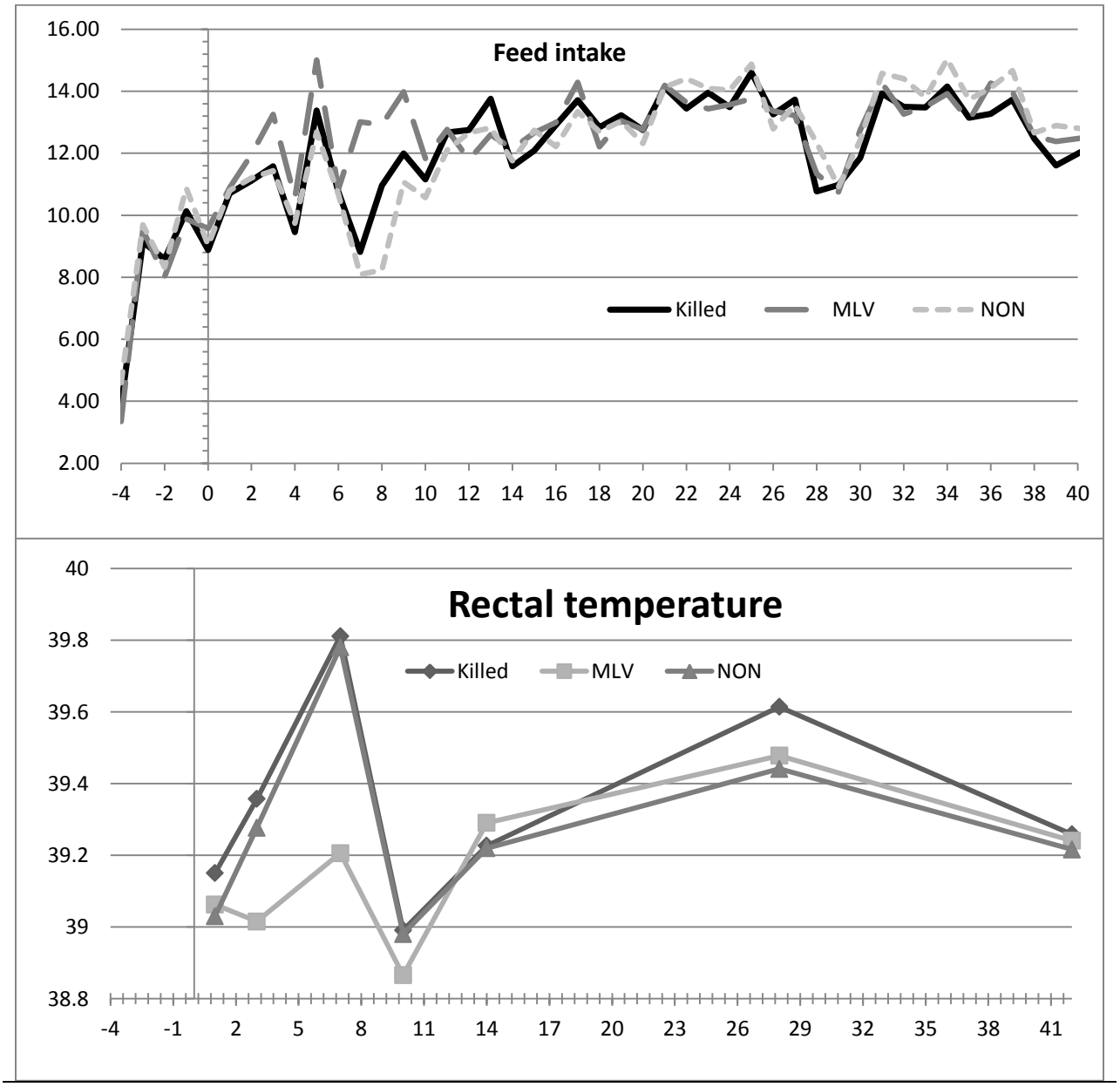

Figure 5. Feed intake (kg) and rectal temperature (^{o}C) across 42 days following BVDV challenge (rectal temperature measured on days 0, 3, 7, 10, 14, 28 and 42; 38.6^{o} C = 101.5^{o} F, 40^{o} C = 104.0^{o} F).

THE ACCURACY OF REAL-TIME ULTRASOUND TO MEASURE CARCASS TRAITS IN BEEF CATTLE PRIOR TO SLAUGHTER

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Summary

The objective of this study was to determine the adequacy of real-time ultrasound to measure carcass traits prior to slaughter in beef cattle (n = 228). Results show that ultrasound measurements of backfat (**uBF**), *longissimus* muscle area (**uREA**) and marbling score (**uMARB**), were highly correlated to carcass backfat (**cBF**), longissimus muscle area (**cREA**) and marbling score (**cMARB**; 0.85, 0.67, and 0.63, respectively). Carcass backfat and cMARB were under predicted by uBF and uMARB (0.04 in, and 0.37 marbling units, respectively). However, carcass cREA was over predicted by uREA by .44 in^2. Ultrasound BW was highly correlated (P < 0.001) with uBF, uREA, cBF, and cREA (0.76, 0.42, 0.37, and 0.67, respectively). These results, along with previously published research, indicate that real-time ultrasound is an accurate tool for measuring carcass traits in beef cattle.

Introduction

Ultrasound has been used to measure body composition in beef cattle since the 1950's. Ultrasound is a non-invasive technique that provides a way to objectively assess what is under the animal's hide. The goal of beef cattle producers and feedlots is to efficiently produce a high quality product. A major problem for the beef industry today is carcasses with excessive subcutaneous fat, resulting in discounts of the price paid to producers. Studies have shown that RTU has the capability of predicting carcass traits early in the feedlot phase (Wall et al., 2004; Rhoades et al., 2009), and thus, can aid in improving how feedlots sort cattle. The objective of this study was to evaluate the accuracy of real-time ultrasound measurements in beef cattle.

Experimental Procedures

Data for this study were obtained from a total of 228 head of animals from 5 different studies. There were 196 steers, 16 heifers, and 16 bulls. Study 1 consisted of 118 Santa Gertrudis steers, Study 2 had 16 Angus bulls and 16 Angus heifers, Study 3 had 18 Angus cross steers, Study 4 had 36 crossbred steers, and Study 5 was comprised of 24 Angus steers. There were 16 steers from study 1 and 1 heifer from study 2 that did not have uREA measurements. RTU measurements were collected at 7 d prior to slaughter. RTU measurements included 12-13th rib backfat thickness (in, **uBF**), 12-13th *longissimus dorsi* muscle area (in^2, **uREA**), and percentage of i.m. fat (%, **uIMF**). Images were collected by an Ultrasound Guidelines Council field-certified technician using an Aloka 500-V instrument with a 17-cm 3.5 MHz transducer (Aloka Co. Ltd., Wallingford, CT). Images were stored in a capturing system and sent for analyses at the National CUP Lab (Ames, IA). Hair was clipped (if longer than 0.64 in) in order to increase image quality and vegetable oil was applied to the animal's hide as a coupling agent. After slaughter, the carcasses were chilled for 48-h before carcass data were collected, consisting of HCW (lb), 12-13th rib backfat thickness (in, **cBF**), 12-13th *longissimus dorsi* muscle area (in^2, **cREA**), and marbling score, were collected by Texas A&M University personnel. Ultrasound measurements of i.m. fat were converted into marbling score units (**uMARB**) using the linear equation: uMARB = ((769.7 + (56.69×uIMF))/100) – 5, reported by Wilson et al. (1998). Marbling scores were converted to a numeric marbling score (**cMARB**) with Traces^{00} = 3, Slight^{00} = 4, Small^{00} = 5, Modest^{00} = 6 and Moderate^{00} = 7 (Wilson et al., 1998). Statistical analyses were performed using the Model Evaluation System (Tedeschi, 2010) and PROC MEANS and PROC CORR of SAS (Version 9.2, SAS Inst. Inc., Cary NC).

Results and Discussion

Table 1 shows the summary statistics of RTU and carcass traits collected for this study. A total of 17 animals were omitted from the analysis for uREA and cREA due to poor image quality and thus an inability to interpret corresponding measurements. The correlation between ultrasound and carcass measurements (Table 2) of 12-13th rib backfat thickness (0.85), 12-13th *longissimus dorsi* muscle area (0.67), and percentage of i.m. fat (0.64) are in agreement with previously reported values. Perkins et al. (1992a; 1992b) reported average correlations of 0.75 and 0.86 for backfat thickness (**BF**) and 0.60 and 0.79 for *longissimus* muscle area (**REA**). Ribeiro et al. (2006) reported similar correlations for BF (0.80) but a lower correlation for REA (0.66). However, Greiner et al. (2003) reported higher values for correlations between uREA and cREA, and uBF and cBF (0.89 and 0.86, respectively). Baker et al. (2006) reported correlations between uMARB and cMARB of 0.31 and 0.81. In the same study by Ribeiro et al. (2006) reported previously, the correlations between uMARB and cMARB were between 0.51 and 0.69.

Another tool used to measure accuracy is mean bias. The mean bias between ultrasound and carcass traits was 0.04 in, -0.44 in^2 and 0.37 marbling score units for BF, REA and MARB. These values are a little higher than the ones reported by Ribeiro et al., (2006) which were 0.02, 0.00, and 0.33, respectively. Greiner et al. (2003) reported similar bias values for BF (0.02 in) but smaller for REA (0.12 in^2). The Ultrasound Guidelines Council (UGC), which is the governing agency who certifies software and technicians for submission of ultrasound data to breed associations for breed improvement purposes, have set standards for correlations and biases between ultrasound and carcass measurements. The standard correlations for BF, REA and IMF need to be greater or equal to 0.85, 0.70, and 0.50, respectively, and mean bias standards for BF, REA and IMF lower or equal to 0.05 in, 1.10 in^2, and 1%, respectively. The results for our study are in agreement with the UGC standards, except for REA, which was lower.

Table 3 shows the correlations between all RTU and carcass traits measured. Ultrasound BW was highly correlated to uBF, uREA, HCW, cBF, and cREA (0.42, 0.76, 0.44, 0.37, 0.67, respectively). The lower correlation between REA and MARB in the current study could be a result of the large number of animals of *Bos indicus* influence (Study 1). It has been observed that the accuracy of RTU for *Bos indicus* influenced cattle is not as high as *Bos taurus* cattle. This has been observed by Rhoades et al. (2009); however no explanation has yet been reported. The current study, along with other research reported all found uBF to have the highest correlation with its carcass counterpart when compared to the other two major traits discussed. This can be attributed to the fact that the uBF measurement is the easiest measurement to accurately obtain since it is a simple, linear measurement. These results, along with data reported in other studies, indicate that real-time ultrasound is an accurate tool for measuring body composition in beef cattle.

Implications

These results show that RTU can accurately measure carcass traits. Additional work is needed in order to explain the differences in accuracy between *Bos indicus* and *Bos taurus* cattle. This technology is useful in the feedlot setting for sorting purposes, and can also be beneficial to seedstock producers as a selection tool, which would allow for a supply of higher quality animals to the feedlot segment.

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Table 1. Summary statistics of ultrasound and carcass traits

Trait	N	Mean	SD	Min	Max
Ultrasound data					
Body weight, lbs	228	1071	157	409	1397
Backfat thickness, in	228	0.37	0.13	0.08	0.95
Longissimus muscle area, in^2	211	11.9	1.75	3.29	16.4
Intramuscular fat, %	228	3.35	0.72	1.47	5.40
Marbling score[a]	228	4.59	0.41	3.53	5.76
Carcass data					
Hot carcass weight, lb	228	689	220	184	1597
Backfat thickness, in	228	0.41	0.23	0.05	1.40
Longissimus muscle area, in^2	211	11.5	1.49	5.80	14.4
Marbling score	228	4.96	0.88	3.00	8.10

[a] Ultrasound Marbling score = ((769.7 + (56.69×uIMF))/100) – 5 (Wilson et al., 1998).
[b] Marbling scores were converted to a numeric marbling score (cMARB) with Traces^{00} = 3, Slight^{00} = 4, Small^{00} = 5, Modest^{00} = 6 and Moderate^{00} = 7 (Wilson et al., 1998).

Table 2. Accuracy statistics of RTU measurements compared to carcass measurements

	Ultrasound Backfat	Ultrasound Ribeye area	Ultrasound Marbling score
N	228	211	228
Correlation	0.85	0.67	0.64
Bias	0.04	-0.44	0.37
SRMSE	0.31	1.41	0.36

Table 3. Correlations between ultrasound and carcass traits[a]

Traits[b]	uBF	uREA	uMARB	HCW	cBF	cREA	cMARB
uBW	**0.42**	**0.76**	-0.07	**0.44**	**0.37**	**0.67**	0.11
uBF		**0.50**	**0.30**	**0.22**	**0.85**	0.18	**0.34**
uREA			0.07	**0.37**	**0.47**	**0.67**	0.23
uMARB				**0.29**	**0.36**	**-0.14**	**0.63**
HCW					**0.23**	**0.22**	**0.18**
cBF						0.09	**0.34**
cREA							0.05

[a] Correlations in bold are different from zero at P < 0.05)
b uBW= ultrasound body weight; uBF = ultrasound backfat; uREA = ultrasound ribeye area; uMARB = ultrasound marbling score; HCW hot carcass weight; cBF carcass backfat; cREA = carcass ribeye area; cMARB = carcass marbling score

THE USE OF SERIAL ULTRASOUND EVALUATION OF BODY COMPOSITION TRAITS TO PREDICT CARCASS ENDPOINTS

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Summary

Crossbred steers (n = 109), born in the spring of 2007 (January through May), were serially scanned beginning at approximately 570 lb of body weight through harvest in 56 day ± 6 intervals. Data collected included ultrasound measurements (ribeye area (REA), 12th rib fat thickness (RibFat), percent intramuscular fat (IMF), and rump fat (UFAT)), weight, and carcass data. Days to choice were calculated for each steer based on a linear regression for each observation. Deposition of IMF could be quantified as quadratic from scans 1-6 and linear when cattle were on a plane of nutrition that exceeded growth requirements (scans 3-6). Steers (n = 35) that finished premium choice (marbling score 600 or greater) reached choice or 4.0% IMF 56 days earlier than steers that did not finish premium choice. Based on logistic regression models, odds ratios suggested that if steers in the study had averaged 1% higher IMF at any scan time relative to average values of the population, the predicted probability for grading premium choice would have been increased from 46% to 76%.

Introduction

The value of carcass ultrasound is the ability to identify and adjust management strategies early in the production phase to optimize an animal's performance. With pressure from rising input costs and increased cost of gain, the implementation of tools that boost efficiency within feeding programs for beef cattle are prevalent, and should continue to be explored in depth. Real time ultrasound has the ability to increase efficiency within the feeding sector in terms of nutritional management, sorting, and marketing. While the identification of cattle that do not fit a certain market prior to exposure of discounts is desirable, a greater advantage would be earlier identification of those cattle, thereby maximizing opportunities that implement favorable management strategies through targeted feeding programs. The research objectives of this study were to determine the optimum time from weaning to harvest to ultrasound cattle, and to identify thresholds for IMF at that time to predict end quality grade.

Experimental Procedures

Angus sired crossbred steers (n = 104) of four origins, born in the spring of 2007 (January through May), were serially scanned beginning at approximately 570 lb of body weight through harvest in 56 day ± 6 intervals. Cattle were placed on feed at Mclean Feeders in Mclean, Texas in May and June of 2008, fed a standard step-up diet, and harvested in three lots in November 2008, January 2009, and March 2009. Carcass data were collected upon harvest through the commercial beef plant by their personnel. Marbling scores were obtained on two of the three sets of cattle which were fed in a feedlot for 146 and 194 days, respectively.

Ultrasound measurements were collected by a single, certified technician and included ribeye area (REA), 12th rib fat thickness (RibFat), percent intramuscular fat (IMF), and rump fat (UFAT). Images were taken with an ALOKA 500V ultrasound machine with a 17 cm 3.5 GHz probe and Biotronics Inc. software. Images were interpreted by the National CUP Lab in Ames, Iowa. Weights were also recorded each time ultrasound measurements were obtained. Carcass data included marbling score, ribeye area, back fat, yield grade, hot carcass weight, and KPH (kidney, pelvic, and heart fat) at slaughter. Ninety two percent of cattle graded small choice or above, and so cattle were classified as 1 for premium (small choice and above), and 0 for non premium (small choice and below).

The trend of body composition values for all traits evaluated were examined among premium status, and across time. Class variables included days in program, origin, and time as main class variables, with appropriate interactions investigated, and least squares means were obtained for each trait across time. Logistic regression was used to determine IMF at which scan time significantly impacted cattle obtaining a premium status of 1 at slaughter. Intramuscular fat percentage at each scan time was used as the independent variable. Probabilities of grading premium choice were generated from regression coefficients.

Investigation of line plots with intramuscular fat plotted against time confirmed a quadratic effect on intramuscular fat deposition for this population. A quadratic effect was confirmed, individual regressions for each observation were performed, and beta coefficients were manipulated to obtain days to choice (4% IMF) for each observation. The intercept, B_1, and B_2 were tested in an ANOVA-Mixed procedure to determine the effect of end quality grade (premium status) as a class variable. Multiple regressions using the stepwise method determined which ultrasound and weight variables were useful in determining days to choice, for each scan time, under the constraint of having a *P*–value of less than 0.15.

Results and Discussion

Repeated Measures

Average daily gains were 1.01, 0.99, 1.82, 4.12, 3.23, and 1.76 lbs for the time periods between scan times beginning at scan 1 and ending at slaughter. Figures 1 – 4 show the trends for weight gain, ribeye area development, IMF and ribfat deposition.

Weight increased in a linear fashion as shown in Figure 1 with the largest increase between scans 4 and 5 with an increase of 226 lbs ($P < 0.001$). Ribeye area did not change between scans 1 and 2 or 2 and 3 with significance values of $P = 0.29$ and $P = 0.079$, respectively. However, beginning at scan 3-6 ribeye area increased for the remainder of the study in a linear fashion ($P < 0.001$). Ribfat remained stagnant and not changing from scans 1-2 ($P = 0.123$), scans 2-3 ($P = 0.596$) but increased beginning at scan 3-6 ($P < 0.001$) (Figure 4). Intramuscular fat (IMF) had a quadratic element. IMF decreased between scans 1 and 2 ($P < 0.001$) and then increased in a linear fashion (Figure 4.) Intramuscular fat was not different at scan times 1 and 3 ($P = 0.972$) due to a drop in IMF from scan 1 to scan 2 ($P < 0.001$) and an increase between scans 2 and 3 ($P < 0.001$).

It should be noted that steers were on pastures from scan times 1 through 3. Between scan times 3 and 4, cattle were placed in a feedlot where nutrition exceeded maintenance requirements which most likely explain the body compositional trends in the figures mentioned. The stair-step marbling deposition pattern as described by Zinn et al. (1970) was not observed in this experiment. Cattle in this experiment lost IMF initially between scans 1 and 2 ($P < 0.001$), and then gained it back between scans 2 and 3 ($P < 0.001$) so the periods of dormancy referred to by Zinn et al. (1970) in IMF deposition were not observed during the first or second half of this study. Cattle in this experiment also accumulated IMF at 0.15% and 0.16% between scans 4 and 5 and scans 5 and 6, respectively. The average IMF of choice equivalent was reached between scans 5 and 6. The substantial increase in IMF when cattle reached the threshold of choice as described by Brethour (2000) was not observed in this study.

Although cattle increased in weight ($P < 0.05$) across scans 1-6, ribeye area did not change between scans 1-3 ($P = 0.54$) and ribfat also stabilized ($P = 0.43$). Likewise IMF did not differ between scans 1 and 3 ($P = 0.097$). This shows that although cattle continue to increase in frame and weight, if nutritional requirements are not being met, cattle may not be increasing in ribeye size or deposition of IMF and ribfat.

Additionally, quality grade (prime, choice, small choice, and select) was investigated across time for the trait of IMF (Figure 5). The class variables in the repeated measures analysis were quality grade, time, and the time by quality grade interaction. The trait IMF was influenced by time ($P < 0.001$), quality grade ($P = 0.001$), but not by the time by quality grade interaction ($P = 0.847$). Therefore, quality grade was not significantly different at any one point in time across quality grades.

Logistic Regression

Cattle were classified as 1 or 0 for premium (Modest Ch or greater), or non premium (Small Ch or less). Although there were 105 steers in the study, marbling scores were only obtained on 70 animals. Of the 70 steers that marbling scores were obtained on, 44.3% of the pen graded premium choice, and models 1 – 5 predicted the probability of grading premium choice to be 46%, 48.3%, 46.2%, 49.7%, and 48.4%, respectively. As shown in Table 1, IMF at all scan times were all significant ($P < 0.05$) in explaining the impact of IMF on whether steers attained premium choice or not, indicating premium cattle consistently displayed higher amounts of IMF throughout the course of the project. Odds ratios expressed in Table 1, and can be defined as the odds of cattle grading premium choice based on the population's average IMF score at that time relative to a one unit increase in average IMF. During scan two, a one unit increase in IMF% would mean that the cattle averaging 3.6% IMF would have 3.8 times greater odds of grading premium choice than cattle averaging 2.6%. On average, predicted probabilities were 43.11% and 51.82% for cattle that failed to or succeeded in grading premium choice, respectively, based on logistic regression models. A matrix in Table 2 illustrates the relationship between weight and IMF and the resulting probability of grading premium choice.

Days to Choice

Upon inspection of line plots plotting IMF across time for each observation, an exponential element to the IMF curve was suspected and confirmed with a regression procedure. The variable days is the number of days beginning at scan 1 and ending on the day of the last scan (scan time 6). Both the variables days and days squared were significant in predicting IMF in a regression procedure. Therefore it was determined that the IMF deposition followed a quadratic curve from scan times 1 through 6, and scans 3 through 6 could be described as linear. The observation of a quadratic or linear curve is inconsistent with Brethour (2000) who suggested that an exponential or modified power curve fit the IMF curve better than a linear curve. Using components of the model that was used to determine days to choice; the intercept and beta coefficients were also tested against marbling score of 600 or greater in an ANOVA procedure. The intercept, "days" parameter coefficient, and days squared parameter coefficients had resulting *P*–values of 0.028, 0.823, and 0.712, respectively. This indicates that scanning once is sufficient to determine if cattle have the propensity to grade Modest Choice or higher.

Implications

Real time ultrasound does provide the opportunity to capture the propensity of IMF deposition in young cattle. Regardless of the trend, these results also suggest that the relative differences in IMF in young cattle have residual

effects throughout the remainder of days on feed and are subsequently expressed in the end quality grade. This provides an opportunity for optimal sorting at any point in time based on ultrasound data. The likelihood or opposing risk for cattle grading premium choice can be quantified for a population, thereby increasing opportunity to capitalize on matching the propensity to grade premium choice to targeted feed programs.

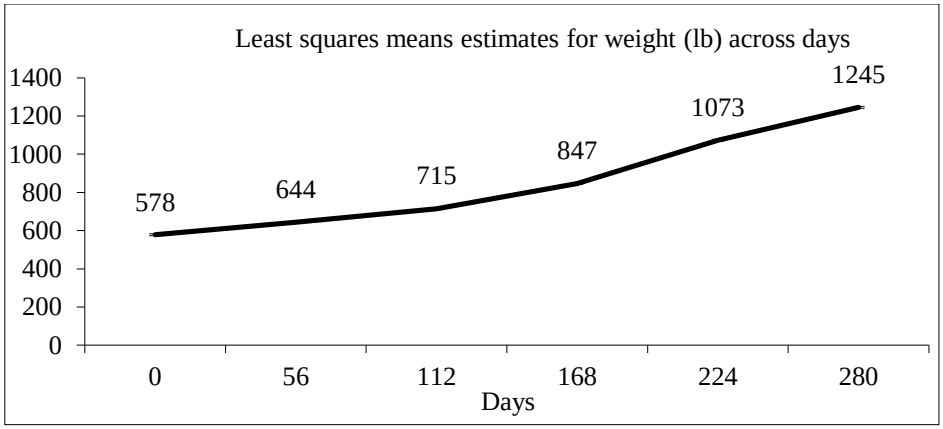

Figure 1. Least squares means for weight (lb) across time.
[a-f] Least square means across time with different superscripts differ by $P < 0.05$.

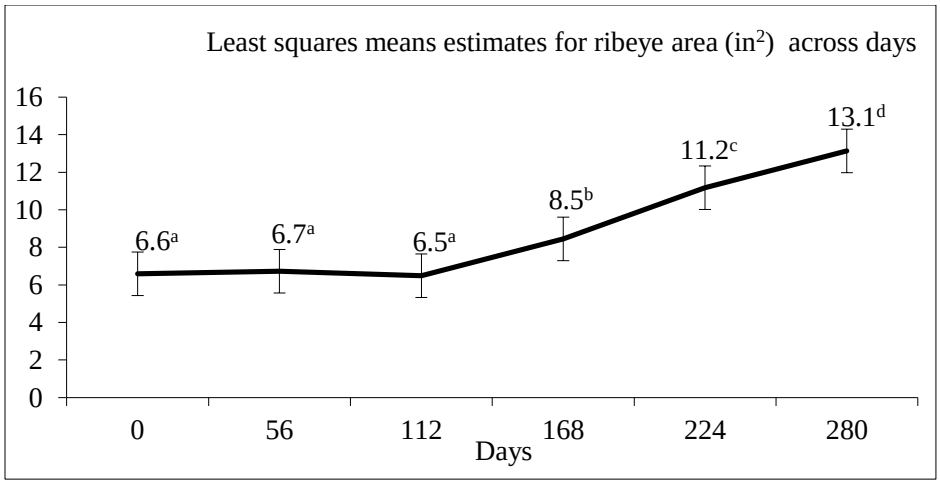

Figure 2. Least squares means for ribeye area (in^2) across time.
[a-d] Least square means across time with different superscripts differ by $P < 0.05$.

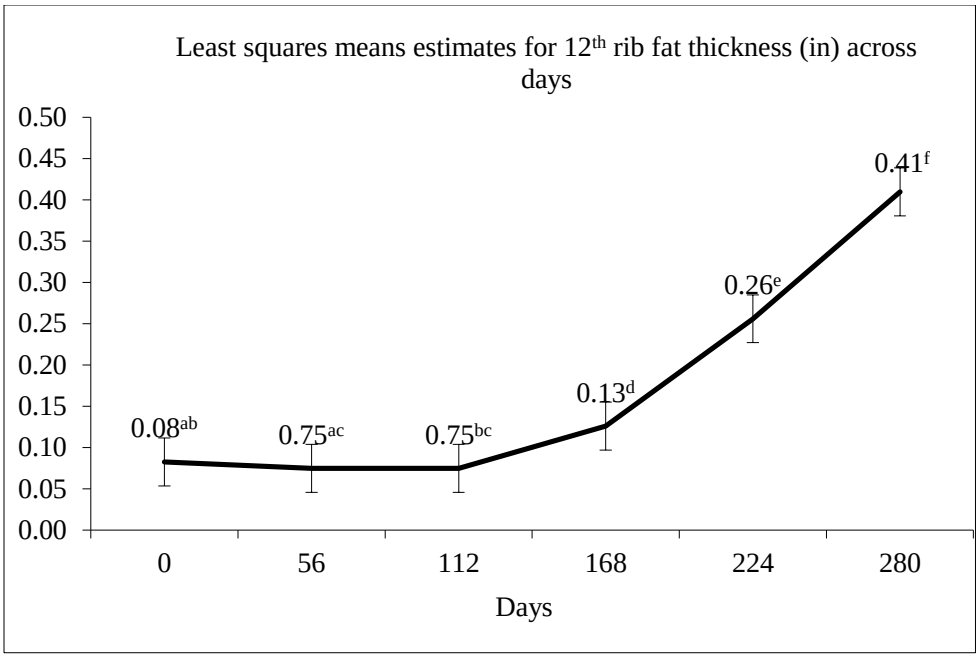

Figure 3. Least squares means for rib fat (in) across time.
[a-f] Least square means across time with different superscripts differ by $P < 0.05$.

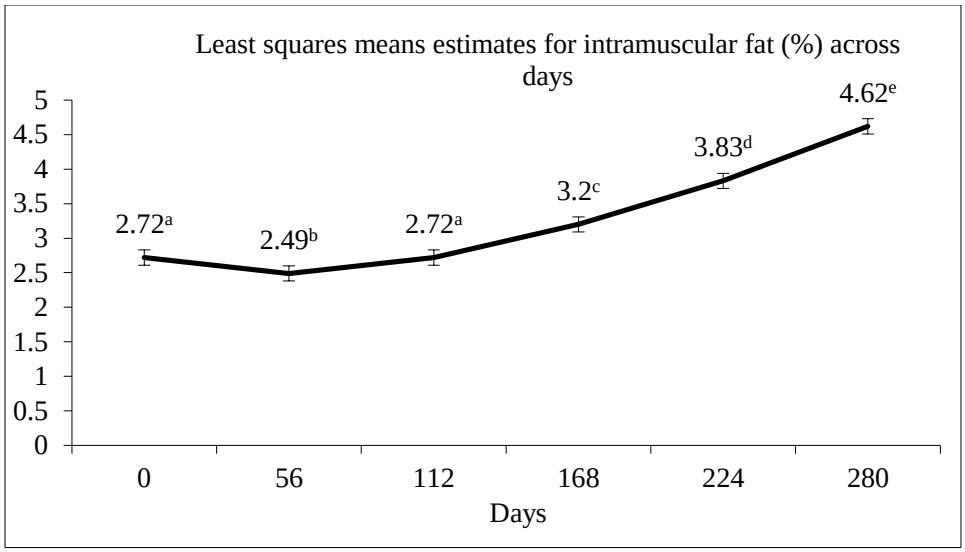

Figure 4. Least squares means for IMF across time (%).
[a-e] Least square means across time with different superscripts differ by $P < 0.05$.

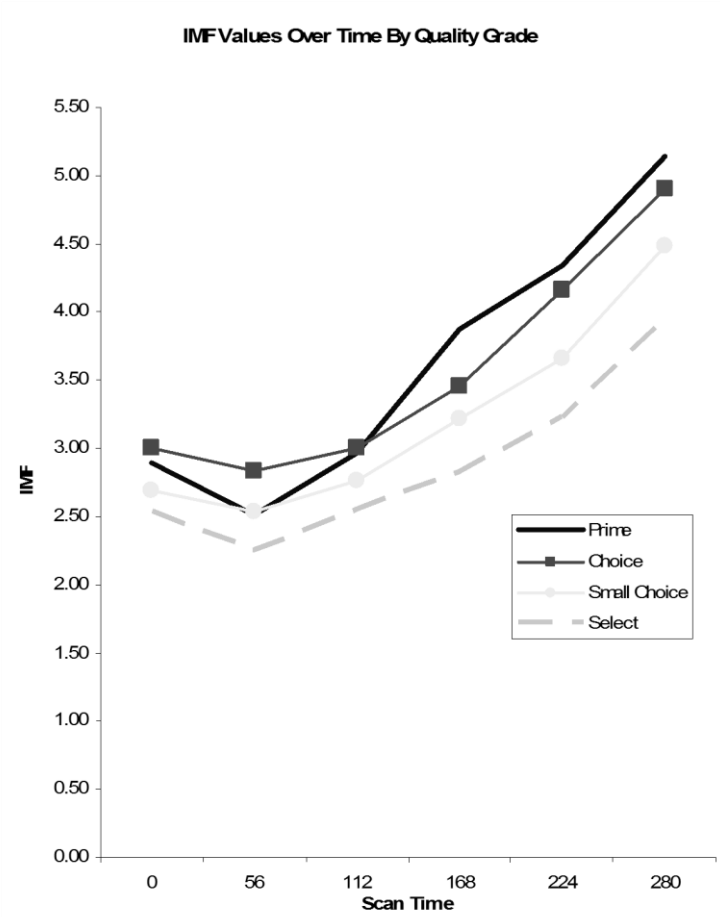

Figure 5. Least squares means for Intramuscular fat (%) across time by quality grade.

Table 1. Effects of ultrasound and animal body composition traits[1] on attaining marbling score 600 or greater across time.

Effect	Estimate ± SE	*P*-value	Odds Ratio
Scan 1			
Intercept	-4.01 ± 1.44	0.0070	
IMF1	1.39 ± 0.50	0.0077	1.360
Scan 2			
Intercept	-3.54 ± 1.28	0.0073	
IMF2	1.35 ± 0.49	0.0084	3.867
Scan 3			
Intercept	-3.11 ± 1.28	0.0182	
IMF3	1.06 ± 0.44	0.0206	2.896
Scan 4			
Intercept	-3.98 ± 1.42	0.0069	
IMF4	1.21 ± 0.43	0.0071	3.380
Scan 5			
Intercept	-4.96 ± 1.42	0.0009	
IMF5	1.28 ± 0.36	0.0009	3.439

[1]IMF = Intramuscular fat percentage measured via real time ultrasound. (Marbling score of 600 or greater (n=31), 600 or less (n=39)).

Table 2. Probability Matrix for Cattle that Graded Premium (Modest Choice +)

	Lbs.	- 2 SD	- 1 SD	Mean IMF	+ 1 SD	+ 2 SD
Weight 1	578	1.60	2.18	2.76	3.35	3.93
Probability[1]		14%	28%	46%	66%	81%
Weight 2	644	1.27	1.93	2.59	3.25	3.91
Probability[1]		14%	28%	49%	70%	85%
Weight 3	715	1.56	2.17	2.78	3.40	4.01
Probability[1]		19%	31%	46%	62%	76%
Weight 4	847	1.78	2.52	3.26	4.00	4.74
Probability[1]		14%	29%	50%	71%	86%
Weight 5	1073	1.98	2.91	3.83	4.75	5.67
Probability[1]		8%	22%	48%	75%	91%

[1]Probability of attaining premium status of 1 (Modest Choice or Greater)

THE RELATIONSHIP OF BODY CONDITION SCORE AND SUBCUTANEOUS AND INTERNAL FAT MEASUREMENTS BY REAL-TIME ULTRASOUND IN CROSSBRED BEEF COWS

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Summary

The objective of this study was to identify the relationship of body condition score (**BCS**) and real-time ultrasound (**RTU**) fat measurements in crossbred beef cows (n = 48). RTU traits measured were backfat (**uBF**), rump fat (**uRUMPFT**), and kidney fat depth (**uKFd**). Total internal fat (**PredIFAT**) was calculated based on previously published equations and also an average of the subcutaneous fat level, uBF and uRUMPFT (**ComboFat**). BCS was highly correlated ($P < 0.05$) to all RTU fat measurements. Prediction equations showed that BCS was a better predictor of ComboFat and PredIFAT. These results agree with previous studies indicating that there is a good relationship between BCS and RTU fat measurements in beef cows.

Introduction

Body condition scoring (**BCS**) is a commonly used method of evaluating total body energy reserves in cattle (Herd and Sprott, 1986). Previous research has indicated that poor condition prior to breeding, during late gestation, and during early lactation have negative effects on reproductive performance of cows (Houghton et al., 1990). Thus, it is important to be able to accurately measure the condition of beef cows. Although BCS is accurate (Hardin, 1990; Bullock et al., 1991), it's a subjective measurement. Real-time ultrasound (**RTU**) is a non-invasive technique to measure body composition in live animals. Studies have demonstrated that real-time ultrasound can be used to accurately determine back fat in live animals (Brethour, 1992; Ribeiro et al., 2006). There are limited reports in the literature that looked at the relationship of BCS and ultrasound measurements. Domecq et al. (1995) and Ayres et al. (2009) showed that RTU was a good predictor of BCS in dairy and Nelore cows, respectively. Therefore, the objective of this study was to identify the relationship of BCS and RTU fat measurements in crossbred beef cows.

Experimental Procedures

Crossbred beef cows (n = 48) from the Texas A&M University-Commerce farm were used in this study. All animals were managed on pasture. Prior to scanning, hair was clipped to a length of approximately 0.5 inches and vegetable oil was used as a coupling agent in order to increase image quality. The cows were scanned prior to the start of the breeding season by an Ultrasound Guidelines Council field-certified technician using an Aloka 500V real time ultrasound machine with a 17-cm, 3.5 MHz transducer (Aloka Co. Ltd., Wallingford, CT). RTU measurements collected included 12-13th rib backfat thickness (**uBF**), rump fat (**uRUMPFT**), and kidney fat depth (**uKFD**). Images were stored using the CUP Lab UICS Software (CUP Lab Walter Associates, LLC, Ames, Iowa) and interpreted by the National CUP Lab in Ames, Iowa. The uKFD image was collected as described by Ribeiro et al. (2008) and interpreted chute side. Combined subcutaneous fat (**ComboFat**), was calculated by averaging uBF and uRUMPFT. Predicted internal fat (**PredIFAT**) was calculated using the equations published by Ribeiro et al. (2008). Body weight (**BW**), hip height (**HH**), and BCS, were also recorded at the time of scanning. Data was analyzed using the PROCREG and PROCGLM procedures of SAS (Version 9.1, SAS Inst. Inc., Cary NC).

Results and Discussion

Summary statistics for all of the live measurements collected from the cows are listed in Table 1. Table 2 shows the correlation coefficients between BCS and the measured traits. BCS is moderately to highly correlated to BW, uKFD, uRUMPFT, uBF, ComboFat, and PredIFAT (r = 0.80, 0.55, 0.46, 0.47, 0.49, and 0.60, respectively). Ayres et al. (2009) reported a higher correlation between BCS and uRUMPFT (0.88 to 0.93) and a lower correlation between BCS and BW (0.37 to 0.50). This difference may be attributed to the present study using crossbred *Bos taurus* influenced cows, where as Ayres et al. (2009) used Nelore cattle, which are *Bos indicus*. In studies using small ruminants differences were also observed. Duff et al. (2010) reported a correlation between BCS and uBF and uRUMPFTof 0.83 and 0.92, respectively, in Boer cross does. While Carter et al. (2010) reported a correlation between BCS and rump fat of 0.46, in Suffolk ewes. At this time, these differences are not well understood, but limited variation of BCS in the current study (BCS = 3 to 5) could be some of the reasons for different observed correlations within study.

Least squares means of all the traits measured in this study separated by BCS are reported in Table 3. These results show that when cows improve their BCS the level of subcutaneous fat and internal fat increases significantly. Table 4 shows equations used to predict subcutaneous fat in different sites and also total internal fat in beef cows. BCS by itself was a better predictor of

total internal fat than ComboFat. (R^2 = 0.30 and 0.24, respectively). In models using BCS, BW, and HH, the prediction of total internal fat and uRUMPFT were improved, explaining 39 and 40% of the variation, respectively. These results show that BCS and BW could be good predictors of subcutaneous fat and total internal fat in beef cows. By assigning BCS to cows we were able to separate the cows into groups with small, medium, and large levels of fat. These relationships obtained were good, however, more studies are needed to improve sorting based on fat thickness as assigned by body condition score for beef cows.

Implications

Results from this study show that BCS can be used to estimate levels of fat in beef cows. Adjustments for different breeds might be needed in order to improve the accuracy. More data will be added to this study in order to increase the number of observations and improve the accuracy of using BCS to estimate fat levels.

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Table 1. Summary statistics for live measurements

Trait	n	Mean	SD	Min.	Max.
Body wieght, lb	48	1256	139	984	1630
Hip height, in	48	54.7	1.47	51.0	59.0
Body condition score[1]	48	3.88	0.57	3.00	5.00
Ultrasound kidney fat depth, in	48	6.74	0.40	5.79	7.83
Ultrasound rump fat thickness, in	48	0.17	0.15	0.03	0.74
Ultrasound backfat thickness, in	46	0.13	0.07	0.05	0.39
Combo subcutaneous fat thickness, in	46	0.15	0.11	0.05	0.53
Predicted total internal fat, lb	46	55.6	9.05	40.5	80.9

[1] Body condition score was recorded on a scale from 1 to 9; 1 = emaciated, 9 = very fat.

Table 2. Correlation coefficients among body weight (BW), hip height (HH), BCS and ultrasound traits

Traits[b]	HH	BCS	uKFD	uRUMPFT	uBF	ComboFat	PredIFat
BW	**0.63**	**0.80**	**0.59**	**0.52**	**0.44**	**0.52**	**0.61**
HH		**0.57**	**0.45**	0.07	0.13	0.09	**0.31**
BCS			**0.55**	**0.46**	**0.47**	**0.49**	**0.60**
uKFD				**0.45**	**0.35**	**0.45**	**0.72**
uRUMPFT					**0.77**	**0.98**	**0.79**
uBF						**0.89**	**0.90**
ComboFat							**0.87**

[a] Correlations in bold are different from zero at $P < 0.05$)
[b] BW = body weight; HH = hip height; BCS = body condition score; uKFD = ultrasound kidney fat depth; uRUMPFT = ultrasound rump fat thickness; uBF = ultrasound backfat thickness; ComboFat = (uBF + uRUMPFT)/2; PredIFAT = predicted total internal fat

Table 3.Characterization of ultrasound and live measurements and body condition score in crossbred beef cows

	BCS				
Trait	3	4	5	SE	P-value
n	11	32	5		
Body weight, lb	1119[a]	1258[b]	1540[c]	36.6	< 0.001
Hip Height, in	53.7[a]	54.7[b]	56.4[c]	0.58	0.002
Ultrasound Rump fat thickness, in	0.08[a]	0.17[b]	0.36[c]	0.06	0.002
Ultrasound backfat thickness, in	0.08[a]	0.14[b]	0.20[b]	0.03	0.008
Combo subcutaneous fat, in[1]	0.08[a]	0.15[b]	0.28[c]	0.04	0.002
Predicted total internal fat, lbs	48.5[a]	56.5[b]	65.8[c]	3.47	<0.001

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

[1] Combo subcutaneous fat = (uBF + uRUMPFT)/2

Table 4. Equations to predict ultrasound backfat (**uBF**), rumpfat (**uRUMPFT**), combo subcutaneous fat (**ComboFat**), or total internal fat (**PredIFAT**)

#	Equation[1]	R^2	RMSE
1	uBF = -0.9111 + (0.05709*BCS)	0.20	0.07
2	uBF = 0.41650 + (0.03396*BCS) + (0.00020078*BW) - (0.01226*HH)	0.26	0.07
3	uRUMPFT = -0.32111 + (0.12709*BCS)	0.22	0.14
4	uRUMPFT = 1.64364 + (0.04140*BCS) + (0.00075588*BW) - (0.04722*HH)	0.40	0.13
5	ComboFat = -0.20611 + (0.09209*BCS)	0.24	0.10
6	ComboFat = 1.03007 + (0.03768*BCS) + (0.00047833*BW) - (0.02974*HH)	0.38	0.09
7	PredIFat = 22.86 + (8.46747*BCS)	0.30	7.68
8	PredIFat = 43.19558 + (2.68006*BCS) + (0.03512*BW) - (0.76925*HH)	0.39	7.33

[1] BCS = body condition score; BW = body weight; HH =- hip height; ComboFat = (uBF + uRUMPFT)/2

USE OF REAL-TIME ULTRASOUND (RTU) MEASUREMENTS AND CARCASS TRAITS TO ASSESS INTERNAL FAT IN RESIDUAL FEED INTAKE (RFI)-INDEXED BRAHMAN BULLS

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Summary

The objective of this study was to evaluate previously published equations by Ribeiro et al. (2008) to estimate total physical separable internal fat (**IFAT**) in 16 residual feed intake (**RFI**)-indexed Brahman bulls subsequently managed under grazing conditions. Real-time ultrasound (**RTU)** as well as carcass measurements were evaluated in the bulls. Ultrasound measurements were collected 5 d prior to slaughter and carcass data was recorded after a 48-h chill. A linear regression to predict IFAT from KPH weight and uRUMP (R^2 of 0.61 and a RMSE of 1.54 kg) was developed. The stepwise selection indicated a partial R^2 of 0.53 for KPH weight and 0.08 for uRUMP. These results demonstrate that KPHwt can be used to predict IFAT in Brahman bulls.

Introduction

Beginning in the 1950's real-time ultrasound (**RTU**) has been used in beef cattle (Temple et al., 1956). It is a non-invasive technique that allows cattle producers to measure carcass traits in the live animal. Until recently RTU had the capability of just measuring the common carcass traits *longissimus* muscle area, backfat thickness, intramuscular fat (marbling) and rump fat thickness. A new technique described by Ribeiro et al. (2008) uses the ultrasound measurement of KPH depth (**uKPHd**) to estimate IFAT in beef cattle. The accuracy of RTU to measure carcass traits has been extensively reported in scientific literature (Perkins et al., 1992; Greiner et al., 2003; Ribeiro et al., 2006). Ribeiro et al. (2008 and 2009) reported that RTU can be used to predict total internal fat in beef cattle. However, no research has been reported on the use of this technique in purebred Brahman cattle. Since Brahman and Brahman influenced cattle are widely used in the southern region of the US, it would be important to test this technique in this breed.

Experimental Procedures

Brahman bulls (n = 16) were grazed on Coastal bermudagrass ([*Cynodon dactylon* (L.) Pers]) for 60 d at two different stocking rates (**SR**). Animals were classified as efficient (**LRFI)** or inefficient (**HRFI**) according to their performance on a high roughage diet fed 70 d before beginning the trial. Animals were then randomly assigned to high (**HSR**) or low (**LSR**) stocking rate. RTU measurements were taken 5 d prior to slaughter. These consisted of uKPHD, uBF, uREA, uRUMP, and uIMF. BW was also recorded at time of ultrasound. The uKPHd image was collected by placing the ultrasound probe on the flank region approximately 15 cm from the mid line of the animal between the 13th rib and first lumbar vertebrae. Images were collected by an Ultrasound Guidelines Council field-certified technician using an Aloka 500V instrument with a 17-cm, 3.5-MHz transducer (Aloka Co. Ltd., Wallingford, CT). Hair was clipped (if longer than 0.64 cm) to increase image quality and vegetable oil was used as a coupling agent. Images were saved in an image capturing system and sent to the National Cup Lab (Ames, IA) for interpretation. The uKPHd images were interpreted chute side by the same technician.

Bulls were slaughtered at 16 to 18 mo of age and average 992 lbs. Whole gastrointestinal tracts were removed at slaughter and dissected to obtain IFAT. Measurements of cKFd were taken from the hot carcass by using a tape measure. The measurement was taken from the midline (vertebrae) to the end of the kidney fat. The KPH depot was removed from the carcass before splitting. The fat depot was then weighed and added to the IFAT. After allowing the carcass to chill for 48-h, complete carcass data were collected.

Data were analyzed using a split-plot design in a 2x2 factorial arrangement using pastures within SR as random factors. Prediction equations were developed using the PROC REG procedure of SAS with a stepwise selection.

Results and Discussion

Table 1 shows the least square means for ultrasound and carcass traits. No interactions were found with SR ($P > 0.05$) or RFI ($P > 0.05$) with any of the RTU or carcass traits measured, except for carcass backfat. This was significant ($P = 0.051$) with LRFI bulls having more backfat than HRFI bulls (0.22 vs. 0.13 cm, respectively).

Table 2 shows the correlation coefficients among all collected traits for this study. The measurements of uREA and uBF were significantly correlated to carcass REA (**cREA**) and backfat thickness (**cBF**; 0.89 and 0.62 respectively), demonstrating that ultrasound can accurately predict carcass traits. KPH weight was highly correlated with IFAT (0.73), indicating that KPH weight

might be the best predictor of IFAT in Brahman cattle. These results are in agreement with Ribeiro et al. (2009).

Using ultrasound to estimate internal fat in beef cattle was reported by Ribeiro et al. (2008). This research used a new technique using the ultrasound measurement of KPH depth to estimate the amount of physically separable internal fat. In 2009, Ribeiro et al. re-examined this technique with a larger number of cattle.

The ability to use ultrasound to estimate IFAT in beef cattle was first reported by Ribeiro et al. (2008). Ribeiro et al. (2009) reported revised equations to predict IFAT which were used in this study. Linear regression equations were developed to predict IFAT (Table 3) using a stepwise procedure of SAS. The first variable included in the model was KPH weight with an R^2 of 0.53. The second variable was uRUMP, which had a partial R^2 of 0.08 increasing the full model R^2 to 0.61. The results from Ribeiro et al. (2009) showed a higher R^2 (0.84). This difference could be attributed to the number of animals used in the study and also to breed differences.

Assessing internal fat has also been studied in different species. Silva et al. (2006) found that internal fat can be estimated using RTU in sheep. Their results showed that BW alone accounted for a large amount of the variation (r^2 range: 0.74 to 0.87); however, when ultrasound measurements were added to the equation, precision was improved. Subcutaneous fat measurements were the strongest measure improving the prediction of amount of fat tissues in carcass, internal fat, and total fat (r^2 increase between 0.05 and 0.17; $P < 0.01$). Teixeira et al. (2008) reported that BW and the ultrasound measurement of fat thickness aided in the prediction of carcass composition as well as body fat depots in Celtiberica goats. In their study, BW explained 91 % of the variation in omental fat depots, while the ultrasound measurement of the 5th and 6th lumbar subcutaneous fat depth explained 80% of the variation in mesenteric fat.

There are different methods available to measure body composition in animals; however, they are costly and require the animal to be physically restrained and sedated. These other methods include Computer Tomography and MRI. Both of these techniques provide a high quality image, in which the different tissues are easily distinguished, but they are not economically feasible to producers, therefore improving the use of ultrasound is important.

Implications

These results show that KPHwt can be used to predict IFAT in Brahman bulls. Results also suggest that uKPHd and cKPHd were good predictors of IFAT. No studies have been reported using this technique in purebred Brahman cattle. Brahman and Brahman-influenced cattle are extensively used in the southern region of the US, therefore testing this technique on them is valuable to producers. Assessing IFAT in cattle can improve management decisions by implementing this as a sorting strategy to potentially decrease waste fat. More research is needed to improve the precision of the IFAT predictive equations.

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Table 1. Characterization of ultrasound and carcass traits in Brahman bulls with low and high RFI following low and high stocking rates.

Traits	RFI Group			Stocking Rate		
	Low	High	SE	Low	High	SE
Ultrasound Traits						
uBF, cm	0.23	0.24	0.02	0.24	0.23	0.02
uRUMP, cm	0.43	0.40	0.03	0.41	0.41	0.03
uREA, cm^2	57.6	56.5	1.97	60.5	53.6	1.97
uKPHd, cm	14.8	14.6	0.54	14.8	14.7	0.68
uIMF, %	10.4	9.1	0.82	9.3	10.2	0.95
Carcass Traits						
cBF, cm	0.22^x	0.13^y	0.04	0.16	0.19	0.04
cREA, cm^2	63.9	61.7	3.05	66.0	59.6	3.05
cKPHd, cm	10.6	11.4	0.53	10.8	11.1	0.67
KPHwt, kg	3.09	3.23	0.68	3.12	3.20	0.95

x,y Least square means within a row with different superscripts differ ($P < 0.05$)

Table 2. Correlations among traits used to develop prediction equations predicting internal fat weight (IFAT).

	uBF	uREA	cREA	uIMF	uKPHd	cKPHd	KPHwt	cBF	IFAT
RFI	0.10	-0.35	-0.43	0.21	-0.04	0.20	-0.21	-0.46	**-0.49**
uBF		0.15	-0.05	-0.01	0.12	**0.64**	0.24	**0.62**	0.37
uREA			**0.89**	**-0.67**	0.21	0.32	0.26	0.16	0.38
cREA				**-0.70**	0.19	-0.03	0.38	0.06	0.37
uIMF					-0.11	0.06	0.00	0.05	-0.01
uKPHd						0.21	-0.18	0.09	0.05
cKPHd							-0.02	0.24	0.36
KPHwt								0.37	**0.73**
cBF									0.41

Table 3. Equations to predict internal fat (IFAT, kg)

Equation no.	Equation	R^2	RMSE	N
1	IFAT = 4.89781 + 1.52828 x KPHwt	0.53	1.64	16
2	IFAT = 2.29639 + 7.5504 x uRUMP + 1.34229 x KPHwt	0.61	1.54	16

EFFECTS OF WET CORN DISTILLER'S GRAINS WITH SOLUBLES (WCDGS) AND NON-PROTEIN NITROGEN ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF YEARLING STEERS

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Summary

Yearling steers (n = 525; initial weight = 822 lb) received dietary treatments involving WCDGS (15 or 30% of DM) and non-protein N (NPN; 0, 1.5, or 3.0% of DM) from urea; a control diet without WCDGS was fed that contained 3.0% NPN and cottonseed meal. Feed intake increased linearly (P = 0.04) as NPN increased, but was not altered by WCDGS. Overall ADG for steers fed 15% WCDGS was greater for 1.5 and 3.0% NPN than for 0% NPN (P < 0.07, quadratic); however, ADG was not influenced by NPN for 30% WCDGS. Overall ADG was not different between the control and 15% WCDGS, but ADG was lower (P < 0.02) for 30% than for 15% WCDGS. Overall gain efficiency among steers fed 15% WCDGS was greatest for 1.5% NPN and least for those fed 0% (P < 0.07, quadratic), whereas gain efficiency decreased linearly (P < 0.09) as NPN increased in 30% WCDGS diets. Dressing percent was greater (P < 0.01) for the control diet than for 15% or 30% WCDGS. Data suggest that optimum performance occurs between 1.5 and 3.0% NPN when diets contain 15% WCDGS, and with 1.5% NPN or less when diets contain 30% WCDGS.

Introduction

The growth of the ethanol industry in the recent past has led to more widespread availability of wet distiller's grains with solubles, most commonly made from corn grain. Wet corn distillers grains with solubles (WCDGS) can be fed at low levels to provide supplemental protein to feedlot cattle, but higher dietary levels may be cost effective if the price difference between corn and WCDGS is favorable. Thus, a range of dietary levels is expected to be utilized in the feedlot industry, depending on current ingredient prices.

As corn grain is replaced with WCDGS, dietary starch is replaced with readily fermentable fiber. This replacement may result in a reduced need for rapidly degraded nitrogen (e.g., feed grade urea) in the rumen to support optimum ruminal fermentation. Therefore, assessment of degradable nitrogen needs in diets containing WCDGS is needed to allow provide information on appropriate diet formulation adjustments to aid the cattle industry in managing feed costs.

Experimental Procedures

Crossbred yearling steers (549 head) were procured, processed on arrival, and adapted over at least 28 days to a 90% concentrate diet based on steam-flaked corn that did not contain grain milling byproducts. Cattle were then weighed before feeding to select study candidates. Scales were validated with certified weights before each use. Cattle were blocked and randomized to treatments based on this weight measurement. On the following day, cattle were weighed a second time, implanted with Revalor-IS, and were sorted into study pens as they exited the chute. Initial weight was the average of these body weight measurements on consecutive days. Treatments were arranged in a 2 x 3 + 1 factorial of WCDGS (15 or 30% of DM) and 0, 1.5, or 3% non-protein N derived from urea; a control diet was also fed that did not contain WCDGS in which 3.0% non-protein N and cottonseed meal were included (Table 1). Cattle assigned to 30% WCDGS diets with 0, 1.5, and 3.0% non-protein N were fed 15% WCDG diets with the appropriate non-protein N for three days before increasing WCDGS to 30% of DM. Feed was mixed and delivered twice daily throughout the study. Cattle were reimplanted with Revalor-S after an average of 55 days on feed and were slaughtered after an average of 129 days on feed.

Steam-flaked corn was prepared approximately 4 times/week. Corn was steamed for 35 minutes after tempering to 18% moisture overnight and was flaked to a bulk density of 27.5 lb/bu. The WCDGS was obtained three times/week from Quality Distiller's Grains in Hereford, TX and stored under shelter in an open-front commodity shed until fed. Shrink from the point of loading at the plant until entering the feed mixer averaged 6.2% over the entire study (April through August). Dry matter of steam-flaked corn and WCDGS were determined 5 days/week at 60°C for 48 hours. Dry matter of remaining ingredients were determined once/week at 60°C for 48 hours. Each week, ingredient DM was updated to determine diet DM. Actual diet DM composition during the study was calculated using the overall average DM of each ingredient.

Samples of ingredients and diets were collected each week and composited before laboratory analysis. Uncompacted ration density was determined by pouring a fresh ration sample into a 3-gallon bucket and removing excess feed

with a straight edge. Compacted ration density was determined in a similar fashion except that feed was compacted by lifting the filled bucket 12 inches and dropping it 10 times. These ration densities were determined on 6 separate occasions during the study.

Growth performance data and continuous carcass data were analyzed using Mixed procedures of SAS. The distribution of carcass quality and yield grades were analyzed using Glimmix procedures of SAS. Means were separated using the contrasts of 0 vs 15% WCDG, 15 vs 30% WCDG, and linear and quadratic effects of non-protein N either within or across WCDG concentrations. Interactions were considered statistically significant at $P < 0.15$, whereas means were declared as different if $P < 0.10$.

Results and Discussion

Actual diet ingredient and chemical composition agreed well with formulation targets (Table 1) with the exception of calcium content of the control ration. This discrepancy is most likely related to sampling challenges because the same supplement was used for the three diets containing 3.0% non-protein N. The WCDGS fed contained 37.8% DM, 33.4% CP, and 12% crude fat (Table 2); the WCDGS was derived from a blend of milo and corn (10:90). Observed diet NEm and NEg based on cattle performance were 98% of expected for cattle fed the control diet; the NEm and NEg values used were 1.093 and 0.766 Mcal/lb for steam-flaked corn, 2.15 and 1.59 Mcal/lb for yellow grease, and 0.81 and 0.526 Mcal/lb for cottonseed meal. Through the process of substitution, the NEg that wet corn distiller's grains with solubles had to contain, assuming no associative effects, was 97% of steam-flaked corn for optimum performance with 15% WCDG (average of 1.5 and 3.0% non-protein N diets, WCDGS = 0.746 Mcal/lb) and 101% of steam-flaked corn for optimum performance with 30% WCDGS (0% non-protein N diet, WCDGS = 0.776 Mcal/lb).

From day 1 through reimplant (Table 3), dry matter intake increased linearly ($P < 0.05$) as dietary non-protein N increased in diets containing either 15 or 30% WCDGS. This response continued throughout the study such that overall dry matter intake increased linearly ($P < 0.05$) with increasing non-protein N. Feed efficiency through reimplant was not different ($P > 0.10$) between the control and diets containing 15% WCDGS, but feed efficiency was poorer for steers fed 30% WCDGS than for steers fed 15% WCDGS. Feed efficiency through reimplant became poorer ($P < 0.05$) as dietary non-protein N increased in diets with 30% WCDGS (WCDG x non-protein N, $P = 0.02$). Overall carcass-adjusted ADG was not different ($P > 0.10$) between steers fed the control and those fed 15% WCDGS, but steers fed 15% WCDGS had greater ADG than those fed 30% WCDGS ($P < 0.05$). Among steers fed 15% WCDGS, ADG was increased by adding 1.5% non-protein N ($P < 0.10$). Overall carcass-adjusted feed efficiency (WCDGS x non-protein N, $P = 0.14$) was not different ($P > 0.10$) between steers fed the control and those fed 15% WCDGS. However, feed efficiency became poorer ($P < 0.05$) when 30% WCDGS was fed than when 15% WCDGS was fed. In addition, feed efficiency was not affected by non-protein N in diets containing 15% WCDGS ($P > 0.10$), whereas increasing non-protein N in diets containing 30% WCDG resulted in poorer feed efficiency ($P < 0.10$).

No interactions ($P > 0.15$) between WCDGS and non-protein N were evident for carcass characteristics. Dressing percent was greater for steers fed the control than for those fed 15 or 30% WCDGS ($P < 0.01$). Hot carcass weight was not different between the control and diets with 15% WCDGS ($P > 0.10$), but hot carcass weight was reduced by feeding 30% WCDGS compared to feeding 15% WCDGS ($P < 0.01$). More carcasses from steers fed 30% WCDGS were yield grade 1 ($P < 0.10$) than from steers fed the control or 15% WCDGS, and steers fed the control had more yield grade 3 carcasses ($P < 0.10$) than those fed 15 or 30% WCDGS.

Implications

Optimum performance by finishing yearling steers fed 15% WCDGS occurred when the diet contained between 1.5 and 3.0% non-protein N, but removing all non-protein N was necessary to optimize performance in diets containing 30% WCDGS.

Acknowledgements

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

		Wet corn distiller's grains with solubles, % of DM					
		15%			30%		
		Dietary non-protein N, % of DM			Dietary non-protein N, % of DM		
Item	Control	0	1.5	3.0	0	1.5	3.0
Steam-flaked corn	76.46	66.54	66.53	66.53	52.66	52.66	52.65
Cottonseed meal	3.85	-	-	-	-	-	-
Urea	1.06	-	0.52	1.06	-	0.52	1.06
Wet corn distiller's grains with solubles	-	14.75	14.76	14.75	29.58	29.57	29.57
Supplement	2.39	3.45	2.93	2.40	3.46	2.94	2.42
Steep liquor	4.12	4.13	4.13	4.12	4.13	4.14	4.14
Yellow grease	2.01	1.00	1.00	0.99	-	-	-
Alfalfa hay	10.11	10.14	10.13	10.14	10.17	10.16	10.16
CP, %	13.6	12.9	15.0	15.6	16.6	18.1	18.9
Non-protein N, %	3.25	0.6	1.8	3.3	0.6	1.7	3.1
ADF, %	8.0	9.9	9.9	9.4	11.7	12.4	11.2
NDF, %	13.8	15.4	18.4	17.4	20.0	22.5	20.3
Crude fat, %	4.8	5.0	4.8	4.8	4.6	4.8	4.5
Ca, %	0.98	0.88	0.87	0.86	0.92	0.89	0.80
P, %	0.33	0.36	0.36	0.35	0.42	0.42	0.40
K, %	0.78	0.81	0.83	0.82	0.90	0.90	0.86
Mg, %	0.19	0.20	0.21	0.19	0.22	0.23	0.20
S, %	0.17	0.23	0.24	0.23	0.31	0.32	0.29
Zn, mg/kg	81	84	87	79	90	91	85
Fe, mg/kg	214	342	240	260	259	278	230
Mn, mg/kg	53	49	46	44	50	53	45
Cu, mg/kg	20	18	18	21	19	19	19
Diet DM, %	82.70	69.79	69.82	69.86	60.61	60.64	60.66
Density of uncompacted diet, lb/ft^3, [a]	25.7	28.4	29.0	28.4	29.8	30.0	29.9
Density of compacted diet, lb/ft^3, [a]	32.8	36.6	37.8	36.5	38.9	39.6	39.9

[a]Control vs 15% distiller's grains and 15% vs 30% distiller's grains ($P < 0.01$).

Table 2. Chemical composition of wet corn distiller's grains with solubles[a]

Analyte	Concentration (DM basis)
DM, %	37.8
CP, %	33.4
Soluble CP, % of CP	13.5
NPN, % of CP	0.1
ADICP, %	5.2
NDICP, %	8.5
ADF, %	18.7
NDF, %	36.2
Lignin, %	6.1
Starch, %	4.8
Crude fat, %	12.2
Ash, %	5.7
Ca, %	0.07
P, %	0.64
K, %	0.71
Mg, %	0.22
Na, %	0.16
Cl, %	0.19
S, %	0.56
Cu, mg/kg	5
Fe, mg/kg	111
Mn, mg/kg	16
Mo, mg/kg	0.9
Zn, mg/kg	55
DCAD, mEq/100 g	-15

[a]Samples assayed were a composite of samples collected once/week throughout the study.

Table 3. Effects of wet corn distiller's grains with solubles and non-protein nitrogen on growth performance by yearling steers

		Wet corn distiller's grains with solubles, % of DM							
		15%			30%				
		Dietary non-protein N, % of DM			Dietary non-protein N, % of DM				
Item	Control	0	1.5	3.0	0	1.5	3.0	SE	DG*U
Pens	8	8	8	8	8	8	8	-	-
Animals	75	75	75	75	75	75	75	-	-
Initial weight, lb[a]	822	824	821	821	820	822	821	28	-
Reimplant weight, lb[a]	1071	1059	1067	1075	1052	1055	1054	33	-
Shrunk, final weight, lb	1322	1316	1346	1317	1297	1294	1297	26	0.31
Adjusted final weight, lb[b,d]	1322	1302	1322	1318	1292	1290	1292	20	0.47
Day 1 to reimplant									
Days on feed	55	55	55	55	55	55	55	-	-
DMI, lb/d[c]	20.6	19.7	20.1	20.7	19.4	19.6	20.4	0.6	0.97
ADG, lb/d[c, d]	4.50	4.21	4.45	4.59	4.21	4.22	4.23	0.15	0.20
DMI:ADG [d, f]	4.59	4.68	4.54	4.52	4.63	4.67	4.87	0.14	0.02
Day 1 to slaughter									
Days on feed	129	129	129	129	129	129	129	-	-
DMI, lb/d [c]	21.49	20.87	21.55	21.65	20.84	20.83	21.52	0.57	0.55
ADG, live basis [d, e]	3.77	3.69	3.92	3.85	3.70	3.66	3.69	0.09	0.12
ADG, lb/d, adjusted basis [d]	5.70	5.67	5.50	5.62	5.63	5.69	5.85	0.08	0.06
DMI:ADG, adjusted basis [d,f]	3.88	3.69	3.86	3.84	3.65	3.63	3.63	0.09	0.37

[a]A pencil shrink of 4% was applied to actual weight.
[b]Calculated as (hot carcass weight ÷ (overall average dressing percentage of 64.22/100)).
[c]Linear urea effect ($P < 0.05$).
[d]15 vs 30% DG ($P < 0.03$).
[e]Quadratic effect of non-protein N within 15% wet corn distiller's grains ($P < 0.10$).
[f]Linear effect of non-protein N within 30% wet corn distiller's grains ($P < 0.10$).
[g,h]Means differ within 15% wet corn distiller's grains ($P < 0.10$).

Table 4. Effects of wet corn distiller's grains with solubles and non-protein nitrogen on carcass characteristics of yearling steers

		Wet corn distiller's grains with solubles, % of DM							
		15%			30%				
		Dietary non-protein N, % of DM			Dietary non-protein N, % of DM				
Item	Control	0	1.5	3.0	0	1.5	3.0	SE	DG*U
Pens	8	8	8	8	8	8	8	-	-
Animals	75	75	75	75	75	75	75	-	-
Dressing percent[a]	65.1	64.3	64.0	64.3	63.9	64.0	63.9	0.3	0.60
Hot carcass weight, lb[b]	849	836	849	846	829	828	829	13	0.47
Ribeye are, in^2	14.3	14.1	13.9	14.2	14.4	14.2	14.4	0.2	0.87
Average yield grade	2.77	2.75	2.86	2.83	2.63	2.67	3.06	0.20	0.53
Fat thickness, in	0.49	0.48	0.49	0.51	0.48	0.47	0.49	0.03	0.86
Marbling score[c]	400	387	405	402	395	400	393	11	0.66

[a]Control vs 15% DG ($P < 0.01$).
[b]15 vs 30% DG ($P < 0.01$).
[c]Small = 400 to 499, etc.

Table 5. Effects of wet corn distiller's grains with solubles and non-protein nitrogen on carcass quality and yield grade distributions

		Wet corn distiller's grains with solubles, % of DM						
		15%			30%			
		Dietary NPN, % of DM			Dietary NPN, % of DM			
Item	Control	0	1.5	3.0	0	1.5	3.0	DG*U
Pens	8	8	8	8	8	8	8	-
Animals	75	75	75	75	75	75	75	-
Yield grade, %								
1[a]	15.6	13.9	11.4	14.1	26.4	15.2	22.8	0.84
2	41.2	53.6	47.4	47.0	43.1	50.8	44.5	0.66
3	38.9	21.0	34.4	31.4	22.2	31.5	23.7	0.59
4 and 5	4.3	11.5	6.8	7.5	8.3	2.5	9.0	0.36
Quality grade, %								
> Choice-	11.5	4.2	9.2	11.8	9.0	14.7	10.5	0.44
Choice-[b]	33.9	36.4	42.0	36.8	35.1	30.2	28.9	0.67
Prime and Choice, %	45.4	40.6	51.2	48.6	44.1	44.9	39.4	0.50
Select	54.6	58.0	48.8	48.2	53.8	51.1	57.6	0.51
Standard	0	1.4	0	3.2	2.1	4.0	3.0	-

[a]15 vs 30% DG ($P < 0.02$).
[b]15 vs 30% DG ($P < 0.09$).

RELATIONSHIPS BETWEEN RESIDUAL FEED INTAKE AND CARCASS-QUALITY TRAITS IN SANTA GERTRUDIS STEERS

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Summary

The objective of this study was to examine the phenotypic associations between residual feed intake, and carcass traits and tenderness in Santa Gertrudis steers (N = 114). Individual intakes were measured while steers were fed a high-grain (ME = 3.0 Mcal/kg) diets for 80 days. Residual feed intake was calculated as the residual value from linear regression of DMI on mid-test $BW^{0.75}$ and ADG. Steers were categorized into low, medium and high RFI phenotype groups based on ± 0.50 SD from the mean of 0.0 ± 0.98. Steers were harvested at about one cm 12th rib fat thickness (**cBF**). After 24 h, *longissimus* muscle samples were removed for calpastatin activity (**CALP**). At 48 h, carcass traits (hot carcass weight, **HCW**; *longissimus* muscle area, **REA**; kidney, pelvic and heart fat, **KPH;** BF and marbling score, **MS**) were measured, and yield grade (**YG**) calculated. Two 12th rib steaks were aged for 1 (**WSF1**) and 14 days (**WSF14**) for Warner-Bratzler shear force. Residual feed intake was correlated ($P < 0.05$) with carcass BF (0.26), YG (0.24), lipid content (0.26), protein content (-0.27), indicating that steers with low RFI were leaner. Steaks from steers with medium RFI had lower ($P < 0.05$) WSF values than steaks from steers with high RFI, with steaks from low-RFI steers being intermediate. Calpastatin activities were actually lower ($P < 0.05$) in steers with low compared to high RFI. While RFI is positively associated with carcass fat traits, results from this study suggest that selection for improved RFI will not have a negative impact on marbling and beef tenderness.

Introduction

Feeding animals is the major cost in almost all animal production systems (Herd et al., 2003), so selection for animals that are more efficient will increase profitability by decreasing the amount of feed needed for a given level of performance. Residual feed intake measures the difference in feed intake beyond that needed to support maintenance and growth requirements and it is independent from growth and body size (Arthur et al., 2001). Additionally, RFI has been shown to be moderately heritable (0.16 to 0.43; Herd et al., 2003). Several studies have evaluated relationships between RFI and ultrasound and carcass traits (Basarab et al., 2003; Nkrumah et al., 2004, 2007; Lancaster et al., 2008c). Results from these studies indicated a weak correlation (0.02 to 0.22) between RFI and ultrasound or carcass traits. Tenderness has been reported to be the most desirable characteristic in beef by consumers. Few studies have examined the relationships between RFI and carcass quality and tenderness traits, especially with *Bos indicus*-influenced cattle. In Angus cattle divergently selected for RFI for one generation, McDonagh et al. (2001) found that steers from parents selected for low RFI had higher calpastatin activity, but similar Warner Bratzler shear force values compared to steers from parents selected for high RFI. However, Baker et al. (2006) found that calpastatin activity and Warner-Bratzler shear force values were similar in Angus steers with divergent RFI phenotypes. Results from these studies have not been consistent and need to be further evaluated. Therefore, the objective of this study was to examine the phenotypic associations between RFI and carcass composition and meat quality traits (tenderness and marbling) in Santa Gertrudis steers fed high-grain diets.

Experimental Procedures

Animal and Management Description

One hundred and fourteen Santa Gertrudis steers from the King Ranch (Kingsville, TX) were used in this study. Steers were transported to the O.D. Butler, Jr. Animal Science Complex and adapted to the experimental diet and trained to eat from Calan gates prior to the commencement of the experiment. A high-grain diet (3.0 Mcal/kg of ME and 10.1% of CP; DM) was fed for 80 d. The diet consisted of 76.5% dry rolled corn, 7.5% cottonseed meal, 5% chopped alfalfa hay, 5% coastal hay, 4% molasses, and 2% premix. Steers were approximately 13 to 15 mo of age and weighed 430 ± 42.5 kg at the start of the study. Individual feed intake data was recorded daily and feed refusals weighed weekly. Anabolic implants were not administered to steers during the study. Individual feed ingredients were sampled at 14-d intervals, and composited samples sent to Dairy One Inc., Forage Testing Lab (Ithaca, NY) for chemical analysis using the Cornell Net Carbohydrate and Protein System fractionation.

Growth and Ultrasound Data Collection

Steers were weighed at 14-d intervals and real-time ultrasound measurements obtained on days 0 and 80 of the study. Real-time ultrasound measurements consisted

of 12-13th rib backfat thickness (**uBF**), 12-13th-longissimus muscle area (**uREA**), and percentage of intramuscular fat (**uIMF**) collected by an Ultrasound Guidelines Council field-certified technician using an Aloka 500V instrument with a 17-cm, 3.5-MHz transducer.

Carcass and 9th- to 11th-rib Data Collection

Following the 80-d test period, steers were harvested in 2 groups (11 d and 40 d following the end of the 80-d test period) at approximately 10 mm of rib fat thickness, as determined by RTU measurements. Steers were transported to Sam Kane Beef Processors, Inc. (Corpus Christi, TX) to be harvested. After a 48 h chill, HCW (kg) 12th- to 13th-rib backfat thickness (**cBF**), 12-13th-rib ribeye area (**REA**), marbling score, KPH and yield grade (**YG**) were obtained by Texas A&M University trained personnel. The 6-12th-rib sections were removed from the carcass, vacuum packaged, and transported to the Rosenthal Meat Science Center. The 9-11th-rib sections were dissected and the protein and lipid content of separable tissue assayed to determine carcass chemical analyses according to Hankins and Howe (1946). Protein was determined using a Leco analyzer, and fat content determined by a Soxhlet apparatus using diethyl ether.

Calpastatin and Tenderness Data Collection

After a 24 h chill, a 50 g sample was collected from the longissimus muscle to determine calpastatin activity (**CALP**). Samples were transported approximately 5 h from Sam Kane Beef Processors, Inc. (Corpus Christy, TX) to the Rosenthal Meat Science Center and immediately extracted to determine CALP following the procedure of Koohmaraie et al. (1995). Two steaks were removed from the 12th-rib section, vacuum packaged and aged for 1- and 14-d and frozen for later analysis of WBSF. Copper constantan thermocouples were inserted into the geometric center of each steak and temperature monitored. Steaks were cooked on a Faberware Open Hearth broiler to an internal temperature of 70°C. Six, 1.27 cm, cores were taken parallel to the steak's muscle fiber orientation, and WBSF force determined using a Universal Testing Instrument equipped with a 20 kg compression load cell.

Calculations and Statistical Analysis

Growth rates of individual steers were obtained by linear regression of serial 14-d BW on days on test using the PROC REG procedure of SAS (SAS, Inst., Cary, NC), and the regression coefficients used to derive ADG, initial and final BW, and mid-test $BW^{0.75}$ (MBW). The RFI was calculated as the difference between actual DMI and expected DMI was obtained from the regression of actual DMI on ADG and MBW using PROC GLM of SAS with herd as a random effect. Steers were classified into low, medium and high RFI phenotype groups based on ± 0.5 SD from the mean RFI of -0.01 ± 1.0 kg/d for the 80-d study. Analysis of variance using the PROC GLM was used to examine the effects of RFI group on performance, efficiency, carcass, and tenderness data. The model included fixed effects of RFI group and the random effects of herd, slaughter date and interaction of herd and RFI group. Least squares means were calculated and the PDIFF option used to detect differences between RFI phenotype groups. Partial correlation coefficients among traits were determined using PROC CORR function of SAS.

Results and Discussion

Steers began the study averaging 430 kg in BW, and during the study, the steers gained 1.05 kg/d, consumed 9.07 kg feed DM per day and had FCR (DMI/ADG) of 8.91. There were no differences in ADG between RFI groups. Steers had an unexpected low performance (ADG = 1.05 kg/d) during the study, which was likely attributable to heat stress of feeding steers during the summer months and the fact that these steers did not receive anabolic implants during the study. Phenotypic correlations between RFI and FCR are shown in Table 1. Residual feed intake was correlated to DMI and FCR (0.58 and 0.51, respectively, $P < 0.01$). As expected FCR was negatively correlated to ADG (-0.65), but positively correlated with RFI (0.43). Similarly, RFI groups did not differ in ADG, IBW, and FBW (Table 2). Significant differences were observed between RFI groups and DMI and FCR. Low-RFI steers consumed 19.4% less feed and had a 22.6% improvement in FCR when compared to high-RFI steers. These results were in agreement with Nkrumah et al. (2006) who reported that steers with low RFI consumed 17.2% less feed and had a 18.1 % better FCR than high-RFI steers. Baker et al. (2006) reported that steers with low RFI consumed 9.7% less feed and had 13% better FCR than high-RFI steers. These differences can be explained in part by when RFI was measured. In our study, as well as in Nkrumah et al. (2006), RFI was measured during the finishing phase, whereas in other two studies, RFI was measured during the growing phase.

The correlations between RFI and uIMF and uREA on day 80 were not different from zero ($P > 0.1$). However, initial uREA was negatively correlated ($r = -0.22$, $P < 0.05$) and final uBF positively correlated to RFI ($r = 0.29$, $P = 0.002$). There were no significant correlations between FCR and any of the ultrasound traits. Recent studies are not consistent in phenotypic correlations between RFI and uBF; results appear to be impacted by the stage of maturity during which RFI is measured (growing vs. finishing). Some studies have reported weak positive phenotypic correlations between RFI and uBF for growing cattle ranging from 0.14 to 0.20 (Arthur et al., 2001; Lancaster et al., 2009). However, in finishing cattle the phenotypic correlations between RFI and uBF were slightly higher ranging from 0.23 to 0.30 (Nkrumah et al., 2004, 2007). Recent studies are not consistent in terms of the associations between RFI groups and uBF. Baker et al. (2006) found no differences in initial or final uBF in growing cattle. Lancaster et al. (2009) found no

differences in initial uBF, but final uBF was different between bulls with divergent RFI phenotypes. Some of these discrepancies could be explained by the model used to compute RFI; Baker et al. (2006) adjusted RFI for body composition, whereas Lancaster et al. (2009) did not. Nkrumah et al. (2004) and Richardson et al. (2001) reported results with finishing cattle, and found that more efficient animals (low RFI) tended to be leaner.

Marbling score and carcass backfat thickness are key carcass traits used to determine USDA quality and yield grades that subsequently impact carcass value. Since feed efficiency has become an important trait for beef cattle production, carcass traits were evaluated to determine if selection for RFI was associated with carcass traits in Santa Gertrudis steers. Table 1 shows the correlations between RFI and carcass traits. Residual feed intake was not correlated with HCW, KPH, cREA, and MARB, but was positively correlated to cBF and YG (0.26 and 0.24, respectively). Carcass traits and FCR were not correlated. Results have not been consistent across studies, which could be due to the time that RFI is measured (growing vs. finishing), and differences in breed, and type of diet. There were no differences between RFI groups in HCW, KPH, cREA and MARB (Table 3). However RFI groups differed in cBF. Low-RFI carcasses had less ($P < 0.05$) cBF than medium-RFI carcasses, with carcasses from steers with high RFI being intermediate. Likewise, carcasses from low-RFI steers had lower ($P < 0.05$) lipid and higher protein concentrations compared to carcasses from medium-RFI steers, with the chemical composition of carcasses from steers with high RFI being intermediate. Richardson et al. (2001) reported no significant differences in cBF and cREA between steer progeny from cattle selected for low and high RFI. Basarab et al. (2003) reported similar cBF for low and high RFI steers (9.7 vs. 9.9 mm, respectively), but found that differences in MARB and YG approached significance. Baker et al. (2006) also reported no differences in cBF, MARB and YG ($P > 0.3$) between RFI groups. Basarab et al. (2003) reported that low-RFI steers tended ($P = 0.08$) to have less carcass dissectible fat. However, Ribeiro et al. (2007) found the bulls with low RFI had similar carcass lipid, but more carcass protein than bulls with high RFI. Discrepancies in results may be attributed to differences in RFI calculation, breedtype, and time when RFI was measured. These results suggest that low RFI steers would produce carcasses that are slightly leaner, but with similar marbling score, HCW, KPH, and cREA. Therefore, selection for low RFI may decrease carcass fat deposition and yield grades over time in progeny fed feedlot diets.

Beef tenderness increases as time postmortem increases, which is a result of postmortem proteolysis caused by the calpain system (Wheeler and Koohmaraie, 1994). Calpastatin is the major inhibitor of the calpain system in postmortem muscle. Several studies have indicated that calpastatin activity is positively correlated with tenderness and that this enzyme is highly heritable (Shackelford et al., 1994). Since consumers are willing to pay premiums for more tender beef (Miller et al., 2001), it is important to evaluate the relationships beef tenderness and RFI. The correlations between feed efficiency traits and WBSF were not significant (Table 1). However, WBSF values were lower ($P < 0.05$) for steers with medium RFI compared to steers with high RFI, with WBSF values for low-RFI steers being intermediate. The correlation between RFI and CALP was significant ($P < 0.05$), and the low-RFI steers had lower ($P < 0.05$) CALP activities than high-RFI steers (Table 4). Two studies have examined the relationships between RFI and tenderness traits. McDonagh et al. (2001) found no differences in WBSF between steer progeny from parents divergently selected for RFI, but that steers from high-RFI parents had 13% higher CALP activities then steers from low-RFI parents. These results suggest the possibility that long-term selection for low RFI may be associated with a reduction in the rate of postmortem protein degradation, which could potentially have a negative impact on tenderness In contrast, Baker et al. (2006) reported that steers with divergent RFI phenotypes had similar WBSF and CALP activities. The higher CALP activities found in carcasses from steers with high RFI phenotypes, and the fact that WBSF values were actually higher in carcasses from high- compared to medium-RFI steers indicates that RFI is not associated in negative manner with beef tenderness.

Implications

Identifying a feed efficiency trait that facilitates reductions in feed inputs without impacting growth or other value-determining traits (e.g., carcass quality grade, tenderness) has considerable potential to improve profitability of beef production systems. Although the phenotypic correlations between RFI and carcass composition traits were positive indicating that steers with low RFI steers were leaner, differences in marbling scores were not detected between steers with divergent RFI phenotypes. Furthermore, CALP activities were positively correlated with RFI and WSBS values were not found to be higher in steers with low RFI. Thus, results from this study suggest that selection for improved RFI will not create unfavorable correlated responses in carcass-quality traits in beef cattle.

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Table 1. Phenotypic correlations (*P*-values) between residual feed intake (RFI) and feed conversion ratio (FCR) with several traits.

Trait	RFI	FCR
Performance traits		
ADG, kg	0.00 (0.995)	-0.65 (<0.001)
DMI, kg/d	0.58 (<0.001)	0.07 (0.461)
RFI, kg/d	-	0.43 (<0.001)
FCR, DMI:ADG	0.51 (<0.001)	-
Initial BW, kg	-0.02 (0.831)	0.23 (0.015)
Final BW, kg	-0.01 (0.899)	-0.04 (0.670)
Ultrasound traits[1]		
Initial uBF, cm	0.16 (0.082)	0.09 (0.348)
Initial uREA, cm^2	-0.22 (0.017)	0.08 (0.377)
Initial uIMF, %	0.08 (0.380)	-0.01 (0.928)
Day 80 uBF, cm	0.29 (0.002)	0.07 (0.428)
Day80 uREA, cm^2	0.05 (0.632)	-0.05 (0.581)
Day 80 uIMF, %	0.08 (0.405)	-0.10 (0.282)
Carcass traits		
HCW, kg	0.02 (0.844)	-0.04 (0.673)
KPH, %	0.10 (0.281)	-0.08 (0.3883)
REA, cm^2	-0.04 (0.645)	-0.03 (0.715)
Fat thickness, cm	0.26 (0.005)	0.01 (0.904)
Yield grade	0.24 (0.012)	-0.01 (0.913)
Marbling score	0.11 (0.229)	0.14 (0.125)
Chemical composition		
Lipid, %	0.26 (0.006)	0.02 (0.861)
Protein, %	-0.27 (0.004)	-0.04 (0.655)
Tenderness traits		
Shear force d 1, kg	0.03 (0.791)	-0.03 (0.788)
Shear force d 14, kg	0.05 (0.627)	-0.09 (0.326)
Shear force change	0.01 (0.942)	0.05 (0.573)
Calpastatin, activity/g	0.19 (0.048)	0.07 (0.445)

[1] Initial = 35 d prior to beginning of trial; uBF ultrasound 12th- to 13th-rib backfat thickness; uREA = ultrasound 12th- to 13th-ribeye area; uIMF = ultrasound percent i.m. fat.

Table 2. Characterization of performance, ultrasound, and feed efficiency traits in Santa Gertrudis steers with high (> 0.5 SD above the mean), medium, and low (< 0.5 SD below the mean) residual feed intake (RFI).

	RFI group[1]				
Trait[2]	High	Medium	Low	SE	P-value
Number of steers	36	39	39		
ADG, kg	1.00	1.06	1.07	0.05	0.513
DMI, kg/d	10.0^{x}	9.10^{y}	8.28^{z}	0.29	<0.001
RFI, kg/d	1.14^{x}	-0.05^{y}	-1.03^{z}	0.09	<0.001
FCR, DMI:ADG	10.4^{x}	8.80^{y}	8.07^{y}	0.36	<0.001
Initial BW, kg	428	429	436	6.53	0.557
Final BW, kg	507	512	519	7.52	0.441
Initial uBF, cm	0.37	0.33	0.29	0.03	0.123
Initial uREA, cm^2	58.8^{x}	58.4^{x}	64.2^{y}	1.16	<0.001
Initial uIMF, %	1.90	2.00	1.71	0.14	0.236
Day 80 uBF, cm	0.91	0.90	0.83	0.05	0.336
Day 80 uREA, cm^2	80.7	79.5	79.9	1.73	0.864
Day 80 uIMF, %	3.00	3.19	2.83	0.15	0.122

[1] Least square means within a row with different superscripts differ ($P < 0.05$).
[2] RFI = residual feed intake; FCR = feed conversion ratio; uBF = ultrasound 12th- to 13th-rib backfat thickness; uREA = ultrasound 12th- to 13th-ribeye area; uIMF = ultrasound percent i.m. fat.

Table 3. Characterization of carcass traits in Santa Gertrudis steers with high (> 0.5 SD above the mean), medium, and low (< 0.5 SD below the mean) residual feed intake (RFI).

	RFI group[1]				
Trait[2]	High	Medium	Low	SE	P-value
Number of steers	36	39	39		
HCW, kg	317	320	321	5.02	0.790
KPH, %	2.19	2.26	2.12	0.12	0.669
REA, cm^2	76.0	76.7	78.1	1.12	0.323
Fat thickness, cm	1.18^{xy}	1.27^{x}	0.99^{y}	0.09	0.030
Yield grade	3.03	3.13	2.77	0.14	0.100
Marbling score	474	503	474	16.8	0.281
9-11th rib lipid, %	34.4^{xy}	35.5^{x}	32.2^{y}	1.05	0.034
9-11th rib protein, %	29.3^{xy}	28.4^{x}	31.4^{y}	1.12	0.075

[1] Least square means within a row with different superscripts differ ($P < 0.05$).
[2] Marbling score = Slight^{00} = 4.00, Small^{00} = 5.00, Modest^{00} = 6.00.

Table 4. Characterization of tenderness traits in Santa Gertrudis steers with high (>0.5 SD above the mean), medium, and low (<0.5 SD below the mean) residual feed intake (RFI).

	RFI group[1]				
Trait	High	Medium	Low	SE	P-value
Number of steers	36	39	39		
Shear force (day 1), kg	3.18^{x}	2.74^{y}	2.83^{xy}	0.14	0.042
Shear force (day 14), kg	2.40^{x}	2.10^{y}	2.26^{xy}	0.09	0.044
Shear force change, kg	0.77	0.63	0.56	0.12	0.386
Calpastatin, activity/g	2.84^{x}	2.69^{xy}	2.60^{y}	0.07	0.032

[1] Least square means within a row with different superscripts differ ($P < 0.05$).

THE USE OF REAL-TIME ULTRASOUND AND CARCASS MEASUREMENTS TO ESTIMATE TOTAL INTERNAL FAT IN BEEF CATTLE

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Summary

The objective of this study was to re-evaluate our previously published technique of estimating total separable internal fat (**IFAT**) in beef cattle using real-time ultrasound (**RTU**) and carcass measurements from live animals. We expanded the original database and performed additional analyses. The database was gathered from 4 studies and contained 110 animals (16 bulls, 16 heifers, and 78 steers). Ultrasound measurements were obtained 7 d prior to slaughter, including the 12 to 13th rib fat thickness (**uBF**) and ultrasound kidney fat depth (**uKFd**). The uKFd was measured in a cross-sectional image collected between the first lumbar and 13th rib as previously published. Carcass data were collected 48 h post-mortem and consisted of backfat thickness (**cBF**), kidney fat depth (**cKFd**), live BW and hot carcass weight. Total separable internal fat was highly correlated to KPH weight (r = 0.88) and cKFd (r = 0.81), and moderately correlated to uKFd (r = 0.71). Prediction equations were developed to estimate IFAT, KPH weight, and cKFd with the PROC REG of SAS using the STEPWISE statement to identify the best predictors of IFAT. The best predictors of IFAT were KPH weight or cKFd and cBF (r^2 = 0.84 and 0.83 and root mean square error (**RMSE**) of 4.23 and 4.33 kg, respectively). Ultrasound measurements of uKFd and uBF had an r^2 of 0.65 and RMSE of 6.07 kg when used to predict IFAT. These results were consistent with previously published evaluation of this technique. These findings demonstrated that this RTU technique allows the measurement of IFAT in a non-invasive way that may improve our ability to estimate IFAT in beef cattle, be used to more accurately formulate rations, and be applied in sorting cattle at feedyard.

Introduction

The use of non-invasive techniques to measure body composition in livestock for genetic evaluation, management and research purposes has increased in the past 20 years. Real-time ultrasound, computer tomography, and magnetic resonance imaging are the most common methods used to measure body composition in the live animal. Real-time ultrasound is more widely used in livestock animals because it is cheaper and can be easily used in typical animal handling facilities. Computer tomography and nuclear magnetic resonance are more expensive and animal sedation is required to obtain good images. Thus, the use of these techniques to assess body composition in animals has been limited to sheep, goats and pigs (Silva et al., 2006; Lambe et al., 2003, 2006). Several researchers have applied these non-invasive techniques to measure body composition in livestock. Lambe et al. (2003) used a computed tomography scan to measure total body tissue in sheep and Lambe et al. (2006) used the same technique to estimate IFAT weight in sheep. Silva et al. (2006) used RTU to estimate sheep carcass composition. Teixeira et al. (2008) used RTU to estimate intermuscular, KPH, and total carcass fat in goats. Others have specifically evaluated the applications of RTU to measure body composition (carcass traits) in beef cattle (Wilson, 1992; Greiner et al., 2003; and Ribeiro et al., 2006). Fat is categorized by Rouse and Wilson (2001) as taste fat (intramuscular fat) and waste fat (internal, seam, and subcutaneous fat). Waste fat is expensive to the industry and requires a lot of energy to be deposited. Therefore, more accurate assessment of non-carcass fat depots in the live animal are needed so better management decisions can be made to decrease the waste fat. Recently, Ribeiro et al. (2008) reported a technique to be used to estimate IFAT in beef cattle. The objective of this study was to revise and further evaluate the technique reported by Ribeiro et al. (2008) to estimate IFAT using RTU and carcass measurements.

Experimental Procedure

Animal and Diet Description

Animals used in this study were fed and managed under the guidelines of the Texas A&M University Institutional Animal Care and Use Committee. Data for this study were obtained from 4 different studies.

Study 1 consisted of 24 Angus steers that were fed either a hay- or corn-based diets during the backgrounding phase at the Texas A&M University AgriLife Research Center at McGregor, TX. Steers were serially slaughtered based on predetermined ages. More details and description of the experimental design were reported by Ribeiro et al. (2008).

Study 2 consisted of 16 Angus bulls and 16 Angus heifers that were progeny from parents divergently selected for serum IGF-I concentration for more than 10 years at the Eastern Agricultural Research Station of The Ohio State University. Selection procedures were reported by Davis et al. (1995). Animals were shipped to the O.D. Butler, Jr.

Animal Science Complex at Texas A&M University and fed a corn-based diet for an average of 126 days. More details and description of the experimental design were provided by Lancaster et al. (2008).

Study 3 consisted of 36 crossbred steers that were used in a trial to test the effects of two sources of tannins: mimosa- and chestnut-tannin, when applied as an antimicrobial hide-spray intervention against generic *E. coli*, total coliforms and total aerobic bacterial loads and as a feed supplement against generic *E. coli*, total coliforms, and *Campylobacter* spp. in steers fed high grain diets. Animals were shipped to the O.D. Butler, Jr. Animal Science Complex at Texas A&M University a fed a high grain diet for 60 days. More details and description of the experimental design were described by Bañuelos (2008).

Study 4 consisted of 18 crossbred steers (Angus x 5/8 Angus x 3/8 Nellore) used on a trial that tested the use of a slow release urea product on N balance and performance of cattle fed steam-flaked corn. Steers were fed for 105 days at the Texas A&M University Agricultural Research Center at McGregor, TX.

Ultrasound Measurements

The RTU measurements were taken at the end of each test 7 d before slaughter. Real-time ultrasound measurements consisted of 12 to 13th-rib backfat thickness, 12 to 13th-ribeye area, percentage of i.m. fat and kidney fat depth. Images were collected by an Ultrasound guidelines Council field-certified technician using an Aloka 500V instrument with a 17-cm, 3.5-MHz transducer (Aloka Co. Ltd., Wallingford, CT). Images for study 1 were collected and interpreted on site at the ultrasound console and for studies 2, 3, and 4 were saved in an image capturing system and sent to the National Cup Lab (Ames, IA) for interpretation. The uKFD images were interpreted chute side for all 4 studies.

RTU of Kidney Fat

The uKFD image collection protocol used in this study was reported by Ribeiro et al. (2008). Briefly, hair was clipped (if longer than 0.64 cm) and oil used as a coupling agent. Images were collected between the 13th rib and first lumbar. The uKFD measurement was taken between the ventral part of abdominal muscles and the end of the kidney fat.

Slaughter Data Collection

All animals were withheld of feed overnight with free access to water and slaughtered at the Rosenthal Meat Science and Technology Center, Texas A&M University (College Station, TX). Live BW and HCW were recorded. Whole gastrointestinal tracts were removed and dissected to obtain total physical separable internal fat weights. Linear measurements of the cKFd were obtained immediately postmortem from the hot carcass by using a tape measure. The measurement was taken from the midline (vertebrae) to the end of the kidney fat. The KPH depot was removed from the carcass before splitting.

Calculation of the Frame Score

The frame score (**FS**) of the animals was assumed to be small, medium, and large based on the relationship between the standard reference weight (**SRW** of 478 kg) of a medium-frame size steer and the shrunk BW adjusted to 28% empty body fat (**AFBW**) as computed by the NRC (2000). The FS was assumed 1 (small-frame score) if the ratio of SRW and AFBW was greater than or equal to 1.13, 2 (medium-frame score) if the ratio of SRW and AFBW was greater than or equal to 0.95 and less than 1.13, and 3 (large size) if this ratio was less than 0.95. These ratio thresholds were obtained from adjustment factors proposed by Fox and Black (1984) to compute frame size of growing steers. The AFBW was computed based on the equation proposed by Guiroy et al. (2001) in which empty BW (**EBW**) changes 14.26 kg per unit of change in Empty body fat (**EBF**) as shown in Eq. 1. [AFBW = (EBW + (28 – EBF)×14.26)/0.891]. The EBF of the animals was computed based on the carcass traits, including cBF in cm, HCW in kg, quality grade (**QG**; 4 = select, 5 = Choice-, 6 = Choice, 7 = Choice +, and 8 = Prime), and cREA in cm^2 as shown in Eq.2 [EBF = 17.76207 + (4.68142×cBF) + (0.01945×HCW) + (0.81855×QG) − (0.06754×cREA)].

Statistical Analyses

All statistical analyses were performed using the PROC GLM and PROC REG (SAS Institute Inc., Cary, NC). The STEPWISE statement was used to identify the best predictors of IFAT. Outliers were tested by plotting studentized residual vs. the predicted values and removed if the studentized residual was outside the range of -2.5 to 2.5. Adequacy of the models developed to predict IFAT was determined by using several measurements as discussed by Tedeschi (2006), including the root of mean square error of prediction and concordance correlation coefficient.

Results and Discussion

Group means and SD of animal's BW, RTU, and carcass measurements are listed in Table 1. Steers BW from study 1 had a larger SD because they were serially slaughtered and heifers from study 2 were lighter as expected. Ultrasound and carcass BF for steers in study 3 were smaller, and this is attributed to these set of steers being larger frame compared to animals in the other 3 studies. Across studies the IFAT values had a large variation to represent the beef cattle population fed in feedyards.

Table 2 shows the correlations among all traits used to develop the prediction equations. The high correlation between cBF and uBF indicated that the RTU measurements were accurate compared to the carcass measurements. The uKFD was also highly correlated to cKFd. However, the correlation between uKFd with KPH weight and IFAT were not as high as cKFD (0.36

and 0.56 vs. 0.65 and 0.81, respectively). This suggests that the cKFd might be a better predictor of KPH weight and IFAT.

The prediction equations developed are listed in Table 3. Equation 1 used uKFd and uBF to predict IFAT with an R^2 of 0.65 and root mean square error (**RMSE**) of 6.07 kg. The R^2 for the present Eq. 1 is smaller than the previous R^2 for Eq. 1 reported by Ribeiro et al. (2008), using a similar approach. The relationship between KPH weight and uKFd was not linear and the untransformed equation yielded an R^2 of 0.52 and a RMSE of 0.36 kg.

The best predictors of IFAT were carcass measurements. When we used only KPH weight to predict IFAT (Eq. 4) a r^2 of 0.84 and RMSE of 4.23 kg was obtained. The prediction of IFAT using cKPHd and cBF (Eq. 6) was very similar to Eq. 4 with an R^2 of 0.83 and RMSE of 4.33 kg. These results are similar to Ribeiro et al. (2008), however a little lower, which could be explained by the inclusion of 3 other studies and animals with different frame sizes and fat levels.

Similar studies using different species had results that were compared to ours. Silva et al. (2006) used the same ultrasound equipment; however, two different probes (5 MHz and 7.5 MHz) to predict sheep carcass composition. The locations of the fat measurements were over the 13th thoracic vertebra (**FAT13**) and the 4th lumbar vertebrae (**FAT4**). Their results showed that when an ultrasound fat measurement was added to the prediction equation with BW it improved the prediction of IFAT by (0.11 and 0.10 for 5 MHz, and 0.13 and 0.17 for 7.5 MHz for FAT13 and FAT4, respectively). Teixeira et al. (2008) used the same RTU machine with a 5 MHz probe to estimate body fat partition in goats. The fat measurement was taken at the sternum fat depth at third sternebra (**STFAT**). Results showed that STFAT alone explained 75% of the variation in kidney fat and 77% in omental fat. Body weight and STFAT together explained 78% of the variation in mesenteric fat.

Implications

These studies and our results suggest that ultrasound can be used to predict carcass and non-carcass fat in livestock. However, animals under different feeding regimen and dietary composition have to be evaluated and also evaluation of these new equations is needed.

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Table 1. Description of body and carcass composition [1].

	Study 1	Study 2		Study 3	Study 4
Trait[2]	Steers	Bulls	Heifers	Steers	Steers
N	24	16	16	36	18
Ultrasound BW, kg	423 ± 128	488 ± 46.4	373 ± 24.0	480 ± 47.8	480 ± 40.1
BW, kg	393 ± 131	480 ± 46.2	354 ± 21.7	468 ± 44.9	451 ± 37.7
HCW, kg	237 ± 83.3	296 ± 28.9	220 ± 13.7	279 ± 28.9	278 ± 24.9
Ultrasound REA, cm^2	71.6 ± 21.7	82.6 ± 6.18	65.8 ± 5.36	73.7 ± 6.28	77.8 ± 5.37
Ultrasound BF, cm	0.87 ± 0.46	0.82 ± 0.18	1.01 ± 0.20	0.72 ± 0.16	0.94 ± 0.17
Ultrasound IMF, %	3.63 ± 0.86	3.19 ± 0.54	4.31 ± 0.43	3.09 ± 0.55	4.23 ± 0.58
Ultrasound KFd, cm	13.0 ± 4.17	16.2 ± 1.10	15.2 ± 0.90	17.8 ± 0.99	16.9 ± 1.26
Carcass REA, cm^2	65.0 ± 13.4	79.9 ± 8.19	61.0 ± 5.58	78.2 ± 7.09	71.2 ± 6.24
Carcass BF, cm	1.05 ± 0.67	0.96 ± 0.32	1.14 ± 0.30	0.70 ± 0.25	1.14 ± 0.20
Carcass Marbling score	4.83 ± 1.19	5.3 ± 0.75	6.13 ± 0.94	4.91 ± 0.71	5.38 ± 0.89
Carcass KFd, cm	13.5 ± 4.30	14.8 ± 1.26	15.8 ± 1.55	16.7 ± 1.58	18.2 ± 1.69
KPH weight, kg	7.50 ± 4.75	7.18 ± 1.57	8.70 ± 1.54	5.11 ± 1.38	9.15 ± 2.05
Internal fat weight, kg	26.5 ± 15.4	28.4 ± 6.05	33.3 ± 4.55	26.6 ± 5.43	42.7 ± 7.36

[1] Values are means ± SD.

[2]Ultrasound BW = BW taken 7 d before slaughter when steers where being scanned, REA = 12th- to 13th-ribeye area, BF = 12th- to 13th-rib fat thickness, IMF = percent of intramuscular fat, KFd = kidney fat depth.

Table 2. Correlations among traits used to develop the prediction equations of internal fat weight (IFAT).

Trait	BW	uBF	uKFd	cBF	cKFd	KPH weight	IFAT
uBW	**0.97**	**0.42**	**0.77**	**0.40**	**0.66**	**0.45**	**0.56**
BW		**0.38**	**0.79**	**0.34**	**0.65**	**0.38**	**0.51**
uBF			**0.34**	**0.86**	**0.53**	**0.72**	**0.71**
uKFd				**0.28**	**0.81**	**0.36**	**0.56**
cBF					**0.48**	**0.76**	**0.72**
cKFd						**0.65**	**0.81**
KPH weight							**0.88**

[1] uBW = BW taken 7 d before slaughter when steers where being scanned uKFd = ultrasound kidney fat depth; uBF 12th- to 13th-rib fat thickness, cBF = carcass 12th- to 13th-rib fat thickness; cKFd = carcass kidney fat depth; IFAT = total internal fat.

Table 3. Equations to predict carcass kidney fat (cKFd, cm), carcass KPH weight (KPHwt, kg), and internal fat (IFAT, kg).

Eq. no.	Equation[1]	R^2	RMSE	n
1	IFAT = -28.61853 + 14.52776×log(uKFd) + 22.242×uBF	0.65	6.07	109
2	Log(KPHwt) = (3.158233068 + A) + (– 0.4632258 + B)×log(uKFd)	0.52	0.36	109
3	$KPHwt = 10^{(3.158233068 + A)} \times loguKFd^{(- 0.4632258 + B)}$			109
4	IFAT = (11.79444828 + C) + (2.63100813 + D)×KPHwt	0.84	4.23	109
5	cKFd = (-0.086067367 + E) + 0.941562887×uKFd	0.68	1.63	109
6	IFAT = (-3.84221299 + F) + (1.34341477 + G)×cKPHd + (14.07377538 + H)×cBF	0.83	4.33	109

[1] uKFd = ultrasound kidney fat depth; uBF 12th- to 13th-rib fat thickness; A, B, C, D, E, F, G and H = adjustment for frame score; A = -6.55, -3.74, and 0 for frame score 1, 2, and 3, respectively; B = 2.50, 1.35 and 0 for frame score 1, 2, and 3, respectively; C = -11.06, 1.89, and 0 for frame score 1, 2, and 3, respectively; D = 1.12, -0.2, and 0 for frame score 1, 2, and 3, respectively; E =1.58, 0.99, and 0 for frame score 1, 2, and 3, respectively; F = -10.97, -20.78, and 0 for frame score 1, 2, and 3, respectively; G = 1.26, 1.35, and 0 for frame score 1, 2, and 3, respectively; H = -8.10, -2.06, and 0 for frame score 1, 2, and 3, respectively.

EVALUATING THE APPLICATION OF DUAL X-RAY ENERGYABSORPTIOMETRY (DEXA) TO ASSESS DISSECTIBLE FAT ANDMUSCLE FROM THE 9 TO 11TH RIB SECTION OF BEEF CATTLE

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Summary

The objective of this study was to evaluate the adequacy of measuring dissectible fat and muscle from the 9-11th rib section of beef cattle using a Dual Energy X-ray Absorptiometry (**DEXA**) scanner (GE Lunar Prodigy Advance, General Electric, Madison, Wisconsin). Data were obtained from 52 animals (20 steers, 16 bulls, and 16 heifers) from two trials. Trial 1 was composed of Angus steers (n = 24) and Trial 2 had Angus bulls (n = 16) and heifers (n = 16). The 9-11th rib section samples were removed from the carcasses and digital images were obtained using the DEXA scanner. The outputs of the DEXA scanner were total fat percentage and lean muscle amount. The lean muscle percentage was calculated and compared with the measured rib dissection composition. Then, the 9-11th rib samples were physically dissected and chemical analyses were performed following the Hankins and Howe procedure. Regression analysis was performed with PROC REG. The DEXA fat prediction explained 84 and 86% of the variation in the physical and chemical rib fats, respectively. For both predictions, the regression analysis indicated that the intercept and the slope were not concurrently different from zero and one ($P < 0.001$), respectively. However, mean biases were significantly different from zero and underpredicted physical and chemical rib fats by 3.4 and 2.3 %, respectively. The DEXA lean prediction explained 82% of the variation in the physically separable lean with a mean bias of -16% (overpredicted). These results indicated that DEXA scanners can precisely predict the 9-11th rib section fat and lean tissue of beef cattle, but accuracy is lacking. More calibration is needed to improve accuracy of DEXA scanners and the development of calibration equations for cattle might be necessary.

Introduction

Measuring body composition in the live animal and carcass of livestock animals is of great importance to understand the energy efficiency and to understand the response to different planes of nutrition. The most common imaging methods used to measure live animal body composition are the real-time ultrasound (**RTU**), X-ray computer tomography, and magnetic resonance imaging. However, only RTU has been used for commercial application likely due to its ease of use. In order to measure energy efficiency of beef cattle, the accurate measurement of the chemical composition of fat and muscle is needed. Several methods have been developed; the most common ones are the 9-11th rib dissection procedure developed by Hankins and Howe (1946), carcass specific gravity (Kraybill et al., 1952), isotope dilution techniques using heavy water – deuterium and tritium – (Byers, 1979) and doubly labeled water (Lifson et al., 1955), urea dilution (Preston and Kock, 1973; Kock and Preston, 1979). These methods are labor intensive and expensive. The dual energy X-ray absorptiometry (**DEXA)** scanner has been widely used to measure body composition in humans (Jensen et al., 1993; Brodowicz et al., 1994; Oates et al., 2006). This scanner has the capability of measuring bone mineral content, bone mineral density, lean tissue mass, fat tissue mass, and percentage fat. However, this scanner has only been calibrated to be used in humans. Therefore, the objective of this study was to evaluate the adequacy of measuring dissectible fat and muscle from the 9-11th rib sections from beef carcass.

Experimental Procedures

Animal Description and 9 to 11th-rib Data Collection

The 9-11th-rib sections were removed from the 6-12th-rib sections and dissected into separable fat, lean, and bone tissue, and moisture. Protein and lipid content of separable fat and lean were assayed to determine carcass chemical analyses according to Hankins and Howe (1946). Protein was determined using a Leco analyzer, moisture percentage was calculated using the oven-dry procedure, and fat content was determined by a Soxhlet apparatus using diethyl ether (AOAC, 1990). Samples were taken from carcass from 2 different studies.

Study 1 consisted of 24 Angus steers that were fed either a hay- or corn-based diets during the backgrounding phase at the Texas A&M University AgriLife Research Center at McGregor, TX. Steers were serially slaughtered based on predetermined ages. More details and description of the experimental design were reported by Ribeiro et al. (2008).

Study 2 consisted of 16 Angus bulls and 16 Angus heifers that were progeny from parents divergently selected for serum IGF-I concentration for more than 10 years at the Eastern Agricultural Research Station of The Ohio State University. Selection procedures were reported by Davis et al. (1995). Animals were shipped to the O.D. Butler, Jr.

Animal Science Complex at Texas A&M University and fed a corn-based diet for an average of 126 days. More details and description of the experimental design were reported by Lancaster et al. (2008).

Dual Energy X-ray Absorptiometry (DEXA) Scanner Data
Prior to the dissection, the 9-11th rib samples were taken to The Sydney and J. L. Huffines Institute for Sport Medicine & Human Performance laboratory at Texas A&M University, College Station, TX and scanned with a DEXA scanner (GE Lunar Prodigy Advance, General Electric, Madison, Wisconsin).

Statistical Analyses
All statistical analyses were performed using the PROC REG procedure of SAS software (SAS Institute Inc., Cary, NC) to develop prediction equations. Adequacy of the models developed to predict total physical dissected 9-11th rib fat (**DISSRFAT**), chemical 9-11th rib fat (**CHEMRFAT**), and percentage of total physical dissected 9-11th rib muscle (**DISSRMPERC;** DISSRM/ Rib weight) was determined by using several measurements as discussed by Tedeschi (2006), including the root of mean square error of prediction, mean bias, and concordance correlation coefficient.

Results and Discussion

Summary statistics are presented in Table 1 and a more detailed description from each study and gender are presented in Table 2. As expected, heifers had higher chemical and physical separable fat than steers, and steers higher than bulls and bulls had higher chemical protein content and physical separable lean than steers and steers higher than heifers.

The prediction equations developed are listed in Table 3. Equations 1 and 2 were developed using DEXAFAT to predict DISSRFAT and CHEMRFAT; they had an r^2 of 0.84 and 0.86 and RMSE of 2.94 kg and 3.25%, respectively. Equation 3 used DEXALEAN to predict DISSRMPERC and had an r^2 of 0.82 and RMSE of 2.32%.

These results showed that DEXA scanner can be used to estimate fat and lean content of the 9-11th rib, which is used to estimate carcass lean, bone and fat content, and our results are also similar to other studies that used different imaging techniques to predict body composition in live animals. Lambe et al. (2003) used X-ray computer tomography to estimate fat and muscle weights of Scottish blackface ewes carcass and obtained r^2 ranging from 0.80 to 0.99). Ribeiro et al. (2009) used RTU to estimate total internal fat in beef cattle with r^2 ranging from 0.65 to 0.83.

Implication

These results indicated that DEXA scanners can precisely predict the 9-11th rib section fat and lean tissue of beef cattle, but accuracy is lacking. More calibration might be needed to improve accuracy of DEXA scanners. The use of DEXA scanner has the potential to decrease the cost related to dissecting the 9-11th rib sections.

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Table 1. Summary statistics of 9-11th rib physical dissection and chemical and DEXA[a] traits for both studies

Traits[b]	N	Mean	SD	Minimum	Maximum
Rib weight, kg	52	4.39	1.18	1.57	7.44
DISSRFATW, kg	52	1.69	0.65	0.42	3.77
DISSRFAT, %	52	37.6	7.26	20.8	51.9
DISSRM, kg	52	2.00	0.52	0.78	2.95
DISSRMPERC, %	52	46.1	5.43	33.8	58.5
CHEMRFAT, %	52	36.5	8.66	14.4	53.6
CHEMRPROT, %	52	14.2	2.53	9.09	20.8
DEXAFAT, %	52	34.2	8.99	12.1	46.7
DEXALEAN, %	52	62.1	8.40	50.3	82.9

[a] DEXA = Dual Energy X-ray Absorptiometry

[b] Rib weight = 9-11th rib total weight before dissection; DISSRFATW= total physical dissected 9-11th rib fat weight; DISSRFAT = total physical dissected 9-11th rib fat; DISSRM = total physical dissected 9-11th rib muscle; DISSRMPERC = percentage of total physical dissected 9-11th rib muscle (DISSRM/ Rib weight); CHEMRFAT = chemical 9-11th rib fat; CHEMRPROT = chemical 9-11th rib protein; DEXAFAT = DEXA fat percentage; DEXALEAN = DEXA lean percentage.

Table 2. Description of 9-11th rib physical dissection and chemical and DEXA[a] traits for each study and gender

	Studies[b]		
	Study 1	Study 2	
Traits[c]	Steers	Heifers	Bulls
N	20	16	16
Rib weight, kg	4.53 ± 1.73	3.81 ± 0.26	4.77 ± 0.61
DISSRFATW, kg	1.81 ± 0.99	1.63 ± 0.20	1.60 ± 0.32
DISSRFAT, %	37.0 ± 9.33	42.6 ±3.02	33.3 ± 3.66
DISSRM, kg	2.00 ± 0.62	1.61 ± 0.11	2.40 ± 0.30
DISSRMPERC, %	45.7 ± 6.02	42.2 ± 2.75	50.4 ± 3.30
CHEMRFAT, %	36.3 ± 10.0	42.7 ± 4.56	30.5 ± 5.23
CHEMRPROT, %	14.2 ± 2.91	12.4 ± 1.38	16.0 ± 1.47
DEXAFAT, %	33.3 ± 10.7	41.5 ± 2.91	27.9 ± 4.67
DEXALEAN, %	62.6 ± 9.81	55.2 ± 2.90	68.1 ± 4.17

[a] DEXA = Dual Energy X-ray Absorptiometry

[b] Values are means and ± SD

[c] Rib weight = 9-11th rib total weight before dissection; DISSRFATW= total physical dissected 9-11th rib fat weight; DISSRFAT = total physical dissected 9-11th rib fat; DISSRM = total physical dissected 9-11th rib muscle; DISSRMPERC = percentage of total physical dissected 9-11th rib muscle (DISSRM/ Rib weight); CHEMRFAT = chemical 9-11th rib fat; CHEMRPROT = chemical 9-11th rib protein; DEXAFAT = DEXA fat percentage; DEXALEAN = DEXA lean percentage.

Table 3. Regression equations to predict physical (DISSRFAT, kg) and chemical (CHEMRFAT , %) fat and lean (DISSRMPERC , %).

#	Equations[a]	r^2	RMSE[b]	N
1	DISSRFAT = 12.33674 + 0.73959 × DEXAFAT	0.84	2.94	52
2	CHEMRFAT = 5.929 + 0.89436 × DEXAFAT	0.86	3.25	52
3	DISSRMPERC = 9.66974 + 0.58667 × DEXALEAN	0.82	2.35	52

[a] DISSRFAT = total physical dissected 9-11th rib fat; DISSRM = total physical dissected 9-11th rib muscle; DISSRMPERC = percentage of total physical dissected 9-11th rib muscle (DISSRM/ Rib weight); CHEMRFAT = chemical 9-11th rib fat; DEXAFAT = DEXA fat percentage; DEXALEAN = DEXA lean percentage.

[b] RMSE = root mean square error

INNOVATIVE FABRICATION OF RIBEYES, TOP SIRLOIN BUTTS, AND STRIPLOINS TO ACCOMMODATE FOR THE GROWING TREND OF HEAVIER CARCASS WEIGHTS IN THE US

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Summary

Retail cutting tests were conducted to determine merchandising strategies to accommodate the growing trend heavy carcass weights. Paired subprimals (top sirloin butt, ribeye, striploin) were collected from 12 carcasses determined to be average weight (700-800 pounds) and 12 carcasses considered to be heavy weight (1000-1100 pounds). One set of subprimals were merchandised in the traditional manner while the other set was merchandised following innovative procedures designed to minimize retail cut size. Carcass size impacted salable yield for the ribeyes and strip loins, as well as processing times for the top sirloin butts and strip loins. There were significant differences between cutting styles for the top sirloin butts and ribeyes as innovative cuts had lower salable yields than those from the conventional style. Processing times differed significantly when comparing cutting styles. This information will be helpful to retailers as they work to adapt merchandising schemes for large sized subprimals.

Introduction

In the US, management practices and genetic selection have collectively contributed to improvements found in producing quality cattle for today's beef industry. One unintended consequence of these improvements has been increased incidence of carcasses that are considered to be too heavy for the marketplace. Findings from the National Beef Quality Audits (Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008) have shown a continued increase in average carcass weights of approximately 41 lbs. Industry goals established by the 2005 National Beef Quality Audit include "targeting weights that maximize profits without creating conflicts with consumer preference." New methods for beef fabrication also create merchandising capabilities that can adapt these cuts to meet consumer demands.

Experimental Procedures

Product Selection

Beef subprimals (n=144) from US Select carcasses were obtained from a major beef processor. Selected subprimals (top sirloin butt, ribeye, strip loin) represented two different carcass weight ranges: 700-800 pound carcasses were designated as average weight, and 1000-1100 pound carcasses were designated as heavyweight. A total of twenty-four carcasses were selected for the study, and subprimals were collected from twelve heavyweight and twelve average weight carcasses. Subprimals were followed through the fabrication process, collected, vacuum packaged, and boxed. They then were shipped commercially via refrigerated truck to Rosenthal Meat Science and Technology Center at Texas A&M University in College Station, Texas. Beef subprimals were obtained by plant personnel from each of the selected carcasses following industry standards as defined by Institutional Meat Purchase Specifications (IMPS) and described by USDA (1996) and NAMP (2003).

Cutting tests

A retail market environment was simulated in the Rosenthal Meat Science and Technology Center by modifying a refrigerated cutting room for the purpose of conducting retail yield tests. National Cattlemen's Beef Association retail meat cutters with extensive knowledge and cutting experience were enlisted for the study. Merchandising schemes that best represented current industry practices for each subprimal were developed for the conventional method. Merchandising schemes that characterized innovative methods of fabrication were discussed and decided upon by the team. These schemes were determined to best utilize the subprimals from heavyweight carcasses when compared to the subprimals from carcasses of average weight.

The cutting tests for the conventional and innovative methods of fabrication were conducted following the procedures used by Voges et al. (2006). Vacuum packaged subprimals were weighed before and after opening, and bags were drained, washed, dried, and weighed to determine purge loss. Subprimals were cut following their defined merchandising schemes. Targeted fat thickness for the generated retail cuts was not to exceed 0.25 in. Cube material was defined as a solid muscle lean source large enough to fit through a commercial cubing machine to produce a beef cutlet. Stew meat and lean trimmings also were identified and documented. Lean trim was estimated visually at 80% lean. The differentiation between cube material, stew meat, and lean trim was made by the retail cutter during processing.

Processing times were recorded as an estimate of labor requirements for each merchandising scheme.

Technicians used handheld stopwatches to record the time (s) required to complete the different stages of cutting. In the conventional cutting, method there were two major phases of the process: bag opening (removing the subprimal from the vacuum-packaged bag) and cutting (removal of external and seam fat, removal of connective tissue, separation of individual muscles, and the production of tray-ready cuts when applicable). Times recorded from the two phases were combined for total processing time. After each cutting test, technicians recorded weights of all cuts, lean trimmings and fat trimmings ensuring at least a 99% recovery of every initial subprimal weight.

Results and Discussion

Statistical analysis

The interaction of cut style versus weight category was analyzed using PROC GLM (SAS Institute, Cary, North Carolina). A predetermined α of 0.05 was used for all determinations of statistical significance. These interactions were found not to be significant, but main effects are reported.

Means of retail yields and processing times

Tables 1-6 illustrate the simple means of retail yields (%) and processing times (s) for subprimals from heavy weight carcasses versus subprimals from average weight carcasses for both the conventional and innovative cutting styles. Each table reported a greater initial cut weight, higher salable yield, and a greater total processing time for the subprimals from heavy weight carcasses when compared to subprimals from carcasses of average weight.

Table 7 reports the least squares means for total time and salable yield stratified by cutting style and weight classification for each subprimal. Differences were found in top sirloin butt total processing time ($P = 0.0107$) and saleable yield ($P = 0.0200$) between cutting styles. When comparing the top sirloin butt in the two weight classifications, total processing time was significantly greater ($P = 0.0006$) for the subprimals from heavy weight carcasses. Cutting style comparisons found differences in total processing times ($P < 0.0001$) and salable yield ($P < 0.0001$) for ribeyes. Salable yield was significantly greater ($P = 0.0049$) for the ribeyes from heavy weight carcasses. Total processing time ($P = 0.0119$) was greater for the innovative strip loins when compared to the conventional total processing times. Differences were found when comparing strip loins from the two weight classifications. Total processing time (P=0.0496) was significantly greater and salable yield (P=0.0029) was higher for the subprimals from heavy weight carcasses.

Retail cutting test profit analysis

To determine a merchandising strategy for the subprimals in the innovative cutting style an average profit per hundred pounds was calculated using the conventional cutting style. Local retail stores in the Bryan/College Station area were surveyed for retail cut prices. Price per pound was assigned to the generated cuts, lean, and cube material when applicable. Lean and cube prices were held constant in both cutting styles. An average profit was calculated and applied to the innovative subprimal in a spreadsheet. From this total, the weight of the cuts generated were used to calculate an average price for all innovative cuts within of that subprimal in order to maintain an equitable value for the two cutting styles.

Table 8 illustrates the average profit per subprimal for a conventional top sirloin butt to be approximately $72.89. Targeting that total, a price for the innovative center cut steaks and coulotte steaks must average $6.08 per kilogram (versus $5.48 per kilogram for conventional cuts) in order to assign one-hundred pounds of the innovative top sirloin butt with a profit of $72.85. To have an equitable sales profit for the two cutting styles, the cuts from the innovative subprimal must be marketed 9.87 % higher than its conventional counterpart.

Table 9 shows the average profit per subprimal for conventional ribeyes at $115.91. With that total, the average price for the cuts generated out of the innovative ribeye must be priced at approximately $25.28 per kilogram (versus $18.66 per kilogram for conventional cuts) to generate a profit per subprimal at $115.87. To have an equitable sales profit for the two cutting styles, the cuts from the innovative ribeye must be marked up 26.19% when compared to the conventional ribeye.

Table 10 illustrates the average profit per subprimal for conventional strip loins to be approximately $88.59. Targeting that total, the cuts generated out of the innovative strip loin must average a price of $19.34 per kilogram (versus $18.66 per kilogram for conventional cuts) to generate a profit of $88.34 per subprimal. In order to have an equitable sales profit, the innovative cuts generated must be marketed 3.52% higher than conventional strip loins.

[1] (Calculations for equitable sales value in Tables 8-10 do not include processing times as a factor of profit. These profits are reflected in differences in saleable yields.)

Implications

Innovative fabrication has been a growing idea presented to retailers. The beef innovations group of the National Cattlemen's Beef Association has launched the Beef Value Cuts page as part of their Website (NCBA, 2009). Their Website teaches innovative fabrication styles to retailers through schematics, step by step instructions, and cutting videos. A desire to utilize portion control at the dinner table by US consumers, in addition to the want for uniform retail cuts in the marketplace, has driven the concern for the increase in carcass weight that has been observed in all four National Beef Quality Audits

(Lorenzen et al., 1993; Boleman et al., 1998; McKenna et al., 2002; Garcia et al., 2008).

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Table 1. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Top Sirloin Butt, Boneless (IMPS #184), cut conventionally

Item	UPC[1]	Average[2] *(n=11)*		Heavy[3] *(n=12)*	
			Steak number		*Steak number*
Initial cut weight (lbs)		15.29		20.72	
Retail Cut (%)					
Top butt steaks	1346	59.88	6.55	61.78	10.34
Lean trimmings		10.76		10.34	
Cube material		7.67		6.89	
Fat		20.84		19.82	
Total salable yield (%)		78.31		79.00	
Total time (s)		440.78		488.25	

[1]UPC = Universal Product Code
[2]Average = Subprimals from carcasses ranging from 700-800 pounds
[3]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 2. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Top Sirloin Butt, Boneless (IMPS #184), cut innovatively

Item	Average[1] *(n=12)*		Heavy[2] *(n=12)*	
		Steak number		*Steak number*
Initial cut weight (lbs)	15.21		20.74	
Retail Cut (%)				
Coulotte steaks	15.75	6.33	16.23	7.50
Center cut steaks	38.12	12.58	38.35	16.50
Lean trimmings	16.98		18.21	
Cube material	2.96		3.01	
Fat	25.17		24.61	
Total salable yield (%)	73.81		75.81	
Total time (s)	465.65		580.88	

[1]Average = Subprimals from carcasses ranging from 700-800 pounds
[2]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 3. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye, Lip-On (IMPS #112A), cut conventionally

Item	UPC[1]	Average[2] *(n=12)*		Heavy[3] *(n=12)*	
			Steak number		*Steak number*
Cut weight (lbs)		13.97		18.49	
Retail Cut (%)					
Lip-on Ribeye steaks	1214	78.63	16.09	81.12	17.17
Lean trimmings		9.55		9.36	
Fat		10.95		8.89	
Total salable yield (%)		88.18		90.48	
Total time (s)		238.18		339.73	

[1]UPC = Universal Product Code
[2]Average = Subprimals from carcasses ranging from 700-800 pounds
[3]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 4. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Rib, Ribeye, Lip-On (IMPS #112A), cut innovatively

Item	Average[1] *(n=12)*		Heavy[2] *(n=12)*	
		Steak number		*Steak number*
Cut weight (lbs)	13.88		18.59	
Retail Cut (%)				
Lip-on Ribeye steaks	20.35	3.92	18.73	4
Spinalis steaks	11.58	3.92	11.92	4.71
Ribeye filet steaks	26.15	9.92	27.16	11.97
Complexus steaks	2.34	1	2.24	1
Lean trimmings	20.33		23.55	
Fat	18.05		15.46	
Total salable yield (%)	80.75		83.60	
Total time (s)	409.28		465.87	

[1]Average = Subprimals from carcasses ranging from 700-800 pounds
[2]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 5. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Strip Loins, Boneless (0×1), (IMPS #180), cut conventionally

Item	UPC[1]	Average[2] *(n=12)*		Heavy[3] *(n=12)*	
			Steak number		*Steak number*
Cut weight (lbs)		11.35		14.67	
Retail Cut (%)					
Strip steaks	1295	55.50	10.58	58.39	11.50
Vein steaks	1297	17.59	3.25	16.11	3.08
Lean trimmings		10.58		12.12	
Fat		14.02		10.71	
Total salable yield (%)		83.67		86.63	
Total time (s)		303.31		317.77	

[1]UPC = Universal Product Code
[2]Average = Subprimals from carcasses ranging from 700-800 pounds
[3]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 6. Simple means of retail yields (%) and processing times (s) for fabrication of Beef Loin, Strip Loins, Boneless (0×1), (IMPS #180), cut innovatively

Item	Average[1] *(n=12)*		Heavy[2] *(n=12)*	
		Steak number		*Steak number*
Cut weight (lbs)	11.13		14.01	
Retail Cut (%)				
Roast	17.89		17.90	
Medial filet	16.40	4.33	15.76	4.18
Lateral filet	24.46	7.42	26.34	8.00
Petite strip steaks	13.68	5.50	13.77	5.82
Lean trimmings	9.03		10.04	
Cube material	0.74		0.89	
Fat	15.42		12.72	
Total salable yield (%)	82.20		84.70	
Total time (s)	324.76		357.43	

[1]Average = Subprimals from carcasses ranging from 700-800 pounds
[2]Heavy = Subprimals from carcasses ranging from 1000-1100 pounds

Table 7. Least squares means for total time and salable yield stratified by cutting style and weight classification

Top sirloin butt						
	Cutting Style			Weight Classification		
	Conventional	Innovative	P-value	Average	Heavy	P-value
Total time	463.76	523.26	0.0107	452.46	534.56	0.0006
Salable yield	78.64	74.81	0.0200	76.05	77.40	0.3959
Ribeye						
	Cutting Style			Weight Classification		
	Conventional	Innovative	P-value	Average	Heavy	P-value
Total time	291.88	440.59	<0.0001	349.56	382.91	0.3015
Salable yield	89.44	82.11	<0.0001	84.52	87.03	0.0049
Strip loin						
	Cutting Style			Weight Classification		
	Conventional	Innovative	P-value	Average	Heavy	P-value
Total time	310.54	340.89	0.0119	314.04	337.4	0.0496
Salable yield	85.15	83.46	0.0572	82.93	85.67	0.0029

Table 8. Simple means of weights from the Top Sirloin butt conventional and innovative cutting test

Conventional

UPC	Retail Cut Name	Weight	Selling Price($)/lb	Sale Value ($)
1346	Top butt steaks	60.87	5.48	333.57
	Lean trimmings	10.54	3.29	34.68
	Cube material	7.26	4.49	32.60
			Total	400.84

Innoavative

URMIS Retail Cut Name	Weight	Selling Price($)/lb	Sale Value ($)
Center cut steaks	38.24	6.08	232.50
Coulotte steaks	15.99	6.08	97.22
Lean trimmings	17.60	3.29	57.90
Cube material	2.99	4.49	13.43
		Total	401.05

Percentage difference in selling price	9.87	%[1]

[1] This number represents the innovative selling price divided by the conventional selling price times 100 to find the percentage increase needed to have an equitable profit for the two cutting styles.

Table 9. Simple means of weights from the Ribeye conventional and innovative cutting test

Conventional				
UPC	Retail Cut Name	Weight	Selling Price($)/lb	Sale Value($)
1214	Lip-On ribeye steaks	76.60	8.48	649.57
	Lean trimmings	9.06	3.29	29.81
			Total	679.38
Innovative				
	URMIS Retail Cut Name	Weight	Selling Price/lb	Sales Values
	Lip-On ribeye steaks	19.45	8.48	164.94
	Spinalis steaks	11.84	10.84	128.35
	Ribeye filet steaks	26.73	10.84	289.75
	Complexus steaks	2.31	10.84	25.04
	Lean trimmings	21.77	3.29	71.62
			Total	679.70
	Percentage difference in selling price		21.77 %[1]	

[1] This number represents the innovative selling price divided by the conventional selling price times 100 to find the percentage increase needed to have an equitable profit for the two cutting styles.

Table 10. Simple means of weights from the Strip Loin conventional and innovative cutting test

Conventional				
UPC	Retail Cut Name	Weight	Selling Price($)/lb	Sale Value($)
1295	Strip steaks	56.95	8.48	482.94
1297	Vein steaks	16.85	8.48	142.89
	Lean trimmings	11.35	3.29	37.34
			Total	663.17
Innovative				
	Retail Cut Name	Weight	Selling Price($)/lb	Sale Value($)
	Roast	17.89	8.60	153.85
	Medial filet	16.09	8.60	138.37
	Lateral filet	25.36	8.60	218.10
	Petite Strip steaks	13.72	8.60	117.99
	Lean trimmings	9.51	3.29	31.29
	Cube material	0.81	4.49	3.64
			Total	663.24
	Percentage difference in selling price		1.40 %[1]	

[1] This number represents the innovative selling price divided by the conventional selling price times 100 to find the percentage increase needed to have an equitable profit for the two cutting styles.

PROXIMATE ANALYSIS OF RAW AND COOKED RETAIL CUTS FROM THE BEEF CHUCK FOR THE NUTRIENT DATABASE IMPROVEMENT PROJECT

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Summary

A total of 40 beef arm chucks were collected from three cities across the United States to study the proximate composition of their separable lean. Chucks were fabricated 5-7 d postmortem and later cooked and dissected, or dissected raw into four separable components, separable lean, external fat, separable seam (intermuscular) fat, and connective tissue (considered inedible). Proximate analysis was conducted on the separable lean component of each dissected retail cut.

This study was designed to acquire data to update the National Nutrient Database for Standard Reference, as well as to provide nutritional information for cuts that are not presently in the database. This project is a collaboration between Texas A&M University, Texas Tech University, Colorado State University, the National Cattlemen's Beef Association, and the Nutrient Data Laboratory. The findings presented are the result of data that were collected only by Texas A&M University.

Introduction

There is a national confusion of lean beef's actual fat composition. Red meat commonly has been published as a fatty food, and this misunderstanding raises serious concerns for consumers (Harrington, 1994). The current data used to calculate the nutrient content of beef are outdated. The 2005 National Beef Market Basket Survey Executive Summary called for the need to update nutrition information (NCBA, 2005). It reports that health professionals and consumers commonly associate the nutritive value of beef as too fat. Often that assumption associates beef with an unhealthy amount and type of fat. This research provides data for beef cuts that are most often marketed in the retail case, and missing from the database. After the information collected in this project is updated, other nutrient databases that use the National Database as a reference point also will have access to the most up-to-date nutrient data.

Experimental Procedures

Product selection

Beef chucks (n=40) were collected from three plants across the country. Carcasses were selected according to a sampling matrix determined for the study (Table 1). The carcasses selected were tagged, followed through fabrication, and the chucks were collected in combos. They then were shipped via refrigerated truck to the Rosenthal Meat Science and Technology Center at Texas A&M University and stored (32-39 °F) until fabrication.

Fabrication

Chucks were fabricated 5-7 d postmortem into retail cuts (Table 2). Chucks were fabricated following the study protocol. Retail cuts were vacuum packaged, boxed, and stored in a cooler (32-39 ºF). Retail cuts were transferred to a -0.4 ºC freezer 21 d postmortem.

Dissection

Dissection was conducted following procedures outlined in the study protocol. Retail cuts were dissected into separable lean, separable fat, and refuse. Following the procedures in Wahrmund-Wyle et al. (2000a), Lean components were bagged in gallon size Ziploc® bags, labeled, and refrigerated for same day homogenization.

Cooking

Cooking method of braised, grilled, or roasted was assigned to the retail cuts that were designated for the cooked treatment (Table 2). For all cook methods, samples were thawed in refrigeration (32-39 ºF) for 24-48 h. Tempering start and stop time, date, cooler temperature, and location in cooler were all recorded. Internal temperature was not to exceed 41 ºF prior to cooking. A thermocouple was placed in the geometric center or thickest portion of the retail cut and cooked to a final endpoint temperature depending on cooking method. After cooking, samples were chilled in refrigeration (32-39 °F) uncovered for 12-24 h post-cooking in preparation for dissection.

Homogenization

Beef samples (cooked and raw) were homogenized. The separable lean from the sample was cut into 1 in pieces. Samples were placed in liquid nitrogen until completely frozen. The sample was blended into a powder, and samples were placed in whirl-pak bags and stored in a -112ºF freezer.

Proximate analysis

Percentage of moisture was determined using AOAC (1990) air, oven-dry method 950.46. Percentage of moisture was calculated by taking the initial weight of the sample, subtracting the dried weight, dividing by the initial weight and multiplying by 100.

Nitrogen content of the powdered beef samples was determined by total combustion (Rapid N Cube; Elementar, Hanau, Germany). Crude protein levels were determined by multiplying the total nitrogen by a factor of 6.25.

Percentage of ash was determined using the ash oven method 920.153 AOAC (1990). Samples that were dried for moisture analysis were used following moisture determination. Loss in weight was used to calculate ash.

Total lipid was extracted using a modified Folch, Lees, and Stanley (1957) method. Samples then were dried for 20 min at 212 ºF, cooled in a desiccator, and weighed to calculate total fat.

Fat Retention

Fat retention values were determined for each retail cut using raw versus cooked data, and expressed using the following equation derived from Murphy, Criner, and Gray (1975), and used by Jones et al. (1992a) and Wahrmund-Wyle et al. (2000b).

Results and Discussion

Separable tissue components of raw and cooked retail cuts

Retail cuts in this study were dissected into three separable components, separable lean, seam fat, and connective tissue considered inedible. Table 3 and 4 report means and standard deviations for the separable components of raw and cooked retail cuts, respectively. Retail cuts that are comprised of multiple muscles, such as the chuck-eye steak (76.33 % separable lean, raw), have numerically lower percentages of separable lean than retail cuts that are derived from a single muscle, like the mock tender steak (95.96 % separable lean, raw). This is because the intermuscular (seam) fat is removed during dissection from in between muscles. The exception to this is the top blade steak, which is a single muscle cut, comprised only of the *M. infraspinatus*. This cut has a large sheet of connective tissue which was removed during dissection, resulting in a mean value for separable lean, raw, of 86.16 %. Separable components were analyzed using least squares means of the percent lean, percent separable fat, and percent inedible connective tissue, stratified by USDA Quality Grade for raw and cooked retail cuts. For the raw retail cuts, USDA Quality Grade did not account for differences for any of the separable components within any retail cuts. The clod steak was the only cooked retail cut that reported significant differences for separable components among USDA Quality Grade. Percentage separable lean and percentage inedible connective tissue for the lower Choice steaks was 97.81 % and 1.57 %, respectively, and percentage separable lean and percentage inedible connective tissue for the Select steaks was 98.86 % and 0.93 %, respectively.

Proximate analysis of the separable lean

Percent total chemical fat, moisture, protein, and ash analyses were conducted on the separable lean component obtained from the dissection of each retail cut. Means and standard deviations for the percentage of each component for raw and cooked retail cuts are presented in Tables 5 and 6, respectively. Mean percentage of moisture decreased as the mean percentage of total fat increased. Jones et al. (1992a), Wahrmund-Wyle et al. (2000b), and Mason et al. (2008) all reported parallel findings. Similarly, after cooking the retail cut, the percentage moisture decreased and the percentage of total fat, protein, and ash increased due to a loss of moisture as a result of cooking.

Table 7 and 8 report the least squares mean of total chemical fat (%) of the separable lean of the beef retail cuts stratified by USDA quality grade. Currently, USDA reports nutrient values for cuts in three different categories, choice, select, and all grades. Some of the retail cuts in this study report significantly different values for percent chemical fat in the separable lean when sorting cuts based on USDA quality grade. This suggests that the National Database continue this method of reporting nutrition values based on USDA quality grade for retail cuts.

Cooking yields of beef retail cuts

Cooking yields of the beef retail cuts are shown in Table 9. The America's roast had the highest cooking yield, and was the only cut assigned to the roasting treatment. The cuts assigned to the grilled method of cooking followed with slightly lower cooking yields. The cuts that were braised exhibited the lowest cooking yields. Similar conclusions were made by Jones et al. (1992a) and Wahrmund-Wyle et al. (2000a). Cuts that are roasted tend to have higher cooking yields than cuts that are braised. Neither study used grilling as a cooking method. Cooking yield differences may be due to differences in final endpoint temperature assigned to each cooking method (Wahrmund-Wyle et al., 2000b), which were braising, 185 °F, grilling, 158 °F, and roasting, 140 °F.

Fat retention of the separable lean

Table 10 reports the percentage of chemical fat retention of the separable lean. In theory, single muscle cuts that are trimmed to have no external fat should have a fat retention value less than 100% because there should be no seam fat to migrate into the lean during cooking. However, our data were not consistent with this theory. The mock tender steaks reported 111.09 % chemical fat retention. Fat migration into the lean from seam fat into some of the retail cuts was observed in this study. Goihl et al. (1992) reported that the fat retentions that are greater than 100% may be influenced by moisture lost during cooking which concentrates the fat in the separable lean. Jones et al. (1992b) conclude that consumers who would like to reduce fat intake should trim cuts prior to cooking rather than after.

Comparisons between data found in the National Database, 2005 National Market Basket Survey, and this study

The primary objective of this study was to collect data to be used in collaboration with research simultaneously conducted at Texas Tech University, Colorado State University, and USDA contracted labs to update and enhance the current data that is used to calculate nutrition information for beef retail cuts consumed in the United States. The data that are currently reported in the National Database have been derived from regression equations from Jones et al. (1992a,b) and actual means from Wahrmund-Wyle et al. (2000b). A number of cuts that were fabricated and collected for this study are not even present in the National Database, so comparisons could not be made. Table 11 compares the raw data collected from this study with values that were reported by Mason et al. (2008) and the current data in the National Database. It is evident that the retail cut composition in this country is not stagnant, but constantly changing. Table 12 compares the data collected in this study for cooked retail cuts with data in the National Database. Tables 11 and 12 are both evidence that the National Database is lacking in the number of retail cuts that it is reported for consumers to search.

Implications

The 2005 National Market Basket Survey (Mason et al., 2008) not only gave us more accurate data about trim levels and fat content of beef sold at market, it also gave us a picture of retail cuts present in the United States. That research illustrated the great need to introduce cuts that are found in US markets into the National Database. As the industry continues to develop innovative retail cutting methods and as improvements in production practices continue, it is imperative the National Database continues to survey the composition of retail cuts found in the market and update the nutrition information.

Currently, The National Cattlemen's Beef Association reports 29 cuts of beef considered lean by government guidelines (NCBA, 2009). Hopefully, data collected during the course of this research will lengthen the list of lean beef cuts available to consumers to incorporate as part of a healthy diet.

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Table 1. Packing plant location and animal assignments

City	Weight (lbs)	Quality grade	Yield grade	Gender	Genetics
Green Bay	700-900	Upper Choice	2	Steer	Dairy
Green Bay	650-850	Upper Choice	3	Heifer	Non-dairy
Green Bay	650-850	Lower Choice	2	Heifer	Non-dairy
Green Bay	700-900	Lower Choice	3	Steer	Dairy
Green Bay	700-900	Select	2	Steer	Non-dairy
Corpus Christi	700-900	Upper Choice	3	Steer	Non-dairy
Corpus Christi	650-850	Lower Choice	3	Heifer	Non-dairy
Corpus Christi	650-850	Select	2	Heifer	Non-dairy
Tolleson	700-900	Lower Choice	2	Steer	Dairy
Tolleson	700-900	Select	3	Steer	Dairy

Table 2. Retail cuts fabricated for the study along with cook method, if applicable

Cut name	UPC[1]	Cooking method
Brisket[2]	1615	
Shoulder (clod) roast	1132	Braised
Shoulder (clod) steak	1133	Grilled
Beef for stew	1727	Braised
Denver cut		Grilled
Country style ribs		Braised
America's roast		Roasted
Chuck-eye steak	1102	Grilled
Under blade roast	1151	Braised
Under blade steak	1158	Braised
Top blade steak	1144	Grilled
Mock tender steak	1116	Braised
Short ribs	1127	Braised

[1]Universal Product Code

[2]The beef brisket was left whole until the dissection phase of the project, where it was separated into the point half (UPC[1] 1628) and flat half (UPC[1] 1623), and each component was dissected separately. Proximate analysis was performed on the flat half, raw, only.

Table 3. Means and standard deviations (SD) for percentage separable components of raw retail cuts from the beef chuck

			Lean (%)		Seam fat (%)		Connective tissue (%)	
Retail cut name	UPC[1]	*n*	Mean	SD	Mean	SD	Mean	SD
Brisket flat half	1623	10	89.68	4.92	9.26	5.45	0.00	0.00
Brisket point half	1628	10	70.66	5.59	29.23	5.53	0.00	0.00
Shoulder (clod) roast	1132	20	95.00	2.14	1.08	1.51	3.05	1.44
Shoulder (clod) steak	1133	20	97.09	1.33	0.62	0.48	1.42	0.75
Country-style ribs		20	76.58	3.87	17.83	5.18	4.67	3.29
America's roast		10	83.55	6.10	11.65	5.55	4.21	1.45
Chuck-eye steak	1102	20	76.33	3.08	19.21	3.84	3.38	2.51
Under blade roast	1151	9	82.03	5.31	14.36	5.53	2.78	2.69
Under blade steak	1158	10	84.68	5.85	13.30	5.69	1.31	0.91
Top blade steak	1144	10	86.16	3.71	0.82	0.84	12.11	2.95
Mock tender steak	1116	20	95.96	1.90	0.68	0.82	2.02	0.96
Short ribs	1127	10	79.75	3.89	14.54	4.27	4.95	3.24

[1]Universal Product Code

Table 4. Means and standard deviations (SD) for percentage separable components of cooked retail cuts from the beef chuck

			Lean (%)		Seam fat (%)		Connective tissue (%)	
Retail cut name	UPC[1]	*n*	Mean	SD	Mean	SD	Mean	SD
Shoulder (clod) roast	1132	20	94.92	1.69	0.95	1.64	4.02	2.25
Shoulder (clod) steak	1133	20	98.30	0.66	0.38	0.44	1.22	0.47
Country-style ribs		20	76.03	5.72	20.52	4.87	3.06	1.58
America's roast		20	88.74	3.18	9.85	3.95	0.91	2.31
Chuck-eye steak	1102	19	77.50	5.02	20.75	5.01	1.27	1.04
Under blade roast	1151	10	80.89	6.34	18.19	6.49	0.64	0.78
Under blade steak	1158	10	83.67	2.85	15.83	2.91	0.29	0.59
Top blade steak	1144	10	86.32	4.53	2.47	4.68	10.70	4.30
Mock tender steak	1116	20	97.49	1.02	0.76	0.42	2.26	0.90
Short ribs	1127	20	77.33	6.71	19.44	6.41	2.97	1.68

[1]Universal Product Code

Table 5. Means and standard deviations (SD) for percentage total chemical fat, moisture, protein, and ash (separable lean only) for raw retail cuts from the beef chuck

			Total fat (%)		Moisture (%)		Protein (%)		Ash (%)	
Cut name	UPC[1]	*n*	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Brisket flat	1623	10	4.20	1.30	75.54	1.23	21.91	0.42	1.24	0.05
Shoulder (clod) roast	1132	20	3.90	1.07	73.98	1.13	21.48	0.69	1.43	0.27
Beef for stew	1727	20	3.33	1.01	74.60	1.06	21.78	0.52	1.37	0.01
Denver cut		10	8.99	2.68	70.44	2.47	19.02	1.71	1.05	0.07
Country style ribs		20	7.21	1.91	71.28	1.85	20.11	0.71	1.11	0.10
America's roast		10	6.00	2.52	72.59	2.28	20.80	1.80	1.11	0.14
Chuck-eye steak	1102	20	8.02	2.22	70.11	1.88	20.50	1.12	1.02	0.04
Under blade roast	1151	10	5.97	1.95	72.46	2.18	20.67	19.99	1.20	0.11
Top blade steak	1144	10	6.37	1.93	73.41	1.90	19.99	0.73	1.37	0.60
Mock tender steak	1116	20	3.39	1.03	75.20	1.02	21.26	0.56	1.40	0.28
Short ribs	1127	10	10.64	3.44	69.89	22.86	19.17	0.99	1.07	0.10
Chuck average		**160**	6.18	2.40	72.68	2.05	20.61	0.98	1.22	0.15

[1]Universal Product Code

Table 6. Means and standard deviations (SD) for percentage total chemical fat, moisture, protein, and ash (separable lean only) for cooked retail cuts from the beef chuck

			Total fat (%)		Moisture (%)		Protein (%)		Ash (%)	
Cut Name	UPC[1]	*n*	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Shoulder (clod) roast	1132	20	7.34	3.06	60.73	2.77	32.01	2.03	2.88	1.01
Shoulder (clod) steak	1133	20	5.67	1.69	65.32	2.14	28.21	1.43	1.52	0.32
Beef for stew	1727	20	5.76	1.77	61.22	1.41	33.12	1.32	1.70	0.47
Denver cut		10	12.65	3.96	60.97	3.29	25.20	1.93	1.09	0.11
Country style ribs		20	11.97	3.04	58.39	2.61	28.64	1.85	1.14	0.13
America's roast		10	9.45	3.22	65.39	3.10	25.18	1.44	1.15	0.07
Chuck-eye steak	1102	19	10.71	2.43	62.32	2.06	26.19	1.28	1.16	0.10
Under blade roast	1151	10	10.33	3.58	58.21	3.21	30.72	2.20	1.78	0.55
Under blade steak	1158	10	9.15	2.10	59.95	2.95	30.88	2.44	1.69	0.41
Top blade steak	1144	10	8.01	2.57	64.65	3.31	26.98	3.29	1.37	0.45
Mock tender steak	1116	20	6.10	1.93	62.29	2.82	31.23	2.77	2.40	0.69
Short ribs	1127	10	14.46	4.87	56.43	4.82	27.11	1.79	0.98	0.10
Chuck average		**179**	9.30	2.85	61.32	2.86	28.79	2.86	1.57	0.57

[1]Universal Product Code

Table 7. Least squares means of total chemical fat percentage of separable lean of raw beef retail cuts from the chuck, stratified by USDA quality grade

			Upper Choice		Lower Choice		Select	
Retail cut name	UPC[a]	*n*	Total fat (%)	SEM[b]	Total fat (%)	SEM[b]	Total fat (%)	SEM[b]
Brisket flat	1623	10	5.50[c]	0.61	3.73[c]	0.53	3.52[c]	0.61
Shoulder (clod) roast	1132	20	5.04[c]	0.27	3.81[d]	0.24	2.88[d]	0.27
Beef for stew	1727	20	4.02[c]	0.35	3.44[cd]	0.30	2.51[d]	0.35
Denver cut		10	11.01[c]	1.18	9.50[c]	1.02	6.30[c]	1.18
Country-style ribs		20	8.31[c]	0.66	7.64[cd]	0.57	5.54[d]	0.66
America's roast		10	7.62[c]	1.48	5.44[c]	1.28	5.12[c]	1.48
Chuck-eye steak	1102	20	9.51[c]	0.86	8.72[c]	0.74	6.59[c]	0.86
Under blade roast	1151	10	7.83[c]	0.94	5.44[c]	0.82	4.81[c]	0.94
Top blade steak	1144	10	8.72[c]	0.61	5.78[d]	0.53	4.79[d]	0.61
Mock tender steak	1116	20	4.43[c]	0.30	3.25[d]	0.26	2.52[d]	0.30
Short ribs	1127	10	13.84[c]	1.72	9.42[c]	1.49	9.07[c]	1.72

[1]Universal Product code

[2]Standard error of the least squares mean

[c-d]Means within the same row lacking a common letter differ (P<0.05)

Table 8. Least squares means of total chemical fat percentage of separable lean of cooked beef retail cuts from the chuck, stratified by USDA quality grade

			Upper Choice		Lower Choice		Select	
Retail cut name	UPC[1]	*n*	Total fat (%)	SEM[2]	Total fat (%)	SEM[2]	Total fat (%)	SEM[2]
Shoulder (clod) roast	1132	20	10.48[c]	0.96	6.04[d]	0.83	5.95[d]	0.96
Shoulder (clod) steak	1133	20	7.35[c]	0.51	5.44[d]	0.44	4.31[d]	0.51
Beef for stew	1727	20	3.34[c]	0.41	2.99[c]	0.35	3.78[c]	0.41
Denver cut		10	15.92[c]	2.09	11.90[c]	1.81	10.39[c]	2.09
Country-style ribs		20	13.84[c]	1.17	11.75[c]	1.01	10.41[c]	1.17
America's roast		10	12.74[c]	1.28	9.21[cd]	1.10	6.48[d]	1.28
Chuck-eye steak	1102	19	12.63[c]	0.86	11.11[cd]	0.68	8.58[d]	0.79
Under blade roast	1151	10	12.62[c]	2.08	9.85[c]	1.80	8.68[c]	2.08
Under blade steak	1158	10	9.85[c]	1.31	9.26[c]	1.13	8.30[c]	1.31
Top blade steak	1144	10	10.88[c]	1.00	7.37[cd]	0.87	6.00[d]	1.00
Mock tender steak	1116	20	6.93[c]	0.71	6.58[c]	0.62	4.62[c]	0.71
Short ribs	1127	10	19.98[c]	1.79	13.42[cd]	1.55	10.35[d]	1.79

[1]Universal Product code

[2]Standard error of the least squares mean

[c-d]Means within the same row lacking a common letter differ (P<0.05)

Table 9. Cooking yields of beef retail cuts from the chuck

Retail cut	Cooking method	Cooking yield, %
	Braising	
Shoulder (clod) roast		64.07
Country-style ribs		69.50
Mock tender steak		61.68
Short ribs		69.50
Under blade roast		66.30
Under blade steak		65.78
	Grilling	
Chuck-eye steak		79.21
Top blade steak		76.88
Shoulder (clod) steak		73.64
	Roasting	
America's roast		80.72

Table 10. Percentage chemical fat retention for the separable lean from cooked beef retail cuts

Retail cut name	UPC[1]	Percentage fat retention[2]
Shoulder (clod) roast	1132	120.66
Country-style ribs		115.37
America's roast		127.13
Chuck-eye steak	1102	105.81
Under blade roast	1151	114.82
Top blade steak	1144	96.72
Mock tender steak	1116	111.09
Short ribs	1127	94.46

[1]Universal Product Code

[2]Values were calculated using percent cooking yields and percentage total fat content of the separable lean for both raw and cooked retail cuts

Table 11. Comparison of USDA National Nutrient Database with information from 2005 National Market Basket survey and the current study for total chemical fat of the separable lean in raw retail cuts

		TAMU data, 2009	Market Basket[2]	National Database[3]	Difference[4] (%)	
		Total chemical fat (%)	Total chemical fat (%)	Total chemical fat (%)	Market Basket[2]	National Database[3]
Retail cut name	UPC[1]	Mean	Mean	Mean		
Brisket flat half	1623	4.20	3.90		+7.69	
Shoulder (clod) roast	1132	3.90	3.96	5.88	-1.52	-33.67
Beef for stew	1727	3.33	4.26		-21.83	
Chuck-eye steak	1102	8.02	8.92		-10.09	
Under blade roast	1151	5.97	7.55		-20.93	
Top blade steak	1144	6.37	7.32	10.52	-12.98	-39.45
Mock tender steak	1116	3.39	3.23		+4.95	
Short ribs	1127	10.64	8.40		+26.67	

[1]Universal Product
[2]2005-National Beef Market Basket Survey (Mason et al., 2008) data
[3]USDA, National Database data
[4]Difference, % = [(TAMU data, 2009 – Market Basket[2]) / Market Basket[2]]*100; % = [(TAMU data, 2009 – NationalDatabase[3]) / National Database[3]]*100

Table 12. Comparisons of USDA National Nutrient Database with the current study for total chemical fat of the separable lean in cooked retail cuts

		TAMU data, 2009	National Database[2]	
		Total chemical fat (%)	Total chemical fat (%)	Difference[3] (%)
Retail cut name	UPC[1]	Mean	Mean	
Shoulder (clod) roast	1132	7.34	6.34	+15.77
Shoulder (clod) steak	1133	5.67	7.66	-25.98
Top blade steak	1144	8.01	12.79	-37.37
Mock tender steak	1116	6.10	5.42	+12.55

[1]Universal Product Code
[2]USDA, National Database data
[3]Difference, % = [(TAMU data, 2009 – National Database[3]) / National Database[3]]*100

NUTRITION

EVALUATION OF PREDICTED DRY MATTER INTAKE OF GRAZING BEEF COWS USING A MECHANISTIC CNCPS MODEL AND FORAGE QUALITY DATA

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Summary

This experiment was conducted with Santa Gertrudis beef cows, grazing native forage in a continuous system at the King Ranch, TX. Three periods were The DMI predicted by the Cornell Net Carbohydrate and Protein System (CNCPS) was not sufficient to maintain cows match their requirements in energy during all months for period 1 except November, December and January; and protein intake were not enough to meet their requirements during May, June, July, and April. For the period 2, DMI predict by the CNCPS model was not sufficient to match cow's energy requirements during all months, excepted by December and January; and protein balance was negative during May, June, and April. The average DMI predicted by the CNCPS model was 1.99% BW. CNCPS model can be used to predict animal requirements and feed nutrients supply, and assist producers to see if their diets are supplying enough nutrients for their animals. However, chemical analysis is require in order to enter the measurement feed composition.

Introduction

According to Molina et al. (2004), nutritional models should be used to predict dry matter intake (DMI) of grazing animals because the measurement of intake of grazing animals is limited. .Nutrition models can accurately estimate nutrient supply and animal requirements in different systems (Tedeschi et al., 2005). Animal performance is totally related to type and quality of the feed that is consumed. Therefore, by knowing the amount of feed intake, producers can properly manage the animal and forage interaction and provide the amount of supplements to animals in order to increase productivity (Lagunez et al., 1999) and consequently increase the profit. According to Fox et al. (2004), the Cornell Net Carbohydrate and Protein System (**CNCPS**) can be used to assist producers to meet their goals by accounting for biological value of diverse forages, predicting animal requirements and feed intake, and animal performance in different environments and breeds.

Experimental Procedures

This experiment was conducted at King Ranch, Kingsville, TX, with multiparous Santa Gertrudis beef cows. Two periods that comprise the breeding season which starts in May and cows calving in March were evaluated: Period 1 was comprised from May 2006 to April 2007 and Period 2 was from May 2007 and April 2008. The average BW of the cows was 553.4 ± 71.12 and 571.8 ± 43.32 kg BW for Periods 1 and 2, respectively. Cows were grazing native forage in a continuous system and supplemented whenever deemed necessary by the ranch personnel.

In order to predict DMI of beef cows, simulations were performance to predict the requirements of metabolizable energy (Mcal/day) and metabolizable protein (g/day) for maintenance, pregnancy, lactation and growth within periods. In order to estimate the amount required and supplied by the forage, DMI was predict by the CNCPS. For each month within the periods, simulations were performed using environmental data (average temperature ºC, average humidity and wind speed) (Table 1), chemical analysis of the forages (Table 2), and the animal data (body weight - **BW**, breed type, days pregnant, days since calving, lactation number, calving interval, expected calf birth weight, age ate first calving, milk production (lactation period) body condition score, breeding system, breed). All animals were weighed there times during each period (Period 1: July, September, and December, and Period 2: July, October, and January). These dates were selected in order to meet management procedures of the King Ranch. Monthly cow weights were estimated using a polynomial regression. Cows were fed with protein supplement (1.7 kg/day) during both period excepted July and August. The chemical analysis of the forage and supplements were determined by Cumberland Valley Analytical Services (CVAS). The following analyses were performed: dry matter, ash, crude protein, neutral detergent fiber, acid detergent fiber, ether extract and lignin. *In vitro* fermentation analysis was performed to obtain digestion rate (kd, 1/h) according to Tedeschi et al. (2008a,b). All simulations were performed using monthly data of animals, climate, and forage quality.

Results and Discussion

The climatic data are presented in Table 1. Table 2 has the chemical analysis for Periods 1 and 2. The prediction of DMI and animal response under grazing systems with tropical grass requires adequate measurements of values of NDF, lignin, CP, soluble protein, and digestion rates for carbohydrate B2 and protein B3 fractions to improve

results (Lagunes et al., 1999). During July and August for both Periods cows did not received any supplements.

For Period 1, the DMI predicted by the CNCPS model for grazing Santa Gertrudis beef cows were not sufficient to meet the energy and protein requirements during all months except for November, December, and January for ME and May, June, July, and April for MP. The average DMI predicted by the CNCPS model was 2.01% of the BW (forage + supplement).

For Period 2, the DMI predict by the CNCPS model were not sufficient to meet the energy and protein requirements during all period except for December and January for ME and MP balance was negative during May, June, and April. This was very similar to Period 1. The average DMI predicted by the CNCPS model was 1.99% BW. For both Periods, cows calved in March and calves are weaned in October, thus the lack of ME and MP might have affected milk production and reproduction rates.

Lagunes et al. (1999) evaluated dual-propose cows and suggested that cows produced milk until they reach the amount of ME allowed to milk production. The average DMI reported in the literature (Hatfield et al., 1989; Lagunes et al., 1999; Sowell et al., 2002; and Molina et al., 2004) for ranging beef cows was 2.6% of BW. This suggests that the CNCPS is underestimating the DMI intake. This underprediction has been reported in other experiments (Fox et al., 1992; Molina et al., 2004).

In the next step, we performed simulations assuming 2.6% of BW of DMI (forage + supplement) and that cows were consuming on average 0.29% and 0.26% of BW of supplement for Periods 1 and 2; respectively. The DMI of forage was computed as the difference between total DMI and supplement intake; no forage substitution or increase was assumed.

When the 2.6% of BW was used to compute total DMI, only for May and June cows were deficient in ME (Mcal/day) and MP for Period 1. For Period 2, cows were deficient in ME during April and MP during June and April. These results are more consistent with the observation of cow performance as shown by the slight increase in BW (Figure 1). Figure 1 supports the concept that cows had an overall positive MP and ME balance throughout the reproductive cycle because the average BW of the cows increased during these periods. Cows likely used the surplus of nutrients for growth and to deposit body reserves. Cows usually are in negative energy balance before calving due to the low amount of nutrients necessary for lactation and during May and June when peak milk occurs. Reynoso-Campos et al. (2004) reported the onset of a negative energy balance on day 115 of lactation. So the amount of nutrients necessary for positive energy balance was high and animals would have to eat large amounts of forage due to its low quality. However, the physical capacity of the rumen would be the first limiting factor. The poor quality of the forage and increase in MP and ME requirements during these months contributed to the negative energy balance.

Lagunes et al. (1999) concluded the CNCPS model should improve the prediction of nutrient requirements and animal performance, but the CNCPS has to be used to predict animal requirements only when feed composition is available. Our results indicated the CNCPS model is sensitive to forage chemical analysis and fermentation kinetics and accurate predictions of forage DMI are needed to adequately predict energy balance and supplementation strategies of grazing beef cows.

Implications

Nutrition models can be used to predict animal requirements and feed nutrients supply, and assist producers to identify strategies to improve animal performance. Chemical analyses of feeds (forage and supplements) are required in order to predict the correct amount of nutrient intake.

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Table 1: Climatic data for the King Ranch, TX, during the experiment

	Temp (◦C)	Dew Point (◦C)	Humidity (%)	Wind (km/h)	Prec. (mm)
			Period 1		
May	26.71	19.21	64.17	15.83	73.66
June	28.53	21.62	64.52	11.72	166.37
July	29.27	23.24	67.88	13.90	80.772
Aug	30.24	22.65	63.77	12.13	28.448
Sep	26.78	21.13	72.25	11.33	202.946
Oct	23.53	17.69	70.96	13.84	33.782
Nov	18.59	11.30	70.37	11.86	0
Dec	15.14	9.98	76.79	11.55	59.182
Jan	11.77	7.97	81.55	14.80	92.456
Feb	15.40	9.44	74.50	12.13	0
March	20.56	14.55	74.35	13.91	53.34
April	21.09	15.70	78.10	11.80	56.134
			Period 2		
May	25.26	20.16	76.64	9.81	224.536
June	27.61	23.13	78.53	11.64	65.024
Sep	27.32	22.62	79.48	5.27	98.044
Oct	23.49	16.16	71.87	7.01	12.7
Nov	18.91	12.98	75.90	9.01	6.35
Dec	16.90	9.73	68.23	13.60	0
Jan	13.53	7.04	72.55	14.95	39.878
Feb	18.87	11.23	70.76	12.93	0
March	19.73	11.31	66.48	16.92	1.27
April	23.15	15.07	67.23	15.24	36.83

Table 2: Chemical analyses of King Ranch pastures used in our experiment

Month	DM, %	ADF	NDF	Lignin	EE	Ash	CP	ADIN	NDIN	SP[1]
		%, DM								
Period 1										
May	88.8	32.8	70.4	7.4	1.6	10.0	12.1	4.0	16.8	-
Jun	95.2	56.8	80.7	10.2	1.1	7.9	2.6	1.2	1.3	28.5
Jul	90.8	38.0	65.5	8.3	1.7	9.9	12.0	3.3	16.1	-
Aug	90.7	38.0	62.1	8.3	1.4	9.2	11.9	4.2	7.0	-
Sep	92.4	39.9	64.0	6.5	1.2	8.8	12.0	3.9	10.5	-
Oct	94.9	41.5	75.3	5.9	1.3	9.7	8.8	1.3	2.8	37.2
Nov	93.1	44.2	73.6	8.5	0.9	8.5	7.4	3.6	7.8	-
Dec	95.7	45.5	76.4	8.0	1.0	9.3	7.2	1.5	2.6	37.9
Jan	94.7	48.1	80.3	10.2	1.2	6.0	7.3	2.2	2.8	31.1
Feb	93.1	51.1	77.4	11.6	1.2	10.2	6.9	4.8	9.7	-
Mar	93.1	53.8	74.0	10.5	1.8	2.0	6.8	1.5	2.5	27.3
Apr	93.2	47.9	72.2	9.3	1.7	3.4	6.9	1.3	2.2	37.0
Suppl.	90.9	15.2	37.6	3.7	3.4	7.7	29.0	1.3	5.0	23.8
Period 2										
May	93.1	37.0	69.0	5.7	1.7	5.1	11.7	1.3	3.3	45.7
Jun	91.7	46.2	72.6	8.8	1.3	4.3	6.2	1.3	2.3	36.7
Sep	93.8	39.2	67.6	7.3	1.9	12.6	11.2	1.5	3.5	43.6
Oct	92.5	40.5	71.1	7.7	1.6	9.8	11.9	1.8	3.9	38.7
Nov	93.4	47.6	75.4	8.0	1.2	9.1	4.9	1.5	3.9	35.3
Dec	94.6	44.6	74.4	9.1	1.2	8.1	4.7	1.5	3.6	26.6
Jan	94.4	50.2	76.3	8.7	1.1	10.6	5.3	1.8	2.0	22.3
Feb	91.7	51.7	76.3	10.1	1.1	10.6	6.2	1.9	2.2	28.2
Mar	91.0	46.3	71.9	10.1	1.2	11.3	10.0	2.6	4.3	22.0
Apr	92.4	57.1	80.3	11.5	0.4	9.7	4.4	1.8	2.0	23.4
Suppl.	87.0	15.3	26.2	3.3	4.4	7.5	35.8	2.3	2.8	18.2

[1] Soluble protein, % of CP.

Figure 1. Computed body weights of the cows evaluated during Periods 1 (May 2006 to April 2007) and 2 (May 2007 to April 2008).

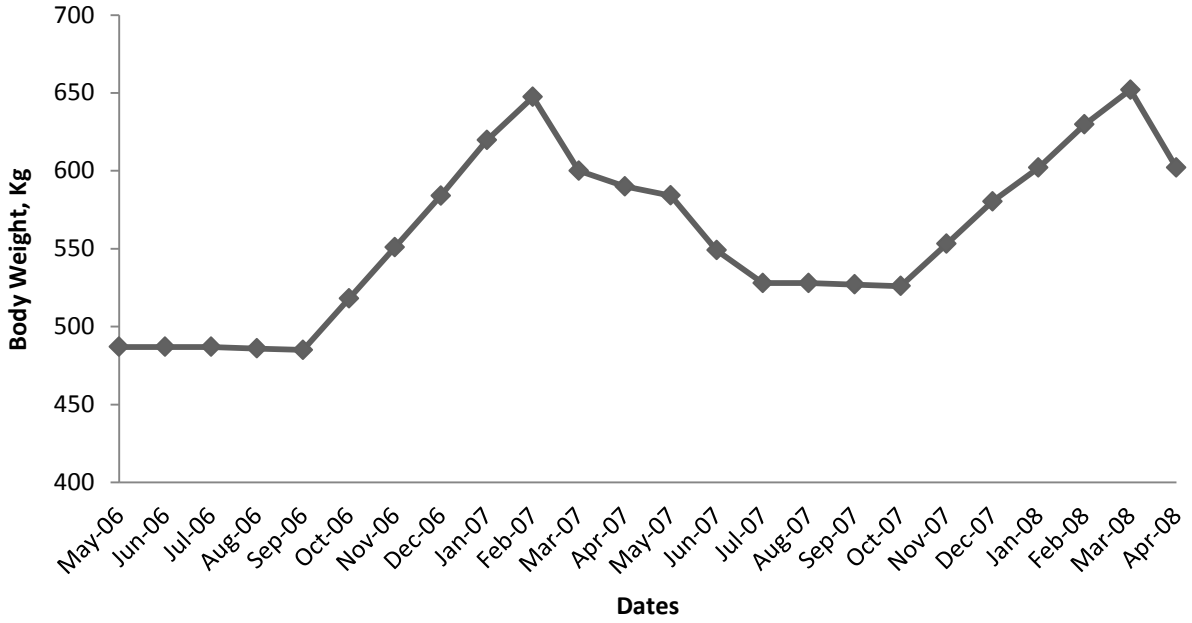


Figure 2. Metabolizable energy (ME, Mcal/d) protein (MP, g/d) balances using the DMI predict by CNCPS for (A) Period 1 and (B) Period 2.

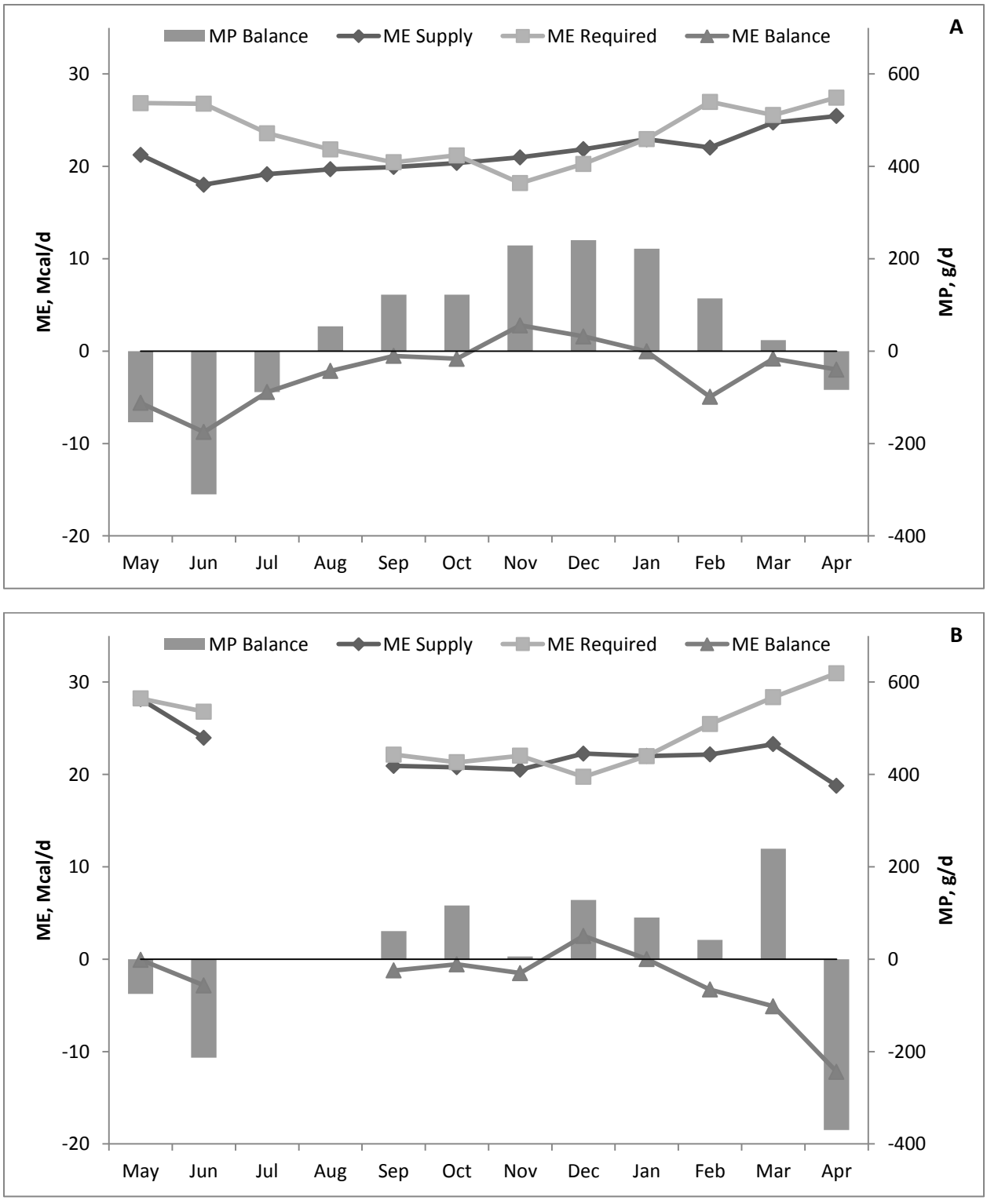
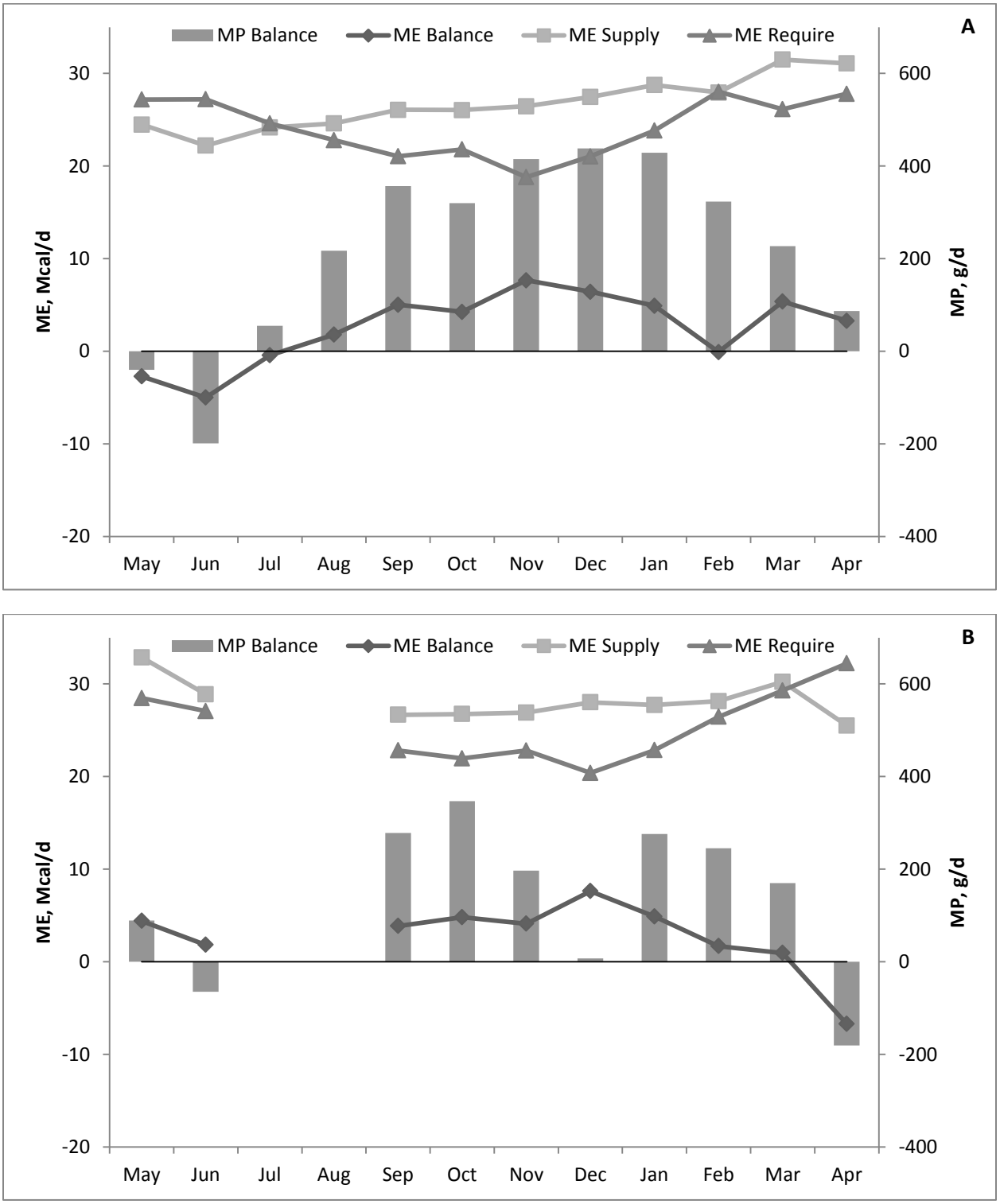


Figure 3: Metabolizable energy (ME, Mcal/d) protein (MP, g/d) balances assuming DMI to be 2.6% of BW for (A) Period 1 and (B) Period 2.



USING A MECHANISTIC NUTRITION MODEL TO IDENTIFY EFFICIENT BEEF COWS UNDER GRAZING CONDITIONS

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Summary

The objectives of this study are to utilize cow body weights, growth, and fatness measurements along with calf age, body weight, and growth measurements, as well as forage quality and quantity to rank cows within a herd based on their efficiency at utilizing available forage to meet maintenance requirements and support calf growth. Data were collected from one herd of approximately 140 Santa Gertrudis cows over a two year period, and analyzed per calving interval, conception to weaning. A strong negative relationship was found between predicted peak milk and energetic efficiency index (EEI), and model predicted values were also strongly correlated across years. Peak milk and EEI were not correlated to either of the 2 temperament measures collected, exit velocity or chute score. Relationships between EEI and peak milk with ultrasound fat measures indicated that more efficient cows, with a lower EEI were leaner, and cows with a higher peak milk were also leaner.

Introduction

With cost of livestock production increasing each year, producers are continually searching for a cheaper, more efficient way to produce their product. By increasing the efficiency by which their product is produced, they can thereby increase profitability. The cow/calf phase of production represents a large portion of the expense involved in the costs of producing beef. Feed consumption during the cow/calf component of the production cycle represented 72% of the ME consumed from conception to harvest (Ferrell and Jenkins, 1982).

In their discussion of matching cow type and milking ability to available land and forage, Fox et al. (2004), stated that the identification of the most efficient cow type for a particular farm requires finding the best match of ME requirements with feed energy available. It is very important to realize that a particular cow that is efficient under one production situation may not be the same under all conditions. There are many factors, such as milk production, temperament, maintenance requirements, or tissue accretion, which may affect why some cows are quite simply more efficient at converting available forage resources to the ultimate product for most cow/calf operations, body weight of calf weaned. Therefore it is very important to be able to identify cows which are more efficient in converting available forage resources into more pounds of weaned calf, while still maintaining adequate condition to ensure rebreeding. Efficient beef cows use less resource to obtain the same outcome in a sustainable environment, according to Tedeschi et al. (2004a).

The objectives of this study are to utilize cow body weights, growth, and fatness measurements along with calf age, body weight, and growth measurements, as well as forage quality and quantity to rank cows within a herd based on their efficiency at utilizing available forage to meet maintenance requirements and support calf growth.

Experimental Procedures

One herd of approximately 140 spring calving purebred Santa Gertrudis cows, ranging in age from 3 to 15 years, were used for this study. Cow data were collected three times per year, at pre-calving (Jan or Dec), at branding (Jul), and at weaning (Sept or Oct). Calf data were collected twice per year, at branding and at weaning. At pre-calving, cow body weight (BW) and body condition score (BCS) were collected. At branding, cow BW, BCS, chute score (CS), and exit velocity (EV) were collected, along with calf BW, hip height (HH) CS, and EV. At weaning, cow BW, BCS, CS, and EV were collected along with calf BW, HH, CS, and EV. At branding and weaning, ultrasound carcass measurements were obtained from each cow, and included 12th-13th rib backfat thickness (BF), rump fat (RF), and kidney fat depth (KPH) depth. As described by Ribeiro et al. (2008),the kidney fat image was collected between the first lumbar vertebra and the 13th rib as shown in as a cross-sectional image. The ultrasound probe was placed on the flank region approximately 15 cm from the midline of the animal. Images were stored in the ultrasound console and interpreted chute side by the same technician. The uKFd measurement was taken between the ventral part of the abdominal muscles (*iliocostalis*, *obliquus abdominis interni*, and *obliquus abdominis externi*) and the end of the kidney fat.

EV was measured as the seconds required for each animal to exit a working chute and travel a distance of 6 ft. (1.83 m). Chute Scores were measured on a 1 to 5 scale, where 1 = calm and 5 = excited, and were determined in a confined area.

Data were analyzed per calving interval (conception to weaning), and divided into 2 years. Year 1contained data from July 2006 to October 2007, and year 2 contained data from December 2006 to September 2008. Within

herd EPD's were obtained for milk, weaning weight (WW), and marbling (MRB).

The data collected were used as model inputs to compute ME requirement for each cow as described by Tedeschi et al. (2005): (1) compute cow mature weight at BCS 5 adjusted for conceptus, (2) compute daily cow net energy required for maintenance (adjusted for activity, environment), (3) compute cow pregnancy requirement, (4) predict cow peak milk from calf weaning weight and age, (5) compute cow lactation requirement, (6) compute calf forage ME intake, (7) compute total ME required, (8) compute ME efficiency (ME required/actual weaning weight, ME required/adjusted weaning weight, ME required/(adjusted weaning weight + % of cull cow wt), (9) compute total herd ME, (10) compute cow fractional share of herd ME, and (11) compute cow cost (total costs × fractional share).

PROC CORR of SAS was used to determine relationships between model predicted peak milk and energetic efficiency index (EEI) with cow and calf performance data and temperament data.

Results and Discussion

Cows in year 1 had an average EEI of 35 Mcal/kg with a SD of 6.99, while cows in year 2 had an average EEI of 36.6 Mcal/kg with a SD of 4.66. For year 1, cows had an average predicted peak milk of 19 lb/d with a SD of 2.56 lb/d. Cows in year 2 had an average predicted peak milk of 20.3 lbs/d with a SD of 2.38 lb/d. Table 1 provides summary data for year 1. For year 1, there were 65 cow-calf with complete data used in the analysis, and for year 2, there were 88 cow-calf with complete data used in the analysis. Both BW and BCS increased from July 2006 to October 2007, from 1074 lb to 1160 lb, and from 4.62 to 5.59; respectively. Cows gained backfat (BF) from July of 2006 to October of 2007, from 0.35 in. to 0.58 in. Chute score was fairly consistent throughout year 1, ranging from 2.29 to 3.05. Cows weaned heavier calves in 2007 as compared to their previous 2006 calf.

Table 2 provides summary data for year 2. Data in July of 2008 was incomplete due to inclement weather on scheduled work days. In year 2, cow BW ranged from an average of 1144 lb in July of 2008 to 1327 lb on average in January of 2008. Cows lost BCS from the fall of 2007 to the fall of 2008, from 5.59 to 5.34. This loss in BCS is likely due to a reduction in forage available in 2008 as compared to 2007. In 2007, cows gained BF from July to October, from 0.51 in to 0.58 in. Chute score ranged from 2.29 in July of 2007 to 1.69 in July 0f 2008. Calves weaned in 2008 were slightly lighter than calves weaned in 2007, 507 lb as compared to 529 lb.

Pearson correlation coefficients between model-predicted values and EPDs for cows in year 1 are given in Table 3. Peak milk was strongly negatively correlated to the energetic efficiency index (EEI) at r = -0.85, such that cows with a higher peak milk had a lower EEI, and were thus more efficient. Actual WW was negatively correlated to EEI (-0.85), and positively correlated to peak milk (0.93). Milk EPD was negatively correlated to EEI (-0.39) and positively correlated to peak milk (0.40). Milk EPD tended to be correlated to WW at r = 0.23. WW EPD was negatively correlated with Milk EPD (-0.28). There were no significant relationships between either WW EPD or marbling EPD and EEI or peak milk.

Pearson correlation coefficients between model-predicted values and EPDs for cows in year 2 are given in Table 4. Similar to year 1, EEI and peak milk were also negatively correlated in year 2, although slightly weaker at r = -0.55. Also in year 2, actual WW was negatively correlated with EEI, and positively correlated with peak milk, such that cows that weaned heavier calves had lower EEI and higher peak milk. This suggests that cows identified as more efficient by the model produced more milk and weaned heavier calves on the same amount of forage. Milk EPD had similar relationships to EEI, peak milk, and actual WW, with significant relationships of -0.23, 0.49, and 0.34; respectively. WW EPD was negatively correlated with milk EPD (r = -0.28).

Table 5 gives Pearson correlation coefficients between model predicted values across years. There were only 44 cow-calf with complete data across both years. EEI was strongly correlated across years at r = 0.74, suggesting that the EEI may be consistently predicted for cows across years. Peak milk was only moderately correlated across years at 0.42, which suggests that many of the conditions affecting peak milk are dependent upon factors more strongly dependent upon conditions within a year. EEI for year 1 was moderately positively correlated (0.42) with peak milk in year 2, while EEI in year 2 was moderately negatively correlated (-0.56) to peak milk in year 1. Preliminary genetic assessment of EEI and ME required (MER) for the observed performance as predicted by the model, indicated additive genetic heritability (h^2) of EEI and MER of 0.25 and 0.21, respectively. The estimated permanent environment h^2 was 0.54 and 0.37, respectively.

Relationships between temperament measures of cows and model predicted values are given in table 6. There were no significant relationships between Chute score in year 1 or 2 with any of the model predicted traits for either year. Exit velocity for both year 1 and 2 were not correlated with either model predicted trait as well.

The relationships between internal fat measures and various model predicted and performance traits are shown in table 7. Year 1 EEI was positively correlated to all ultrasound fatness measures. This suggests that more efficient cows, as identified by a lower EEI, were leaner. Similar relationships were observed for EEI in year 2, although correlations were slightly weaker for all traits, with the exception of KPH in year 1. There was a

negative relationship observed between EEI in year 2 and KPH in year 1. For year 1, Peak milk was moderately negatively correlated with all fatness measures, such that cows with a higher peak milk were leaner. Contrasting relationships were observed for peak milk in year 2. There tended to be negative relationships between peak milk in year 2 and KPH in year 1, as well as internal fat (IFAT) in year 1. The lack of correlation may be due to the size of available data, for year 2, there were only 2 data points included in the average for each trait. When correlated with our observed fatness measure of BCS, for year 1, there were only significant positive relationships with BF in year 1, and KPH in year 2. There tended to be a weak positive correlation between year 1 BCS and BF in year 2. For year 2 BCS, there were no significant relationships with any of the ultrasound fatness measures. For year 1 actual WW, there were moderate negative correlations with all ultrasound fatness measures. This suggests that leaner cows weaned heavier calves. For year 2, the same relationships between actual WW and ultrasound fatness measures were not observed. The only significant relationship observed was with IFAT in year 1, although there tended to be a negative relationship with KPH in year 1. Relationships with the subjective temperament measure of CS were also analyzed. For year 1, CS was negatively correlated with BF for both years, KPH in year 2, and IFAT in year 2. For year 2, CS was again negatively correlated with BF for both years and IFAT in year 2, but also tended to be negatively correlated to IFAT in year 1. These observed relationships between CS and ultrasound fatness measures suggest that cows classified as more excitable, with a higher CS, were also leaner.

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Table 1. Cow and calf summary data year 1(All cows)*#

	Jul-06	Sep-06	Dec-06	Jul-07	Oct-07
N	138	140	101	136	132
Cow					
BW, lb	1074 ± 105	1069± 108	1287±127	1164± 134	1160 ± 150
BCS	4.62 ± 0.61	5.05 ± 0.53	4.83 ± 0.78	5.32 ± 0.69	5.59 ± 0.89
KPH, in	4.29 ± 0.43	4.29 ± 0.57		6.38 ± 0.60	6.46 ± 0.57
uBF, in	0.35 ± 0.14	0.46 ± 0.23		0.51 ± 0.34	0.58 ± 0.42
uRF, in	0.47 ± 0.38	0.67 ± 0.57		0.94 ± 0.84	0.99 ± 0.91
CS	3.05 ± 0.79	2.92 ± 0.82		2.29 ± 0.92	2.29 ± 0.81
Calf					
Birth wt, lb			77.2 ± 8.93		
BW, lb	335 ± 63.1	492 ± 69.2		390 ± 75.2	529.1 ± 83.1
HH, cm		46.5± 1.69		42.9± 1.83	46.9± 1.76
CS		2.71 ± 0.71		2.09 ± 0.74	2.20 ± 0.83

* BW= body weight, BCS= body condition score, KPH = kidney, pelvic, and heart fat, uBF= ultrasound back fat, uRF= ultrasound rump fat, CS= chute score, EV=exit velocity

#Mean ± standard deviation

Table 2. Cow and calf summary data year 2 (All cows)*#

	Jul-07	Oct-07	Jan-08	Jul-08	Sept-08
N	136	132	145	140	138
Cow					
BW, kg	1164± 134	1160 ± 150	1327 ± 206	1144 ± 146	1177 ± 149
BCS	5.32 ± 0.69	5.59 ± 0.89	5.02 ± 0.80	5.21 ± 0.58	5.34 ± 0.65
KPH, cm	6.38 ± 0.60	6.46 ± 0.57			6.69 ± 0.50
uBF, cm	0.51 ± 0.34	0.58 ± 0.42			
uRF, cm	0.94 ± 0.84	0.99 ± 0.91			
CS	2.29 ± 0.92	2.29 ± 0.81		1.69 ± 0.65	2.17 ± 0.75
Calf					
Birth wt, kg			79.1 ± 9.48		
BW, kg	390 ± 75.2	529 ± 83.1		370 ± 59.7	507 ± 70.8
HH, cm	42.9± 1.83	46.9± 1.76			46.1 ± 4.51
CS	2.09 ± 0.74	2.20 ± 0.83			2.14 ± 0.81

* BW= body weight, BCS= body condition score, KPH = kidney, pelvic, and heart fat, uBF= ultrasound back fat, uRF= ultrasound rump fat, CS= chute score, EV=exit velocity

#Mean ± standard deviation

Table 3. Pearson correlation coefficients between model predicted values and EPD's for year 1[1]

	EEI	Peak Milk	WW	Milk EPD	WW EPD	MRB EPD
EEI		-0.85*	-0.85*	-0.39*	0.004	0.01
Peak Milk			0.93*	0.40*	0.02	-0.09
WW				0.23#	0.03	-0.04
Milk EPD					-0.28*	0.001
WW EPD						0.70*
MRB EPD						

[1] EEI= energetic efficiency index
* Correlations differ from zero at P < 0.05
# Correlations differ from zero at P < 0.10

Table 4. Pearson correlation coefficients between model predicted values and EPD's for year 2[1]

	EEI	Peak Milk	WW	Milk EPD	WW EPD	MRB EPD
EEI		-0.55*	-0.75*	-0.23*	0.05	0.11
Peak Milk			0.79*	0.49*	-0.005	-0.05
WW				0.34*	-0.03	-0.06
Milk EPD					-0.28*	0.001
WW EPD						0.70*
MRB EPD						

[1] EEI= energetic efficiency index
* Correlations differ from zero at P < 0.05
# Correlations differ from zero at P < 0.10

Table 5. Pearson correlation coefficients between model predicted values between years[1]

	EEI Yr 1	EEI Yr 2	Peak Milk Yr 1	Peak Milk Yr 2
EEI Yr 1		0.74*	-0.85*	0.42*
EEI Yr 2			-0.56*	-0.55*
Peak Milk Yr 1				0.42*
Peak Milk Yr 2				

[1] EEI= energetic efficiency index
* Correlations differ from zero at P < 0.05
# Correlations differ from zero at P < 0.10

Table 6. Pearson correlation coefficients between model predicted values and temperament values[1]

	EEI Yr 1	EEI Yr 2	Peak Milk Yr 1	Peak Milk Yr 2
CS Yr 1	-0.18	-0.05	-0.07	-0.21
CS Yr 2	-0.22	-0.07	0.02	-0.15
EV Yr 1	-0.01	0.02	-0.0004	-0.03
EV Yr 2	-0.05	0.01	-0.02	-0.08

[1] EEI= energetic efficiency index, CS= chute score, EV= exit velocity
* Correlations differ from zero at P < 0.05
# Correlations differ from zero at P < 0.10

Table 7. Pearson correlation coefficients between internal fat measures and model predicted traits, BCS, calf WW, and CS[1]

	$AvgBF_{Y1}$	$AvgBF_{Y2}$	$AvgKPH_{Y1}$	$AvgKPH_{Y2}$	$IFAT_{Y1}$	$IFAT_{Y2}$
EEI_{Y1}	0.60*	0.57*	0.76*	0.53*	0.77*	0.65*
EEI_{Y2}	0.51*	0.38*	-0.63*	0.47*	0.75*	0.40*
$PeakMilk_{Y1}$	-0.38*	-0.37*	-0.57*	-0.37*	-0.44*	-0.40*
$PeakMilk_{Y2}$	-0.04	0.09	-0.38#	0.05	-0.41#	0.09
BCS_{Y1}	0.30*	0.22#	0.13	0.39*	0.24	0.24
BCS_{Y2}	-0.07	0.01	0.14	0.12	-0.28	0.01
WW_{Y1}	-0.31*	-0.37*	-0.54*	-0.30*	-0.47*	-0.42*
WW_{Y2}	-0.10	0.08	-0.42#	-0.05	-0.47*	0.08
CS_{Y1}	-0.24*	-0.23*	-0.03	-0.27*	-0.11	-0.34*
CS_{Y2}	-0.27*	-0.22*	-0.25	-0.15	-0.40#	-0.27*

[1] EEI= energetic efficiency index, BCS= body condition score, WW=weaning weight, CS= chute score, BF= backfat, KPH=kidney, pelvic, and heart fay, IFAT= internal fat
* Correlations differ from zero at P < 0.05
# Correlations differ from zero at P < 0.10

USE OF DRIED DISTILLERS GRAINS THROUGHOUT A BEEF PRODUCTION SYSTEM

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Summary

To evaluate the effects of feeding dried distillers grains throughout a beef production system, a 2-yr study was conducted using a 3 X 2 factorial arrangement of treatments. Factors were wheat pasture supplement (no supplement, dry-rolled corn, and dried distillers grains; CON, DRC, and DDG, respectively) and finishing diet (steam-flaked corn based diet containing 0 or 35% dried distillers grains, SFC and 35DDG, respectively). Each yr, Hereford steers (initial BW = 437 ± 6 lb) were stratified by BW and randomly assigned to one of fifteen wheat pastures. Supplements were fed at 0.5% BW daily, pro-rated and delivered 6 d/wk. Following the grazing period, pastures within supplement treatment were randomly assigned to SFC or 35DDG. Steers were fed once daily *ad libitum* and pens of steers were harvested when estimated fat thickness reached 0.5 in. Wheat pasture ADG was greater for DDG steers compared to CON and DRC steers ($P < 0.01$). With the exception of carcass-adjusted G:F, finishing performance and carcass traits were not affected by wheat pasture supplement ($P \geq 0.12$). Initial and final BW, DMI, and ADG were similar for SFC and 35DDG steers ($P \geq 0.20$). Steers receiving SFC had greater carcass-adjusted G:F ($P < 0.01$), dressing percent ($P = 0.01$), and twelfth rib fat thickness ($P < 0.01$) than 35DDG steers. The use of dried distillers grains as a supplement to wheat pasture results in greater ADG on wheat. However dried distillers grains included in steam-flaked corn based finishing diets appears to reduce G:F and dressing percent.

Introduction

Expansion of the ethanol industry in the Southern High Plains has resulted in an increase in the supply of distillers grains. Due to their availability and nutrient value, distillers grains are an attractive feedstuff for use in both stocker and finishing cattle operations. Supplemental dried distillers grains has increased gain in growing cattle grazing high-quality forages (MacDonald et al., 2006; Morris et al., 2006). Furthermore, gain was similar for cattle fed 0% or 30% dried distillers grains in dry-rolled corn- (Leupp et al., 2009) and steam-flaked corn-(Depenbusch et al., 2009) based finishing diets. Effects of feeding distillers grains on carcass characteristics are inconclusive and may vary according to inclusion level, source of distillers grains, and grain processing method, among others. Moreover, few studies have evaluated effects of long-term feeding of distillers grains on performance and carcass characteristics. In order to further characterize production responses and applications in the cattle industry, the objectives of this research were to determine: 1) performance responses to dried distillers grains when used as a supplement to winter wheat pasture; 2) effects of dried distillers grains on finishing performance and carcass characteristics when included at 35% DM in steam-flaked corn based finishing diets; and 3) effects of feeding dried distillers grains throughout a beef production system on performance and carcass characteristics.

Experimental Procedures

This study was conducted at the Texas AgriLife Research facilities in Bushland, Texas.

Stocker phase

In both years of a 2-year study, preconditioned Hereford steer calves (n = 120; BW = 437 lb) of known parentage were purchased from a single ranch. Steers were stratified by initial BW and randomly assigned to one of fifteen 5.5 acre dryland wheat pastures (4 hd/pasture). Treatments were randomly assigned within five blocks of three pastures and included no supplement, dry rolled corn and dried distiller's grains (CON, DRC, and DDG, respectively). Supplements were offered at 0.5% BW daily, pro-rated and delivered 6 d/wk. Steers in all pastures had *ad libitum* access to water and a monensin-containing mineral supplement throughout the duration of grazing.

Steers were weaned in late fall, preconditioned, and grazed on dormant native rangeland until arrival at the research facilities. Upon arrival, steers received a zeranol implant and were revaccinated against viral and Clostridial diseases. Individual weights were recorded and ultrasound estimates of external fat and intramuscular fat were collected. Wheat pasture grazing began on January 22 (year 1) and December 18 (year 2). Full BW was measured and supplement amounts were adjusted at 28-day intervals. In year 1, grazing was terminated when forage availability in a pasture was deemed inadequate by visual assessment, resulting in differing pull-off dates. In year 2, grazing was terminated on a single day. Across years, steers grazed an average of 128 days.

Forage samples were obtained at initiation and termination of grazing to characterize forage availability. Forage was clipped at ground level from six stratified locations across each pasture. Clipped forage was dried and weighed to calculate total forage dry matter.

Finishing phase

Following wheat grazing, pastures within supplement treatment were randomly assigned to a finishing treatment (steam-flaked corn based finishing diet containing 0 or 35% dried distillers grains; SFC and 35DDG, respectively). Upon arrival at the feedlot, steers were revaccinated against viral and Clostridial diseases, treated against internal and external parasites with an injectable anthelmintic, and implanted with a TBA/estradiol combination implant. Full BW was measured at 28-day intervals and dry matter intake was recorded to calculate ADG and feed efficiency.

Steers were fed once daily *ad libitum* at 0700 h and were on feed an average of 95 days. Pens of steers were harvested when estimated fat thickness reached 0.5 inch. Steers were harvested at a federally inspected commercial facility and carcass data was collected by an independent carcass data collection service following a 48-hour chill.

Statistical analysis

Data were analyzed using the mixed model procedures (PROC MIXED) of SAS (SAS Inst. Inc., Cary, NC) with pasture/pen serving as the experimental unit. Stocker phase data were analyzed with supplement, year, and the interaction included as fixed effects in the model. Finishing performance and carcass data were analyzed with supplement, finishing diet, year, and all interactions included as fixed effects in the model.

Results and Discussion

Stocker Phase

Stocker phase data are presented in Table 1. There was not a supplement by year interaction effect for any response variable tested ($P \geq 0.28$). There was a year effect detected for all response variables ($P < 0.0001$), however this data will not be presented. Across years, steers grazed wheat pasture an average of 127 days. Forage dry matter availability at initiation of grazing was similar across treatments ($P = 0.49$). At the conclusion of grazing, DRC pastures had more residual forage mass than CON pastures ($P = 0.03$) and DDG pastures were intermediate, suggesting DRC depressed forage intake while DDG had less influence on intake. Initial BW was similar among treatments ($P = 0.80$). Final BW differed among treatments ($P = 0.05$) in which DDG steers were heavier than CON and DRC steers. Steers supplemented with DDG gained faster ($P < 0.01$) than CON and DRC steers.

Finishing Phase

Effects of stocker supplement on finishing performance and carcass characteristics are presented in Table 2. There was no supplement by finishing diet interaction effect on finishing performance. Because DDG steers were heavier than CON and DRC at the conclusion of wheat grazing, they were heavier at feedlot entry ($P = 0.02$). There were no differences in final BW, DMI, or ADG among stocker treatments ($P \geq 0.20$), however stocker supplement affected efficiency ($P = 0.08$). Carcass characteristics were not affected by stocker supplement treatment ($P \geq 0.12$).

Effects of finishing diet on finishing performance and carcass characteristics are presented in Table 3. Feedlot entry BW, final BW, days on feed, DMI, and ADG were similar among SFC and 35DDG steers ($P \geq 0.16$); however steers consuming the SFC finishing diet were more efficient than steers consuming the 35DDG diet ($P = 0.009$). SFC steers had greater HCW ($P = 0.02$), dressing percent ($P = 0.01$), and 12th rib fat thickness ($P = 0.003$) than 35DDG steers. Ribeye area, marbling score, and USDA yield grade were not different ($P \geq 0.11$) among SFC and 35DDG.

Implications

Steers receiving dried distillers grains as a supplement to winter wheat pasture had greater ADG and heavier BW at feedlot entry than steers receiving dry rolled corn or no supplement. Residual forage mass data suggests dry rolled corn may have suppressed forage intake whereas dried distillers grains had less influence on forage intake while maintaining gain. Wheat pasture supplement had no effect on carcass characteristics. Dried distillers grains included at 35% of a steam-flaked corn based finishing diet reduced efficiency and dressing percent.

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Table 1. Effect of supplement on forage mass and performance during wheat pasture grazing

Item	CON[a]	DRC	DDG	SEM
Initial forage mass, lb DM/ac	2245	2454	2406	182
Final forage mass, lb DM/ac[b,c]	572	866	757	120
Initial BW, lb	439	437	434	6
Final BW, lb[d]	794	801	826	12
Gain, lb/d[e]	2.84	2.88	3.09	0.07

[a]Experimental treatment; CON = control; DRC = dry rolled corn offered at 0.5% BW/d; DDG = dried distillers grains offered at 0.5% BW/d.
[b]Initial forage mass used as covariate.
[c]Treatment effect, $P = 0.07$; pairwise CON < DRC, $P = 0.03$.
[d]Treatment effect, $P = 0.05$; pairwise CON < DDG, $P = 0.02$ and DRC < DDG, $P = 0.07$.
[e]Treatment effect, $P = 0.003$; pairwise DDG > CON and DDG > DRC, $P < 0.01$.

Table 2. Effect of supplement on finishing performance and carcass characteristics.

Item	CON[a]	DRC	DDG	SEM
Performance data				
Initial BW, lb[b]	828	838	864	12
Final BW, lb[c]	1152	1181	1166	16
DMI, lb/d	22.1	22.2	21.7	0.5
Gain, lb/d[d]	3.31	3.56	3.34	0.15
G:F[d,e]	0.150	0.161	0.154	0.004
Total system gain	679	708	693	16
Carcass characteristics				
HCW, lb	728	747	737	10
Dress, %	63.05	63.47	63.12	0.35
Ribeye area, in^2	12.9	12.9	13.1	0.3
12^{th} rib fat, in	0.45	0.50	0.47	0.02
Yield grade	2.65	2.85	2.65	0.11
Marbling score[f]	40.7	40.3	41.0	1.6

[a]Experimental treatment; CON = control; DRC = dry rolled corn offered at 0.5% BW/d; DDG = dried distillers grains offered at 0.5% BW/d.
[b]Treatment effect, $P = 0.02$; pairwise DDG > CON and DDG > DRC, $P \leq 0.04$.
[c]Carcass adjusted final BW calculated by dividing HCW by common dressing percent.
[d]Carcass adjusted.
[e]Treatment effect, $P = 0.08$; pairwise DRC > CON, $P = 0.02$.
[f]30 = Slight00; 40 = Small00; 50 = Modest00.

Table 3. Effect of finishing diet on finishing performance and carcass characteristics.

Item	SFC[a]	35DDG	SEM
Performance data			
Initial BW, lb	847	840	10
Final BW, lb[b]	1176	1157	13
DMI, lb/d	21.7	22.3	0.5
Gain, lb/d[c]	3.48	3.33	0.12
G:F[c,d]	0.160	0.149	0.003
Total system gain	703	684	16
Carcass characteristics			
HCW, lb[e]	748	726	8
Dress, %[e]	63.63	62.80	0.35
Ribeye area, in^2	13.1	12.8	0.2
12^{th} rib fat, in[e]	0.50	0.44	0.02
Yield grade	2.79	2.64	0.09
Marbling score[f]	41.7	39.6	1.3

[a]Experimental treatment; SFC = 0% dried distillers grains in finishing diet; 35DDG = 35% dried distillers grains in finishing diet.
[b]Carcass adjusted final BW calculated by dividing HCW by common dressing percent.
[c]Carcass adjusted.
[d]Treatment effect, $P = 0.009$.
[e]Treatment effect, $P \leq 0.02$
[f]30 = Slight00; 40 = Small00; 50 = Modest00.

RELATIONSHIPS BETWEEN RESIDUAL FEED INTAKE AND APPARENT NUTRIENT DIGESTIBILITY IN GROWING BEEF CALVES

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Summary

The objectives of this study were to examine the relationships between residual feed intake (RFI) and nutrient digestibility in growing Brangus heifers. The study consisted of Brangus heifers (n = 468; initial BW = 271.4 ± 26.1 kg) fed a high-roughage based diet (ME = 2.1 Mcal/kg DM) for 70-d in a Calan gate feeding barn. Individual DMI and BW were measured weekly for 70 d. Residual feed intake was calculated as the residual from the linear regression of DMI on ADG and mid-test $BW^{0.75}$ (metabolic BW; MBW). Within trial, the 18 to 20 highest and 18 to 20 lowest RFI heifers were selected for diet and nutrient digestibility. Heifers with low RFI consumed 18% less ($P < 0.001$) DMI compared to heifers with high RFI and had 6 – 8% higher DMD and nutrient digestibility. Mineral digestibility was 9 - 11% higher ($P < 0.01$) in heifers with low RFI vs. high RFI. Results from these studies suggest that inter-animal variation in apparent nutrient digestibility contributes to observed phenotypic differences in RFI in growing beef animals.

Introduction

Crews (2005) estimated that it costs $38.00 less to feed an efficient bull for 150 d compared to an inefficient bull assuming a feed cost of $0.101 per kg and a difference in DMI of 2.5 kg. That translates into a substantial economic advantage to try and improve feed efficiency. A potential way to increase efficiency is to use residual feed intake (**RFI**) as a tool in cattle selection. Herd et al. (2004) estimated that approximately 14% of the biological variation in RFI was associated with differences in digestion and its processes in growing animals of divergent RFI phenotypes fed a pelleted roughage-based diet. Recent studies with cattle fed high-grain diets suggested that inter-animal variation in RFI may be due to differences in digestibility (Channon et al., 2004; Richardson et al., 1996). However, few studies have examined the effects of RFI on nutrient digestibility in growing calves fed a high-roughage diet. The objectives of these studies were to quantify differences in nutrient digestibility in growing Brangus heifers with divergent phenotypes for RFI.

Experimental Procedures

Animals and Management

All experimental procedures were approved by the Animal Care and Use Committee for Livestock at Texas A&M University. Brangus heifers (n = 468) from Camp Cooley Ranch (Franklin, TX) were used; the study consisted of 4 trials conducted in 4 consecutive years. All tests were conducted at the O.D. Butler Jr. Animal Science Complex, College Station, TX. Heifers were 231.4 ± 11.5 d of age and weighed 271.4 ± 26.1 kg at the start of the studies. Calves were allotted by BW to Calan-gate pens (6 hd/pen), adapted to the experimental diets and trained to eat from Calan-gate feeders for 24 to 28 d. Heifers were fed twice daily, a high-roughage diet (Table 1), sufficient to allow ad libitum intake, and had free access to water. Body weight, feed intake, and orts were measured weekly for 70-d. Residual feed intake was calculated as the residual of linear regression of DMI on mid-test $BW^{0.75}$ and ADG [i.e. the difference between actual DMI and expected DMI to meet growth and maintenance energy requirements (Koch et al., 1963)].

Residual feed intake was computed using data collected from the first 56-d of the 70-d trials, and the 18 - 20 heifers with the lowest and highest RFI phenotypes identified for subsequent measurements. Final analysis of RFI using data collected during the entire 70-d period revealed that 5 heifers were no longer classified as having divergent RFI phenotypes, and were excluded from the dataset. The heifers with low (n = 55) and high (n = 56) RFI phenotypes had 70-d RFI that were ± 1.1 SD from the mean RFI of 0.0 ± 0.70 SD for the 468 heifers.

Estimates of Digestibility

During the fecal collection period, feed intake and orts were weighed daily, and feed ingredients and orts were collected daily. Fecal samples were collected between d 62 and 68 of the trial at 0700 and frozen. Feed ingredient, fecal, and ort samples were dried and ground to pass a 1 mm screen. Daily fecal and ort samples were composited by weight to generate separate fecal and ort samples for each calf. Individual feed ingredient samples were also composited by weight resulting in 1 sample for each feed ingredient used in the experimental diets. A weighted average of each feed ingredient was used to calculate diet internal marker concentrations. Acid

insoluble ash (**AIA**) was used as an internal marker to estimate digestibility coefficients.

Chemical Analysis and Calculations

Acid insoluble ash was determined according to Van Keulen and Young (1977). Neutral detergent fiber and ADF were determined using an ANKOM Fiber Analyzer F200 (ANKOM Technology Corporation, Fairport, NY.;(Ankom, 2006a, b). CP was determined using a LECO FP2000 (LECO Corporation, St. Joseph, MI). Mineral analysis was determined using ICP analysis of a nitric acid digest.

Statistics

Preliminary analysis of data from the individual trials revealed that results from trial 1 diverged from trials 2, 3, and 4, and was analyzed separately. For trial 1, least squares procedures using PROC MIXED of SAS (SAS Inst., Cary, NC) were used to examine the effects of RFI phenotype group on performance and feed efficiency traits and nutrient digestibilities. Trials 2, 3, and 4, included the random effect of trial to examine the effect of RFI phenotype group on nutrient digestibility data. Dry matter intake was tested as a covariate in the analyses of data; when insignificant, it was dropped from the model. Significance was declared at $P < 0.05$.

Results and Discussion

Descriptive statistics of the traits measured are presented in Table 2. During the 70-d trials, heifers (n = 468) averaged 1.01 kg/d (range 0.59 to 1.53 kg/d) for ADG, and 9.51 kg/d (range 6.94 to 12.68 kg/d) for DMI, and 0.107 kg gain/kg DMI (range 0.064 to 0.149 kg gain/kg DMI). Mean phenotypic RFI was 0.00 kg/d and ranged from 2.01 (most efficient) to 2.20 kg/d (least efficient). The least-squares means for performance and feed efficiency traits of heifers with divergent RFI phenotypes are presented separately for trial 1 (Table 3) and trials 2, 3, and 4 (Table 4). Heifers with low RFI consumed 18% less ($P < 0.001$) DMI than high RFI heifers and had 18% higher gain:feed ratio. However, orts as a proportion of DMI was different between trial 1 and trials 2, 3, and 4. During the 7-d fecal collection period, orts as a percent of DMI were 72% lower trial 1 than for trials 2, 3, and 4. Animal performance (initial BW and ADG) traits were similar amongst low and high RFI heifers.

There was no difference in diet DM or nutrient digestibilities between heifers with divergent RFI phenotypes in trial 1 (Table 3). However, RFI phenotype group did affect diet and nutrient digestibility estimates in trials 2, 3, and 4 (Table 4). Heifers with low RFI had 6% higher ($P < 0.001$) apparent DMD, 7% higher ($P < 0.001$) NDF digestibility, 8% higher ($P < 0.001$) ADF digestibility, and 8% higher ($P < 0.001$) apparent CP digestibility compared to high RFI heifers. Digestibility coefficients for heifers with low RFI were higher ($P < 0.005$) for P, Ca, and Cu compared to heifers with high RFI.

Channon et al. (2004) found differences in starch digestibility in divergent RFI steers fed a high energy feedlot diet. Angus and Angus-cross steers used were progeny of lines selected for RFI. Fecal pH and fecal DM was used as a proxy for lower gut starch fermentation because when starch is fermented in the hindgut, fecal pH (Degregorio et al., 1982) and fecal DM are likely to be decreased leading to diarrhea (Huber, 1976), giving a visual appraisal of ruminal starch fermentation. Steers with low RFI (from efficient parents) had higher fecal pH and DM content compared to high RFI steers (from inefficient parents) suggesting that progeny from low RFI parents fermented more starch in the rumen. This provides evidence of genetic differences in starch digestion. The authors note that a measure of fecal starch would have been useful to definitively relate the fecal parameters to actual starch digestion; however, fecal starch is closely associated with total tract starch digestibility ($R^2 = 0.95$; Zinn, 1994).

Richardson et al. (1996) found a difference in DMD in cattle fed a high-roughage pelleted ration (70 alfalfa hay:30 wheat mixture). A total of 575 head of cattle that included Angus, Hereford, and Shorthorn heifers and Angus bulls were tested for RFI. Of the tested animals, a smaller subset (n = 58) of calves was selected to determine DMD in metabolism crates. Low RFI animals had 1% unit higher ($P < 0.1$) DMD compared to high RFI animals which is lower than the 4 to 5% units difference in digestibility observed in the current study. This may have been due to lack of sample size in the former study where 58 head of 575 were selected for fecal collections, less divergence in RFI between low and high steers, or variable/incomplete recovery rates of internal markers for digestibility (n-alkanes in this case). The authors calculated that the 1% unit difference in DMD equates to a 2.3% reduction in DMI in 450 kg cattle gaining 1.3 kg/d. In the current study, an approximate 4.5% unit difference in DMD in medium frame heifers gaining 1 kg/d equates to a 5.7% reduction in DMI for low RFI heifers (NRC, 1996), which is slightly higher than Richardson et al. (1996) due to the wider spread in digestibility between heifers with low and high RFI phenotype. Richardson et al. (1996) estimated that DMD may account for up to 14% of the observed difference in feed intake between divergent RFI groups. Richardson et al. (2000) reported a tendency ($P < 0.09$) for 3% increase in DMD in steers with low RFI compared to steers with high RFI fed a high-energy feedlot ration.

Nkrumah et al. (2006) reported a tendency ($P = 0.1$) for low RFI Continental x British crossbred steers fed a high energy feedlot ration to have 6% higher DMD compared to high RFI steers. The authors also reported a tendency ($P = 0.09$) for low RFI steers to have 7% higher apparent CP digestibility. There were no differences in NDF and ADF digestibility. This is in congruence with the current study with higher DMD and apparent CP digestibilities in

low RFI heifers; however, the current study showed differences in NDF and ADF digestibilities, as well. This is likely due to the fact that the high energy diet that was fed in Nkrumah et al. (2006) had very low concentrations of NDF (20%$_{DM}$) and ADF (8%$_{DM}$) and resulted in a very high standard error negating any significance; numerically, the low RFI steers had higher NDF and ADF digestibilities.

This is similar to the difference observed in trials 2, 3, and 4; a negative relationship was observed such that as RFI increased, diet and nutrient digestibility decreased. The lack of a relationship in trial 1 may be due to the fact that during the first trial, orts as a percent of DMI were 72% lower than trials 2, 3, and4 (3.8 vs. 13.4 orts, %DMI); however, heifers with low RFI still consumed 18% less DMI compared to heifers with high RFI. Animals with high RFI had lower diet refusals expressed as a proportion of DMI compared to animals with low RFI possibly indicating that DMI of animals with high RFI were restricted to a greater extent than that of animals with low RFI.

It is generally recognized in ruminants that as DMI increases, DMD decreases (NRC, 2001) primarily due to a reduction in the amount of time digesta spends in the rumen (Staples et al., 1984). However, this does not appear to be the case in the current study. Dry matter intake and DMI X RFI group were evaluated as covariates and were found to be non-significant. In fact, the estimates for the covariates DMI and DMI X RFI group were not different ($P > 0.20$) than zero implying that, in this case, level of intake does not seem to affect DMD resulting in calves with low RFI having higher DMD compared to high calves with high RFI. However, a negative correlation between DMI and DMD was observed. Heifers with low RFI were consuming the high-roughage diet at 1.7X estimated net energy requirement for maintenance (**M**) while heifers with high RFI were consuming it at 2.1X M. This is not a wide spread in intake so it is reasonable that DMI would not affect DMD. Nkrumah et al. (2006) reported that DMI was a significant covariate when evaluating DMD; however, it did not eliminate the relationship between RFI and DMD indicating that part of the variation in steers with divergent RFI in DMD might be independent of level of intake. The authors offer that the increased DMI in steers of high RFI might be partly related to the decreased metabolizability of consumed feed (decreased DMD), and the associated increased need to attain the levels of energy intake required for maintaining BW and growth.

Robertson and Van Soest (1975) reported a decrease of 5% units in DMD when the feeding level of a mixed diet was increased from maintenance to 2X maintenance in sheep. Tyrell and Moe (1975), using dairy cattle fed a total mixed ration, found that for each multiple of maintenance increase there was a 4% unit decrease in diet digestibility. However, Colucci et al. (1982) found that there was a greater degree of depression in digestibility with increased DMI when there was less forage in the diet. This is due to the fact that cell solubles and N digestibility account for the majority of the depression in digestibility with increased DMI so high fiber diets would be less affected by the depression in DMD when feeding level increases, similar to the high forage diet in the current study.

This research is the first to demonstrate a difference in mineral digestibility in divergent RFI heifers. Heifers with low RFI were able to digest more of the measured minerals compared to high RFI heifers. This is especially profound when considering environmentally important minerals such as phosphorus. Not only are less minerals being excreted in the feces, there are potentially less environmental effects of the feces through things such as direct run-off and plant phytotoxicity if the manure is used as fertilizer.

Implications

It has been shown that selection for RFI can decrease feed inputs and increase DMD, with little effect on animal performance; however, inconsistent results have been published concerning DMD. Even though the variation in RFI that is explained by DMD is small (≈ 11%), it still has a huge impact on feed inputs. Progeny of a single selection for low RFI parents required 5% less feed with no detrimental effects on growth translating into increased efficiency and economic profit to the cattle producer (Johnson et al., 2006). More research is needed to further elucidate the relationship between RFI and diet and nutrient digestibility in growing Brangus heifers.

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Table 1. Ingredient and chemical composition of the experimental diet

Item	Study 2 Value, %
Feed Ingredient[1]	
Chopped alfalfa	35.00
Pelleted alfalfa	15.00
Dry rolled corn	20.95
Cottonseed hulls	21.50
Molasses	7.00
Salt	0.40
Vitamin E[2]	0.14
Trace mineral[3]	0.02
Chemical composition[4]	
DM, %	87.9
ME[5], Mcal/kg$_{DM}$	1.98
CP, %$_{DM}$	12.7
NDF, %$_{DM}$	45.6
ADF, %$_{DM}$	32.3
P, %$_{DM}$	0.25
Ca, %$_{DM}$	0.86

[1]Expressed on an as-fed basis.
[2]Vitamin E contained 44,000 IU/kg product.
[3]Trace mineral contained minimum 19.0% Zn, 7.0% Mn, 4.5% Cu, 4,000 ppm Fe, 2,300 ppm I, 1,000 ppm **Se,** and 500 ppm Co.
[4]Study 2 represents the average of four yr.
[5]Metabolizable energy content computed using Cornell Net Carbohydrate and Protein System.

Table 2. Descriptive statistics (mean ± SD) for traits measured during **70-d** experimental periods for heifers (4 trials)

Item[1]	n = 468
Initial BW, kg	271.4 ± 26.1
ADG, kg/d	1.01 ± 0.15
DMI, kg/d	9.51 ± 1.02
Gain:feed	0.107 ± 0.015
RFI, kg/d	0.00 ± 0.71

[1]RFI = residual feed intake.

Table 3. Performance, efficiency, and apparent nutrient digestibility estimates for heifers with low and high RFI phenotype in trial 1

Item[1]	Low RFI n = 20	High RFI n = 19	SE	*P* - value
Animal performance and efficiency				
Initial BW, kg	297.2	289.3	6.68	0.422
ADG, kg/d	0.90	0.94	0.04	0.517
DMI, kg/d	8.34	10.19	0.30	< 0.001
RFI, kg/d	-0.96	1.17	0.09	< 0.001
Feed intake during fecal collection period				
DMI, kg/d	8.35	10.21	0.30	< 0.001
Orts, % DMI	4.10	3.48	0.66	0.513
Apparent nutrient digestibility, g/kg DM				
DM	683.3	696.5	17.3	0.593
CP	677.8	695.6	17.6	0.479
NDF	599.0	620.0	20.4	0.474
ADF	584.2	609.9	20.0	0.375
Phosphorus	496.5	546.4	26.0	0.185
Calcium	536.6	572.2	23.0	0.276
Zinc	424.5	470.9	30.0	0.279
Copper	549.7	583.3	23.0	0.312

[1]Orts, % DMI = [(orts / DMI)*100], RFI = residual feed intake, DM = apparent dry matter digestibility, CP = apparent crude protein digestibility, NDF = NDF digestibility,
ADF = ADF digestibility.

Table 4. Performance, efficiency, and apparent nutrient digestibility estimates for heifers with low and high RFI phenotype in trials 2, 3, and 4

Item[1]	Low RFI n = 55	High RFI n = 56	SE	*P* - value
Animal performance and efficiency				
Initial BW, kg	267.3	264.4	3.87	0.537
ADG, kg/d	1.05	1.08	0.04	0.334
DMI, kg/d	8.76	10.69	0.21	< 0.001
RFI, kg/d	-0.94	0.96	0.05	< 0.001
Feed intake during fecal collection period				
DMI, kg/d	8.79	10.81	0.20	< 0.001
Orts, % DMI	15.6	11.2	1.31	< 0.001
Apparent nutrient Digestibility, g/kg DM				
DM	790.4	745.1	38.2	< 0.001
CP	744.4	690.0	52.4	< 0.001
NDF	744.7	694.7	46.2	< 0.001
ADF	707.0	653.0	49.1	< 0.001
Phosphorus	661.1	592.9	105.4	< 0.001
Calcium	573.3	514.5	58.4	0.005
Zinc	570.4	530.4	79.9	0.285
Copper	642.2	585.4	76.8	0.002

[1] Ort, % DMI = [(orts / DMI)*100], RFI = residual feed intake, DM = apparent dry matter digestibility, CP = apparent crude protein digestibility, NDF = NDF digestibility, ADF = ADF digestibility.

EFFECTS OF SODIUM BISULFATE ON IN SITU DIGESTIBILITY AND RUMINAL CHARACTERISTICS OF STEERS FED A RECEIVING DIET

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Summary

Two ruminally fistulated steers were used in a switchback design to determine effects of mixing sodium bisulfate into the drinking water of steers on intake and digestion characteristics. Steers were fed a common high forage receiving diet and consumed water that was either untreated or treated with sodium bisulfate to reduce the pH to approximately 3.7. Sodium bisulfate reduced DMI and the rate of alfalfa NDF digestion ($P < 0.01$), but did not significantly impact rumen pH ($P = 0.52$). No other significant differences due to sodium bisulfate treatment were detected ($P > 0.27$), although this study had limited statistical power. Strategies to circumvent negative impacts on DMI and rate of fiber digestion may need to be considered before adding sodium bisulfate to drinking water of ruminants to reduce microbial load and improve animal health.

Introduction

Sodium bisulfate is used in the poultry industry as a water acidifier to reduce microbial load in drinking water and improve animal health. A similar application in newly received beef cattle may be beneficial to beef producers. However, sodium bisulfate in ruminant diets may affect rumen digestibility. If consuming acidified water were to greatly reduce ruminal pH, fiber digestibility may be negatively affected. However, a slight reduction in ruminal pH may minimally affect fiber digestibility but may improve the efficiency of nitrogen utilization because ammonium cannot escape through the rumen wall. Therefore, it is necessary to determine the potential impact of sodium bisulfate on rumen function before developing a market for newly received calves.

Experimental Procedures

Two ruminally fistulated steers were used in a switchback design to determine effects of mixing sodium bisulfate into the drinking water of steers on intake and digestion characteristics. Steers consumed one diet which consisted of 50% alfalfa hay, 42.5% steam-flaked corn, 5% crude glycerin, and 2.5% pelleted supplement. The receiving diet used in this study was 12.4% CP, 0.79% Ca, and 0.23% P. Sodium bisulfate was mixed into the drinking water of one steer at a rate of 630 mg/L resulting in an average water pH of 3.72 (SD = 0.11). There were two periods so that each steer consumed both acidified and non-acidified water. Periods were 21-d in length with 14-d for adaptation and 7-d for collections. During the collection periods, water intake was measured twice daily in a 20 L carboy with 1 L graduated markings. Water consumption was read to the nearest 0.5 L and the carboy was refilled at each reading. Steers were fed once daily at approximately 0700 h at an ad libitum level that resulted in approximately 0.25 kg feed remaining in the bunk at the time of the next feeding. The first three days of collections consisted of collecting rumen fluid every 6-h daily with collections advancing 2-h each d so that the rumen was sampled every 2-h over a 24-h period. At each collection time point, rumen fluid was strained through four layers of cheese cloth, ruminal pH was recorded, and an aliquot was frozen for analysis of ruminal ammonia. The final four d of collections consisted of in-situ incubation of corn and alfalfa hay. Incubation time points were 96, 48, 24, 16, 12, 8, 4, 2, and 0 h. The alfalfa hay and dry rolled corn were ground though 2-mm and 6-mm screens, respectively in Wiley mills. The 6-mm screen was selected based on data suggesting it simulates mastication of corn. The alfalfa hay and alfalfa hay residue from incubated samples were analyzed for neutral detergent fiber and the corn and corn residue were analyzed for starch. Rate and extent of ruminal digestion of neutral detergent fiber and starch were calculated for the alfalfa hay and corn, respectively. Data were analyzed using the Mixed Procedures of SAS with sodium bisulfate treatment included in the model. For variables measured over time (ruminal pH and ammonia), regression was used to determine the highest order of significance for time, and to test for time by treatment interactions.

Results and Discussion

Intake and digestion characteristics are shown in Table 1. Sodium bisulfate had no statistical effect on water intake ($P = 0.33$). However, water intake was numerically reduced nearly 10%. Given the limitations in statistical power in this study, it is unclear if the addition of sodium bisulfate results in a biologically meaningful reduction in water intake. Dry matter intake (DMI) was significantly reduced ($P < 0.01$) by 16.8%. Sodium bisulfate had no effect on 96-h extent of digestion of either the alfalfa DM and NDF, or the corn DM and starch ($P > 0.44$).

While sodium bisulfate had no significant effect on the rate of alfalfa DM digestion ($P = 0.65$), it did significantly reduce the rate of NDF digestion ($P < 0.01$). This 31% reduction in the rate of alfalfa NDF results in a reduction in the calculated effective fiber digestion from 34.8% to 29.6% assuming a passage rate of 5%/h. However, it is important to note that the reduction in rate of fiber digestion likely reduced the rate of passage when steers consumed sodium bisulfate. Therefore, using a constant

rate of passage may not be appropriate and actual differences in effective digestibility of NDF may be less than we have calculated. In fact, it is likely that the reduction in fiber digestion and reduced DMI due to sodium bisulfate addition to drinking water are related through passage rate. It is possible that slowing the rate of digestion of fiber may have increased the ruminal retention time such that DMI was decreased due to gut fill. Additionally, the reduction in DMI may be the result of reduced water intake.

Sodium bisulfate numerically reduced the rate of corn DM digestion and corn starch digestion. While the differences in corn DM and starch digestion rates are not statistically significant (P = 0.28 and 0.27 for corn DM and starch, respectively), we are not willing to conclude no difference in the digestion rates of these parameters given the magnitude of difference due to treatment (approximately 25% reduction in digestion rates due to sodium bisulfate) and the limited replication in the study.

There was no difference in mean ruminal pH (P = 0.52; Table 1) and no difference in ruminal pH due to treatment across time (P = 0.55; Figure 1). One primary objective of the study was to determine effects of sodium bisulfate on ruminal pH because we hypothesized that acidifying drinking water may reduce ruminal pH. This clearly did not occur. One explanation is that volatile fatty acid (VFA) production may have been reduced when steers consumed sodium bisulfate due to reduced DMI and rate of fiber digestion. Steers may have also compensated for the acidified water by increasing chewing time to increase buffering from saliva flow. Neither VFA production nor salivary flow was measured as a part of this study.

We further hypothesized that a slight reduction in ruminal pH may trap more nitrogen as ammonium (NH_4) which is not permeable to the rumen wall thereby increasing the efficiency of nitrogen utilization in the rumen. Given that we observed no difference in rumen pH, it is not surprising that we saw no differences in average rumen ammonia concentrations (P = 0.32; Table 1) and no difference in rumen ammonia concentrations due to treatment across time (P = 0.42; Figure 2). The spike in rumen ammonia concentration at 2 h post-feeding and subsequent decline past 6 h post-feeding is characteristic in the diets of ruminant animals. The increase in rumen ammonia concentration after 6 h post-feeding may be due to release of secondary pools of nitrogen from digestion or recycling of nitrogen into the rumen. Regardless, we conclude that sodium bisulfate had no effect on rumen ammonia concentration in this study.

Implications

The addition of sodium bisulfate in the drinking water of steers may reduce DMI and the rate of ruminal fiber digestion. Further research may elucidate strategies to overcome this negative effect of acidifying water so that potential benefits on animal health may be realized.

Acknowledgements

The authors acknowledge Jones Hamilton Company for financial support of this project.

Table 1. Effect of sodium bisulfate on intake and digestion characteristics of steers.

Item	Control	Sodium Bisulfate	SEM	P-Value
DMI, lb	19.6	16.3	1.3	<0.01
Water intake, L/d	25.7	23.2	2.2	0.33
Alfalfa DM digestion				
Rate, %/h	13.3	11.4	2.5	0.65
Extent, % at 96 h	70.3	70.4	0.9	0.94
Alfalfa NDF digestion				
Rate, %/h	10.9	7.49	0.21	<0.01
Extent, % at 96 h	50.8	49.4	1.5	0.60
Corn DM digestion				
Rate, %/h	4.99	3.72	0.62	0.28
Extent, % at 96 h	93.6	90.1	2.7	0.46
Corn starch digestion				
Rate, %/h	5.31	4.02	0.60	0.27
Extent, % at 96 h	98.9	95.8	2.3	0.44
Mean rumen ammonia-N, mg/dL	5.66	6.60	1.17	0.32
Mean rumen pH	6.23	6.18	0.07	0.52

Figure 1. Effect of sodium bisulfate on ruminal pH of steers.

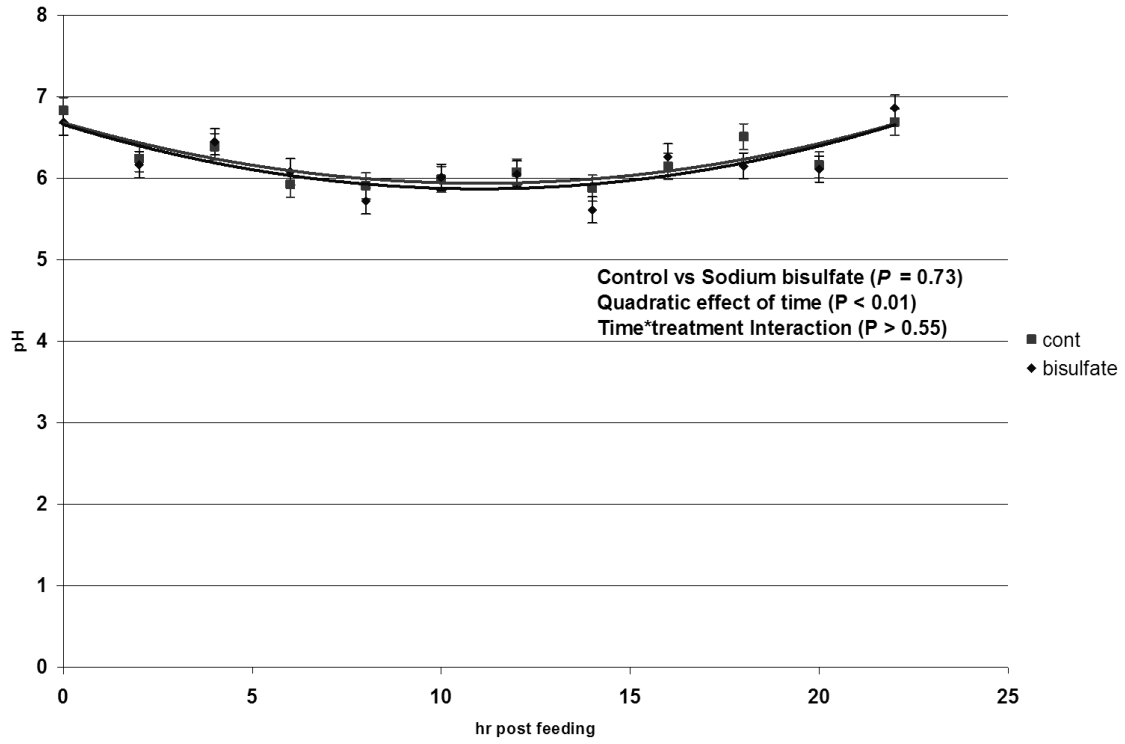
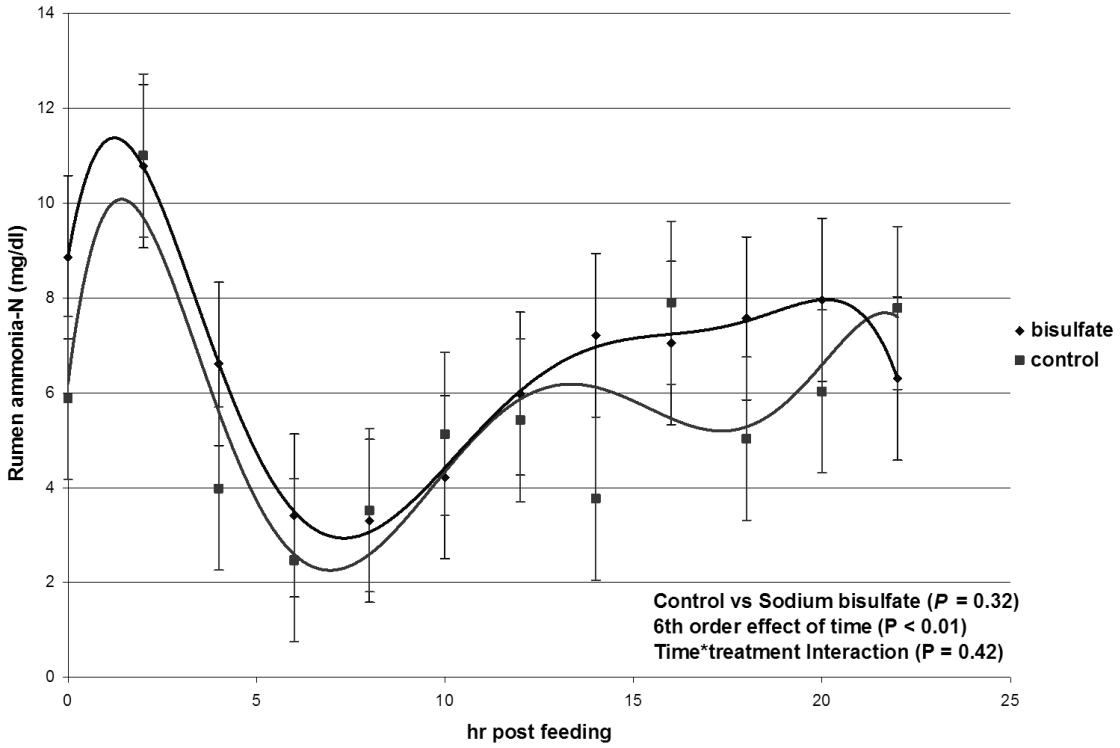


Figure 2. Effect of sodium bisulfate on rumen ammonia-N concentration of steers.



EFFECTS OF AMAFERM ON THE PERFORMANCE OF STEERS CONSUMING STEAM-FLAKED CORN-BASED FINISHING DIETS CONTAINING 35% WET DISTILLER'S GRAINS

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Summary

One hundred eighty crossbred steers (559 ± 1 lb) were blocked by weight and randomly assigned to one of two treatments to determine the effects of Amaferm on the performance of steers consuming a steam-flaked corn-based finishing diet containing 35% corn wet distiller's grains plus solubles. Steers consuming diets containing Amaferm consumed less DM (P = 0.03) and tended to have a corresponding reduction in ADG (P = 0.14) and no difference in feed efficiency (P = 0.96). Accordingly, the carcasses resulting from steers consuming diets containing Amaferm had reduced fat thickness (P = 0.03) and a tendency for reduced percent kidney, pelvic, heart fat (P = 0.14), which is consistent with reduced energy intake. No other differences were detected. Amaferm does not appear to improve the performance of steers consuming a steam-flaked corn-based finishing diet containing 35% corn wet distiller's grains plus solubles.

Introduction

Incorporation of wet distiller's grains plus solubles (WDGS) into finishing diets in the Southern Plains has yielded less desirable animal performance relative to incorporation of WDGS into finishing diets in the Northern Plains. This may be partially related to the relative energy densities of the corn processing methods (dry-rolling and steam-flaking) commonly utilized on those regions. However, the energy values of the WDGS fed in those regions also appear to differ. When WDGS produced in the Northern Plains was transported to the Texas Panhandle and fed in dry-rolled and steam-flaked diets, animal performance was maintained or improved (MacDonald et al., 2008; MacDonald et al., 2009a). Conversely, when WDGS produced in the Southern Plains was incorporated into similar diets, animal performance was reduced (MacDonald et al., 2009b). Lewis et al., (2009) demonstrated that WDGS produced in the Northern Plains had lower NDF content and higher digestibility compared to WDGS produced in the Southern Plains.

Amaferm (Biozyme Inc., St. Joseph, MO) is a direct fed microbial known to improve animal performance in high forage diets (Dhuyvetter et al., 1996). The modes of action of Amaferm include increasing rumen fungal mass (Welch et al., 1996), increasing ruminal cellulosic bacteria concentration (Wiedmeier et al., 1987), and increasing lactate utilizing bacteria concentrations (Beharka and Nagaraja, 1998). These mechanisms may improve performance of steer consuming steam-flaked corn-based finishing diets containing WDGS with high fiber content. Therefore, objective of the current study was to determine the effects of Amaferm on the performance of steers consuming steam-flaked corn based diets with 35% distiller's grains.

Experimental Procedures

One hundred eighty crossbred steers (559 ± 1 lb) were blocked by weight and randomly assigned to one of two treatments to determine the effects of Amaferm on the performance of steers consuming a steam-flaked corn-based finishing diet containing 35% corn wet distiller's grains plus solubles. Two experimental treatments included the presence or absence of Amaferm in the finishing diets. Upon arrival to the feedlot, steers were limit-fed (1.8% BW) a common diet consisting of 47.5% steam-flaked corn (SFC), 45% alfalfa hay, 5% molasses, and 2.5% supplement for five consecutive days. During the final three days of the limit-fed period, steers were individually identified with a unique ear tag, weighed, vaccinated against viral pathogens (Vista 5, Intervet Inc., Millsboro, DE) and clostridial bacterin-toxoid (Vision 7, Intervet, Inc.), treated for parasites with Ivomec (Merial Ltd., Deluth, GA), implanted with Revalor-XS, Intervet, Inc.), blocked by weight, stratified by weight within blocks, and randomly assigned to one of 18 pens**.** Steers receiving the Amaferm treatment received 30 ml of a liquid drench containing Amaferm (Vita Charge Appetite Plus, AgriLabs, St. Joseph, MO).

There were 18 pens and two experimental treatments (n=9). Treatments were: Amarferm included at a rate of 2 ml · head^{-1} · day^{-1}(Amaferm), and a control without Amaferm (Control). Liquid Amaferm was mixed with 4L water and distributed over the ration in a water pot as the ration mixed. The control diet was fed first, followed by the Amaferm diet. The mixer was hand cleaned daily to ensure no cross contamination.

Once the study was initiated, steers were stepped up to their finishing diet over a 21 day period in three steps containing 35, 25, and 15% alfalfa hay. Steers were weighed weekly (once per step) via pen scale until they were consuming the finishing rations. After they were stepped up and consuming the finishing rations, they were weighed via pen scale every 28 days and the day they were shipped to the abattoir.

The final diet consisted of 52% SFC, 35% wet distiller's grains, 10% alfalfa hay, 1.45% limestone, 0.50% urea, and 1.05% premix (Table 1). Monensin and tylosin were excluded from the diets. Due to limitations in feed storage, the wet distiller's grains and alfalfa hay was be mixed and bagged together in a 3.5:1.0 ratio (DM-basis) and this mixture was included at 45% of the diet DM. Steers were fed once daily (approximately 0700h) in quantities sufficient to achieve ad libitum consumption as quantified by approximately 0.10 lb residual feed DM per head remaining in bunks approximately 30 minutes prior to feeding. Ingredient samples were taken three times weekly for WDGS and SFC and weekly for all other ingredients for DM analysis. Ingredient DM was updated weekly for ration formulation. A composite of the DM samples was created for all ingredients and sent to a commercial laboratory (Servi-Tech Laboratories, Amarillo, TX) for nutrient analysis.

Steers were harvested at a commercial abattoir and carcass data collected by the West Texas A&M University Cattlemen's Carcass Data Service when he average 12th rib fat thickness for the block reached approximately 0.50 in. Data were analyzed as a randomized complete block using Mixed procedures of SAS with block considered to be a random variable. The model included the treatment of Amaferm.

Results and Discussion

Steers were on feed an average of 192 days. Interim animal performance is provided in Table 2. After the 21-d step-up period, steers consuming Amaferm had a 9% reduction in ADG (3.65 vs. 3.33 lb for Control and Amaferm, respectively; $P = 0.05$) and a 6% reduction in feed efficiency (G:F = 0.212 vs. 0.200 for Control and Amaferm, respectively; $P = 0.05$) resulting in a slight 7 lb reduction in BW (635 vs. 628 lb for Control and Amaferm, respectively; $P = 0.04$). We expected Amaferm to improve animal performance during the step up period because Amaferm is known to improve performance in high forage diets, especially when alfalfa hay is used as the forage source. Dhuyvetter et al. (1996) observed a marked 31% increase in ADG in heifers consuming Amaferm during the first 28-d of an 84-d growing study utilizing greater than 60% forage. The overall improvement in ADG due to the inclusion of Amaferm was 5% at the end of the 84-d study by Dhuyvetter et al. (1996), indicating the response from Amaferm occurred early in the feeding period. Conversely, the current study observed a slight reduction in animal performance in steers consuming Amaferm during the 21-d step-up program. However, this observation was not consistent throughout the step-up period, or the remainder of the study. Therefore, while we cannot conclude that Amaferm reduces animal performance during the step-up period, performance was clearly not improved. The step-up period in a finishing program is characterized by large rapid changes in the microbial populations as predominant substrates shift from cellulose to starch. We hypothesized that Amaferm would be beneficial in step-up programs utilizing high levels of WDGS because the relative proportion of cellulose is increased throughout the step-up program compared to a step-up program utilized in a traditional steam-flaked corn-based finishing ration. It is possible that even with 35% WDGS in the finishing diet, the change in substrate was substantial enough that the microbial populations which benefit from the addition of Amaferm were not able to persist in the rumen environment as the diet changed.

Final live and carcass-adjusted animal performance is presented in Table 3, and carcass characteristics are presented in Table 4. Amaferm reduced dry matter intake (DMI) by 0.60 lb/d (19.3 vs. 18.7 lb/d for Control and Amaferm, respectively; $P = 0.03$; Table 3), a trend that was detected after 105 days on feed (18.7 vs. 18.3 lb/d for Control and Amaferm, respectively; $P = 0.08$; Table 2), but that was numerically visible throughout the study (Table 2). The reduction in DMI occurred without a corresponding improvement in G:F when calculated on either a live-animal basis (G:F = 0.175 vs. 0.175 for Control and Amaferm, respectively; $P = 0.96$; Table 3), or carcass-adjusted basis (G:F = 0.173 vs. 0.175 for Control and Amaferm, respectively; $P = 0.53$). There was a tendency for a corresponding 3% reduction in ADG when animal performance was reported on a live basis (3.36 vs. 3.26 lb/d for Control and Amaferm, respectively; $P = 0.14$, Table 3). The response to ADG was numerically evident, but did not approach statistical significance when expressed on a carcass-adjusted basis (3.35 vs. 3.27 lb/d for Control and Amaferm, respectively; $P = 0.26$, Table 3). This suggests the BW differences due to Amaferm inclusion were reduced when evaluating HCW. There was no difference in dressing percentage (63.3% vs. 63.6% for Control and Amaferm, respectively; $P = 0.43$, Table 4). It is interesting that dressing percentage was maintained in steers consuming Amaferm given the response to DMI resulted in reduced 12th rib fat thickness in steers consuming Amaferm (0.454 vs. 0.397 in. for Control and Amaferm, respectively; $P = 0.03$; Table 4). The reduction in relative adiposity in steers consuming Amaferm is further supported by a tendency for a reduction in % kidney, pelvic, heart fat (1.93% vs. 1.83% for Control and Amaferm, respectively; $P = 0.12$, Table 4) and a non-significant numeric reduction in yield grade (YG = 2.73 vs. 2.59 for Control and Amaferm, respectively; $P = 0.28$; Table 4). This raises the question if Amaferm would improve dressing percentage had steers been marketed at a similar finish. Nevertheless, the increased days on feed required to achieve a similar degree of finish likely would not be attractive to producers given the lack of improvement in feed efficiency.

It is important to note that any reduction in adiposity, BW, or ADG is likely due to the reduction in DMI rather than being directly attributed to Amaferm per se. The

reduction in DMI resulted in reduced caloric intake by the steers which caused them to be leaner and/or lighter at the same days on feed. The reason for the reduction in DMI is not readily apparent and is beyond the scope of this study. However, it is possible that the liquid form of Amaferm contains some characteristic (such as scent) that negatively impacts palatability. A less likely possibility is that Amaferm interacted with the excess CP in the diet to affect the melanocortin system and induce satiety.

Irrespective of effects on DMI, we did not observe an improvement in feed efficiency as we had hypothesized. This may suggest Amaferm was not successful in increasing the digestibility of WDGS. Several reasons for the lack of response are possible. As discussed with the response during the step-up phase it is possible that the cellulolytic microbial populations that benefit from Amaferm were not able to persist. This may be influence by the level of fat in diets containing high levels of WDGS since fat is known to negatively affect cellulolytic bacteria. Additionally, acidosis may be adequately controlled in high WDGS diets so that there is not sufficient lactate present for lactate utilizing bacteria to persist. Finally, the fibrous fraction of WDGS may be sufficiently high in digestibility and may have a small particle size so that the fungal population may not have opportunity to significantly affect the digestibility.

Implications

Amaferm did not improve the performance of steers consuming steam-flaked corn-based diet with 35% WDGS. Further investigation into the potential for Amaferm to improve performance in finishing diets is recommended. Possible strategies may be to evaluate effects in traditional steam-flaked corn-based diets, in diets containing different levels of WDGS, or in diets containing other fibrous byproducts and no fat. However, the fat issue may be problematic in the Southern Plains since supplemental fat is commonly added to finishing diets.

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Table 1. Composition of base diet fed to steers receiving Amaferm or no additive.

Item	Control	Amaferm[1]
Steam-flaked corn	52.0	52.0
Wet corn distiller's grains[2]	35.0	35.0
Alfalfa hay[2]	10.0	10.0
Supplement[3]	3.0	3.0
Nutrient composition, %		
CP	19.5	19.5
NDF	23.6	23.6
ADF	14.0	14.0
Fat	6.19	6.19
Ca	0.766	0.766
P	0.424	0.424
Mg	0.193	0.193
K	0.746	0.746
S	0.302	0.302

[1]Amaferm was added to the diet by mixing the required amount (2 ml · head^{-1} · day^{-1}) in 4 L water, adding the solution to the mixer via a sprinkling can and mixing for approximately 3 min prior to delivery to the pens.
[2]Wet corn distiller's grains and alfalfa hay were mixed at a 3.5:1 ratio and bagged for storage.
[3]Supplement was formulated to provide a dietary inclusion of 1.45% limestone, 0.50% urea, 0.30% salt, 60 ppm Fe, 40 ppm Zn, 30 ppm Mg, 25 ppm Mn, 10 ppm Cu, 1 ppm I, 0.15 ppm Co, 0.10 ppm Se, 1.5 IU/g vitamin A, 0.15 IU/g vitamin D, 8.81 IU/kg vitamin E. Monensin and tylosin were excluded from the supplement.

Table 2. Effects of Amaferm on interim performance of steers consuming steam-flaked corn-based finishing diets containing 35% wet distiller's grains.

Item	Control	Amaferm[1]	SE	P-value
Initial BW, lb	559	559	1	0.79
d 0-7 performance[2]				
BW, lb	586	583	3	0.35
DMI, lb	14.5	14.4	0.18	0.42
ADG, lb	3.87	3.49	0.39	0.35
Gain:feed	0.263	0.244	0.026	0.49
d 0-14 performance[2]				
BW, lb	608	607	3	0.65
DMI, lb	15.9	15.8	0.31	0.63
ADG, lb	3.50	3.43	0.19	0.73
Gain:feed	0.219	0.218	0.012	0.94
d 0-21 performance[2]				
BW, lb	635	628	3	0.04
DMI, lb	17.1	16.6	0.34	0.20
ADG, lb	3.65	3.33	0.15	0.05
Gain:feed	0.212	0.200	0.006	0.05
d 0-49 performance[2]				
BW, lb	749	747	4	0.63
DMI, lb	18.1	17.8	0.25	0.26
ADG, lb	3.88	3.85	0.08	0.64
Gain:feed	0.214	0.217	0.003	0.52
d 0-77 performance[2]				
BW, lb	841	836	5	0.41
DMI, lb	18.5	18.2	0.25	0.22
ADG, lb	3.67	3.61	0.07	0.40
Gain:feed	0.198	0.198	0.003	0.92
d 0-105 performance[2]				
BW, lb	943	931	9	0.12
DMI, lb	18.7	18.3	0.22	0.08
ADG, lb	3.67	3.56	0.07	0.13
Gain:feed	0.197	0.195	0.003	0.73
d 0-133 performance[2]				
BW, lb	1028	1019	9	0.31
DMI, lb	18.8	18.4	0.24	0.09
ADG, lb	3.53	3.46	0.06	0.31
Gain:feed	0.188	0.189	0.003	0.73
d 0-161 performance[2]				
BW, lb	1104	1088	11	0.19
DMI, lb	19.1	18.6	0.24	0.06
ADG, lb	3.39	3.29	0.07	0.18
Gain:feed	0.178	0.177	0.002	0.91

[1]Amaferm was added to the diet by mixing the required amount (2 ml · head^{-1} · day^{-1}) in 4 L water, adding the solution to the mixer via a sprinkling can and mixing for approximately 3 min prior to delivery to the pens.
[2] Pen BW measured live and shrunk 4%.

Table 3. Effects of Amaferm on final performance of steers consuming steam-flaked corn-based finishing diets containing 35% wet distiller's grains.

Item	Control	Amaferm[1]	SE	P-value
Dry matter intake, lb	19.3	18.7	0.23	0.03
Live-animal performance[2]				
BW, lb	1207	1189	12	0.15
ADG, lb	3.36	3.26	0.06	0.14
Gain:feed	0.175	0.175	0.002	0.96
Carcass-adjusted performance[3]				
BW, lb	1202	1188	13	0.27
ADG, lb	3.35	3.27	0.07	0.26
Gain:feed	0.173	0.175	0.002	0.53

[1]Amaferm was added to the diet by mixing the required amount (2 ml · head^{-1} · day^{-1}) in 4 L water, adding the solution to the mixer via a sprinkling can and mixing for approximately 3 min prior to delivery to the pens.
[2]Final individual BW measured live and shrunk 4%.
[3]Final individual BW calculated as individual HCW / 63.5% (common dressing percent).

Table 4. Effects of Amaferm on carcass characteristics of steers consuming steam-flaked corn-based finishing diets containing 35% wet distiller's grains.

Item	Control	Amaferm[1]	SE	P-value
Dressing percentage[2]	63.3	63.6	0.3	0.43
Hot carcass weight, lb	765	755	8	0.27
Fat thickness, in	0.454	0.397	0.023	0.03
Rib-eye area, in^2	13.1	13.1	0.3	0.78
KPH, %	1.93	1.83	0.06	0.12
Marbling score[3]	507	497	15	0.55
Yield grade	2.73	2.59	0.12	0.28
Liver abscesses, % incidence	16.1	16.1	4.0	0.99

[1]Amaferm was added to the diet by mixing the required amount (2 ml · head^{-1} · day^{-1}) in 4 L water, adding the solution to the mixer via a sprinkling can and mixing for approximately 3 min prior to delivery to the pens.
[2]HCW/Final live BW shrunk 4%.
[3]400 = Slight^{00}, 500 = Small^{00}, 600 = Modest^{00}, etc.

IDENTIFICATION OF RUMEN BACTERIA POPULATION SHIFTS USING 16S rDNA BACTERIAL TAG-ENCODED FLX AMPLICON PYROSEQUENCING WHEN FERMENTING CORN MILLING (CO)PRODUCTS OF DIFFERENT PROCESSING METHODS

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Summary

The objective of this study was to investigate bacterial population shifts in rumen fluid after fermenting two commonly-fed corn milling (co)products and their defatted forms in vitro for 24 or 48 h. Chemical analysis was performed on the intact and defatted feeds and used to compare physiochemical profiles. Intact and defatted forms and an internal alfalfa hay as laboratory standard were fermented and then analyzed using the16S rDNA bacterial tag-encoded FLX ampolicon pyrosequencing technique to explore resulting bacterial profiles. Bacterial profiles revealed that removal of lipids had no effect (P = 0.461) on the lipolytic bacteria activity for either feed. However, lipid removal significantly reduced the sugar utilizing bacteria populations for both feeds ($P < 0.001$). The difference in the bacterial profiles of these two feeds and their defatted forms may be due to the cross-feeding of glycerol and sugar utilizing bacteria.

Introduction

The ethanol wet and dry milling industry produces a number of corn milling (co)products that can be utilized as ruminant feeds. As drying and distilling technology and nutrition research moves forward, more information about the quality of dried distillers grain plus solubles (**DDGS**) is available which should aid in developing new strategies in feeding these (co)products to ruminants. Processing methods have been shown to produce differences in feed efficiency, production (Anderson et al., 2006), and quality (Tedeschi et al. 2009; Powers et al. 1995).

Hence, not only understanding the broader effects of feed processing but also how the rumen microflora changes in response to nutrients contained in different corn (co)products may be valuable. One of the latest methods to identify bacteria is through DNA pyrosequencing, analyzing bacteria on a genetic basis (Russell 2002). This research could provide insight to microbial preferences of DDGS processing methods and possibly increase its feeding efficiency.

Experimental Procedures

Sample Description and Chemical Analysis

Two corn (co)products were used in this study acquired from Poet Bio-refinery of Dakota Gold Manufacturing (Souix Falls, SD). Briefly, the first corn (co)product (Dakota Gold BPX DDG; **BPX**) is the resulting DDGS from a low heat processing method prior to fermentation, and likely to have less heat-damaged protein. The second corn (co)product (Dakota Gold HP DDG; **HP**), another DDGS, comes from a process that promotes the physical removal of bran and germ prior to fermentation and has higher protein content than BPX. Alfalfa hay was used as an internal laboratory standard feed. Chemical analyses were performed by Cumberland Valley Analytical Services of Hagerstown, MD, shown in Table 1.

Defatted Residue

Defatted residues were obtained using the AOAC (2000) Method 971.09. Extraction was performed using 1000-mL Soxhlet extractor and Freidrichs condenser. Whole samples (2 g) of HP and BPX were wrapped in Whatman #54 paper, inserted into thimble, and extracted with petroleum ether at condensation rate of 2-4 drops per second for 1 h. Samples were removed and dried at 60 °C overnight.

In vitro Anaerobic Fermentation

Feed samples (200 mg) were transferred into 125 mL Wheaton bottles, flushed with CO_2 to create in vitro anaerobic atmosphere. Goering and Van Soest's (1970) media (14 mL) was transferred to each bottle using strict anaerobic technique then closed with butyl rubber stoppers, crimp sealed, and placed in the fermentation chamber. Rumen fluid inoculum from a nonlactating, rumen-cannulated Jersey cow was filtered through one layer of cheesecloth and then again through glass wool. Once the chamber temperature reached 39 °C, 4mL inoculum was injected into each bottle. After 24 h of fermentation, selected samples were removed from the chamber. Duplicate samples were removed at 48 h. After removal, pH was recorded, and samples transferred to (50

mL) plastic falcon tubes, immediately set in ice water, and frozen overnight.

Pyrosequencing Analysis

The most recent 16S rDNA bacterial tag-encoded FLX amplicon pyrosequencing (**bTEFAP**) technique was used as described by Dowd et al. (2008) to assess bacteria population. Frozen samples were shipped overnight on dry ice to the Medical Biofilm Research Institute (Lubbock, TX) for bTEFAP analysis. Briefly, genomic DNA was extracted from fermented samples using a QIAmp DNA mini kit, concentrations equalized and products amplified in accordance with manufacturers recommended procedures (Qiagen, Valencia, California). A secondary PCR was performed using FLX amplicon sequencing. This secondary PCR prevents amplification of any potential bias. All products were purified and underwent bTEFAP FLX massive parallel pyrosequencing using a Genome Sequencer FLX System following the manufacturer's instructions (Roche, Nutley, New Jersey). Tentative consensus FASTA files for each sample were evaluated using BLASTn against a custom database derived from the RDP-II database and Gen-Bank (http://ncbi.nlm.nih.gov). The output of this analysis is given in percent of DNA found in each sample belonging to a classification of known rumen bacteria. That is to say, not the percentage of actual bacteria, but either whole or partial DNA found.

Statistical Analyses of pH and bacteria

Statistical analyses were done with SAS v. 9.2 (SAS Inst. Inc, Cary, NC) and R v 2.9 (R Development Core Team, 2009). The data from the pyrosequencing analysis was analyzed as completely randomized design (**CRD**) with factorial arrangements using the PROC Mixed (Kuehl, 2000; Littell et al., 2006). No data transformation was used because preliminary analysis indicated no improvement in normality of the residue. Least-square means were used for multiple comparisons using the Tukey adjustment for the P-value. A three-way factorial arrangement of 2 feeds (HP or BPX) × 2 forms (intact or defatted) × 2 incubation time (24 or 48 h) was used. Only data applicable to all three blocks were utilized to analyze significant differences in pH, between the two feeds in question. When the alfalfa hay data was used, only intact form data was used because alfalfa hay did not have a defatted form. In this case, a two-way factorial arrangement of 3 feeds (alfalfa hay, HP, and BPX) × 2 incubation times (24 and 48 h) was used.

When feeds were compared with the bacteria population of the blank (no feed added) at 48 h of incubation, five treatments were considered in a CRD.

Bacteria were analyzed at the species level. Only major bacteria species or highly prevalent species were used. Bacteria were grouped by their known substrate affinities for cellulose, hemicellulose, pectin, starch, sugars, protein, lipid and lactate according to Dehority (2003), Russell (2002), and Church (1988) (Table 2). These bacteria were used on the basis that their DNA was identified on a species level. Bacteria known to degrade these substrates were not used if their specific DNA was not detected by analysis.

Results and Discussion

pH Analysis

Table 4 lists a comparison of HP and BPX, the effect of time, form, and their interactions on pH. No significant difference in the average pH between BPX and HP (P = 0.651) was observed, nor was there a difference between forms (P = 0.062). Time, however, had a small but significant effect on pH (P = 0.006), showing a decrease in the average pH from 6.56 at 24 h to 6.46 at 48 h. This decrease in pH is likely due to the production of acids from the fermentation and lack of end product removal from the *in vitro* technique (Hobson et al. 1963). Hence, it is not likely that pH played a major role in the bacterial shifts of this experiment.

Pyrosequencing Analysis

Table 3 lists the comparison of the intact feeds, excluding the blank, over time 24 h to 48 h. The pyrosequencing analysis indicated a significantly greater percentage (P = 0.002) of fiber carbohydrate (FC) degrading bacterial DNA in HP relative to BPX (32.1% vs. 21.5%), being more similar to the population in the alfalfa fermentations. This was anticipated given the greater percentage of NDF and ADF residue in HP relative to BPX according to the chemical analysis of the feeds in Table 1. As expected, HP also had more protein degrading bacteria than BPX (30.9% vs. 21.3%; P = 0.004) and this is likely due to the higher CP content of the HP feed. However, alfalfa hay also had a greater percentage of protein degraders than BPX (29.3% vs. 21.3%; P = 0.004). Even though alfalfa hay had the lower CP, the chemical analysis indicated the solubility of the CP in the alfalfa hay was greater than HP and BPX, which explains the presence of protein degrading bacteria. Another reason could be that it would take longer for the bacteria to degrade the fiber bound proteins, which were shown to be highest in the HP product (NDF protein = 8.50%). The higher fat content of BPX was evident by a greater percentage of lipid degrading bacteria in the BPX samples than HP samples (0.80% vs. 0.08%; respectively, P < 0.001). Lactate fermenters also tended to be greater for BPX than HP and alfalfa hay (4.04% vs. 2.07% and 1.04%; respectively, P < 0.001). Aside from the cellulolytic and sugar fermenting bacteria, all bacteria significantly decreased from 24 to 48 h (Table 3). The sugar fermenting bacteria showed a significant increase from 24 to 48 hours (7.94% vs. 12.6%; P = 0.007). This result is likely due to the to the fact that there was no significant difference in the cellulolytic bacteria over time, therefore still converting cellulose to glucose, increasing the amount of substrate available for the sugar-utilizing bacteria over time. The interaction of feed and time was significant for all bacteria except the cellulolytic bacteria

population where instead of decreasing over time, did not change significantly.

The comparison for bacterial populations of feeds (BPX and HP), over time (24 and 48 h) and form (intact and defatted) (Table 4), indicated that there was no significant effect of feed on the cellulolytic bacteria, nor was it affected by either time or form. However, the interaction of feed and form was significant ($P = 0.002$). This may in part be explained by the inhibition of the lipid coating effect of the intact feeds. Maczulak et al. (1981) reported detrimental effects of several long chain fatty acids on the growth of seven FC degrading rumen bacteria. Jenkins (1993) has also suggested substrates in the presence of fat, are subject to lipid coating along with their hydrolytic enzymes. Hence bacteria degrading defatted feeds are uninhibited by this factor, having free access to the substrates. There was no significant difference observed in the lipolytic activity for feed, time or form. Even though BPX still maintained a greater percentage of lipolytic bacteria than HP, it was not such a significant difference between the two when not being compared to the alfalfa hay. All other guilds were consistent with the results of the first analysis, which included alfalfa hay, for feed and time. Form had a significant effect on the hemicellulolytic-, sugar-, proteolytic-, fiber carbohydrate-, and lactate-utilizing bacteria (Table 4). The defatted forms tended to have a greater population of bacteria preferring hemicellulose, protein, and fiber carbohydrates than the intact forms. This can be partially attributed to the relative increase in percentage of these substrates upon removal of fat. Conversely, sugar- and lactate-utilizing bacteria were more prevalent in the intact forms than defatted forms (14.6%vs 5.17%; $P < 0.001$, and 3.06% vs. 1.44%; $P = 0.015$, respectively). This may be due to cross feeding among bacteria fermenting the intact feed, where one bacterium requires the end product of another bacterium specie for growth (Wolin, 1975). Interactions among feed and form were significant for the cellulolytic- and sugar-utilizing bacteria, which again may be partially due to the relative increase of these components due to fat extraction. Time and form interactions were significant for hemicellulolytic-, amylolytic-, pectinolytic-, and sugar-utilizing bacteria as well as the collective group of fiber carbohydrates and non-fiber carbohydrates (NFC), which, with the exception of sugar, decreased over time as substrate diminished. The only significant three-way interaction ($P = 0.029$) of feed, time, and form was observed for the sugar-utilizing bacteria. This may be partially explained by the feeds initial composition of different sugar percentages, and the fact that ultimately all carbohydrates are reduced to sugar over time.

The third analysis was primarily used to look at the difference in bacterial prevalence among the different forms of feed at 48 h. Table 5 lists these results in detail. As expected, cellulolytic bacteria were most prevalent for the alfalfa hay and lowest for the blank (11.4% vs. 2.41%; $P = 0.022$). There was no significant difference between the intact and defatted forms of BPX and HP for these bacteria. Additionally there was no difference in prevalence of amylolytic and NFC bacteria, among the defatted and intact forms of BPX and HP feeds but as expected all were significantly greater than the Alfalfa and Blank. The sugar-utilizing bacteria were significantly more prevalent ($P < 0.001$) in the intact BPX and HP feeds as compared to the defatted feeds (18.4% and 17.4% vs. 5.92% and 6.08% respectively). This is particularly interesting because it is generally believed that the fat-removal process does not remove sugars. However, this may be due to the inclusion of the bacteria *Treponema bryantii* for both guilds, which is known to ferment both sugar and glycerol (Church, 1988). Specifically this organism would thus be less prevalent without the glycerol substrate, which ultimately affects the percent of bacteria present in the sugar guild. Interestingly, at 48 h, lipolytic bacteria however, showed no significant difference between any of the six feed types. Time is most likely responsible for such low average percentages of the bacterial DNA identified in these six fermentation bottles. Although there was no significant difference of the lipolytic bacteria between any of the feeds at 48 h, there is no method to statistically compare these feeds at 0 h and 24 h due to limitations of the experimental design and thus no way to conclude that there would not be a difference in activity at these times.

Implications

Although the activity of the lipolytic bacteria is still somewhat unclear, its significance is overshadowed by the significant effects feed, time, and form have on other bacterial guilds which are ultimately the results of interest. Identifying the prominent bacteria degrading these common (co)products in their intact and defatted forms yields far more valuable results and room for further research in the area of DDGS processing techniques.

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Table 1. Chemical analysis of alfalfa hay and composite BPX-DDG and HP-DDG feeds on a dry matter basis

Items	Feeds[1]		
	Alfalfa Hay	BPX-DDG	HP-DDG
DM, % as fed	92.6	91.7	92.9
CP, % DM	21.2	28.2	42.4
Soluble protein, % CP	37.3	4.21	3.13
ADF protein, % DM	1.3	1.44	2.65
NDF protein, % DM	4.6	4.72	8.50
Fat, % DM	2.0	11.38	3.88
Starch, % DM	1.1	5.77	8.38
Sugar, % DM	4.5	4.2	2.3
NFC, % DM	26.3	27.6	22.9
ADF, % DM	36.3	7.92	10.1
NDF, % DM	44.3	32.0	36.5
Lignin, % DM	7.7	1.80	2.07

[1]Feeds analyzed, Alfalfa Hay= internal laboratory standard feed, BPX and HP = corn dried distillers grain (co)products where BPX undergoes a low heat process and HP has high protein content.

Table 2. Guilds of major bacterial species identified by bTAFEP [1]

Species	Substrate guild [2]									
	C	H	St	Pec	Su	Pro	Li	FC	NFC	La
Anaerovibrio lipolyticus							X			
Bacteroides sp			X						X	
Butyrivibrio sp	X	X		X		X		X	X	
Clostridium aminophilum						X				
Eubacterium ruminantium			X		X				X	
Fibrobacter sp	X							X		
Lachnospira sp				X					X	
Lactococcus lactis					X				X	
Lactococcus sp					X				X	
Megasphaera elsdenii						X				X
Prevotella bryantii		X		X				X	X	
Prevotella sp		X	X	X		X		X	X	
Ruminococcus sp	X	X						X		
Selenomonas sp										X
Streptococcus sp			X	X	X				X	
Succinimonas sp			X						X	
Succinivibrio dextrinosolvens				X					X	
Treponema bryantii				X	X		X		X	

[1]X = bacterial inclusion of substrate guild.
[2]C= Cellulose, H= Hemicellulose, St= Starch, Pec= Pectin, Su=Sugar, Pro= Protein, Li= Lipid, La= Lactate.

Table 3. Effects of feed and time on the percentages of microbial DNA identified in mixed ruminal fluid of in vitro fermentations

Guild		Feeds				Time, h			*P*-values		
	n	Alfalfa	BPX	HP	SEM	24	48	SEM	Feed	Time	Feed*Time[3]
Cellulose	1 2	9.89[a]	3.96[b]	6.97[ab]	1.13	6.10	7.78	0.92	0.028	0.245	0.603
Hemicellulose	1 2	31.1[a]	21.5[b]	32.1[a]	1.32	33.5[a]	22.9[b]	1.08	0.002	<0.001	0.005
Starch	1 2	24.0[b]	35.3[a]	36.5[a]	1.10	36.0[a]	27.9[b]	0.90	<0.001	<0.001	<0.001
Pectin	1 2	31.6[b]	39.8[a]	43.5[a]	1.25	43.7[a]	32.9[b]	1.02	0.001	<0.001	<0.001
Sugar	1 2	1.74[b]	17.8[a]	11.3[a]	1.01	7.94[b]	12.6[a]	0.82	<0.001	0.007	0.012
Protein	1 2	29.3[a]	21.3[b]	30.9[a]	1.32	33.1[a]	21.2[b]	1.08	0.004	<0.001	0.003
Fat	1 2	0.05[b]	0.80[a]	0.08[b]	0.06	0.43[a]	0.18[b]	0.05	<0.001	0.013	0.038
FC[3]	1 2	32.1[a]	21.5[b]	32.1[a]	1.38	34.1[a]	23.1[b]	1.13	0.002	<0.001	0.004
NFC[3]	1 2	32.7[b]	40.4[a]	44.4[a]	1.33	44.1[a]	34.2[b]	1.09	0.002	<0.001	<0.001
Lactate	1 2	1.04[b]	4.04[a]	2.07[b]	0.27	3.11[a]	1.65[b]	0.22	<0.001	0.003	0.046

[a-c] Within a row, LSM without a common superscript letter differ ($P < 0.05$).
[1]Values are least squares means (LSM) and SEM is the average of the SE of the LSM.
[2]Computed using intact feed where BPX and HP = corn dried distillers grain (co)products where BPX undergoes a low heat process and HP has high protein content.
[3]Feed*Time = Interaction of Feed and Time, FC = fiber carbohydrates, NFC = non fiber carbohydrates.

Table 4. Effects of Feed, Time and Form on pH and percentages of microbial DNA identified in mixed ruminal fluid of in vitro fermentations (n = 16)

Items	Feed[2]		Time, h		Form[2]			*P*-values						
	BPX	HP	24	48	I	D	SEM	Feed	Time	Form	F*T	F*Fm	T*Fm	F*T*Fm
pH	6.52	6.51	6.56[a]	6.46[b]	6.54	6.48	0.02	0.651	0.006	0.062	0.717	0.148	0.717	0.855
Cellulose	5.99	5.12	5.09	6.03	5.47	5.65	0.60	0.340	0.299	0.833	0.448	0.002	0.956	0.577
Hemi	28.5[b]	36.2[a]	36.8[a]	28.0[b]	26.8[b]	37.9[a]	1.16	0.002	<0.001	<0.001	0.673	0.104	0.044	0.484
Starch	34.9[b]	39.1[a]	40.0[a]	34.0[b]	35.9	38.1	1.24	0.041	0.001	0.256	0.152	0.122	0.006	0.313
Pectin	39.3[b]	43.7[a]	45.9[a]	37.1[b]	41.6	41.4	1.10	0.021	<0.001	0.887	0.441	0.622	0.0027	0.588
Sugar	11.5[a]	8.19[b]	7.79[b]	11.9[a]	14.6[a]	5.17[b]	0.69	0.009	0.003	<0.001	0.018	0.012	0.035	0.029
Protein	28.1[b]	35.2[a]	36.4[a]	26.9[b]	26.1[b]	37.2[a]	0.92	0.003	<0.001	<0.001	0.492	0.187	0.063	0.451
Fat	0.50	0.24	0.41	0.34	0.44	0.31	0.14	0.235	0.760	0.541	0.079	0.051	0.226	0.545
FC	29.3[b]	36.2[a]	45.6[a]	37.7[b]	26.8[b]	38.7[a]	1.16	0.003	<0.001	<0.001	0.700	0.052	0.038	0.461
NFC	41.0[b]	45.2[a]	46.9[a]	39.3[b]	42.4	43.8	1.13	0.030	0.002	0.409	0.570	0.908	0.006	0.548
Lactate	2.77[a]	1.73[b]	3.21[a]	1.23[b]	3.06[a]	1.44[b]	0.50	0.078	0.006	0.015	0.915	0.113	0.716	0.272

[a-b] Within a row, LSM without a common superscript letter differ ($P < 0.05$).

[1]Values are least squares means (LSM) and SEM is the average of the SE of the LSM.

[2] BPX and HP = corn dried distillers grain (co)products where BPX undergoes a low heat process and HP has high protein content, I = Intact Feed, D = Defatted Feed, Hemi= Hemicellulose., FC = fiber carbohydrates, NFC = non fiber carbohydrates.

[3]F*T = interaction of Feed and Time, F*Fm = interaction of Feed and Form, T*Fm = interaction of Time and Form, F*T*Fm = interaction of Feed, Time, and Form.

Table 5. Effects of different forms of Feed on the percentages of microbial DNA identified in mixed ruminal fluid of in vitro fermentations at 48 h

Guilds		Forms of feeds						SEM	*P*-value
			Alfalfa	BPX[2]		HP[2]			
	n	Blank	Intact	Intact	Defatted	Intact	Defatted		
Cellulose	12	2.41[b]	11.4[a]	5.05[ab]	8.55[ab]	6.88[ab]	3.65[b]	1.32	0.022
Hemicellulose	12	12.1[c]	20.0[bc]	20.0[bc]	29.0[ab]	28.7[ab]	34.2[a]	2.32	0.004
Starch	12	9.72[b]	11.2[b]	33.3[a]	27.7[a]	39.2[a]	35.9[a]	2.63	<0.001
Pectin	12	12.2[c]	17.5[c]	37.6[ab]	30.8[b]	43.4[a]	36.5[ab]	2.10	<0.001
Sugar	12	0.37[c]	2.17[bc]	18.4[a]	5.92[bc]	17.4[a]	6.08[b]	1.00	<0.001
Protein	12	11.7[c]	17.0[bc]	19.7[abc]	28.2[ab]	26.7[ab]	33.0[a]	2.46	0.006
Fat	12	0.00	0.00	0.49	0.04	0.05	0.77	0.32	0.461
FC[3]	12	12.1[c]	24.0[bc]	20.0[bc]	30.3[ab]	28.7[ab]	34.2[a]	2.33	0.004
NFC[3]	12	12.2[b]	19.3[b]	38.6[a]	34.8[a]	39.2[a]	44.6[a]	2.45	<0.001
Lactate	12	0.51[b]	0.96[b]	2.71[a]	0.98[b]	1.29[b]	0.18[b]	2.03	0.001

[a-b] Within a row, LSM without a common superscript letter differ ($P < 0.05$).

[1]Values are least squares means (LSM) and SEM is the average of the SE of the LSM.

[2] BPX and HP = corn dried distillers grain (co)products where BPX undergoes a low heat process and HP has high protein content.

[3] FC = fiber carbohydrates, NFC = non fiber carbohydrates.

PASTURE AND FORAGE

STATISTICAL VARIATION IN PREDICTING DRY MATTER INTAKE OF BRAHMAN BULLS UNDER GRAZING CONDITION USING THE N-ALKANE TECHNIQUE

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Summary

Sixteen Brahman bulls were randomly assigned into 4 Coastal bermudagrass pastures [*Cynodon dactylon* (L.) Pers.] and stocked at a moderate to low grazing pressure. Corn gluten dosed with C_{32} n-alkane was used to estimate DMI. There were 3 periods (Aug-Sept) of 4 fecal collections per day during 5 days. The variances of DMI were similar using C_{31} across days, but the Pearson correlations between days were low, suggesting that several days of collection are needed to accurately predict DMI. There were moderate to high correlations between times of collection for all periods and they varied from 0.65 to 0.97 for C_{31} and from 0.26 to 0.96 for C_{33}. Estimates of DMI either using C_{31} or C_{33} had low correlations between days of collection when all periods were analyzed together. The optimum times for fecal collection were 0700 and 1500 h, and minimum of 5 days of continuous collection is needed when predicting DMI in Brahman bulls grazing Coastal bermudagrass.

Introduction

Efficiency of animal production under grazing systems is one of the most important components of economic sustainability of the livestock operation. Efficiency of production may be measured in an array of factors; however, intake and utilization of forages under grazing conditions is one of the primary parameters of concern. Using alkanes to predict dry matter intake (DMI) was initially proposed by Mayes and Lamb (1984). According to Mayes and Lamb (1984), n-alkanes (waxes) can be used as an indigestible marker because they are more chemically inert and simpler to analyze than long-chain fatty acids. Malossini et al. (1996) concluded that increasing the number of samples per day decreases the error of the methodology and increases precision of estimating DMI. The recovery of fecal n-alkanes increases as carbon chain length increases (Mayes et al. 1986; Bovolenta et al., 1994). The objectives of this study were to determine the variation structure within a day and across days when determining DMI using C_{32} alkane as an external marker; to determine the optimum fecal collection periods to estimate DMI; and to compare C_{31} and C_{33} as plant markers in estimating DMI.

Experimental Procedures

The study was conducted at the Texas AgriLife Research & Extension Center at Overton, TX, during the summer of 2008. Purebred Brahman bulls (n=16) with an average age of 18 months were assessed for RFI via Calan gates in confinement. Bulls were stratified by weight and RFI grouping into four groups and randomly allotted into 4 Coastal bermudagrass pastures [*Cynodon dactylon* (L.) Pers.]. Corn gluten pellets were used as the carrier for C_{32} n-alkane.

Bulls were fed individually twice a day (0700 and 1900) with 400 g of marked corn gluten using Calan gates. Fecal samples were collected four times daily (0700, 1100, 1500 and 1900 h) for 5 days and during 3 periods (Aug-Sept) of fecal collection. Forage samples were collected daily from the plant parts that visually approximated bulls selection of bermudagrass.. Alkanes in the fecal and forage samples were extracted and analyzed using separatory columns and gas chromatography as described by Dove and Mayes (2006).

The experiment was designed as double repeated measurements (5 days of fecal collection and 4 times of fecal collection within a day) in a completely randomized block design (3 periods as blocks) (SAS date Inst., Cary, NC). Animals were the experimental unit and they were kept in the same pasture during all periods to maintain the established hierarchy within a pasture. Two statistical analysis procedures were performed in order to analyze the variance and (co)variance (**var-(co)var**) structure of days and times of collection for both C_{31} and C_{33} with and without adjustments for C_{32} across periods (SAS date Inst., Cary, NC).

The first statistical model was performed for each period independently, as follows:

$$Y_{ijklm} = \mu + T_j + D_k + T_{ij} + D_{ik} + T\times D_{jk} + T\times D_{ijk} + P_m + \varepsilon_{ijklm} \quad \textbf{Eq. [1]}$$

Where Y is the observed variable; μ is the overall mean; T is the fixed effect of time of fecal collection within a day; D is the fixed effect of day of collection; P is the random effect of pasture; and ε is the identical, independent, and normally distributed random error with $N\sim(0, \sigma^2)$.

The second statistical model was done with all periods together as shown below:

$Y_{ijklm} = \mu + + T_j + D_k + T_{ij} + D_{ik} + T \times D_{jk} + T \times D_{ijk} + P_m + I_n + \varepsilon_{ijklmi}$ **Eq. [2]**

Where Y is the observed variable; μ is the overall mean; T is the fixed effect of time of fecal collection within a day; D is the fixed effect of day of collection; P is the random effect of pasture; I is the random effect of period; and ε is the identical, independent, and normally distributed random error with $N \sim (0, \sigma^2)$.

PROC MIXED of SAS was used to performed the analyzes, and the the -2×Log and the Akaike's Information Criteria (**AIC**) statistics (SAS Inst., Cary, NC) were used to assess the goodness-of-fit for prediction of DMI. Since days and times of collection were evaluated (two levels of repeated measure) the var-(co)var structure for un@un (unstructured @ unstructured) and un@ar(1) (unstructured @ autoregressive first degree) were used.

Results and Discussion

The concentration of C_{31} in the bermudagrass was less than the concentration of n-alkane C_{33} for all periods ($P < 0.0001$); however, the concentration in the feces was not different between C_{31} and C_{33}. During P1, P2, and P3 the prediction of DMI using C_{33} had a better fit (smaller -2×Log and AIC) than C_{31} either with or without adjustments for forage C_{32} (Table 1). An improved in alkane fecal recovery have been reported as carbon length increases (Mayes and Lamb, 1984; Mayes et al., 1986).

Correlations between times of fecal collection were medium to high for all periods and varied from 0.65 to 0.97 for C_{31} and from 0.26 to 0.96 for C_{33}. When all periods were analyzed together, estimates of DMI using either C_{31} or C_{33} had low correlations between days of collection. In addition, the adjustment for forage C_{32} did not improve the variance and (co)variance matrix.

The variances of DMI using C_{31} without adjustment for forage C_{32} were similar across days (Table 2). A similar outcome was obtained when DMI was computed with adjustments for C_{32} content of the forage. Correlations between times were medium to high for all periods and varied from 0.65 to 0.97 for C_{31} and from 0.26 to 0.96 for C_{33}. The correlation among different days of collection was either very low or zero, suggesting that days of collection yielded completely different estimates of DMI and therefore several days of collection were necessary to accurately estimate DMI.

A first-order autoregressive var-(co)var structure was observed when the DMI was predicted using C_{31} and without adjustment for C_{32} (Table 2) for days of collection and unstructured var-(co)var was observed for times of collection: however using C_{33} the var-(co)var was unstructured for days was also observed. A first-order autoregressive var-(co)var indicated a lower correlation that the further the levels were apart from each other, but with the same variance. Similar to the individual periods, estimates of DMI either using C_{31} or C_{33} had low correlations between days of collection (Table 2) and the variance varied from 0.38 to 1.40 kg^2/d^2.

These results indicated that at least 5 d were needed to estimate DMI using alkanes and that time of collection were highly correlated. Therefore, fewer collections within a day may be adequate to accurately estimate DMI, such as at 0700 and 1500 h. The estimates of DMI using C_{33} for times of collection within days had less variance than C_{31}, but there was indication that C_{31} had the least variance across days of collection.

Implications

Alkane technique is a viable method to predict DMI in grazing animals. The C_{33}/C_{32} pair had a lower variation compared to the C_{31}/C_{32} pair in order to predict DMI. There were a small to medium correlation between times and days of collection. A minimum of 5 days of collection and two times a day (0700 and 1500) are needed to estimate DMI in Brahman Bulls grazing bermudagrass. The estimation and quantification of DMI of grazing livestock will enhance the ability to select animals for production efficiency. These alkane techniques offer potential opportunity to screen cattle for RFI under grazing conditions and eliminate the confined feeding component.

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Table 1: Variance (diagonal) and correlation matrices for selected days (D) and times (T) of fecal collection to estimate DMI using C_{31} and C_{33} without adjustments for C_{32} for individual and combined periods 1, 2, and 3 [1]

Periods																					
1						2					3					1, 2, and 3					
--- C31 ---																					
	Days: ar(1)					Days: ar(1)					Days: ar(1)					Days: un					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
1	1.00					1	1.00				1	1.00				1	1.00				
2	0.01	1.00				2	0.02	1.00			2	0.38	1.00			2	0.26	1.02			
3	0.00	0.01	1.00			3	0.02	0.02	1.00		3	0.14	0.38	1.00		3	0.18	0.32	0.38		
4	0.00	0.00	0.01	1.00		4	0.02	0.02	0.02	1.00	4	0.05	0.14	0.38	1.00	4	0.18	0.17	0.15	1.40	
5	0.00	0.00	0.00	0.01	1.00	5	0.02	0.02	0.02	0.02	1.00	5	0.02	0.05	0.14	0.38	1.00	5	0.09	0.27	0.09	0.04	0.48
	Times: un					Times: un					Times: un					Times: un					
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4		
1	3.53					1	6.89				1	1.53				1	6.56				
2	0.88	2.81				2	0.96	10.08			2	0.80	1.60			2	0.92	6.95			
3	0.80	0.86	3.82			3	0.90	0.97	12.41		3	0.78	0.96	1.76		3	0.88	0.96	8.29		
4	0.65	0.73	0.79	3.10		4	0.92	0.97	0.97	13.1	4	0.70	0.85	0.86	1.77	4	0.83	0.92	0.93	8.32	
--- C33 ---																					
	Days: un					Days: un					Days: un					Days: un					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
1	1.00					1	3.00				1	1.31				1	2.49				
2	0.07	0.51				2	-0.4	0.69			2	0.33	0.67			2	0.25	1.41			
3	0.24	0.43	0.18			3	0.01	0.00	1.11		3	0.02	0.23	1.11		3	0.20	0.31	1.15		
4	0.17	0.29	0.22	0.54		4	0.54	-0.07	-0.11	4.78	4	0.22	0.10	0.50	0.53	4	0.56	0.08	0.10	2.79	
5	0.00	0.37	0.18	0	0.28	5	0.12	0.28	-0.24	-0.04	1.92	5	0.13	0.56	0.37	-0.1	1.38	5	0.13	0.38	0.16	0.02	1.49
	Times: un					Times: un					Times: un					Times: un					
	1	2	3	4		1	2	3	4		1	2	3	4		1	2	3	4		
1	1.21					1	1.00				1	1.00				1	1.00				
2	0.78	1.30				2	0.94	1.28			2	0.80	0.78			2	0.89	1.04			
3	0.66	0.85	1.42			3	0.88	0.96	1.44		3	0.73	0.93	0.70		3	0.84	0.95	1.20		
4	0.26	0.60	0.70	1.34		4	0.87	0.95	0.95	1.45	4	0.63	0.80	0.76	0.83	4	0.78	0.90	0.92	1.22	

[1] ar(1) and un are first-order autoregressive and unstructured variance and (co)variance structures, respectively. Times 1, 2, 3, and 4 are fecal collections at 0700, 1100, 1500, and 1900 h, respectively, within a day. These are symmetrical matrices, therefore, the top values are identical to the values shown in the bottom part within a matrix.

Table 2: Variance (diagonal) and correlation matrices for selected days (D) and times (T) of fecal collection to estimate DMI using C_{31} and C_{33} with adjustments for C_{32} for individual and combined periods 1, 2, and 3 [1]

Periods																					
1						2						3					1, 2, and 3				
--- C31 ---																					
Days: ar(1)						Days: ar(1)						Days: ar(1)					Days: un				
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
1	1.0					1	1.0					1	1.0					1	1.0				
2	0.07	1.0				2	0.01	1.0				2	0.35	1.0				2	0.24	1.06			
3	0.01	0.07	1.0			3	0.00	0.01	1.0			3	0.12	0.35	1.0			3	0.18	0.31	0.44		
4	0.00	0.01	0.07	1.0		4	0.00	0.00	0.01	1.0		4	0.04	0.12	0.35	1.0		4	0.11	0.15	0.17	1.36	
5	0.00	0.00	0.01	0.07	1.0	5	0.00	0.00	0.00	0.01	1.0	5	0.02	0.04	0.12	0.35	1.0	5	0.07	0.21	0.08	0.09	0.50
Times: un						Times: un						Times: un						Times: un					
	1	2	3	4			1	2	3	4			1	2	3	4			1	2	3	4	
1	4.05					1	7.40					1	2.04					1	7.18				
2	0.86	3.11				2	0.94	11.8				2	0.75	2.28				2	0.89	7.85			
3	0.81	0.87	3.92			3	0.88	0.96	14.2			3	0.69	0.91	2.43			3	0.85	0.99	9.24		
4	0.62	0.70	0.74	3.30		4	0.90	0.96	0.96	15.0		4	0.65	0.82	0.83	2.44		4	0.80	0.90	0.92	9.25	
--- C33 ---																							
Days: un						Days: un						Days: un						Days: un					
	1	2	3	4	5		1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
1	1.0					1	3.12					1	1.32					1	2.54				
2	0.08	0.54				2	-0.3	0.64				2	0.26	0.97				2	0.27	1.68			
3	0.25	0.44	0.16			3	0.08	0.01	1.25			3	0.03	0.24	1.31			3	0.21	0.32	1.48		
4	0.06	0.27	0.12	0.63		4	0.28	-0.11	-0.13	5.33		4	0.28	0	0.52	0.97		4	0.42	0.05	0.12	3.41	
5	0.03	0.37	0.23	-0.2	0.3	5	0.06	0.26	-0.27	-0.01	2.67	5	0	0.40	0.39	-0.1	1.1	5	0.10	0.27	0.16	0.08	1.84
Times: un						Times: un						Times: un						Times: un					
	1	2	3	4			1	2	3	4			1	2	3	4			1	2	3	4	
1	1.25					1	1.00					1	1.00					1	1.00				
2	0.76	1.45				2	0.92	1.38				2	0.79	0.63				2	0.86	1.05			
3	0.64	0.81	1.81			3	0.85	0.94	1.48			3	0.58	1.01	0.80			3	0.79	0.93	1.22		
4	0.23	0.58	0.71	1.53		4	0.84	0.94	0.93	1.51		4	0.50	0.86	0.67	1.00		4	0.74	0.88	0.89	1.21	

[1] ar(1) and un are first-order autoregressive and unstructured variance and (co)variance structures, respectively. Times 1, 2, 3, and 4 are fecal collections at 0700, 1100, 1500, and 1900 h, respectively, within a day. These are symmetrical matrices, therefore, the top values are identical to the values shown in the bottom part within a matrix.

EVALUATION OF WARM-SEASON PERENNIAL GRASSES UNDER THREE IRRIGATION REGIMES AS POSSIBLE ALTERNATIVES TO IRRIGATED ROW CROPS

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Summary

A multi-year study is being conducted to evaluate production and nutrient composition responses of 6 warm-season perennial grasses under 3 irrigation regimes. Irrigation regimes include: 1) dryland, 2) limited, and 3) full. The first year of the study has been completed and data were collected and analyzed. Grass plots were harvested four times during the growing season to determine dry matter yield at each harvest and total dry matter yield over the growing season. Nutrient analysis was performed on the final harvest sample only. Irrigation, grass species, and their interaction affected dry matter forage yield ($P < 0.001$). Crude protein content of forage was affected by both irrigation and grass species ($P < 0.01$), but not the interaction ($P = 0.192$). A significant irrigation by grass species interaction was also detected for *in vitro* true digestibility ($P = 0.028$).

Introduction

The Ogallala Aquifer is declining by an average of almost 1.5 feet each year, with agriculture as the major consumer of water, particularly for irrigation purposes. With increasing concerns of water availability in the region, alternatives to corn and other high water use crops are needed. Perennial summer grasses could potentially be used as a cropping alternative, however many of the introduced grasses use as much or more water to produce high yielding, high quality forage. Our hypothesis is that some of the improved varieties of native warm-season grasses could be highly productive under limited irrigation schemes, replacing row crops that consume large amounts of water each year from the Ogallala Aquifer.

Experimental Procedures

The study was initiated in 2006 at the Texas AgriLife Research field lab near Etter, TX. Six grass species were planted in May 2006. Late planting and above average temperatures during the early summer of 2006 led to unsatisfactory plant establishment by early fall of 2006. The decision was made to reseed plots in 2007. By spring of 2008, grasses were well established, irrigation treatments were initiated, and data collection began. The six grass species being examined are:

Wrangler bermudagrass
Hatchita blue grama
Texoka buffalograss
WW Spar old world bluestem
Haskell sideoats grama
Blackwell switchgrass

Treatments included irrigation level (dryland, limited, and full) and warm-season grass species (previously mentioned). Each treatment combination appeared in three replicated 30 × 70 ft plots arranged in a split plot randomized complete block design. Irrigation level served as the main plot and grass species served as the sub-plot for analysis of variance. Irrigation level was determined based on the reference evapotranspiration (ET) value of bermudagrass as estimated by the North Plains ET Network for the location at Etter. Plots assigned to full irrigation received water equal to the bermudagrass ET value minus any rainfall that occurred in the preceding seven days. Plots on the limited irrigation treatment received one-half of the amount of water for full irrigation plots. During the growing season, irrigation water was applied in 1 or 2 applications each week as needed using a linear move sprinkler system. From June 9 to August 28, 14.7 inches of irrigation water was applied to plots in the full irrigation treatment and 7.33 inches of irrigation water was applied to limited irrigation plots. Additionally, during that same time period, plots received 5.82 inches of rainfall. Plots were fertilized as needed based on soil sample analysis.

Grass was harvested 4 times during the growing season using a Carter Harvester. Samples were weighed and dried to determine yield and dry matter. A sub-sample from each plot from the final harvest was analyzed for nutrient composition.

Soil core samples were collected at the beginning of the growing season and after the last harvest to determine total water use and water use efficiency. Total water use (ET) was calculated as the sum of soil water balance, irrigation, rainfall values. Water use efficiency was determined as the ratio of dry biomass yield and seasonal ET.

Results and Discussion

Perhaps not surprising, forage dry matter yield increased ($P < 0.001$) as irrigation level increased (1.1, 2.7, and 5.2 tons/acre for dryland, limited, and full irrigation, respectively). A significant irrigation × grass species interaction was detected ($P < 0.001$, Figure 1) for dry matter yield. Under full and limited irrigation, old world bluestem and bermudagrass yielded the greatest forage dry matter. Buffalograss tended to yield the lowest amount of dry matter at each irrigation level. Crude

protein content of the forage was affected by irrigation ($P < 0.01$), with grasses grown under dryland conditions containing the highest amount of crude protein (16.4%). Grasses under limited irrigation contained the lowest amount (13.3 %) and grasses under full irrigation were intermediate (15.0 %). No interaction was detected for crude protein ($P = 0.19$, Figure 2). The highest amount of crude protein in any of the treatments was 20% CP for the bermudagrass grown under dryland conditions; however, dry matter yield was only 1.1 tons/acre. There was little difference in crude protein content between bermudagrass, blue grama, and switchgrass species under full and limited irrigation. In vitro true digestibility of forage was similar across irrigation all treatments ($P = 0.67$). The irrigation × grass species interaction was significant for in vitro true digestibility ($P < 0.05$; Figure 3). Under full and limited irrigation, digestibility tended to be highest for switchgrass, followed by blue grama. Under dryland conditions, digestibility was greater than 75% for switchgrass, bermudagrass, and sideoats grama.

Implications

Care should be taken in drawing conclusions from one year of a multi-year study. Data presented here is from the first year of a planned 3-year study.

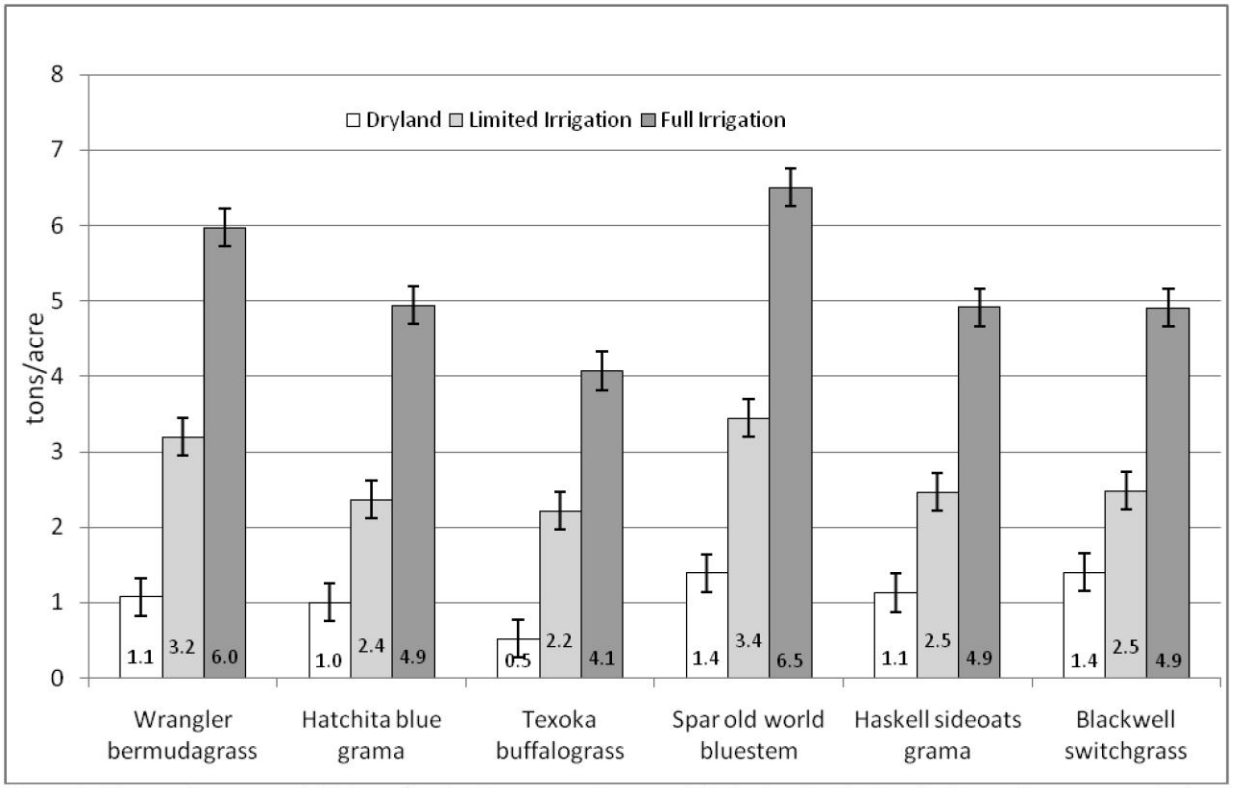

Figure 1. Forage dry matter yield (tons/acre) of grass species at each irrigation level. Standard error bars are attached to the means. Irrigation, grass species, and irrigation × grass species interaction effects ($P < 0.001$).

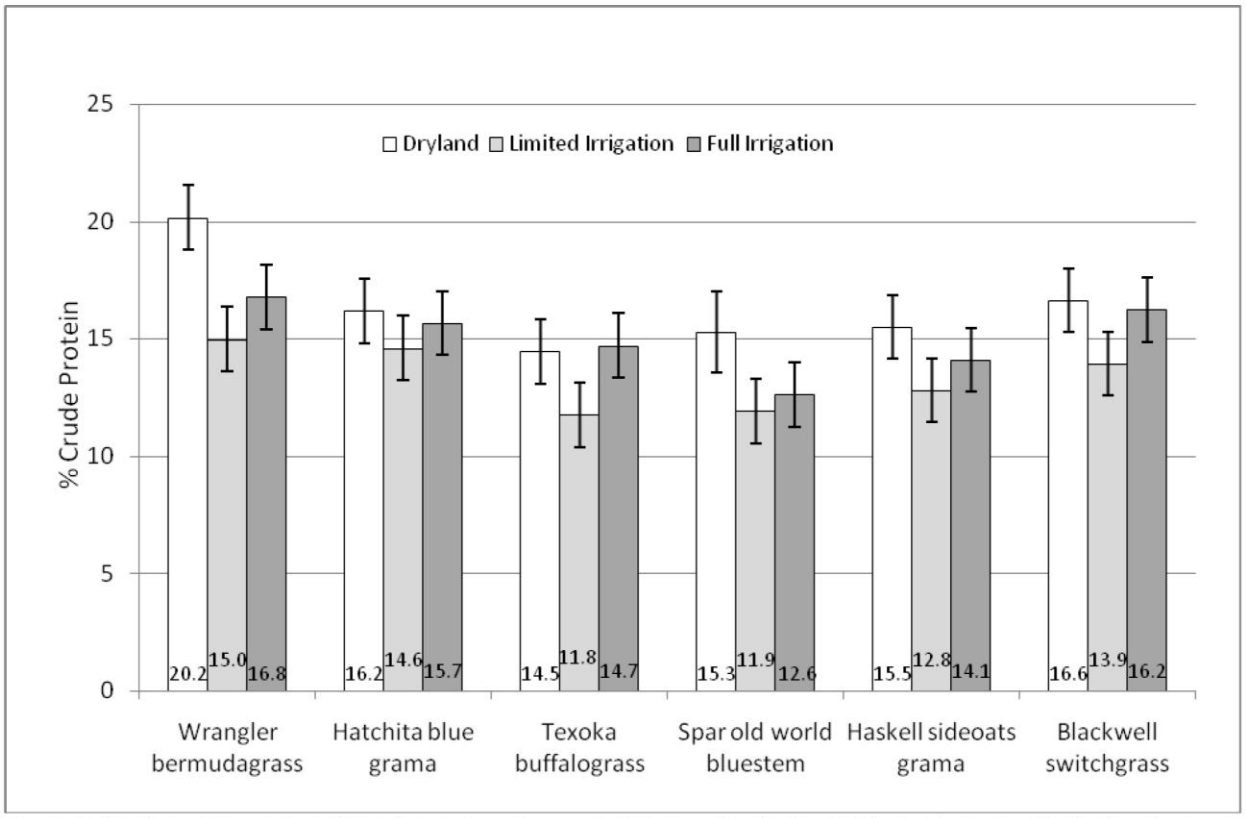

Figure 2. Crude protein content (%) of grass species at each irrigation level. Standard error bars are attached to the means. Irrigation and grass species effects ($P < 0.005$). Irrigation × grass species interaction ($P = 0.19$).

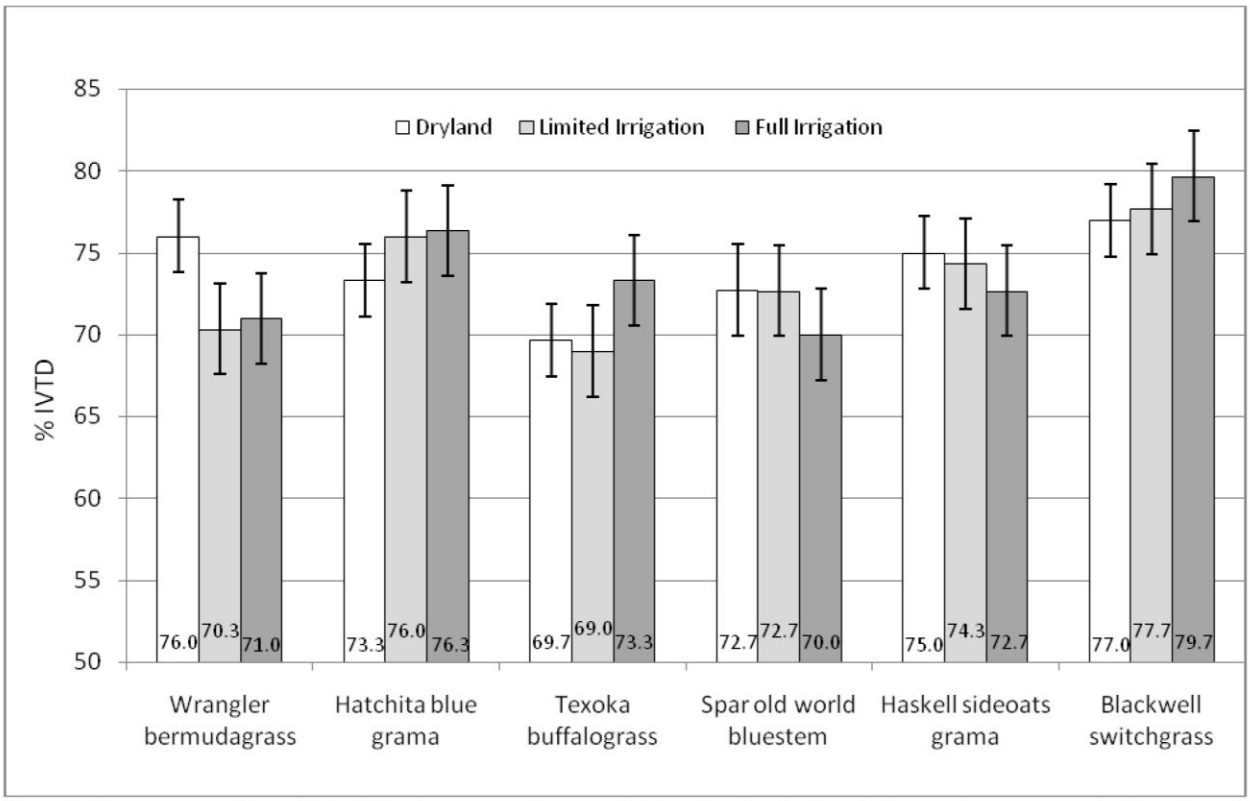

Figure 3. In vitro true digestibility (%) of grass species at each irrigation level. Standard error bars are attached to the means. Irrigation × grass species interaction ($P = 0.028$).

DISTILLER'S GRAINS AS A SUPPLEMENT FOR WHEAT PASTURE STOCKERS

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Summary

A two year study was conducted during the winters of 2008 and 2009 to evaluate the use of dried distiller's grains (DDG) as a supplement to wheat pasture on cattle performance. In each year, 60 Hereford steers were randomly assigned to one of 15 wheat pastures. Pastures were blocked and supplement treatments were assigned. Treatments were: 1) Control (CON)- no additional supplement 2) Dry rolled corn (DRC)- offered at 0.5% of body weight per day (dry matter basis), pro-rated and delivered 6 days/week, and 3) Dried distiller's grains (DDG)- offered at same rate and frequency as DRC. Initial weight was similar among treatments (P = 0.59). Final weight tended to be greater (P = 0.11) for DDG-fed steers compared to CON and DRC-fed steers. Likewise, ADG was tended to be greater (P = 0.11) for DDG-fed steers than CON steers and DRC-fed steers. Following graze-out on wheat, steers were moved to the research feedlot to evaluate the use of DDG in finishing diets on performance, carcass traits, and fatty acid composition.

Introduction

The recent increase in the ethanol industry has resulted in an increase in the availability of distiller's grains, a nutrient rich co-product of ethanol production. Little is known about the use of DDG as a supplement for wheat pasture and effects of long-term (growing and finishing) use of DDG on animal performance, carcass traits, and meat composition in a wheat pasture production system. In order to further characterize production responses and applications in the cattle industry, the primary objective of this research was to determine performance responses to DDG when used as a supplement to winter wheat pasture. Subsequent objectives in the finishing phase are to 1) determine performance responses and carcass characteristics when DDG replaces steam-flaked corn in finishing diets, and 2) determine overall performance and carcass responses as affected by use of DDG from beginning of the growing phase through finishing.

Experimental Procedures

This study was conducted at the Texas AgriLife Research facilities in Bushland, Texas. Each year, Hereford steer calves (n = 60; BW = 438 lb) of known parentage were purchased from a single ranch to determine effects of using DDG in the growing and finishing phases on animal performance, carcass characteristics, and meat composition. Fifteen 5.5 ac wheat pastures were assigned to five blocks of three pastures and stocked with four steers per pasture. Within each block pastures were assigned to each of three treatments: 1) Control (CON)- no additional supplement 2) Dry rolled corn (DRC)- offered at 0.5% of body weight per day (dry matter basis), pro-rated and delivered 6 days/week, and 3) Dried distiller's grains (DDG)- offered at same rate and frequency as DRC. Steers in all pastures had *ad libitum* access to water and a monensin-containing mineral supplement throughout the duration of grazing.

Steers were weaned in late fall, preconditioned, and grazed on dormant native rangeland until arrival at the research facilities. Upon arrival, steers were revaccinated for viral and Clostridial diseases and implanted with Ralgro®. Individual weights were recorded and ultrasound estimates of external fat and intramuscular fat were collected. Wheat pasture grazing began on January 22 (year 1) and December 18 (year 2). Full BW was measured every 28 d. Supplements were hand-delivered 6 d/wk for the duration of grazing. Amount of supplement offered was re-calculated every 28 d to account for increases in BW. In year 1, grazing was terminated when forage availability in a pasture was deemed inadequate by visual assessment, resulting in differing pull-off dates. In year 2, grazing was terminated on a single day. Across years, steers grazed an average of 115 days.

Forage samples were obtained at initiation and termination of grazing to characterize forage availability. Forage was clipped at ground level from six stratified locations across each pasture. Clipped forage was dried and weighed to calculate total forage dry matter.

Data were analyzed using the mixed model procedures (PROC MIXED) of SAS (SAS Inst. Inc., Cary, NC) with treatment as the fixed effect and year, year by treatment interaction, and block within year as random effects.

Results and Discussion

Forage dry matter availability at initiation of grazing was similar across treatments (P = 0.89). Though not statistically different (P = 0.35), final forage dry matter was numerically greater for supplemented pastures than non-supplemented pastures (Table 1).

On average, steers grazed wheat pasture for 115 days. By design, initial BW was similar for all treatments (P = 0.59). Final BW tended to be greater for DDG steers compared to CON and DRC groups (P = 0.11). Total pounds of gain was greater for steers supplemented with DDG than CON and DRC steers (P = 0.09) and average daily gain tended to increase with DDG supplementation

(P = 0.11), however, there were no differences in gain between CON and DRC groups (Table 2).

Responses to supplements were similar to results from other grazing trials (Horn et al., 1995; MacDonald et al., 2006; Morris et al., 2006; Corrigan et al., 2007) with similar supplementation rates. The different responses to DRC and DDG possibly reflect differences in the starch, digestible fiber, and undegradable protein composition of DRC and DDG and accompanying influences on forage digestion, intake, and intestinal protein supply. However, Horn at al. (1995) and Cravey et al. (1992) reported that gain response and forage consumption on wheat pasture were not different for high starch and high digestible fiber supplements. In addition, supplementing undegradable protein to stockers on wheat pasture has not proven beneficial (Horn et al., 2005).

Implications

Based on results of this study, supplementing dried distiller's grains to stockers grazing wheat pasture increased total pounds of gain when compared to dry rolled corn supplement or no supplement. Though not statistically significant, final forage availability was numerically higher in supplemented pastures than non-supplemented pastures.

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Table 1. Initial and final forage dry matter availability of wheat pastures.

Item	CON[1]	DRC	DDG	SEM	*P*
Initial forage dry matter, lb/ac	2169	2238	2200	136.6	0.89
Final forage dry matter, lb/ac	597	848	749	131.6	0.35

[1]Experimental treatment; CON = control; DRC = dry rolled corn pro-rated and fed at 0.50% BW/d and delivered six days/wk; DDG = dried distillers grains pro-rated and fed at 0.50% BW/d and delivered six days/wk.

Table 2. Effects of stocker supplementation on performance.

Item	CON[1]	DRC	DDG	SEM	*P*
Initial BW, lb	440	438	436	3.59	0.59
Final BW, lb	794[a]	801[a]	826[b]	8.29	0.11
Total gain, lb	354[y]	364[y]	390[z]	8.48	0.09
ADG, lb	2.86[a]	2.91[a]	3.12[b]	0.07	0.11

[1]Experimental treatment; CON = control; DRC = dry rolled corn pro-rated and fed at 0.50% BW/d and delivered six days/wk; DDG = dried distillers grains pro-rated and fed at 0.50% BW/d and delivered six days/wk.

[a,b] Values with unlike superscripts tend to differ (P = 0.11).

[y,z] Values with unlike superscripts differ (P = 0.09).

PREDICTING STEER PERFORMANCE ON WINTER PASTURES

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Texas AgriLife Research Center at Uvalde[1] and Texas AgriLife Research Center at Overton[2]

Summary

Weanling Bonsmara × Beefmaster steers from a single source were used in experiments at the Texas AgriLife Research Centers at Uvalde and Overton to study the relationship of animal performance to stocking rate on winter pasture. Grazing management treatments were superimposed on the basic management scheme, continuous fixed stocking, at each location. Very strong ($r^2 > .9$) and similar relationships between pasture ADG and steer-days per acre were found at both locations. The equation describing this relationship, ADG = 2.82 (± .045) – .0020 (± .00013) × steer-days / acre, was calculated from the merged data of both locations.

At Uvalde, supplementing poor quality sorghum hay with high levels of CSM during the pre-grazing period reduced weight loss 33 lb per steer ($P < .01$). At Overton, continuously grazed pastures had a small advantage (0.11 lb ADG, $P < .05$) over rotationally grazed pastures.

Introduction

A negative relationship between pasture stocking rates and rate of gain is commonly observed in grazing experiments with young cattle. Experiments at any one location usually do not afford enough different stocking rates to enable calculation of a robust mathematical description of this relationship. Additionally, variations in grazing management are frequently imposed as experimental treatments in grazing trials in an attempt to bring the nutritional requirements of growing cattle, qualitatively and quantitatively, into better alignment with the seasonal growth patterns of pasture forages, complicating efforts to better describe the basic stocking rate – performance relationship.

In this experiment, weanling steers from a single source were evaluated, paired, and then distributed to Research Centers at Uvalde and Overton to allow subsequent evaluation of differences between locations. In addition to variations in stocking rate, pre-grazing and grazing management treatments were imposed at Uvalde and grazing management treatments were imposed at Overton.

Experimental Procedures

Steer Acquisition

Bonsmara x Beefmaster steers (n = 139) were weighed and otherwise evaluated at weaning in Lincoln County, NM, on 11 Nov 2002. Of these, 112 were paired by weight, and the paired groups were randomly assigned to be used in winter grazing studies at Texas AgriLife Research Centers at Overton and Uvalde. The group assigned to Uvalde plus 6 additional steers (n = 62) were shipped immediately, while the group assigned to Overton plus 21 additional steers (n = 77) were transported on 5 Dec 2002 after being backgrounded in drylot in NM.

Uvalde

'TAM90' annual ryegrass sward was established on prepared seedbed under a 28-acre pivot irrigation system and fertilized at the rate of 100 – 28 – 0 in two applications. Four pie-shaped pastures (2.6 or 3.1 acres) were fenced in the center of the pivot system for continuous grazing and two concentric rings were fenced within the two outer tracks of the system for frontal grazing. Steers from NM plus 10 Bonsmara crossbred steers weaned in Uvalde County, TX were blocked by weight and randomly assigned to the six pastures to provide initial stocking rates ranging from 1.95 to 2.96 animals per acre for continuous grazing and 2.97 animals per acre for frontal grazing.

All steers were fed *ad libitum* amounts of poor quality sorghum hay in drylot for at least two weeks before being released to ryegrass pasture. During the last two weeks before ryegrass grazing, half of the steers assigned to each pasture were also offered increasing amounts of cottonseed cake to a maximum of 10 lb per head daily. Steers assigned to continuous grazing were released to pasture 28 Nov 2002, while steers assigned to the frontal grazing system were released two weeks later. The steers in each major grouping (continuous stocking and frontal grazing) were weighed onto the grazing trial four days after being released onto ryegrass pasture, weighed periodically during the trial, and weighed off the trial 13 May 2003.

Overton

Winter pastures were established by seeding into an existing bermudagrass sward 100 lb of 'Maton' rye and 25 lb of 'TAM90' annual ryegrass per acre. The pastures were fertilized with a total of 192 – 16 – 42 per acre in four applications. Grazing treatments were designed to evaluate two grazing methods (continuous and 8-paddock, 16-d rotation) and two stocking rates (0.9 steer/ac and 1.7 steer/ac at grazing initiation) in a factorial arrangement with two replications. Steers (mean weight = 493 lb, s = 90) were stratified into eight groups by weight; groups were randomly assigned to pastures.

Steers remained in drylot until 18 Dec 2002 where they were offered *ad libitum* amounts of low quality Coastal

bermudagrass hay plus corn:SBM (4:1) at the rate of 2 lb each daily. All steers were weighed on 18 Dec 2002 and released to pasture. The 18 Dec weight minus 5% was recorded as the starting weight. The steers were also weighed at termination of the grazing trial (15 May 2003) and periodically between those dates.

Results and Discussion

Uvalde

Average weights at weaning were 490 lb (*s* = 90) for steers from NM and 469 lb (*s* = 46) for steers from Uvalde. Three NM steers were removed from the experiment within the first two months of grazing due to disease unrelated to treatments. On 7 Feb 2003, 12 Bonsmara crossbred grazer steers replaced those animals and modified the stocking rates on all pastures to achieve desired grazing pressures with onset of spring flush of ryegrass growth.

For steers released to pasture on 28 Nov, average weight loss was 49 lb per steer during the pre-grazing period for those offered only sorghum hay but was much less (14 lb, $P < .01$) for those also offered CSM. This difference was almost totally negated (309 *vs* 310 lb gain from weaning) by compensatory growth during the grazing season. Similarly, for steers released to pasture on 12 Dec, weight loss was 38 lb for those fed only sorghum hay, while those also fed CSM lost only 7 lb ($P < .01$). However, in this case the weight difference persisted (293 *vs* 264 lb, $P = .066$) throughout the grazing season.

Average daily gain on pasture (total pasture gain / total pasture steer-days) was regressed on initial and final stocking rates in terms of both number of steers and weight of steers for continuously grazed pastures, which were all stocked on 28 Nov. The best relationship was with initial steers / ac in terms of intercept and slope ($a = 3.27 \pm .081$, $b = -0.54 \pm .033$) and fit statistics ($r^2 = .993$, $MSE = 6.07 \times 10^{-4}$). The value of the intercept may be regarded as an estimate of maximum ADG that can be achieved under these grazing conditions.

Data from frontal grazing pastures, where grazing began on 12 Dec, did not fit well with the data from continuously grazed pastures, probably because of the difference in date of grazing onset. Regressing data for pasture ADG on an overarching term, steer-days / ac, brought all six pastures into a single equation with good fit statistics ($r^2 = .921$, $MSE = 34.1 \times 10^{-4}$; $P < .01$) and reasonable intercept and slope ($a = 2.86 \pm .138$, $b = -.0021 \pm .00030$).

Overton

Each of eight pastures was stocked with four Bonsmara × Beefmaster steers, one Brahman steer, and sufficient Simmental, Angus, and Bonsmara crossbred steers, designated as 'grazers', to achieve desired stocking rates. A few additional young cattle, including heifers, were added to some pastures during the spring flush of growth.

Table 1 shows ADG means for Bonsmara × Beefmaster steers and for all cattle during the grazing season. Weight gain for one Bonsmara × Beefmaster steer on a moderately-stocked, continuously-grazed pasture was more than three standard deviations greater than the mean of other Bonsmara × Beefmaster steers in that pasture, and that datum was not used in calculating the means in Table 1 nor in the statistical analyses.

Increased stocking rate decreased ADG between .3 and .4 lb ($P < .01$). Qualitatively, such a result is almost universally observed. The advantage of continuous grazing over rotational grazing ($P = .045$) was somewhat surprising and, among Bonsmara × Beefmaster steers, was more distinct at the higher stocking rate. In a two-day residence and 14-d deferment rotation schedule, cattle are confined to only 12.5 % of the total pasture. And depending upon grazing pressure, cattle are forced to consume leaf-stem components that may not be selected under a continuous stocking system of ad libitum selection of diet. Thus, cattle adopt different behavior of diet selection and the potential differences in DM intake and/or nutritive value of diet would be accentuated at higher stocking rates and lead to the results found here.

Pasture ADG was regressed on steer-days / ac. Intercept, slope, and goodness of fit statistics were all similar to those from the Uvalde experiment, i.e., $a = 2.94 \pm .077$ ($P < .01$), $b = -.0026 \pm .00033$ ($P < .01$), $r^2 = .908$, $MSE = 40.1 \times 10^{-4}$. The constant and coefficient in each local equation are within the standard error range of the other equation, indicating a close similarity in the gain responses to stocking rate at Overton and Uvalde.

Combined data

Merged data for pasture ADG and steer-days / ac from Overton and Uvalde are shown graphically in Figure 1. The relationship is described by the equation, $ADG = 2.82 (\pm .045) - .0020 (\pm .00013) \times$ steer-days / ac ($r^2 = .952$, $MSE = 43.4 \times 10^{-4}$). Undoubtedly the strength of the relationship between data from two locations is supported by the use of experimental animals from a single source. However, it also requires pastures of similar forage quality and productivity. This equation, when coupled with economic market data, can provide a helpful tool for setting stocking rate for maximum profit at acceptable levels of risk.

Of the 56 pairs of steers identified in NM, 47 pairs were available for comparison at the end of the grazing season. Average weight gains on pasture were 348 and 352 lb at Overton and Uvalde, respectively, but averages for ADG were 2.44 and 2.06 lb ($P < .01$). The higher ADG at Overton compared to almost equal total gains at the two

locations is explained by the shorter grazing season at Overton.

Implications

Very similar strong equations relating steer performance on winter pasture to stocking rate were independently derived from data gathered at two locations. Therefore, the equation derived from combined data, i.e., ADG = 2.82 – .0020 × steer-days / ac, takes on a robust quality that allows its use with economic market data to calculate levels of profit at various levels of risk for a winter grazing enterprise.

Table 1. Effect of stocking rate and grazing method on ADG (pounds) by Bonsmara × Beefmaster steers and by all cattle grazing rye – ryegrass pastures at Overton.

	Bonsmara × Beefmaster steers			All cattle		
Stocking Rate	Grazing Method			Grazing Method		
	Continuous	Rotational	Mean[1]	Continuous	Rotational	Mean[1]
Low	2.69	2.65	2.67[a]	2.59	2.48	2.53[a]
Moderate	2.41	2.22	2.31[b]	2.26	2.14	2.20[b]
Mean[2]	2.54[c]	2.43[d]	2.49	2.42[c]	2.3[d]	2.37

[1] Means with different letter superscripts are statistically different ($P < .01$).

[2] Means with different letter superscripts are statistically different ($P = .045$).

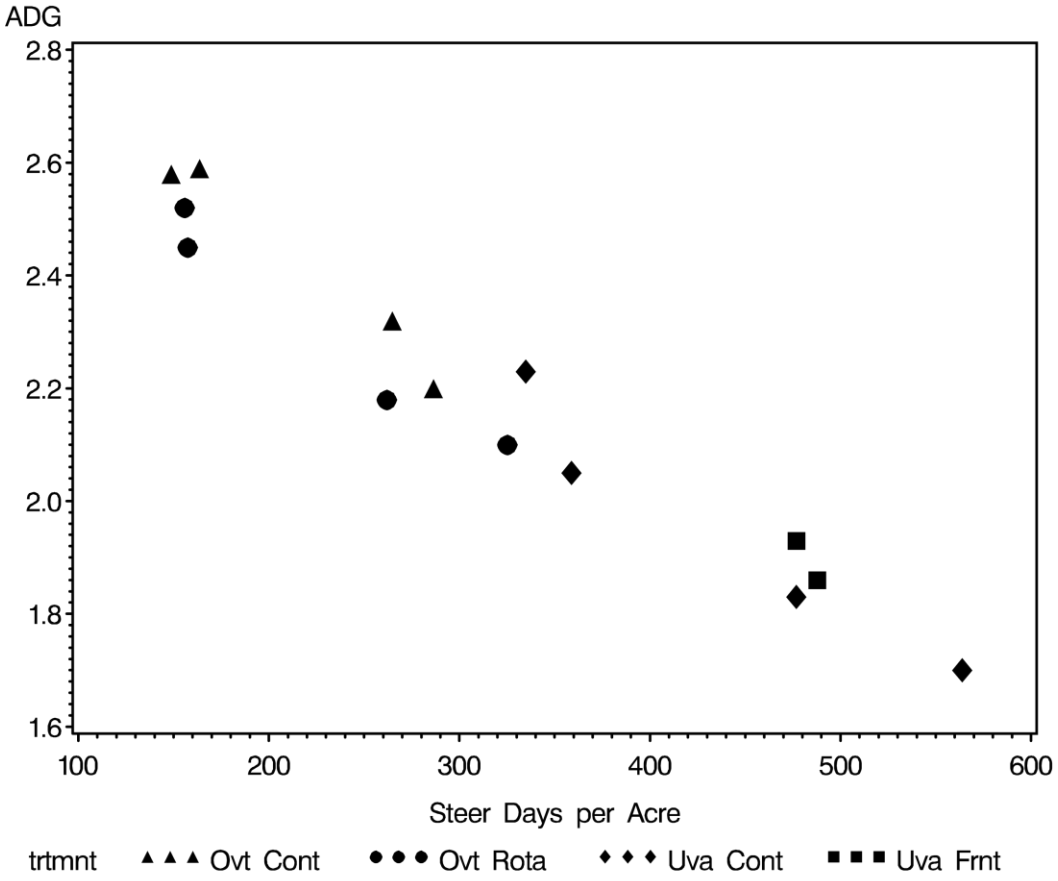

Figure 1. Pasture ADG related to steer-days per acre. The positions of continuous (Ovt Cont) and rotational grazing (Ovt Rota) treatments and continuous (Uva Cont) and frontal grazing (Uva Frnt) treatments are depicted in the graph.

PHYSIOLOGY

INFLUENCE OF TEMPERAMENT AND TRANSPORTATION ON RECTAL TEMPERATURE AND SECRETION OF CORTISOL, EPINEPHRINE AND NOREPINEPHRINE

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Summary

Automated blood collection devices were programmed to collect samples before and during transportation from the 8 calmest (temperament score = 0.84 ± 0.03) and 8 most temperamental (temperament score = 3.37 ± 0.18) 10-month-old Brahman bulls from our 2008 calf crop. Bulls were fitted with indwelling jugular catheters and rectal temperature recorders, and loaded onto a trailer which remained stationary for 120 min before transportation. Bulls were transported for 240 min (224 mi roundtrip). Rectal temperature increased over time but was not affected by temperament. Cortisol concentration increased in Calm but not Temperamental bulls in response to transportation. Epinephrine concentration remained unchanged in Calm but decreased in Temperamental bulls throughout the sampling period. Norepinephrine concentration was not affected by transportation or temperament. Although some changes in stress hormone secretion were attributable to handling and temperament, the transportation process did not result in similar responses between temperament groups.

Introduction

Transportation is a common management procedure that young beef cattle may experience. Divergent conclusions regarding the effect of transportation on secretion of the stress-related hormone cortisol have been reported (Murata et al., 1987; Blecha et al., 1984; Buckham Sporer et al., 2007; Burdick et al., 2008). For example, Murata et al. (1987) found an increase in cortisol following a 4-hr transport. However, following an 8-transport cortisol concentration did not differ between the transported calves and the non-transported control calves (Blecha et al., 1984). The authors suggested that cortisol concentration increased in response to transport and then decreased by the time the post-transport samples were obtained (Blecha et al., 1984). To overcome that challenge, we utilized automatic sampling devices (IceSampler™) to determine in 'real-time' whether endocrine indices of stress responsiveness change during transportation, and if these changes were related to temperament.

Experimental Procedures

For this study, 10-month-old Brahman bull calves from the Texas AgriLife Research Center in Overton were selected based on temperament score measured 28 days prior to weaning. Temperament score is an average of exit velocity and pen score (Curley et al., 2006; King et al., 2006). Exit velocity is an objective measurement which records the rate (m/s) at which cattle exit a working chute (Burrow et al., 1988; Curley et al., 2006). Pen score (Hammond et al., 1995) is a subjective measurement in which cattle are separated into small groups of 3-to-5 and their reactivity to a human observer scored on a scale of 1 (calm, docile, approachable) to 5 (aggressive, volatile, crazy). Based on temperament score the 7 most Calm (temperament score = 0.84 ± 0.03) and the 8 most Temperamental (temperament score = 3.37 ± 0.18) were selected from a pool of 60 bulls. Prior to transportation the bulls were fitted with indwelling jugular catheters and rectal temperature recorders. Bulls were loaded into a trailer with individual stalls, and the trailer remained stationary for 120 min to allow bulls to acclimate to their stall. The 120-min acclimation period also allowed for the subsequent discrimination of the response to transportation versus the combined response of loading plus transportation. After initiation of transportation at Time 0, bulls were transported for 240 min (224 mi roundtrip, 56 mph average speed). Whole blood was collected into heparinized syringes and plasma isolated and stored at -80°C until radioimmunoassay for cortisol and enzyme-immunoassay for the catecholamines epinephrine and norepinephrine. Plasma creatinine concentrations were also determined by enzyme-immunoassay to correct for possible sample dilution by the anticoagulant solution during collection of samples by the automated IceSampler™ device (IceRobotics, Roslin, Midlothian, Scotland UK). Therefore, the data for each stress-related hormone (e.g., cortisol, epinephrine and norepinephrine) are presented as a ratio of the concentration of the hormone relative to the concentration of creatinine in each blood sample.

Results and Discussion

Rectal Temperature

Rectal temperature increased (Figure 1; $P < 0.01$) in both Calm and Temperamental bulls throughout the experiment (prior to and during transportation). The

increases in rectal temperature during transport may be partially explained by the temporal elevation in ambient temperature as these indices were highly correlated ($r = 0.73$ and $r = 0.72$, $P < 0.001$ for Calm and Temperamental bulls, respectively). Rectal temperature during transport was not affected by temperament. This is in contrast with our previous report that rectal temperature increased during the first 30 min of transportation (Burdick et al., 2008). However, in our previous study there was no rest for the cattle between the time they were loaded onto the trailer and the initiation of transportation. Therefore, the initial increase in rectal temperature during transportation previously reported may be associated more with the process of boarding the trailer than solely with the act of transportation.

Cortisol, Epinephrine, and Norepinephrine Concentrations

Cortisol concentrations increased in Calm bulls ($P < 0.05$) in response to the initiation of transportation, and remained elevated throughout transportation (Figure 2). In contrast, cortisol concentrations in Temperamental bulls did not change in response to transportation. Epinephrine concentrations in Calm bulls remained relatively constant throughout the experiment whereas the epinephrine concentrations in Temperamental bulls decreased ($P < 0.05$) throughout the experiment (Figure 3). The concentrations of cortisol and epinephrine were greater in Temperamental bulls than Calm bulls, an observation that is consistent with previous reports from our laboratory (Curley et al., 2006; 2008; Burdick et al., 2008). Concentrations of norepinephrine were not affected by transportation or by temperament (data not shown).

Implications

The use of a remote sampling device enabled us to monitor specific endocrine indices that purportedly reflect transportation-induced stress in cattle. The resultant data indicate that transportation only affected cortisol concentrations in Calm bulls. Temperamental bulls may have not been affected due to their high cortisol concentrations prior to the initiation of transport. Although some changes in hormone secretion were attributable to handling and temperament, transportation did not result in similar responses between temperament groups. Future research needs to elucidate the potential influence of temperament on stress responses to loading, transporting and unloading beef cattle.

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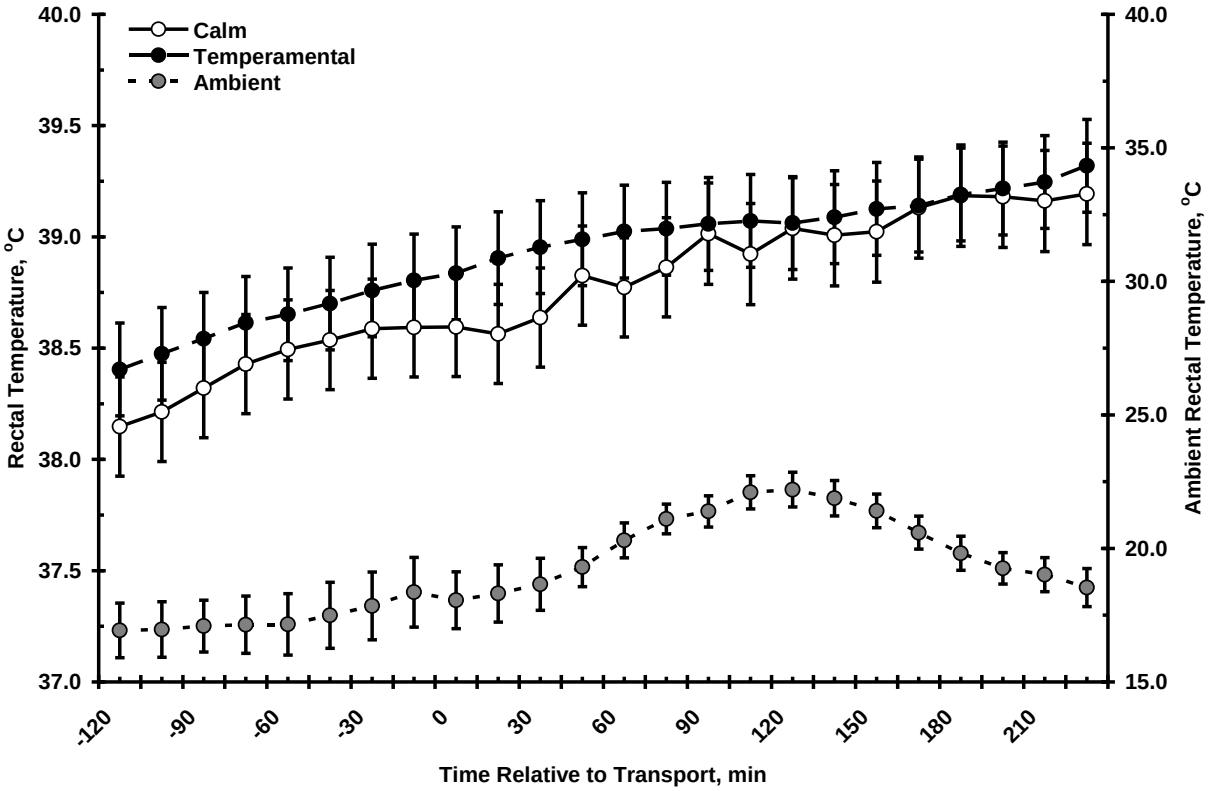

Figure 1. Rectal and ambient temperature prior to and during transportation. Transportation was initiated immediately after the Time 0 data collection. Rectal temperature increased ($P < 0.01$) in all bulls throughout the experiment and was not affected by temperament. Ambient temperature similarly increased through 135 min when it then decreased over the remainder of the transportation period.

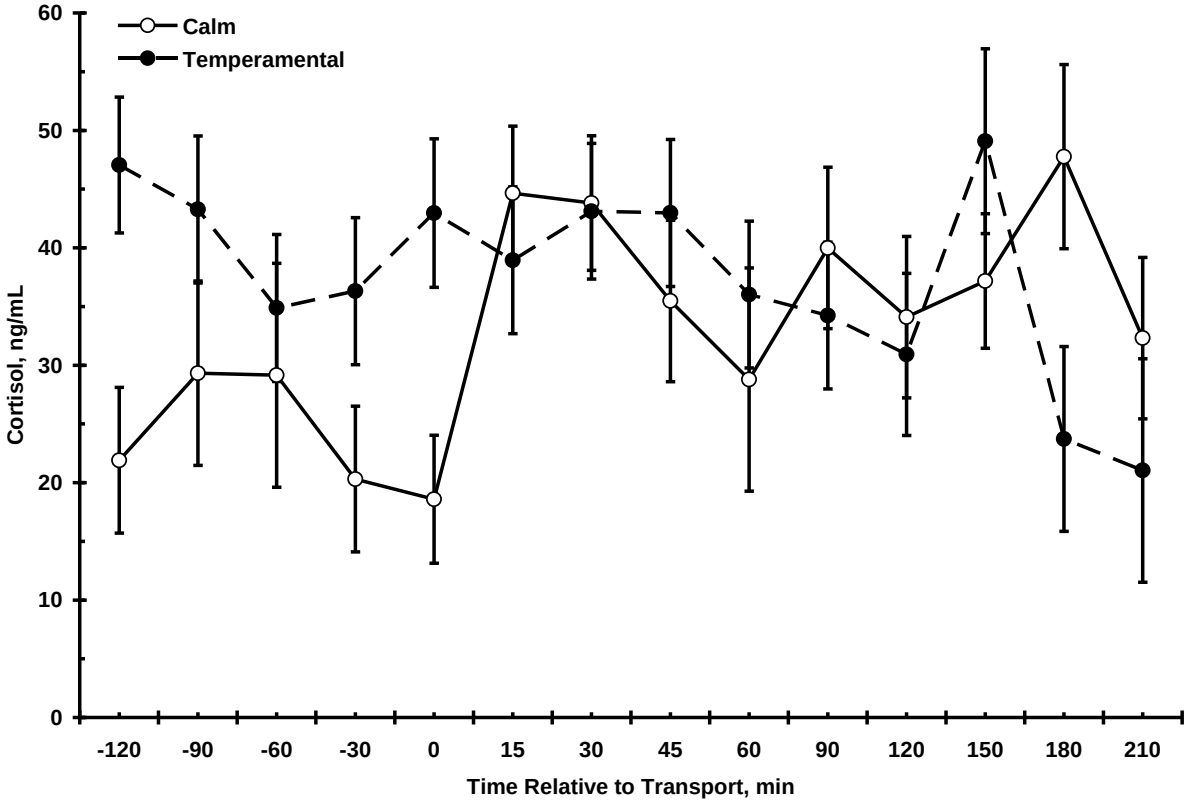

Figure 2. Plasma cortisol concentration prior to and during transportation. Transportation was initiated immediately after the Time 0 data collection. Plasma cortisol concentration increased in Calm bulls ($P < 0.05$) in response to transportation and remained elevated throughout the remainder of transportation period. In contrast, Temperamental bulls maintained consistent concentrations of cortisol throughout the transportation period.

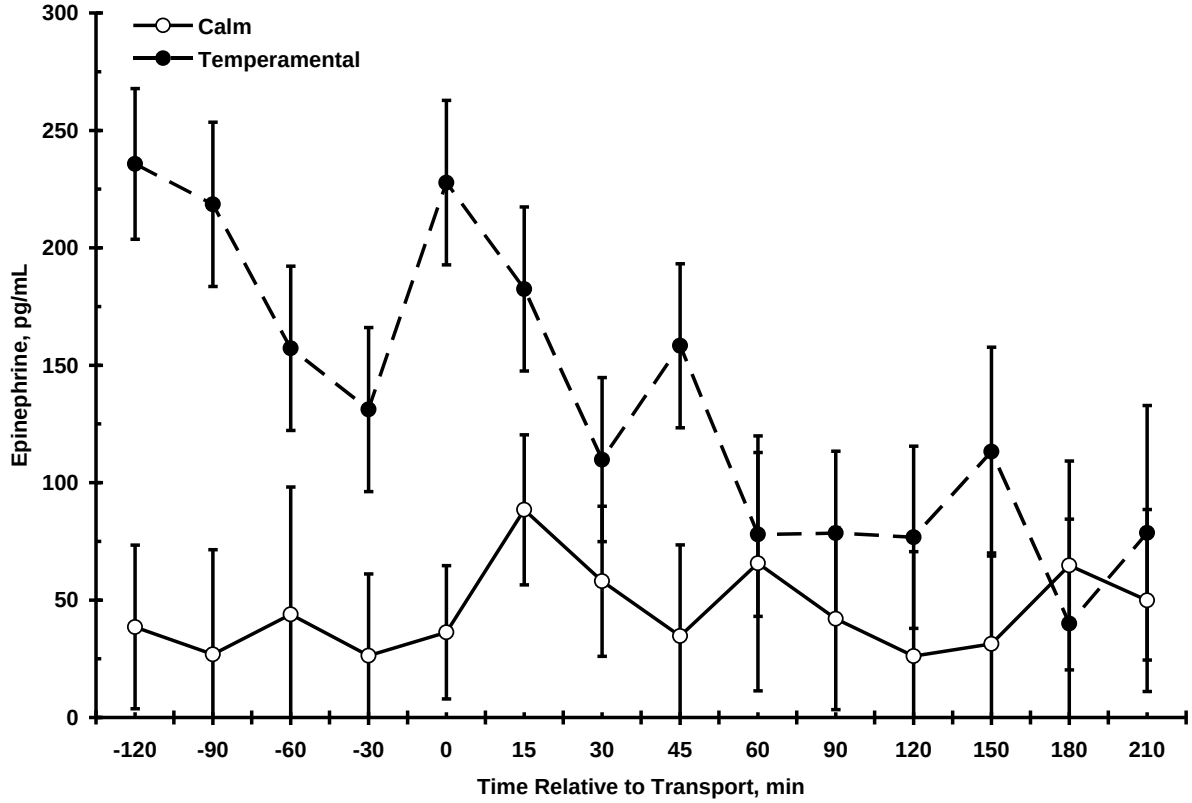

Figure 3. Plasma epinephrine concentration prior to and during transportation. Transportation was initiated immediately after the Time 0 data collection. Plasma epinephrine concentration in Calm bulls remained consistent throughout the sampling period. In contrast, plasma epinephrine concentration in Temperamental bulls decreased throughout the study ($P < 0.05$)

THE EVOLUTION OF EXIT VELOCITY IN THE SUCKLING BRAHMAN CALF

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Summary

The purpose of this study was to assess changes in exit velocity (EV) of Brahman calves from 21 d of age (DOA) to 56 d post-weaning (231.30 ± 1.23 DOA). Spring born calves (n = 308) from 2006-2008 were sired by 18 bulls. Calf EV (m/s) was determined as the rate of speed of a calf traversing 1.83 m after being released from a chute. Differences in EV were observed between the 2006 compared to the 2007 and 2008 calves, but the 2007 and the 2008 calves did not differ. The random effect of sire approached significance and accounted for some of the variation observed. Exit velocity increased as DOA increased. Exit velocity of Temperamental calves increased at a faster rate with age compared to Intermediate and Calm calves. Exit velocity is a useful and viable indicator of temperament classification. Results suggest that Temperamental calves increase their EV at a faster rate and may be identified prior to weaning.

Introduction

Temperament is described as the reactivity of cattle to humans and to novel environments (Fordyce et al., 1988). The increased cost associated with the potential for more excitable or temperamental cattle to injure themselves, workers and facilities, in addition to the negative effects of temperament on growth, immunity and carcass characteristics, motivates selection against more temperamental cattle (Voisinet et al., 1997; Fell et al., 1999; King et al., 2006; Cooke et al., 2009). Temperament is most often measured at weaning, and therefore most of the published literature has focused on the effects of temperament during the early pre-weaning and post-weaning period. Burdick et al. (2009) demonstrated that exit velocity **(EV)** can be measured at an earlier age (21 to 24 d of age), yet EV measurements made that early predicted temperament at weaning in less than 60% of the calves. Therefore, this study was designed to investigate the evolution of EV in calves from 21 d of age **(DOA)** through 56 d post-weaning (i.e., 231.30 ± 1.23 DOA).

Experimental Procedures

This study utilized 308 Brahman calves sired by 18 bulls, born in 2006 (60 male and 56 female), 2007 (54 male and 55 female) and 2008 (45 male and 38 female). Calves were weaned at average ages of 173 ± 2, 174 ± 2, and 163 ± 2 DOA for 2006, 2007, and 2008, respectively. All procedures were approved by the Institutional Animal Care and Use Committee of Texas A&M University.

Exit velocity was measured as an indicator of temperament as previously described by Curley et al. (2006). Exit velocity data are presented as m/s. Exit velocity was measured between 21 to 24 DOA and at 28-d intervals through 56 d post-weaning (n = 8-10 records per calf; Burrow et al., 1988; Curley et al., 2006). All EV measurements were carried out in one facility in which the calves were isolated temporarily from the sight of but not hearing range of their dams.

To determine if EV change over time was different relative to temperament classification (Calm, Intermediate, Temperamental), calves were ranked from lowest to highest (best to worst temperament) based on a direct average of values for EV and pen score (Hammond et al., 1995; temperament score; Burdick et al., 2010) measured 28 d prior to and at weaning. Ranking based on temperament score was performed within each year. Based on temperament score the calves were grouped into temperament classifications. Calm calves were those 1 SD lower than the mean (n = 76; 1.21 ± 0.02), Temperamental calves were those 1 SD greater than the mean (n = 76; 2.88 ± 0.04), and Intermediate calves were all remaining calves (within mean ± 1 SD; n = 156; 1.96 ± 0.03).

Within each year calves were ranked by EV at specific data collection times: 21 to 24 DOA, approximately 90 DOA (89.9 ± 0.5 DOA), weaning (175 ± 1 DOA) and 56 d post-weaning (231.30 ± 1.23 DOA). Calves were assigned to one of three temperament classifications based upon EV at each specific data collection time: Calm calves were those 1 SD lower than the mean for EV (0.34 ± 0.02 m/s, n = 44; 0.94 ± 0.07 m/s, n = 42; 0.87 ± 0.04 m/s, n = 57; 0.92 ± 0.05 m/s, n = 50 for 21 to 24 DOA, 90 DOA, weaning, and 56 d post-weaning, respectively), Temperamental calves were those 1 SD greater than the mean for EV (2.66 ± 0.07 m/s, n = 56; 3.71 ± 0.10 m/s, n = 44; 3.74 ± 0.07 m/s, n = 58; 3.80 ± 0.08 m/s, n = 49 for 21 to 24 DOA, 90 DOA, weaning, and 56 d post-weaning, respectively), and Intermediate calves were all others (within mean EV ± 1 SD; 1.15 ± 0.03 m/s, n = 208; 1.93 ± 0.05 m/s, n = 221; 2.05 ± 0.05 m/s, n = 193; 2.12 ± 0.05 m/s, n = 209 for 21 to 24 DOA, 90 DOA, weaning, and 56 d post-weaning, respectively).

Results and Discussion

The distribution of calves in temperament classifications did not differ from X^2 expectation ($P > 0.05$) at any time point. Approximately 15.7% were expected to be in the Calm group (determined by dividing total observations classified as Calm by the total number of observations), 67.5% were expected to be in the Intermediate group, and 16.8% were expected to be in the Temperamental group. Spearman rank order correlations were also determined between EV at 21 to 24 DOA, 90 DOA, weaning, and 56 d post-weaning. Spearman rank correlation values decreased as the number of days between EV measurements increased.

Average of EV across all dates differed across years, with the 2006 calves having a greater average EV (2.23 ± 0.06 m/s; $P < 0.001$) compared to calves in 2007 (1.90 ± 0.06 m/s) and 2008 (1.83 ± 0.06). There was no difference in EV between calves in 2007 and 2008 ($P = 0.75$). There was no difference in EV between bulls and heifers ($P = 0.18$; 1.91 ± 0.08 m/s and 2.02 ± 0.09 m/s, respectively). A study with Braford, Simmental x Red Angus, Red Brangus, Simbrah, and Tarentaise x Angus breeds, has reported that heifers had a greater temperament score than steers (Voisinet et al., 1997). Burdick et al. (2009) did not find an effect of sex on EV at either at 21 to 24 DOA or at weaning in Brahman calves. In the current study the random effects of sire ($P = 0.07$) and calf within sire ($P < 0.001$) explained substantial variation in EV; thus suggesting additive genetic variation for EV in this population.

Exit velocity increased as DOA increased (slope estimate = 0.0029 ± 0.0002; $P < 0.001$). These data are in agreement with our earlier work (Burdick et al., 2009) which demonstrated that EV at weaning was greater than at 21 to 24 DOA. The current study is apparently one of the first to document and assess temporal changes in EV in suckling beef calves.

The variable "temperament group" was analyzed to determine differences in EV based on temperament at weaning. Analysis revealed that the EV of Temperamental calves increased at a faster rate ($P < 0.001$; Figure 1; slope estimate = 0.005 ± 0.0004 m/s each day) compared to Intermediate (slope estimate = 0.003 ± 0.0005 m/s each day; $P < 0.001$) and Calm calves (slope estimate = 0.00007 ± 0.0005 m/s each day; $P < 0.001$). Therefore, not only did Temperamental calves have a greater EV at 21 to 24 DOA, their EV increased at a faster rate than did the EV of Calm and Intermediate calves.

The use of EV to determine temperament of cattle is simple to implement and is safe for both cattle and workers (Burrow, 1997; Müller and Keyserlingk, 2006). Exit velocity can be determined without restricting animal movement, in contrast to other methods including chute score and determination of eye white percentage (Grandin, 1993; Core et al., 2009).

Implications

In conclusion, EV increases over time in suckling Brahman calves and was not affected by sex of calf. Calf sire may account for some variability in EV. Exit Velocity of Temperamental calves increased at a faster rate compared to the EV of Calm and Intermediate calves. Results of the current study suggest that temperament may be identified prior to weaning using EV, which may enhance the ability of producers to select against temperamental animals.

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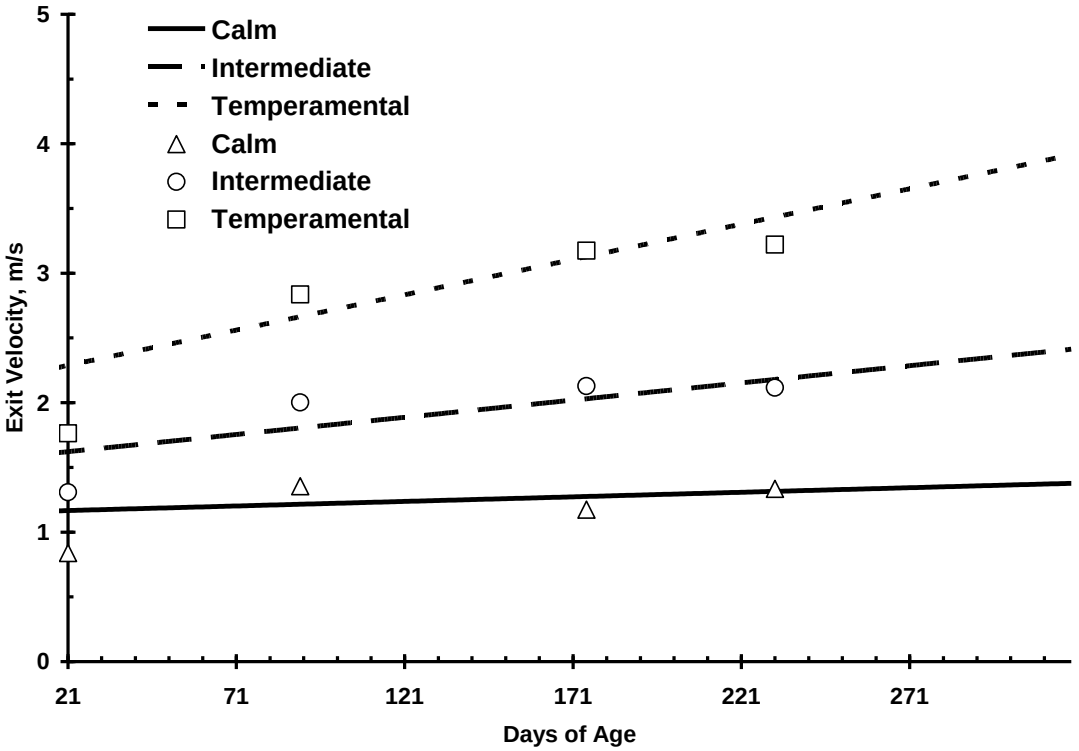

Figure 1. Change in exit velocity (EV) over days of age by temperament group in Brahman calves. Exit velocity, the rate of speed of a calf traversing a distance of 1.83 m after its exit from a working chute, was determined using two infrared sensors (FarmTek Inc., North Wylie, TX) and was done by calculating velocity [velocity = distance (m) / time (s)]. Exit velocity data are presented as m/s. Exit velocity was measured between 21 to 24 d after birth and at 28-d intervals through 56 d post-weaning. Calves were grouped into temperament groups based on temperament score (average of EV and pen score) measured 28 d prior to weaning. Calm: n = 76, slope estimate = 0.0007 ± 0.0005; Intermediate: n = 156, slope estimate = 0.003 ± 0.0005, and Temperamental: n = 76, m = 0.005 ± 0.0004 (temperament group $P < 0.001$). Average EV at 21 to 24 DOA, approximately 90 DOA (89.9 ± 0.5 DOA), weaning (175 ± 1 DOA) and 56 d post-weaning (231.30 ± 1.23 DOA) represented by triangles (Calm), circles (Intermediate), and squares (Temperamental).

INFLUENCE OF TROPICAL ADAPTATION ON CONCENTRATIONS OF INSULIN-LIKE GROWTH FACTOR-I IN PUREBRED AND CROSSBRED BEEF CATTLE

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Summary

In an effort to determine whether tropical adaptation influences circulating concentrations of the growth related hormone insulin-like growth factor-I (IGF-I), three-breed diallel matings were conducted using temperate *Bos taurus* (A; Angus), tropical *Bos indicus* (B; Brahman), and tropical *Bos taurus* (R; Romosinuano). Purebred (AA, BB, RR) and crossbred (ABX, ARX, BRX) heifers and steers were evaluated in two separate calf crops from the years 2003 and 2004. Blood samples were obtained from 10 heifers of each breed group (n= 90) for each year at weaning and on days 0 and 84 of post-weaning trials. Samples were also taken from 10 steers of each breed group (n= 90) at weaning and on days 0 and 60 of individual finishing phase feeding trials for each year. Concentrations of IGF-I were determined by radioimmunoassay. Breed differences in IGF-I were observed ($P < 0.05$). Relative to the temperate *Bos taurus* breed, plasma concentrations of IGF-I were greater in male and female tropically-adapted breed groups.

Introduction

Due to an abundance of forage, a large number of the US cow herd is located in the hot and humid Gulf Coast region. While many temperate breeds struggle, tropically adapted breeds of cattle thrive in these areas. The objective of this research was to assess the influence of breed on plasma concentrations of IGF-1 in purebred and crossbred Angus, Brahman, and Romosinuano (a tropically-adapted *Bos taurus* breed) steers and heifers. IGF-I is a polypeptide growth hormone responsible for regulating a variety of cellular processes associated with growth. Concentrations of IGF-I are moderately to highly heritable (Davis and Simmen, 2000) and studies have shown that IGF-I has favorable correlations with several traits that are economically important in beef cattle (Wood et al., 2004). Previous studies have reported higher concentrations of IGF-I in *Bos indicus* breeds when compared to *Bos taurus* breeds (Simpson et al., 1997).

Experimental Procedures

Animals and Experimental Design

All management and procedures involving cattle were performed at the USDA-ARS Subtropical Agricultural Research Station (STARS) in Brooksville, Florida as described by Riley et al., (2007). Purebred Romosinuano, Brahman and Angus cows were exposed in approximately equal numbers to bulls of all three breeds in single-sire breeding herds. Calf breed groups consisted of 3 purebred groups and 6 crossbred groups (considering reciprocals as distinct groups; e.g., Brahman-sired calves out of Romosinuano dams and Romosinuano-sired calves out of Brahman dams represented 2 of the crossbred groups). Calves were born from late December to early April in each year. Shortly after birth, all calves were individually identified by tattoo and ear tag and male calves were castrated. Both steers and heifers were weaned at approximately 7 mo of age. All heifers remained in Brooksville for the duration of the study. Steers were shipped to the USDA Agricultural Research Station (ARS), El Reno, OK for stocker grazing and individual finishing phase feeding trials. Blood samples were obtained via venipuncture from 10 heifers of each breed group of pure-and cross-bred cattle (n= 90 for each year) at weaning and on days 0 and 84 of each post-weaning trial period (2003 and 2004). Samples were also taken from 10 steers of each breed group of pure-and cross-bred cattle (n= 90 for each year) at weaning and on days 0 and 60 of the finishing phase feeding trials (2003 and 2004).

IGF-I Concentration

Plasma was harvested from blood samples collected via venipuncture. Concentrations of IGF-I were determined by radioimmunoassay using anti-hIGF-I (AFP4892898, A.F. Parlow, National Hormone and Peptide Program, Torrance, CA).

Statistical Analysis

Analysis of variance, specific for repeated measures, was conducted using the mixed model procedure of SAS (2002) for analysis of year and breed effects on concentrations of IGF-I. The model included year, breed group and year X breed group interaction. Preliminary analyses indicated that there were no differences in concentration of IGF-I between reciprocal crossbred groups at the different sampling times; therefore reciprocals were combined into one group per cross (ABX, ARX, BRX) for final analyses. Separate analyses were conducted for heifers and steers. Probability values of less than 0.05 were considered statistically significant.

Results and Discussion

Differences in plasma concentrations of IGF-I from all sampling dates are summarized in Table 1. Breed was an

important source of variation among heifers at weaning ($P < 0.003$). Purebred temperate AA exhibited the lowest values of IGF-I compared to all other breeds ($P < 0.02$). Crossbred heifers (ARX and ABX) did not differ in concentrations of IGF-I ($P = 0.38$). Tropically adapted BB and RR did not differ ($P = 0.93$) but both were higher than temperate AA ($P < 0.0001$). The crossbred BRX had the highest circulating concentration of IGF-I. Although BRX did not significantly differ from BB ($P = 0.4$) or RR ($P = 0.46$), the tropically adapted crosses had higher concentrations than the temperate x tropical crosses ($P < 0.0006$). Thus, the tropically adapted purebred and crossbred heifers exhibited greater concentrations of IGF-I at weaning.

Results from d 0 of the heifer post-weaning growth studies varied slightly from data obtained at weaning. Breed was an important source of variation ($P < 0.001$). Temperate AA had lower concentrations of IGF-I compared to all breed groups ($P < 0.02$) except the *Bos taurus* crossbred ARX ($P = 0.50$). The purebred RR and BB along with crossbred ABX and BRX did not differ but all were higher than both *Bos taurus* AA and ARX ($P < 0.02$).

Breed was also an important source of variation at d 84 post weaning ($P < 0.001$). All purebred breed groups had lower concentrations compared to the crossbreds. The temperate AA did not differ from BB but was lower than all other breed groups ($P < 0.03$). Although the ranking of breed groups does change over time, the temperate, *Bos taurus* AA consistently had the lowest concentraions of IGF-I throughout the sampling dates.

Similar results were observed among the steers. Breed was an important source of variation at weaning ($P < 0.007$). Temperate AA had a lower concentration of IGF-I compared to all other breed groups ($P < 0.003$). The crossbred ABX and ARX did not differ although both were lower than the tropically adapted crosses ($P < 0.003$). There were no differences observed between the tropically adapted purebred; BB, RR and crossbred BRX.

No differences were observed in concentrations of IGF-I at d 0 of the individual finishing phase feeding trials. Mean IGF-I in ng/mL ranged from 176.23 to 200.09. The lack of difference in concentration of IGF-I is perhaps due to individual variabilty at the onset of the finishing phase. Although, similar to data odtained from the heifers, temperate *Bos taurus* AA exhibited lower concentrations of IGF-I compared to the tropically adapted breed groups ($P > 0.05$).

Results from d 60 of the finishing phase showed that temperate AA and the temperate-tropically adapted crosses, ABX and ARX, did not differ. All three had numerically lower average values compared to purebred BB but did not significantly differ. The tropically adapted BRX and RR did not differ from BB but were both significantly higher than the temperate AA steers ($P < 0.01$).

Relative to the temperate *Bos taurus* breed, plasma concentrations of IGF-I were greater in male and female tropically-adapted breed-types. Simpson et al. (1997) similarly found that Brahman cows have greater concentrations of IGF-I relative to Angus cows. This difference in concentration of IGF-I could possibly be due to a greater quantity of IGF binding protein 3 (IGFBP3) as Simpson et al. (1997) also reported that Brahman cows had greater IGFBP3 binding activity compared to Angus. Since IGF-I has not been reported to be stored in tissue, the pool being circulated by IGFBPs is the only form of storage for this growth promoting peptide. The IGFBP3 has a very high binding affinity for IGF-I, higher even than the type I IGF receptor (IGFR) (Baxter, 1986). This high binding affinity has been known to act in an inhibitory manner on the actions of IGF-I (Baxter, 1988). Presumably, the high concentrations of IGF-I detected in the tropically adapted breed groups may result from greater concentrations of IGFBPs.

Greater concentrations of GH among the tropically adapted breeds could also explain the increase in circulating IGF-I. This theory is less likely due to research that has demonstrated that concentrations of GH do not differ between cattle of varying frame size (Verde and Trenkle, 1986). In the same study, cattle of varying frame size did have differing concentrations of IGF-I. Perhaps the differences observed in concentrations of IGF-I are due to unstable numbers of hepatic GH receptors or inconsistent transcription post binding; thus explaining why cattle with similar concentrations of GH exhibit inconsistent growth patterns. It seems that the mechanisms controlling circulating concentrations of IGF-I are unclear.

Implications (86 of 100 limit)

Tropical adaptation influences circulating concentrations of IGF-I. Breed significantly influenced concentrations of IGF-I with both tropically adapted *Bos indicus* (Brahman), and *Bos taurus* (Romosinuano) cattle having elevated IGF-I, analogous to findings in previous reports (Simpson et al., 1997; Alvarez, 2000). Recent studies have targeted the use of concentration of IGF-I as a physiological indicator of performance, particularly relative to feed efficiency (Johnston et al., 2002). Results from this study suggest that further research is needed to fully understand the mechanisms that control circulating concentrations of IGF-I before implementing its use as a physiological indicator trait, especially across breedtypes.

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Table 1. Least Square Means for Plasma Concentrations of IGF-I

Heifers	AA	BB	RR	ABX	ARX	BRX
Wean IGF-I, ng/mL	[a]76.2 ± 6.8	[b]118.4 ± 6.8	[b]119.2 ± 6.8	[c]101.5 ± 4.8	[c]95.5 ± 4.8	[b]125.4 ± 4.8
d 0 IGF-I, ng/mL	[a]49.8 ± 4.7	[b]71.3 ± 4.7	[b]64.7 ± 4.7	[b]67.8 ± 3.3	[a]53.6 ± 3.3	[b]74.6 ± 3.3
d 84 IGF-I, ng/mL	[a]62.4 ± 6.1	[a,c]71.6 ± 6.1	[a,c]77.6 ± 6.1	[b]93.4 ± 4.2	[c]78.1 ± 4.2	[b,c]87.4 ± 4.2

Steers	AA	BB	RR	ABX	ARX	BRX
Wean IGF-I, ng/mL	[a]86.9 ± 9.1	[c]171.4 ± 9.1	[c]167 ± 8.6	[b]134.2 ± 6.4	[b]120.9 ± 6.4	[c]161.9 ± 6.3
d 0 IGF-I, ng/mL	[a]176.2 ± 11.5	[a]200 ± 11.8	[a]188.1 ± 11.2	[a]182.4 ± 8.8	[a]186 ± 8.7	[a]197.3 ± 8.8
d 60 IGF-I, ng/mL	[a]154.9 ± 10.8	[a,b]184 ± 11.4	[b]193.1 ± 10.5	[a]168 ± 7.8	[a]176.8 ± 7.7	[b]202.7 ± 7.9

[a, b, c] Means within each row that do not share a common superscript differ ($P < 0.05$).

EFFECT OF TEMPERAMENT ON CIRCULATING CONCENTRATIONS OF INSULIN-LIKE GROWTH FACTOR I (IGF-I) IN BRAHMAN CALVES

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Summary

The purpose of this study was to assess whether temperament is associated with circulating concentrations of insulin-like growth factor-I (IGF-I) in Brahman calves. Spring born Brahman calves from the years 2005, 2006, 2007 and 2008 were utilized. Samples from 10 calm, 10 intermediate and 10 temperamental calves of both sexes were chosen from each year. Temperament, determined by the average of exit velocity and pen score, was evaluated at weaning. Concentrations of IGF-I were determined by radioimmunoassay from serum samples collected 28d pre-weaning, at weaning, and on days 28 and 56 post-weaning (n = 240) during each year. Least squares means for the calm, intermediate and temperamental groups were 134.9ng/mL ± 3.4, 139.8ng/mL ± 3.3 and 130.1ng/mL ± 3.4, respectively. Although IGF-I has been positively linked to growth traits in beef cattle, no relationship was observed between temperament and circulating concentrations of IGF-I among Brahman calves.

Introduction

The concentration of circulating IGF-I is a quantitative and heritable (h = ~0.4) trait (Herd et al., 1995) that has been used successfully as a selection tool for improvement of economically important traits in both pigs (Bunter et al., 2002) and sheep (Blair et al., 2002). Johnston et al. (2001) found favorable correlations between the circulating concentration of IGF-I and beef cattle traits, such as live and carcass weight, carcass fatness and the feed efficiency measurements of ADG and residual feed intake (RFI). Temperament, defined as a fear response to handling, has been negatively linked to ADG (Fell et al., 1999) and beef carcass quality traits (Petherick et al., 2002; Voisinet et al., 1997b). Preliminary work from our lab suggests temperament may affect IGF-I in Brahman bulls (P = 0.04), with calmer bulls having higher concentrations of IGF-I (Figure 1; Matheney, 2009).

Experimental Procedures

Animals and Experimental Design

The larger sampling size in this experiment was intended to better assess the effects of temperament on circulating IGF-I. The preliminary study in Brahman bulls utilized 41 animals (calm = 16, intermediate = 15, temperamental = 10) and 1 sampling date. This sampling set consisted of a total of 960 samples. Spring born Brahman calves at the Texas AgriLife Research Station in Overton, TX from the years 2005, 2006, 2007 and 2008 were utilized. Samples from 10 calm, 10 intermediate and 10 temperamental calves of both sexes (n = 60) were chosen from each calf crop. During each year, samples were collected 28d pre-weaning, at weaning, and on days 28 and 56 post-weaning (n = 240). Body weights collected at weaning and the two dates post-weaning were used to calculate ADG.

Temperament

The objective measurement of exit velocity (Burrow et al., 1988; Curley et al., 2006) was used to measure in m/sec the rate at which each calf exited a squeeze chute and traversed a fixed distance of 1.83m. Pen scores (Hammond et al., 1996) were also assigned to each calf. Scores were given on a 1 (calm) to 5 (excitable) scale based upon the degree of aggressiveness exhibited towards a handler located inside a pen with a small group of calves (n=5). Both measurements were assessed at weaning. An overall temperament score for each animal was determined by averaging exit velocity and pen score. Each calf was then ranked as calm, intermediate or temperamental based upon 1 standard deviation above or below the mean temperament score.

Concentration of IGF-I

Serum was harvested from whole blood samples collected via venipuncture. Concentrations of IGF-I were determined by radioimmunoassay using anti-hIGF-I (AFP4892898, A.F. Parlow, National Hormone and Peptide Program, Torrance, CA).

Statistical Analysis

Analysis of variance, specific for repeated measures, was conducted using the MIXED model procedure of SAS (2002) for analysis of year and temperament effects on concentrations of IGF-I. Separate analysis was also conducted on the effects of temperament, year, and sex on concentrations of IGF-I at each sampling date. The bivariate correlation program of SPSS (SPSS Inc., Chicago, IL) was used to obtain Pearson correlation coefficients to test the strength of relationship between

ADG and IGF-I. Probability values of less than 0.05 were considered statistically significant.

Results and Discussion

In the repeated measures analysis, temperament had no significant effect on circulating concentrations of IGF-I in Brahman calves. Least squares means for the calm, intermediate and temperamental groups were 134.9ng/mL ± 3.4, 139.8ng/mL ± 3.3 and 130.1ng/mL ± 3.4, respectively. Year was an important source of variation (P< 0.0001). Least squares means from the 2005, 2006, 2007 and 2008 calf crops were 131.9ng/mL ± 3.6, 151.9ng/mL ± 4.7, 124.4ng/mL ± 3.3 and 131.6ng/mL ± 4, respectively.

Analysis of the effects of temperament, sex, and year on concentrations of IGF-I at each sampling date revealed, similar to the repeated measures analysis, that year of sampling affects concentration of IGF-I. Both weaning and the two post-weaning sample dates were significantly affected by year. Sex was an important source of variation among calves both pre-weaning (P = 0.0016) and at weaning (P = 0.0289). Pre-weaning and weaning concentrations of IGF-I among the bull calves were 171.51ng/mL and 149.33ng/mL, respectively. Heifers had lower concentrations for both sampling dates (152.62ng/mL; 137.99ng/mL). This difference in IGF-I between sexes is due, in part, to the greater growth potential of males compared to females. Concentration of IGF-I was positively correlated to ADG (r = 0.159, P = 0.014).

In the single analysis, temperament did significantly affect concentration of IGF-I at weaning (P = 0.0008) with the intermediate animals having higher concentrations than both the calm and temperamental groups. Temperament was not an important source of variation for any of the other sampling dates. Mean concentrations of IGF-I for all sampling dates separated by temperament classification are shown in Figure 2.

Implications

Although IGF-I has been positively linked to growth traits in beef cattle, no relationship was observed between temperament and circulating concentrations of IGF-I among Brahman calves. Year of sampling significantly affects circulating IGF-I, implying that the use of IGF-I as an early indicator of performance may not be beneficial.

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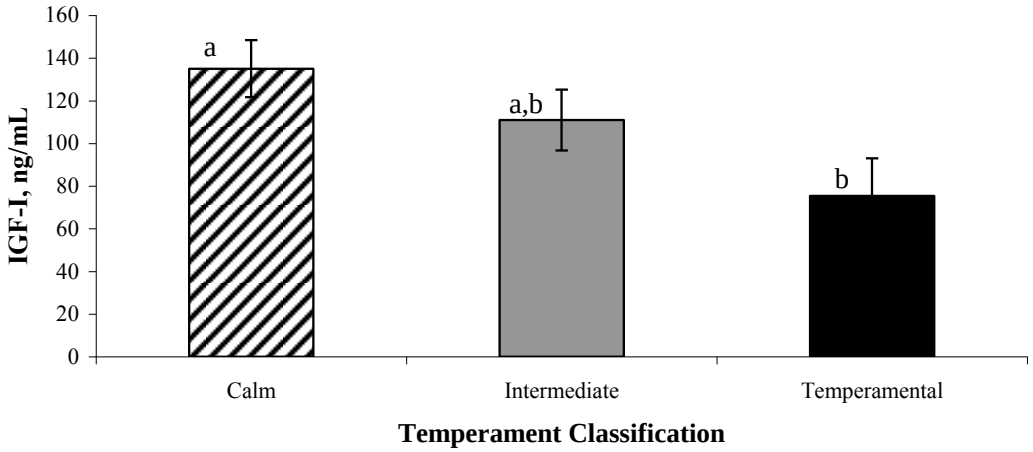

Figure 1. Mean concentrations of IGF-I at d 0 of a feeding trial in calm, intermediate, and temperamental Brahman bulls. [a,b]Means without a common superscript differ ($P < 0.05$).

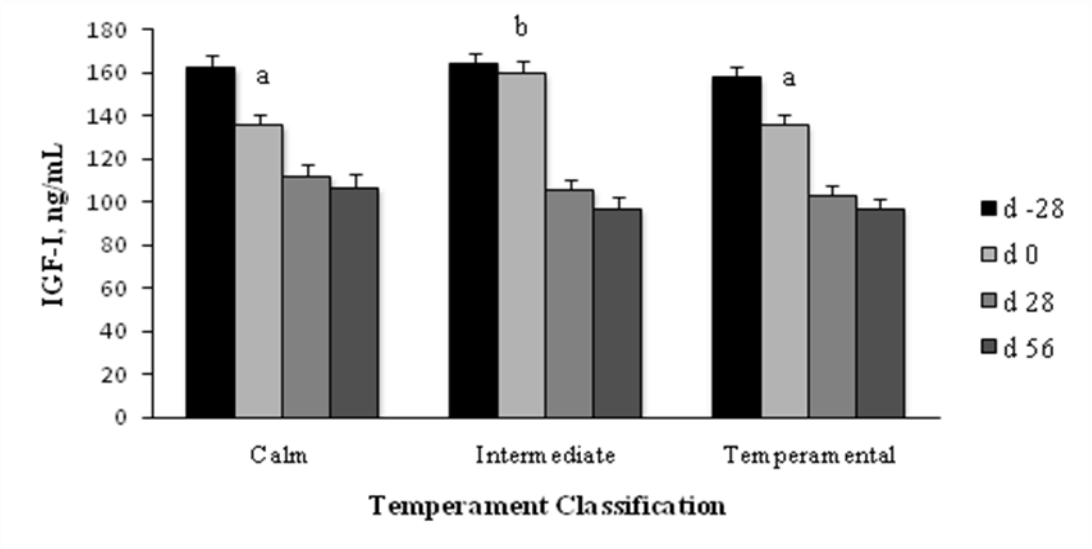

Figure 2. Mean concentrations of IGF-I at each sampling date in calm, intermediate, and temperamental Brahman calves. [a,b]Means across sampling dates without a common superscript differ ($P < 0.05$). Non-significant differences were omitted.

REPRODUCTION

THE USE OF SERIAL ULTRASOUND EVALUATION OF BODY COMPOSITION TRAITS TO PREDICT REBREEDING PERFORMANCE IN COMMERCIAL BEEF FEMALES

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Summary

Bos indicus influenced first calf heifers (n = 211) were evaluated multiple times to determine relationships between serial carcass ultrasound traits and ability to rebreed in a 45 day breeding season. Data collected included weight, body condition score, and carcass ultrasound traits: ribeye area (REA), intramuscular fat (IMF), and ribfat. Data were collected at four points of time: one year of age, initial pregnancy determination, prior to breeding after first calving, and after the subsequent breeding season when pregnancy status was simultaneously recorded. Predicting rebreeding success using methods of carcass ultrasound and conventional body condition evaluation were compared. Body composition measures with ultrasound can be used to quantify the likelihood of rebreeding success in first calf heifers. First calf heifers that rebred in a 45 day breeding season had greater ribeye area, intramuscular, and rib fat during certain physiological stages than their counterparts which failed to rebreed.

Introduction

The higher metabolic requirements in first calf heifers can compromise reproductive performance. The efficiency of first calf heifers that will rebreed for their second calf with minimal inputs is indicative to overall lifetime production efficiency. If the probability of rebreeding under challenging conditions could be quantified, the opportunities for value differentials, and the opportunity for replacement heifers to be sorted, managed, or culled accordingly exist. Cattle with shorter post partum intervals typically wean heavier calves, have lower risk of failing to conceive within the breeding season, and overall amplified profit margins. Body condition score has been used with a high degree of accuracy to influence reproductive performance. The objectives of this research were to study relationships between physiological changes and body compositional responses, and to compare the abilities of carcass ultrasound to body condition evaluation in predicting rebreeding performance in commercial first calf heifers.

Experimental Procedures

Commercial Brahman x Hereford heifers (n = 220) ranging in weight from 400 to 800 lbs were acquired from Nixon and Poteet, TX in January of 2006. Data such as birthdates were not available as is typical with the purchase of commercial replacement heifers. Cattle were exposed to Angus bulls and palpated for pregnancy in the fall of 2006. Open cattle (n = 76) were removed from the study and bred cattle calved between January and May of 2007. The breeding performance trait accessed was the ability for the first calf heifer to rebreed in the postpartum breeding season of 45 days. A summary of dates and data collection points relevant to the study are shown in Table 1.

Three ultrasound measurements of ribeye area (REA), 12th rib fat thickness (RibFat), and percent intramuscular fat (IMF) were collected by a single, certified ultrasound technician utilizing an ALOKA 500V ultrasound machine with a 17 cm 3.5 GHz probe and Biotronics Inc. (Ames, IA) software. Images were interpreted by the National CUP Lab in Ames, Iowa. In addition to ultrasound data, body condition scores (BCS) and weights were collected at the same times. Data collection points corresponded with yearling status or arrival, initial pregnancy determination, following calving, and at weaning of calves. Rebreeding status (1 = pregnant and 0 = open) as confirmed via reproductive ultrasound by a veterinarian was recorded with the last data collection point.

The trend of body composition values for all traits evaluated were examined among rebreeding class (1, 0), and across time. Logistic regression was used to evaluate rebreeding success (1, 0) as the dependent variable to determine which traits significantly impacted breeding success/failure. Objective measurements of weight and carcass ultrasound traits at each collection time were compared to the subjective, conventional method of body condition score evaluation to predict rebreeding success. Regression coefficients were used to generate prediction equations and resulting probabilities for rebreeding success.

Results and Discussion

Heifers that initially fell out of the study as they were diagnosed open in the fall for the initial breeding season differed from heifers that remained in the study with regard to weight ($P < 0.0001$) and REA ($P = 0.088$). These findings concurred with a study conducted on Angus cattle by Minick et al. (2001) who found that heavier yearling heifers were more likely to possess mature reproductive tracts at breeding than their lighter

weight contemporaries. Among cattle retained for the study and calved out, weaning weights, below or above the 312 pound average, of calves was investigated as a class variable to determine the influence of weaning weight on ultrasound traits and body condition score. Weaning weight influenced body condition score (P = 0.001) but did not influence IMF (P = 0.315), REA (P = 0.080), or ribfat (P = 0.496). There was a marginal trend for weaning status (whether a cow weaned her first calf or not) to impact BCS (P = 0.0822). Heifers that calved in the first half of the calving season (34%) differed from heifers that calved in the last half of the calving season in IMF at scans 1 (P = 0.0165), 2 (P = 0.0442), and 4 (P = 0.0457) and in REA at scan 3 (P = 0.0295).

Repeated Measures Analyses

Least squares means estimates are reported in Table 2. Cattle with a rebreeding status of 1 weighed more at scan time 4 than cattle with a rebreeding status of 0 ($P < 0.05$). Body condition score was lower ($P < 0.05$) in females that failed to rebreed at time 2 (6.2 vs. 6.7) and time 4 (4.6 vs. 5.2). Although body condition score was not found to be statistically different at time 3, cattle that rebred were able to maintain body condition relative to their counterparts, or their counterparts lost body condition to create a significant difference by scan 4. It is important to note that between scans 3 and 4, the lactation stress was the greatest, calves were growing, the first calf heifers were still growing, and it is probably the most critical time to lose body condition prior to breeding. These findings concur with previous research that suggests a threshold body condition score of 5 to 6 at calving is essential for cows to rebreed following parturition (Spitzer et al., 1995; Ciccioli et al., 2003; Lake et al., 2007).

Although in this analysis, IMF was not found to be statically different, on average, heifers that bred back had 3.27% IMF, but heifers that failed to breed back only had 2.79% IMF. The initial increase in IMF and then subsequent decreases concurs with literature published by Rouse et al. (2001) in Angus females scanned five times from yearling age to the weaning of their second calf. Cattle with a pregnancy status of 1 did not differ in ribeye area at times 1 and 3 (P = 0.370). Cattle that rebred had not decreased in ribeye area compared to cattle that failed to rebreed that may have compromised muscle loss to make up for increased metabolic. All cattle differed in ribfat at scan time 2 and 3 ($P < 0.001$), but ribfat did not differ at scans 1 and 4 (P = 0.066 and P = 0.549), respectively. Rouse et al. (2001) reported ribfat recovered in first calf heifers after the weaning of the first calf.

Logistic Regression - Ultrasound Traits

Among traits evaluated at scan time 1, the traits that impacted pregnancy status were IMF (P = 0.0253) and Ribfat (P = 0.0145). Among traits evaluated at scan 2, the only trait that impacted pregnancy status was ribfat (P <0.0001). After calving (scan 3), IMF impacted pregnancy (P = 0.0009). At scan 4, after the breeding season, REA impacted pregnancy (P = 0.012).

Actual rebreeding rate was 48%. Prediction models yielded probabilities of a successful rebreeding (pregnancy status of 1) to be 44%, 59%, 53%, and 57% at scan times 1, 2, 3, and 4, respectively, using carcass ultrasound traits as predictors. Relationships between the variation in significant carcass ultrasound traits and probability of rebreeding are expressed in Table 3 in the form of a matrix. Under the mean values of carcass ultrasound traits for this population, the probability of rebreeding ranges between 44 and 57% which corresponds to the observed rebreeding rate of 48%. Increases in IMF favored an increased likelihood for rebreeding status of 1 at a year of age and following calving. Similarly, increases in ribfat increase the probability for rebreeding yearling age and initial pregnancy determination, while the increase in ribeye area at scan 4 favored a heightened probability of rebreeding status of 1. Body composition differences between cattle that rebred versus cattle that did not were evident even at a year of age in terms of IMF and Ribfat. Those body compositional fat depots continued to remain different through the growing and calving stages for those heifers. A difference in ribeye area at weaning and immediately following breeding suggests that cattle with lactation stresses may have compromised body compositional stores of muscle to compensate.

Logistic Regression - Body Condition Score

Body condition scores were not taken at scan time 1. Body condition scores impacted pregnancy at significance levels of $P < 0.05$, at scan times 2 (P = 0.001), 3 (P = 0.0016), 4 ($P < 0.001$), and 30 days post parturition (BCS PP) (P = 0.001). This agrees with work done by DeRouen et al. (1994) who found that pre-partum body weight and condition fluctuations of increasing or decreasing up to one condition score ranging from BCS of 4–7 had lesser influence on reproductive performance than body condition at calving. De Rouen et al. (1994) concluded that cows in a body condition score of 6-7 had the shortest post partum interval while cattle with a body condition score of >5 had a shorter post partum interval than cows in body condition of 4. Cattle in the study published by DeRouen et al. (1994) were primiparous crossbred cows.

Prediction models yielded probabilities of a successful rebreeding (pregnancy status of 1) to be 49%, 49%, 50%, and 47% at scan times 2, 3, 4 and body condition score taken 30 days postpartum, respectively. Relationships between the variation in body condition scores and probability of rebreeding are expressed in Table 4. Under the mean value of body condition score (5.6), for this population, the probability of rebreeding ranged between 26 and 46%. Increased body condition corresponded to increased probability of rebreeding and agrees with previous literature (Corah et al., 1975; Dunn and Moss,

1992; DeRouen et al., 1994; Spitzer et al., 1995; Ciccioli et al., 2003.) Body condition score should be managed so that cows have sufficient reserves to calve, lactate, and maintain an adequate amount of condition during the breeding season. Body condition score at calving is a good indicator of body condition score at breeding if cattle are managed to account for the increased nutritional demands that parturition and lactation present. Although a body condition score of 5-6 has been recommended in previous literature, it should be noted that this "optimum" condition score is based on achieving the shortest post partum interval. Probabilities were somewhat lower than literature suggests under a score of 5, but it should be noted that the average body condition score for the study was 5.6 and rebreeding success was 47%. It should also be noted that body condition score is a subjectively measured trait and emphasis is placed on consistency.

Implications

Body composition is influenced by physiological changes, and can be measured through evaluation methods of carcass ultrasound and body condition evaluation, thresholds can be quantified, and prediction models are obtainable. Carcass ultrasound offers the potential to provide early knowledge for awareness of relative differences in body compositional traits among a herd, and the opportunity to adjust management accordingly before those differences are reflected in poor body condition. These results suggest that ribfat area and intramuscular fat percentage evaluated on yearling cattle may be a useful indicator of cattle that will maintain higher body condition scores at calving and through the breeding season post parturition.

Table 1. Summary of relevant dates

	Calving Season			Breeding Season				
Herd/ Group	Start	End	Length (days)	Calves worked[1]	Start	End	Length (days)	Weaning[2]
1	12/24/2007	02/01/2007	38	03/01/2007	04/15/2007	06/01/2007	46	6/23/2007
2	02/03/2007	03/20/2007	45	04/11/2007	05/17/2007	07/01/2007	43	8/29/2007
3	03/21/2007	04/09/2007	19	04/13/2007	05/17/2007	07/12/2007	53	8/29/2007
4	04/09/2007	05/15/2007	36	06/12/2007	06/15/2007	08/1/2007	46	10/4/2007

[1]First calf heifers were scanned for the third time on this date.
[2]First calf heifers were scanned for the fourth time on this date.

Table 2. Least squares means for body composition traits[1] across time[2] and rebreeding status

Failed to rebreed in a 45 day breeding season.					
Scan	BCS	IMF	REA	Weight	RibFat
1	--	2.48 ± 0.0858^{w}	7.4 ± 0.15^{w}	620 ± 12^{w}	0.11 ± 0.0006^{w}
2	6.2 ± 0.088^{aw}	3.29 ± 0.0892^{x}	8.2 ± 0.14^{ax}	--	0.17 ± 0.003^{ax}
3	--	2.79 ± 0.086^{ay}	6.9 ± 0.15^{ay}	--	0.12 ± 0.006^{aw}
4	4.6 ± 0.084^{ax}	3.02 ± 0.096^{z}	6.0 ± 0.16^{az}	895 ± 11^{ax}	0.08 ± 0.006^{y}
Successfully rebred in a 45 day breeding season.					
Scan	BCS	IMF	REA	Weight	RibFat
1	--	2.66 ± 0.095^{w}	7.5 ± 1.082^{w}	633 ± 14^{w}	0.13 ± 0.007^{w}
2	6.7 ± 0.089^{bw}	3.54 ± 0.094^{x}	8.9 ± 0.969^{bx}	--	0.22 ± 0.006^{bx}
3	--	3.27 ± 0.082^{by}	7.1 ± 0.946^{bw}	--	0.15 ± 0.006^{by}
4	5.2 ± 0.084^{bx}	3.18 ± 0.083^{y}	6.8 ± 975^{by}	967 ± 11^{bx}	0.09 ± 0.006^{z}

[1]BCS = body condition score, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (in^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (in), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm). [2]Time 1 = time at which animal was scanned for the first time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination), Time 3 = time at which animal was scanned for the third time (approximately 30 days after calving) and prior to breeding season, Time 4 = time at which animal was scanned for the fourth time.

[a-b]Least squares means across rebreeding status within time within an effect with different superscripts differ ($P < 0.05$).

[w-z]Least squares means across time within rebreeding status within an effect with different superscripts differ ($P < 0.05$).

Table 3. Associated Probabilities of Rebreeding By Scan Time[1]

IMF Measures - Scan 1						
		- 2 SD	- 1 SD	Mean	+ 1 SD	+ 2 SD
Ribfat Measures		1.27	1.90	2.53	3.16	3.80
- 2 SD	0.05	**11.6%**	**16.6%**	**23.2%**	**31.4%**	**41.0%**
- 1 SD	0.08	**17.5%**	**24.4%**	**32.8%**	**42.5%**	**52.8%**
Mean	0.11	**25.5%**	**34.2%**	**44.0%**	**54.4%**	**64.4%**
+ 1 SD	0.14	**35.6%**	**45.6%**	**55.9%**	**65.8%**	**74.4%**
+ 2 SD	0.17	**47.1%**	**57.5%**	**67.2%**	**75.6%**	**82.4%**

Ribfat Measures - Scan 2					
- 2 SD	- 1 SD	Mean	+ 1 SD	+ 2 SD	
0.01	0.10	0.19	0.28	0.37	
17.7%	**31.6%**	**49.6%**	**67.8%**	**81.8%**	

IMF Measures - Scan 3					
- 2 SD	- 1 SD	Mean	+ 1 SD	+ 2 SD	
1.15	2.11	3.07	4.03	4.99	
26.6%	**39.0%**	**53.1%**	**66.6%**	**77.9%**	

REA MEASURES - Scan 4					
- 2 SD	- 1 SD	Mean	+ 1 SD	+ 2 SD	
3.6	5.0	6.4	7.8	9.2	
34.8%	**45.5%**	**56.7%**	**67.2%**	**76.2%**	

[1]Time 2 = second scan time (pregnancy determination), Time 3 = third scan time (approximately 30 days after calving) - prior to breeding season, Time 4 = fourth scan time (weaning of first calf and pregnancy determination for rebreeding performance)

Table 4. Body Condition Scores and Associated Probabilities of Rebreeding

	Body Condition Scores				
	3	4	5	6	7
Physiological Stage					
Pregnancy Determination	**12.3%**	**19.7%**	**30.1%**	**43.1%**	**57.0%**
45 days post calving	**12.3%**	**19.7%**	**30.1%**	**43.1%**	**57.0%**
30 Days Postpartum	**5.3%**	**12.3%**	**26.0%**	**46.7%**	**68.6%**
Immediately after Breeding	**12.3%**	**19.7%**	**30.1%**	**43.1%**	**57.0%**

POSTPARTUM PERFORMANCE OF BRAHMAN COWS DIVERGENTLY SELECTED FOR RESIDUAL FEED INTAKE

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Summary

The postpartum performance of Brahman primiparous (n=16) and multiparous (n=38) cows previously evaluated postweaning for residual feed intake (RFI) was investigated. The cattle were weighed and evaluated for body condition score (BCS) at 28-day intervals prior to the start of the 2008 calving season. Weekly weights, BCS and blood serum samples for progesterone analysis were collected beginning 21 days after calving. Females were exposed to vasectomized marker bulls after calving for estrus detection. Eight and ten days following estrus, females were evaluated using ultrasonography via rectal palpation to determine the presence of a corpus luteum (CL). No differences were observed between efficient and inefficient primiparous cows. However, efficient multiparous cows exhibited estrus, developed functional corpora lutea, and exhibited estrus with CL formation earlier ($P < 0.05$) than inefficient multiparous cows. A greater percentage ($P < 0.05$) of efficient than inefficient multiparous cows were pregnant at the end of the breeding season.

Introduction

Feed costs comprise 60-65% of the total cost of producing beef (Sainz and Paulino, 2004). Therefore, finding ways to minimize feed expenses is important for maximizing the profitability of cattle operations. Identifying and selecting animals that are more efficient at utilizing feed resources may be one method of reducing feed costs. Residual feed intake is a measure of feed efficiency that reflects the difference between an animal's actual feed intake and its expected intake as determined by body size and growth rate (Koch et al., 1963). Many studies have evaluated young, growing cattle for RFI; however, there is a lack of data regarding potential relationships between RFI and other traits of economic importance, particularly in *Bos indicus* cattle. This study was designed to determine the effect of divergent selection for RFI on the postpartum performance of primiparous and multiparous Brahman cows.

Experimental Procedures

Brahman primiparous (n = 16) and multiparous cows (n = 38) from the Texas *Agri*Life Research facility in Overton were utilized for this study. All females had been previously evaluated for RFI in contemporary groups. Females were weighed and evaluated for BCS at 28-day intervals for 3 months prior to the expected start of the 2008 calving season. Females were again weighed and evaluated for BCS 24 hours after calving. Beginning 21 days post-calving, females were weighed and evaluated for BCS weekly. Calves born from these cows were weighed within 24 hours of birth and again at weaning to determine weaning weight (WW) and pre-weaning average daily gain (ADG). Calf WW was adjusted for calf sex and cow parity according to Beef Improvement Federation guidelines (BIF, 2002).

After calving, females were exposed to vasectomized bulls fitted with chin-ball markers and were visually observed at least once daily to detect estrus. A cow was determined to be in estrus when she allowed another cow or bull to mount her or when ink marks indicated she had been mounted. Eight and ten days following observed estrus, cows were examined using real-time ultrasonography to determine the presence of a CL. If a CL was present, weekly blood sampling, weighing and body condition scoring terminated. If no CL was detected, weekly blood sampling and collection of BW and BCS data continued as previously described until a CL was detected. Beginning May 13 and continuing through June 30, females were artificially inseminated 12 hours following observed estrus. On July 1, cows were exposed to intact Brahman bulls fitted with chin-ball markers for natural mating until July 31. Approximately 45 days after the bulls were removed; cows were examined by rectal palpation to determine pregnancy status and to estimate breeding dates for the cows.

Blood serum samples were collected weekly for progesterone analysis beginning 21 days after calving until a functional CL was detected via ultrasonography. Blood samples were also collected when ultrasonography was performed to ensure the observed CL was functional. Formation of a functional CL was determined when a cow had elevated blood progesterone concentrations above 1 ng/mL for 2 consecutive weeks (Day et al., 1984).

Since numerical RFI values cannot be compared across contemporary groups, females were assigned to an RFI grouping for statistical analysis. A negative RFI indicated an efficient female, whereas a positive RFI indicated an inefficient female. Using the GLM specific for repeated measures function of SAS (2002), BW, BCS, and calf weight data were analyzed with RFI group as a class variable. Reproductive performance and changes in BW

and BCS were analyzed by RFI group using the GLM procedure of SAS (2002). Considering multiparous and primiparous cows separately, differences in cumulative return to estrus, CL formation, estrus with CL formation, and conception were analyzed by RFI group using the chi-square function of SAS (2002). Within parity group, chi-square was also used to evaluate differences in first service conception rate and pregnancy rate between the efficient and inefficient females.

Results and Discussion

Body weight was not different between efficient and inefficient Brahman cows pre- or post-calving (Table 1). This is in agreement with Arthur et al. (2005) who observed no statistical difference in BW between high and low RFI Angus cows at any stage of the production cycle. Inefficient cows gained more weight ($P < 0.05$) than efficient cows from calving to estrus with CL formation (Figure 1). Inefficient cows tended ($P < 0.10$) to be in better body condition than efficient cows at the first and second pre-calving BCS evaluations. However, inefficient and efficient cows had similar BCS at the last pre-calving measurement, 24 hours after calving, and 21 days after calving. Inefficient cows were again in better body condition ($P < 0.05$) when they first expressed estrus with subsequent CL formation, which may have resulted in the increased weight gain of inefficient cows post-calving. There were no differences in BCS change during either the pre- or postpartum period between efficient and inefficient cows (Figure 2).

Julian date of calving was not different between efficient and inefficient cows (Table 2). However, inefficient cows conceived an average of 13 days sooner ($P < 0.05$) than efficient cows. Efficient cows had shorter intervals from calving to first estrus, functional CL formation, and estrus with subsequent luteal formation than inefficient cows ($P < 0.05$). Although more ($P < 0.05$) efficient cows were pregnant at the end of the breeding season than inefficient cows, there were no significant differences observed for first service conception rate by RFI group.

Since reproductive parameters also differed by parity, primiparous and multiparous cows were separated for analysis of cumulative return to estrus, CL formation, estrus with CL formation, and conception, in addition to first service conception rate and end of breeding season pregnancy rate. Cumulative return to estrus for multiparous cows results are presented in Figure 3. Similar proportions of efficient and inefficient multiparous cows had expressed first estrus between day 21 and 30 following calving. Between day 31 and 40, 65% of efficient multiparous cows had expressed estrus as compared to 29% of inefficient multiparous cows ($P < 0.05$). There was a tendency ($P < 0.10$) for more efficient multiparous cows to have expressed first estrus by day 41 to 50. Ninety-four percent of efficient multiparous cows compared to 62% of inefficient multiparous cows had shown estrus by day 51-60 ($P < 0.05$). Another tendency ($P < 0.10$) was observed between day 61 and 70 for more efficient multiparous cows to have expressed estrus than inefficient multiparous cows. The proportion of multiparous cows showing estrus by day 71 to 80 was not statistically different by RFI group, although two multiparous inefficient cows did not express estrus within 80 days of calving.

There was no observed difference between RFI groups for the percentage of multiparous cows forming a CL between day 21 and 30 after calving (Figure 4). More ($P < 0.05$) efficient cows had developed a functional CL by day 31 to 60 than inefficient multiparous cows. There were no statistical differences between RFI groups for the proportion of multiparous cows that had developed a functional CL by day 61 to 70 or day 71 to 80.

No difference was detected between the proportion of efficient and inefficient multiparous cows that had expressed estrus and subsequently developed a functional CL by day 21 to 30 after calving (Figure 5). By day 31 to 40, more efficient multiparous cows had exhibited estrus with CL formation than inefficient multiparous cows (65 vs. 29%; $P < 0.05$). There was a tendency ($P < 0.10$) for a greater proportion of efficient multiparous cows to have shown estrus and developed a CL by day 41 to 50 (71 vs. 43%). More ($P < 0.05$) efficient cows were detected in estrus with subsequent luteal formation by day 51 to 60 (94 vs. 62%) and by day 61 to 70 (100 vs. 71%) than inefficient. Although four inefficient multiparous cows never expressed estrus with subsequent CL formation, statistically similar proportions of efficient and inefficient multiparous cows had achieved estrus with CL formation by day 71 to 80.

As depicted in Figure 6, there were no differences observed in first service conception rate between efficient and inefficient multiparous cows. Furthermore, there were no differences between RFI groups in pregnancy rate by days 1-20, 21-40, or 41-60 of the breeding season (Figure 7). However, a greater proportion of efficient multiparous cows had conceived by day 61 to 80 (100 vs. 62%; $P < 0.01$) resulting in a significantly higher proportion of efficient than inefficient multiparous cows (100 vs. 62%; $P < 0.01$) confirmed pregnant at the end of the breeding season (Figure 8). As first service conception rate was not different by RFI group, it appears that the ability of efficient cows to initiate estrous cycles sooner than inefficient cows afforded them more opportunities to become pregnant during the defined breeding season. This agrees with a report made by Thatcher and Wilcox (1973) where cows that exhibited more estrous cycles had improved fertility.

No statistical differences were observed between efficient and inefficient primiparous cows for cumulative return to estrus (Figure 9), CL formation (Figure 10), estrus with CL formation (Figure 11), or pregnancy (Figure 12). Furthermore, only 30% of the efficient and 17% of the

inefficient primiparous cows were confirmed pregnant at the end of the breeding season (Figure 13). This is a reflection of the failure of the majority of primiparous cows to initiate estrous cycles prior to the end of the breeding season. It is important to note that the primiparous cows in this study calved for the first time as 2-yr-olds. Most Brahman cows do not calve for the first time until 3 years of age. Therefore, it appears that regardless of RFI group, the primiparous cows in this study were simply not physiologically ready to conceive and support pregnancy during the restricted breeding season following their first parity.

Inefficient cows gave birth to heavier calves than efficient cows (Table 3). These results conflict with results published by Basarab et al. (2007) who observed no statistical differences in calf birth weight among *Bos taurus* dams that produced high, medium, or low RFI calves. No further differences in calf performance were detected between efficient and efficient cows, suggesting that selection for RFI in Brahman cattle should not impact calf pre-weaning performance.

Implications

Results from this study suggest that selection of Brahman cattle for RFI should not impede reproduction in multiparous cows. Selection of low RFI cattle may shorten the interval from calving to first estrus, CL formation, and estrus with CL formation and improves pregnancy rates in multiparous Brahman cows without altering calf performance. Reproductive performance differences between efficient and inefficient primiparous cows were not detected because the young age at which the primiparous cows calved was apparently limiting postpartum reproductive performance. Results from this study suggest that selection of efficient cattle using RFI as a selection tool may result in a shorter postpartum interval and improved pregnancy rates in multiparous Brahman cows.

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Table 1. Body weight and body condition score of efficient and inefficient Brahman cows

	RFI group		
Trait[a]	Efficient	Inefficient	P-value
n	23	31	
Pre-calving BW1, lb	1033.5 ± 39.0	1081.8 ± 32.8	0.2671
Pre-calving BW2, lb	1040.8 ± 40.1	1090.4 ± 33.7	0.2687
Pre-calving BW3, lb	1040.6 ± 37.7	1087.7 ± 32.8	0.2796
24 hour post-calving BW, lb	969.4 ± 35.9	1055.6 ± 30.4	0.7815
21 day post-calving BW, lb	1050.3 ± 35.5	1086.6 ± 30.9	0.3703
BW at estrus with CL formation, lb	1075.8 ± 35.5	1113.5 ± 30.0	0.3385
Pre-calving change in BW, lb	7.3 ± 7.3	4.0 ± 6.2	0.7277
Post-calving change in BW, lb	31.3 ± 11.9[b]	54.0 ± 10.1[c]	0.0480
Pre-calving BCS1	5.8 ± 0.2[d]	6.2 ± 0.2[e]	0.0615
Pre-calving BCS2	5.8 ± 0.2[b]	6.3 ± 0.2[c]	0.0455
Pre-calving BCS3	6.2 ± 0.2	6.5 ± 0.2	0.2097
24 hour post-calving BCS	5.7 ± 0.2	5.9 ± 0.2	0.4896
21 day post-calving BCS	5.7 ± 0.2	6.0 ± 0.2	0.1122
BCS at estrus with CL formation	5.6 ± 0.2	5.9 ± 0.1	0.0487
Pre-calving change in BCS	0.3 ± 0.1	0.1 ± 0.1	0.2161
Post-calving change in BCS	-0.2 ± 0.2	0.1 ± 0.1	0.1928

[a] BW = body weight, CL = corpus luteum, and BCS = body condition score.
[b,c] Least square means within a row differ ($P < 0.05$).
[d,e] Least square means within a row differ ($P < 0.10$).

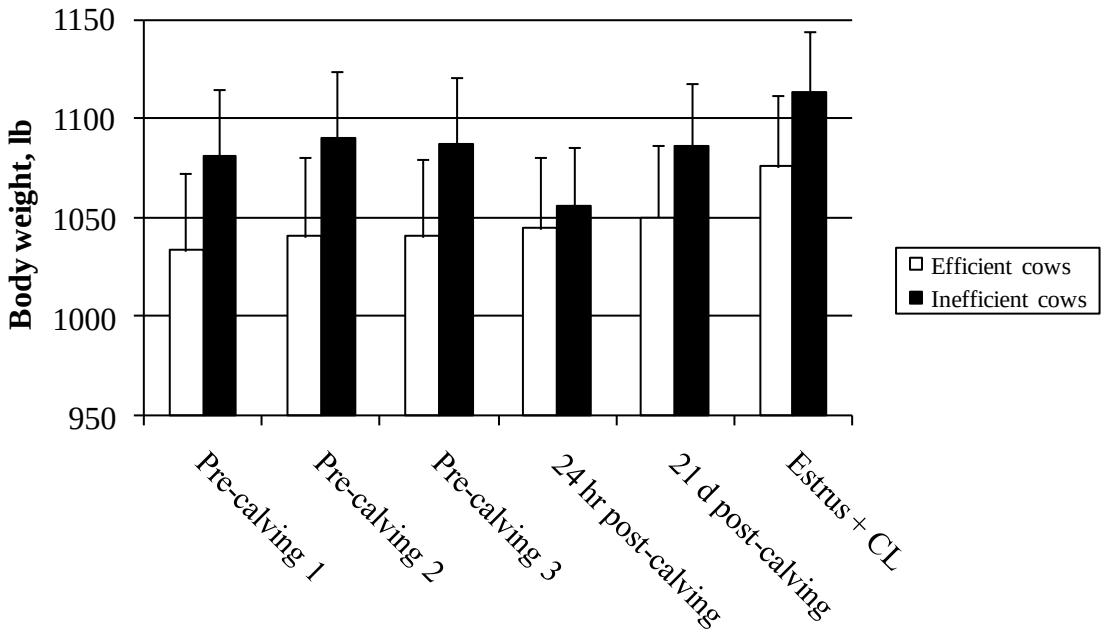

Figure 1. Pre- and post-calving mean body weights for efficient (n = 23) and inefficient (n = 31) Brahman cows. RFI effect P = 0.35, time effect P < 0.01, and time x RFI effect P = 0.15, pooled SEM = 15.8.

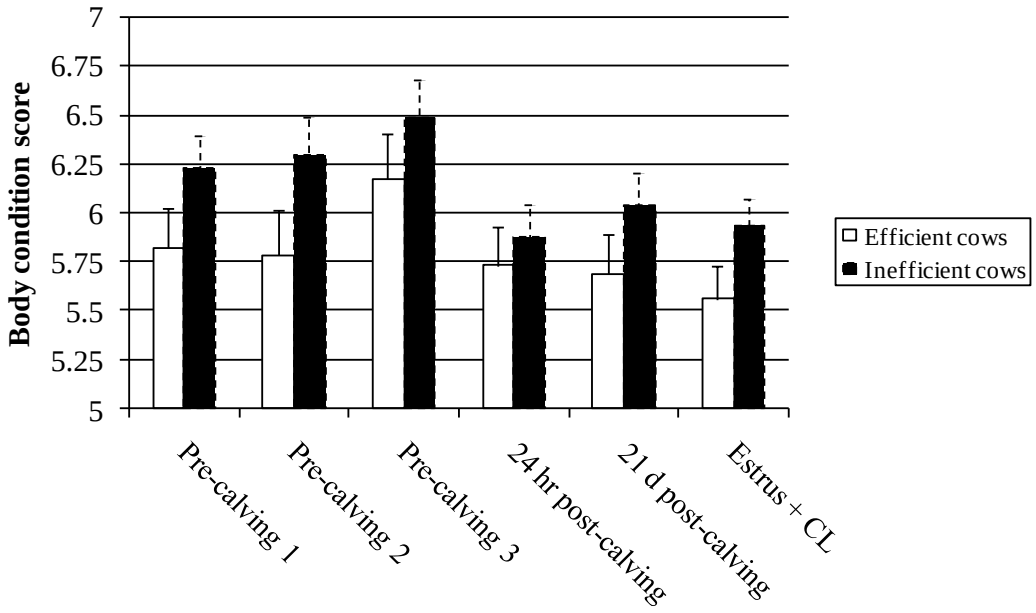

Figure 2. Pre- and post-calving mean body condition scores for efficient (n = 23) and inefficient (n =31) Brahman cows. RFI effect P < 0.10, time effect P < 0.0001, and time x RFI effect P = 0.40, pooled SEM = 0.2.

Table 2. Reproductive performance of efficient and inefficient Brahman cows

	RFI group		
Trait[a]	Efficient	Inefficient	P-value
n	23	31	
Julian date of calving, d	108 ± 5	100 ± 4	0.1461
Julian date of conception, d	187 ± 6[b]	175 ± 5[c]	0.0451
Days to first estrus	63 ± 4[b]	76 ± 4[c]	0.0122
Days to CL formation	63 ± 5[b]	77 ± 4[c]	0.0103
Days to estrus with CL formation	64 ± 5[b]	77 ± 4[c]	0.0181
First service conception rate, %	39	32	0.6010
End of breeding season pregnancy rate, %	78	52	0.0449

[a] CL = corpus luteum.

[b,c] Least square means within a row differ (P < 0.05).

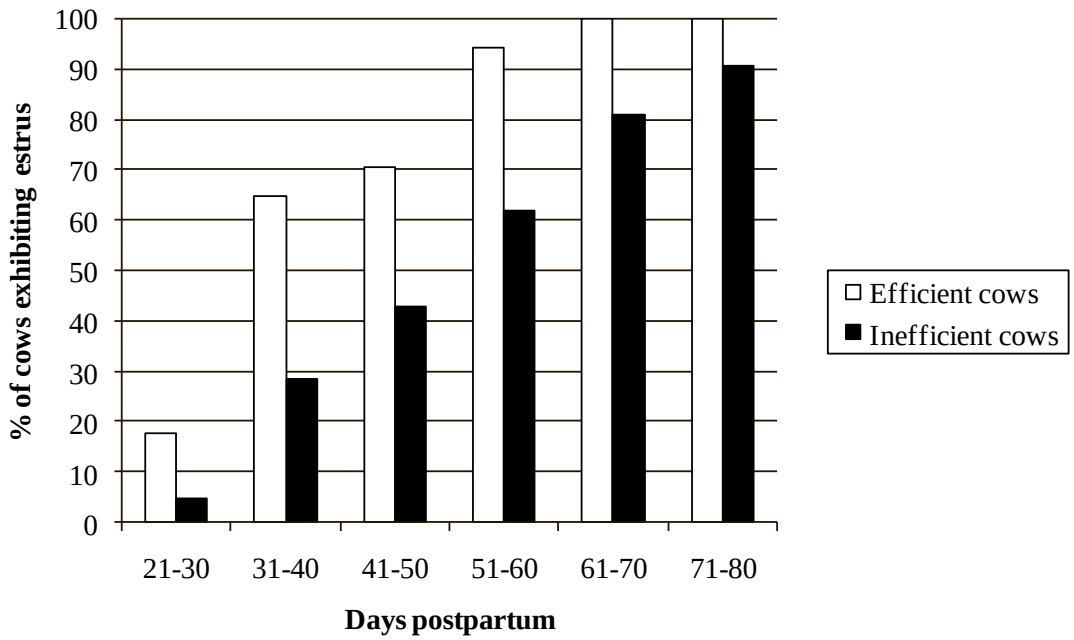

Figure 3. Cumulative return to estrus for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

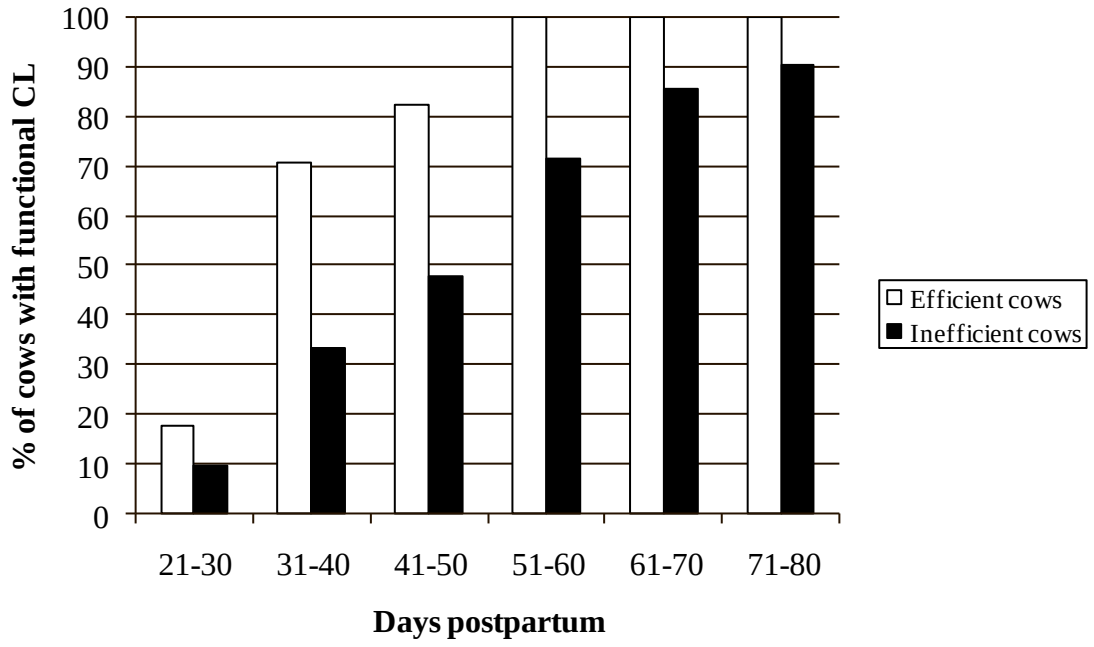

Figure 4. Cumulative achievement of corpus luteum formation for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

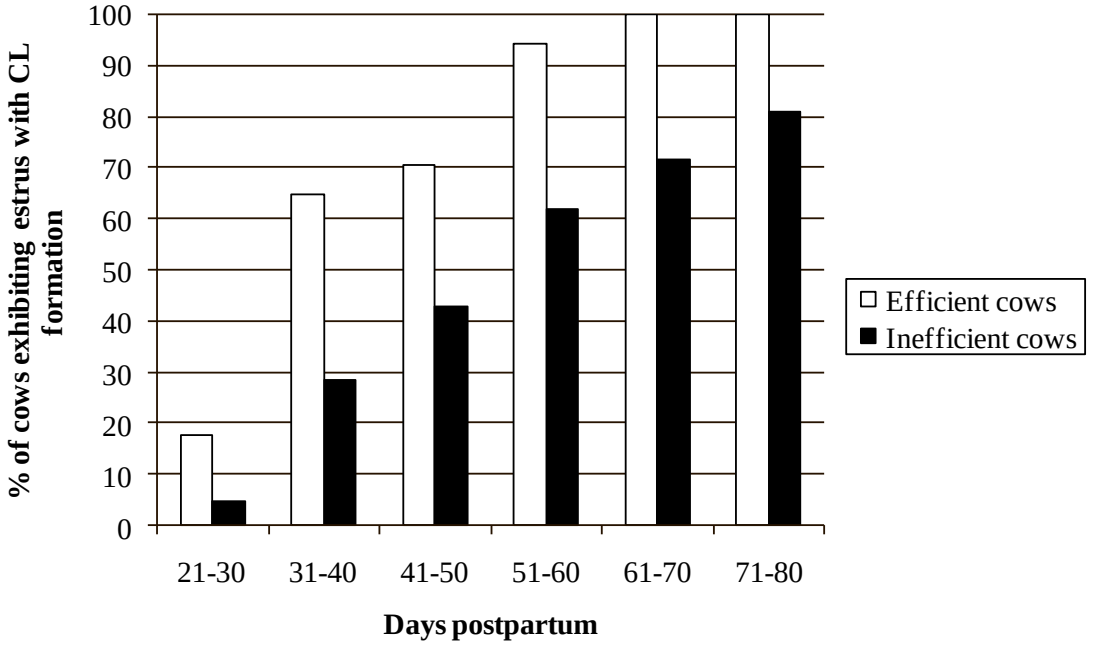

Figure 5. Cumulative return to estrus with subsequent corpus luteum formation for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

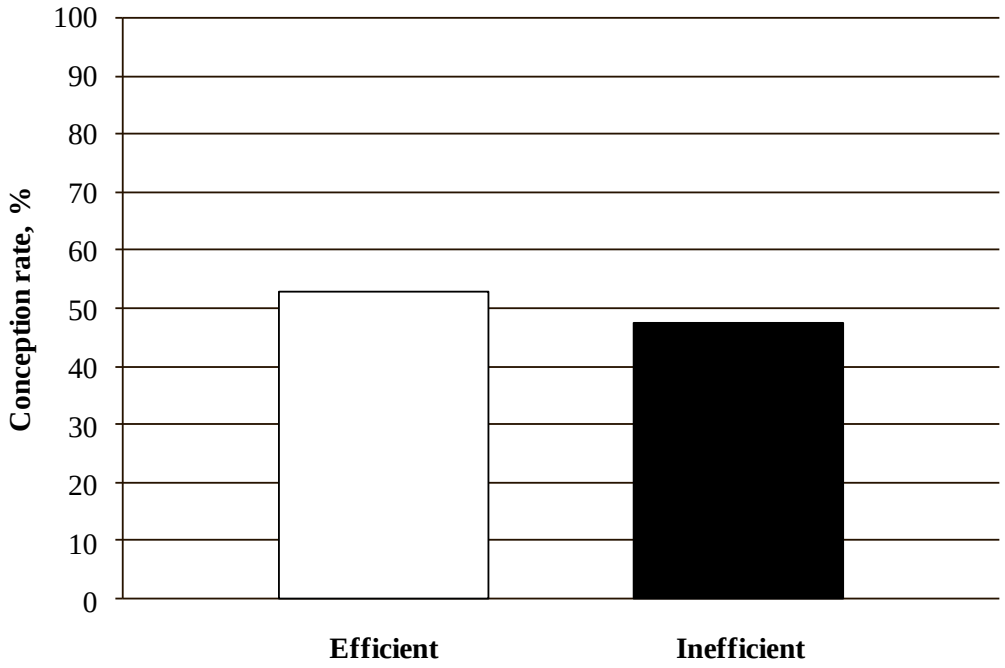

Figure 6. First service conception rate for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

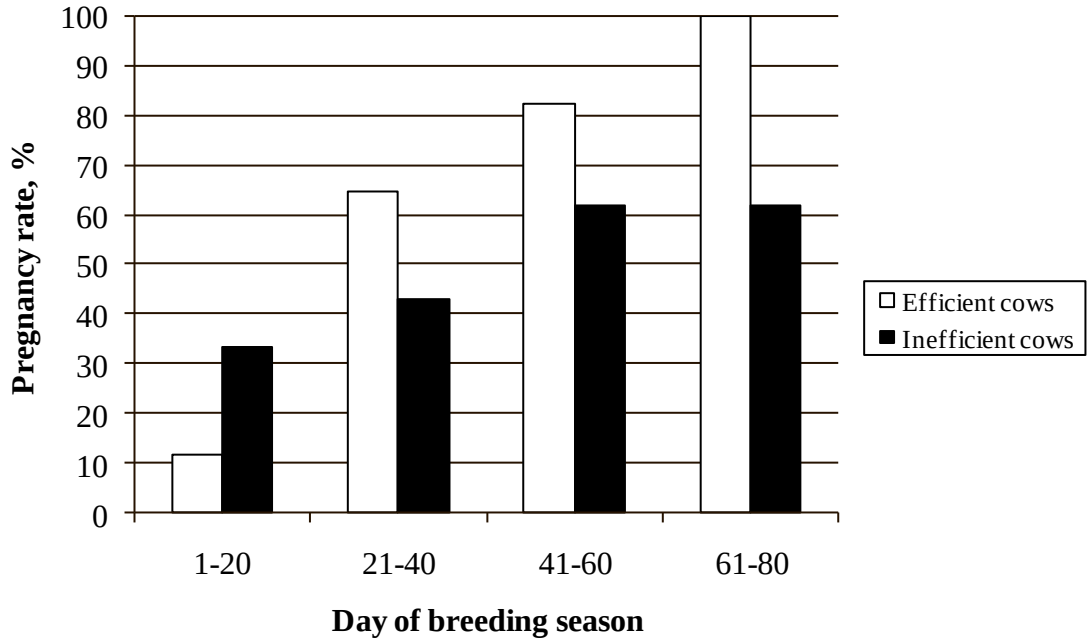

Figure 7. Cumulative pregnancy rate for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

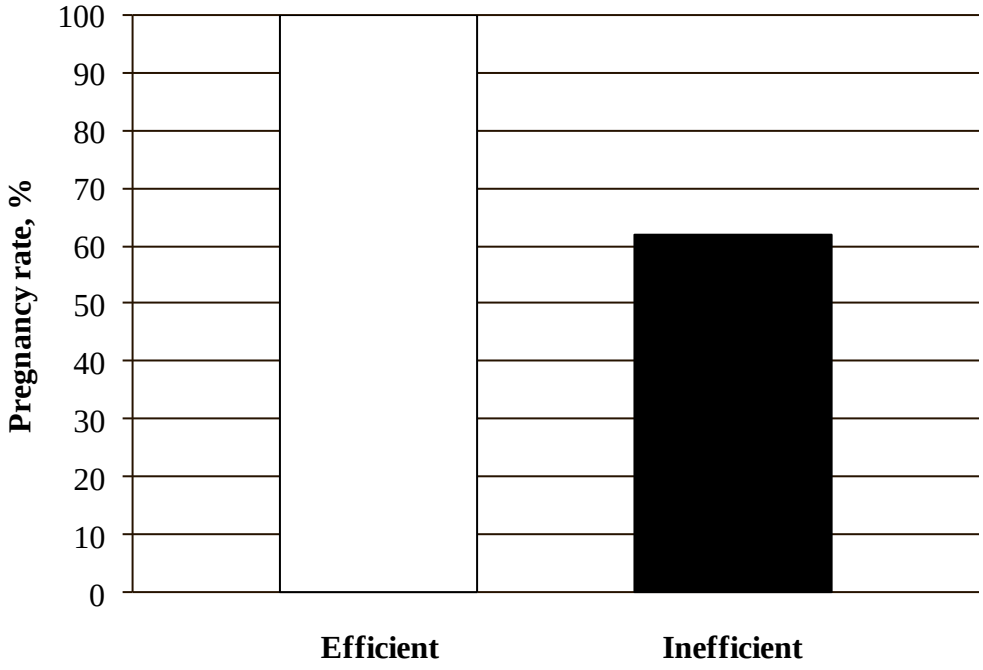

Figure 8. End of breeding season pregnancy rate for efficient (n = 17) and inefficient (n = 21) multiparous Brahman cows.

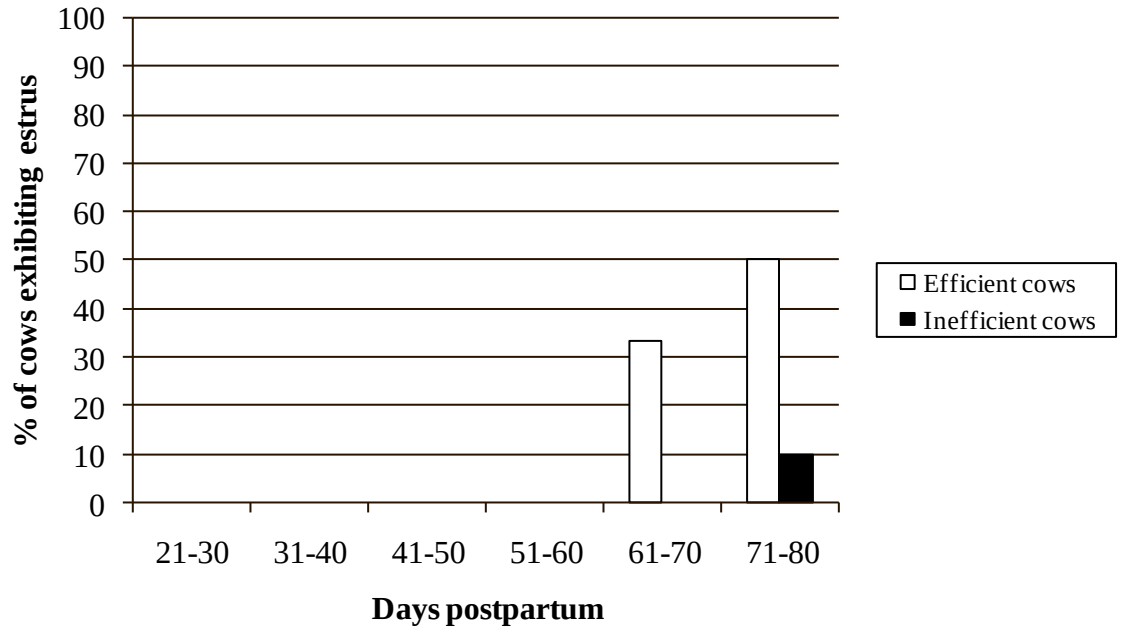

Figure 9. Cumulative return to estrus for efficient (n = 6) and inefficient (n = 10) primiparous Brahman cows.

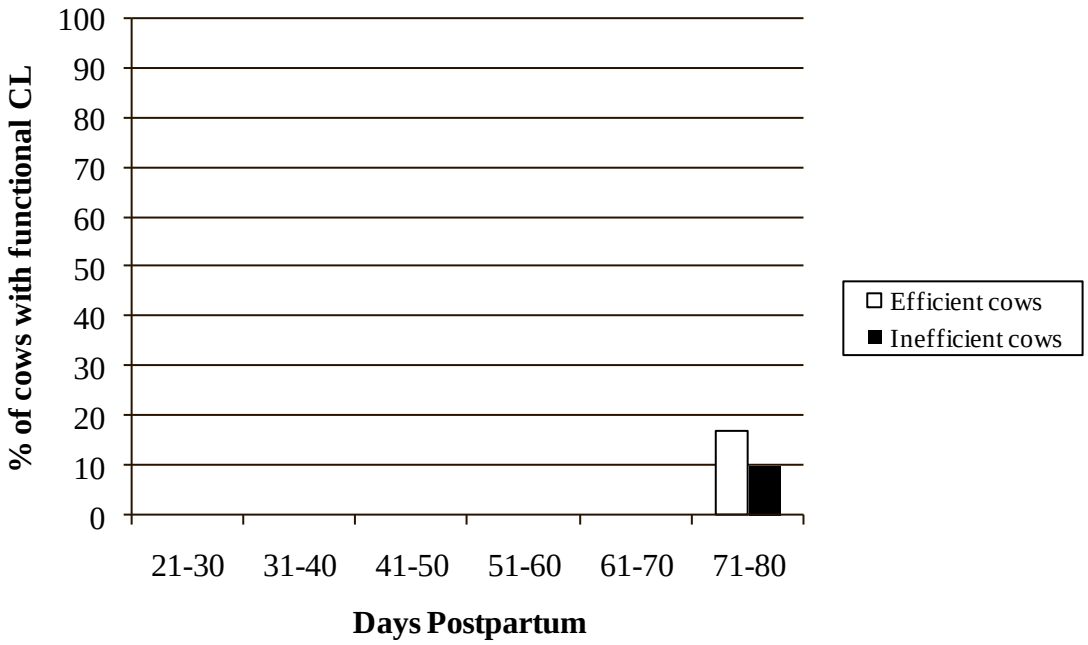

Figure 10. Cumulative achievement of corpus luteum formation for efficient (n = 6) and inefficient (n = 10) primiparous Brahman cows.

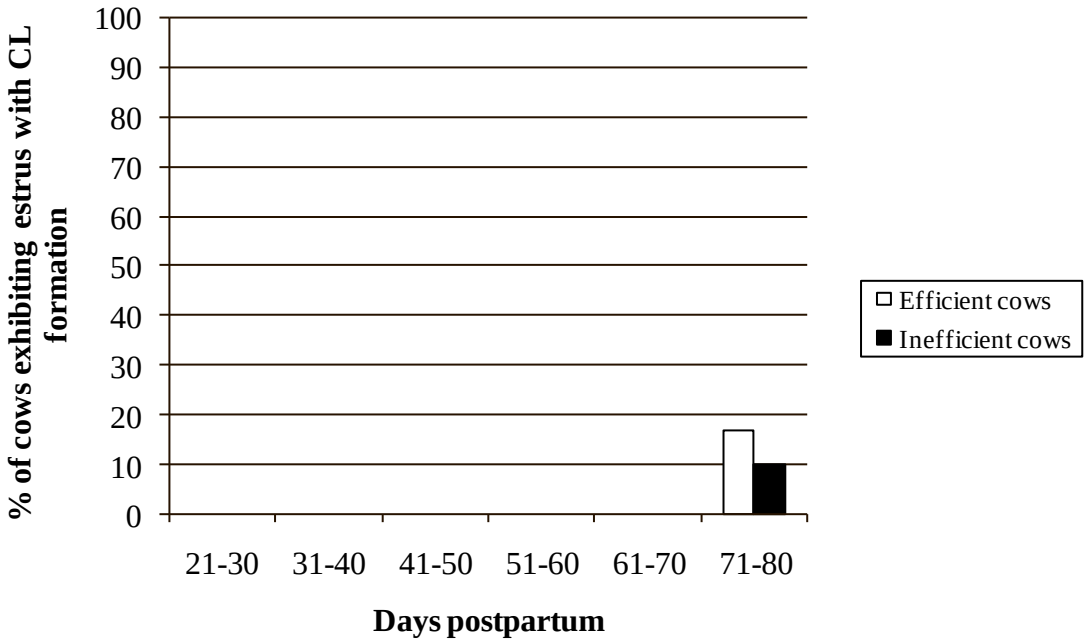

Figure 11. Cumulative return to estrus with subsequent corpus luteum formation for efficient (n = 6) and inefficient (n = 10) primiparous Brahman cows.

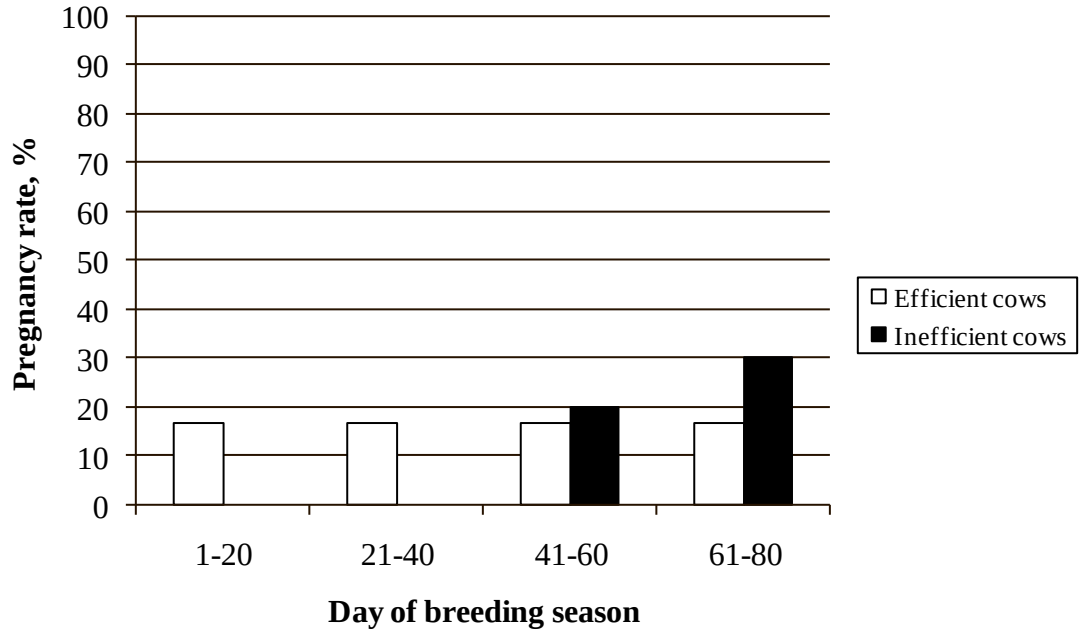

Figure 12. Cumulative pregnancy rate for efficient (n = 6) and inefficient (n = 10) primiparous Brahman cows.

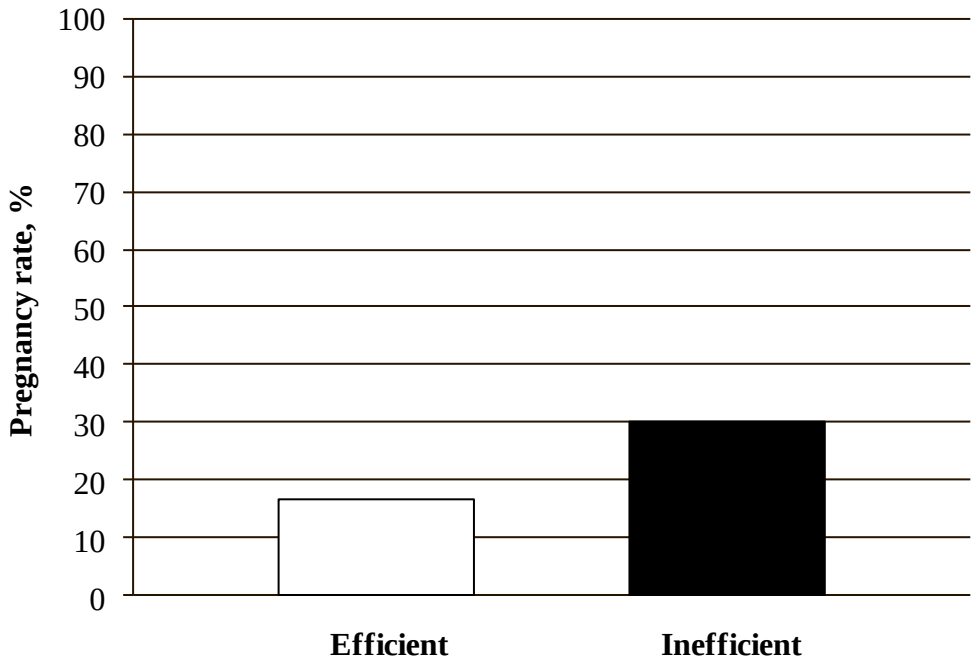

Figure 13. End of breeding season pregnancy rate for efficient (n = 6) and inefficient (n = 10) primiparous Brahman cows.

Table 3. Calf performance of efficient and inefficient Brahman cows

	RFI group		
Trait	Efficient	Inefficient	P-value
n	23	31	
Calf birth weight, lb	70.1 ± 2.2[a]	76.3 ± 2.0[b]	0.0386
Calf weaning weight, lb	371.3 ± 11.2	391.3 ± 9.5	0.1616
Adjusted calf weaning weight, lb	431.7 ± 7.9	442.5 ± 6.6	0.2729
Calf ADG, lb/d	2.0 ± 0.0	2.0 ± 0.0	0.2182
Adjusted calf ADG, lb/d	2.2 ± 0.0	2.4 ± 0.0	0.7076
Proportion calf weaned, %	36.1 ± 1.2	37.9 ± 1.0	0.2292
Adjusted proportion calf weaned, %	42.6 ± 1.1	43.3 ± 0.9	0.6298

[a,b] Least square means within a row differ ($P < 0.05$).

SELECTION BASED ON EITHER TEMPERAMENT OR RESIDUAL FEED INTAKE AND THE EFFECTS ON SEXUAL MATURITY IN BRAHMAN HEIFERS

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Summary

Selection against temperamental cattle or selection for feed efficient cattle using residual feed intake (RFI) may improve the profitability of cattle operations. Most studies have investigated the relationships of temperament and RFI with growth parameters but few evaluated reproductive traits. In this study, Brahman heifers were evaluated for temperament at weaning and were classified as calm, intermediate, or temperamental. Heifers were also categorized as efficient, intermediate or inefficient based on RFI. Heifers were exposed continuously to a mature, fertile Brahman bull to determine sexual maturity. Age at sexual maturity did not differ among temperament groups. Weight at sexual maturity was heavier for calm heifers as compared to temperamental heifers due to increased weight per day of age. Age, weight, and weight per day of age did not differ among RFI groups. These results suggest that selection against temperamental cattle or selection for feed efficient cattle using RFI should not affect age at sexual maturity in Brahman heifers.

Introduction

Maximizing profit is the goal of beef cattle operations. Profitability can be increased by maximizing outputs or minimizing inputs. Previous research has shown that temperamental cattle exhibit reduced body weight gain (Burrow, 1997), produce tougher meat (Voisinet et al., 1997) and yield increased bruise trim (Fordyce et al., 1988) when compared to their calmer cohorts. Therefore, selection against temperamental cattle may help maximize outputs. Feed represents 60-65% of the cost of beef production (Sainz and Paulino, 2004). Identifying feed efficient cattle using RFI may help reduce feed inputs without compromising production outputs (Koch et al., 1963). Even so, reproduction has been estimated to be five times more economically important than growth traits (Trenkle and Willham, 1977). The age at which heifers reach sexual maturity is important since heifers that calve at a younger age have greater lifetime productivity (Lesmeister et al., 1973). As a result, this study was designed to determine if either selection against temperamental cattle or selection for feed efficient cattle affects age, weight, or weight per day of age at sexual maturity in Brahman heifers.

Experimental Procedures

Animals

Brahman heifers born in the spring of 2005 and 2006 at the Texas AgriLife Research Center in Overton, TX were used in this study. Heifers were allowed to suckle their dams until weaning at 6.5 ± 0.8 months of age in 2005 and 5.8 ± 0.7 months of age in 2006.

Temperament Evaluation

At weaning, heifers (n=37 in 2005 and n=53 in 2006) were evaluated for temperament using two different measures. Pen score (PS) was used as a subjective measurement of temperament. Heifers were sorted into small groups of three to five head and confined in a small pen. A trained person approached each heifer in the pen and assigned a PS of one through 5 based on the heifer's reaction to the human handler (Table 1; Hammond et al., 1996). In addition, heifers were objectively evaluated for temperament using exit velocity (EV). Two infrared sensors (FarmTek Inc., North Wylie, TX) were used to determine how quickly each heifer exited the working chute and traversed six feet (Figure 1). This time (in seconds) was divided by six feet (the distance between the two infrared beams) to express EV in feet/second. An overall temperament score (TS) was then calculated as the average between PS and EV. Heifers were classified as calm (n=6 in 2005 and n=12 in 2006), intermediate (n=18 in 2005 and n=29 in 2006), or temperamental (n=23 in 2005 and n=12 in 2006) based on ±0.5 standard deviation from the mean TS.

RFI Evaluation

Following weaning, heifers (n=38 in 2005 and n=41 in 2006) were individually fed a total mixed ration (Table 2) using a Calan gate individual feeding system (American Calan, Northwood, NH). Heifers were fed twice daily at 2.5% body weight for 70 days. Weekly body weight and feed intake data were collected. Initial body weight and average daily gain were computed from the linear regression of body weight on day of test. Mid-test body weight was estimated using initial body weight and average daily gain and adjusting for a 3% shrink. Residual feed intake was determined for each heifer for each year as the residual from the linear regression of average daily feed intake on mid-test body weight$^{0.75}$ and average daily gain.

Sexual Maturity

After the RFI feeding trial, heifers were maintained in one breeding herd for each year and were exposed continuously to one mature, fertile Brahman bull. Periodically, heifers were rectally palpated to determine pregnancy. Once heifers were determined to be pregnant, they were removed from the bull. Age at calving for each heifer was recorded. Sexual maturity was determined as the age at calving minus 292 days, the average gestation length for Brahman cattle (Plasse et al., 1968). Weight at sexual maturity was determined from the linear regression of body weight data collected every 28 days. Weight per day of age at sexual maturity was calculated as the weight at sexual maturity divided by the age at sexual maturity.

Results and Discussion

Although numerically lower for calm heifers, age at sexual maturity did not differ among TS groups (Figure 2; $P = 0.21$). Calm heifers tended to be heavier at sexual maturity than temperamental heifers (Figure 3; $P < 0.08$), but calm heifers did not differ from intermediate heifers ($P = 0.45$). When both of these traits were combined and expressed as weight per day of age at sexual maturity, calm heifers exhibited a significantly greater weight per day of age (Figure 4; $P < 0.005$) than intermediate or temperamental heifers. To our knowledge, there have been no published data reporting relationships, or lack thereof, between temperament and sexual maturity in cattle. Our findings are the first to suggest that selecting against temperamental cattle will not affect the age at which Brahman heifers reach sexual maturity. Rather, selecting against temperamental cattle may improve the weight per day of age at sexual maturity for Brahman heifers.

No differences were detected among RFI groups for age at sexual maturity (Figure 5; $P = 0.67$), weight at sexual maturity (Figure 6; $P = 0.78$), or weight per day of age at sexual maturity (Figure 7; $P = 0.53$). Therefore, selection of feed efficient cattle using RFI to quantify feed efficiency should not affect the age, weight or weight per day of age at which Brahman heifers achieve sexual maturity. These findings are in agreement with Lancaster et al. (2006) and Loyd et al. (2010) who detected no difference in age at puberty between efficient and inefficient Brangus and Bonsmara heifers, respectively.

Implications

Maximizing profit is the primary goal of beef cattle operations. Selecting against temperamental cattle may help improve production outputs such as growth performance and meat quality. Selecting for feed efficient cattle using RFI may help reduce feed inputs. While both of these selection tools may influence profitability, reproductive traits also play a considerable role in determining the overall profitability of a cattle operation. Therefore, understanding the relationships of temperament and feed efficiency with reproduction is important. This study revealed that neither selection against temperamental cattle nor selection for feed efficient cattle should have negative effects on the achievement of sexual maturity in Brahman heifers.

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Table 1. Description of pen scoring system

Pen Score	Description
1	**Nonaggressive (docile)** – walks slowly, can approach closely, not excited by humans or facilities
2	**Slightly aggressive** – runs along fences, will stand in corner if humans stay away, may pace fence
3	**Moderately aggressive** – runs along fences, head up and will run if humans move closer, stops before hitting gates and fences, avoids humans
4	**Aggressive** – runs, stays in back of group, head high and very aware of humans, may run into fences and gates even with some distance, will likely run into fences if alone in pen
5	**Very aggressive** – excited, runs into fences, runs over humans and anything else in path, "crazy"

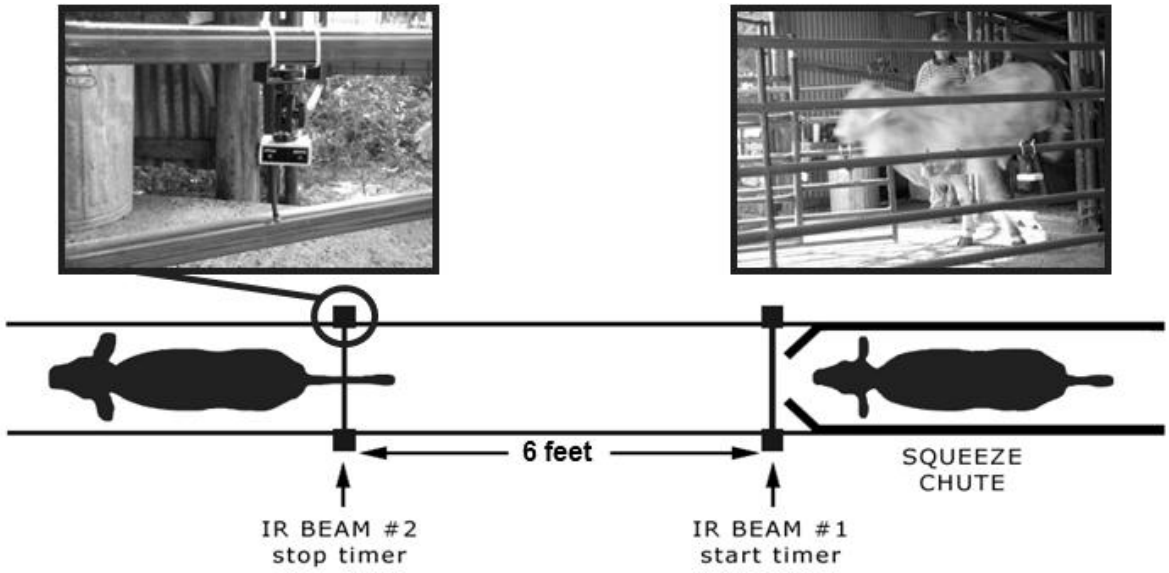

Figure 1. Brahman heifer exiting the working chute and passing the infrared beams used to determine exit velocity.

Table 2. Ingredients and nutrient content of experimental diets

	Year	
Diet	2005	2006
Ingredients (as-fed-basis):		
Cotton seed hulls	25.00	37.50
Soy hulls	20.00	-
Corn, ground	10.00	6.37
Alfalfa dehy 20%	8.73	12.50
Wheat midds	7.35	5.53
Rice bran	6.25	8.50
Cottonseed meal 41	6.01	4.33
Corn gluten feed	5.00	5.00
Corn, cracked	5.00	5.00
Binder molasses	2.00	2.00
Calcium	1.25	1.27
Whole cotton seed	0.93	-
Salt	0.62	0.67
BIOFOS 21P 18CA	0.56	0.51
Soybean meal	0.50	4.75
Dynamate	0.26	0.25
BGY 28	0.25	0.25
Xtra-bond	0.15	0.15
T/M for dairy	0.05	0.05
Dairy (ADE)	0.04	0.04
Vitamin A-30	0.04	0.04
Zinpro	0.03	0.03
Equine T/M	-	0.01
Rice hulls	-	5.25
Nutrients (dry-matter-basis):		
DM, %	90.33	90.24
CP, %	13.40	13.41
NE_m, Mcal/kg	1.59	1.41
NE_g, Mcal/kg	0.90	0.68
ADF, %	34.36	38.17
NDF, %	48.34	51.23
Calcium,%	1.00	1.00
Phosphorus,%	0.55	0.55

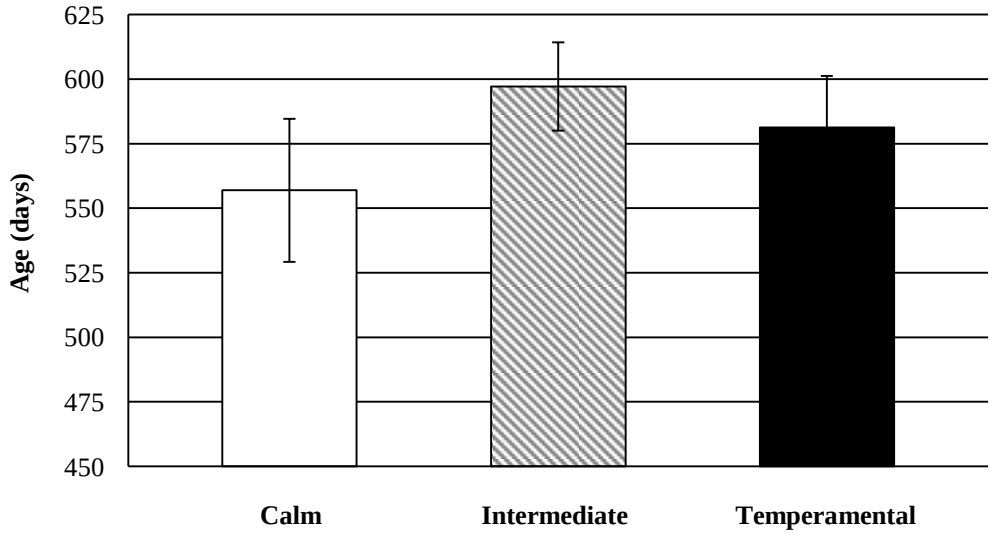

Figure 2. Age at sexual maturity by temperament score (TS) group. No differences among TS groups (P = 0.21).

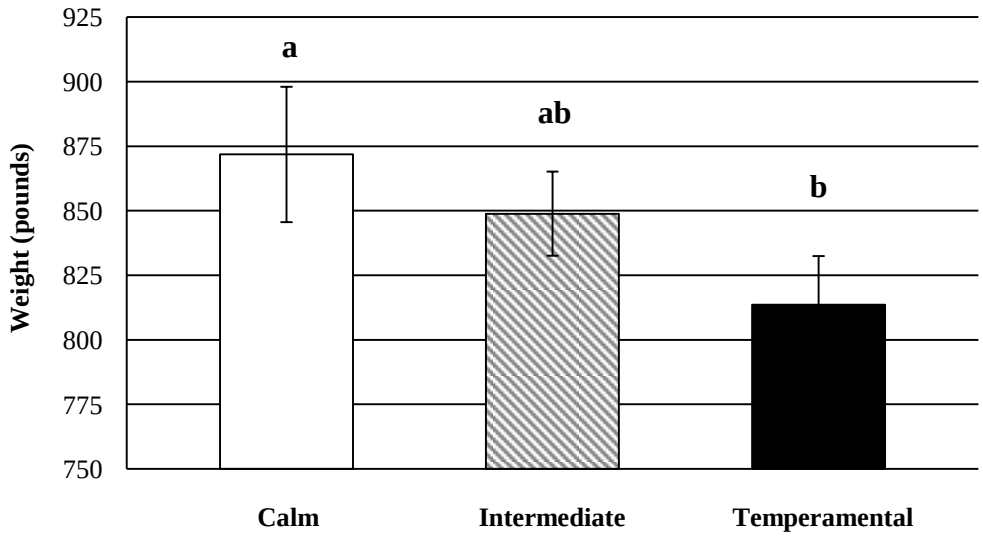

Figure 3. Weight at sexual maturity by temperament score (TS) group. Means without a common superscript letter differ (P < 0.08).

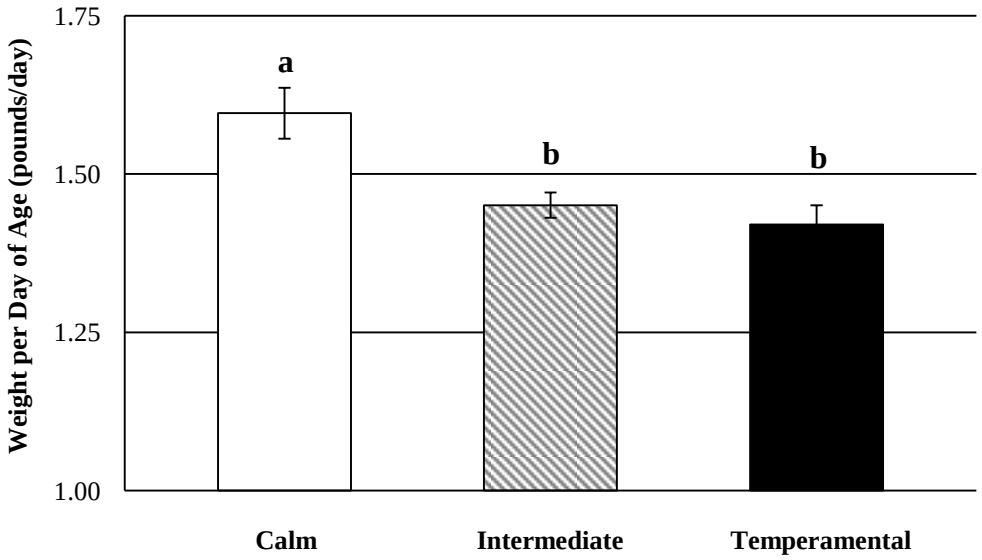

Figure 4. Weight per day of age at sexual maturity by temperament score (TS) group. Means without a common superscript letter differ ($P < 0.005$).

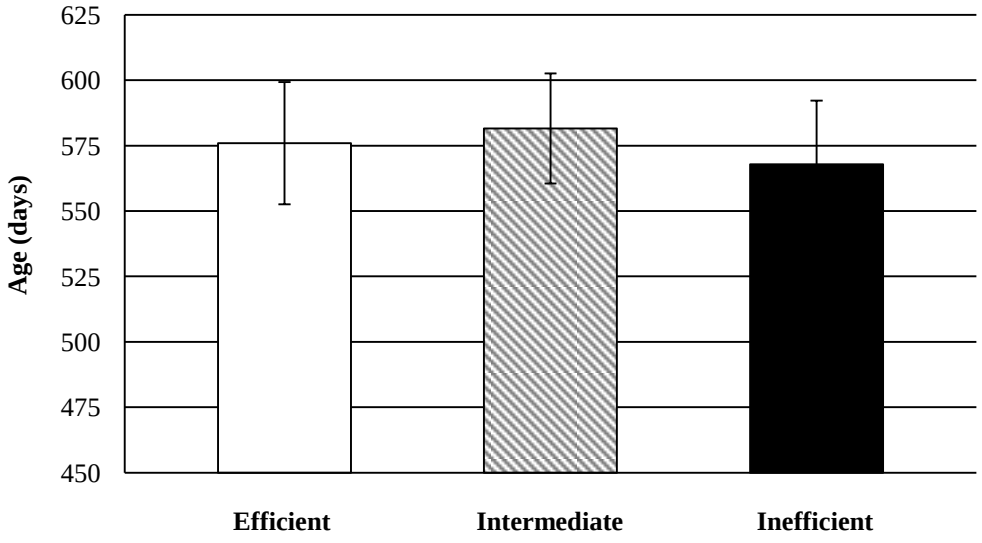

Figure 5. Age at sexual maturity by residual feed intake (RFI) group. No differences among RFI groups ($P = 0.67$).

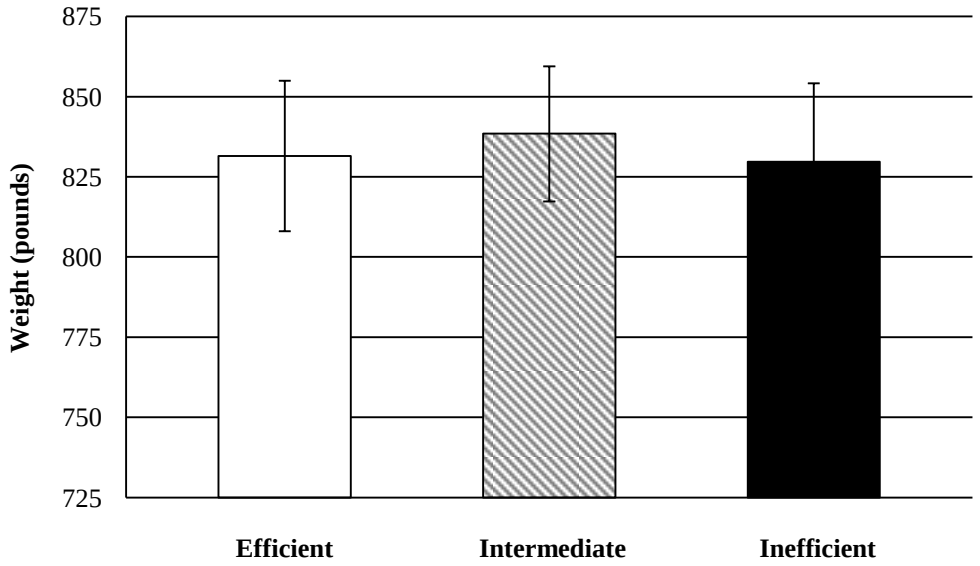

Figure 6. Weight at sexual maturity by residual feed intake (RFI) group. No differences among RFI groups (P = 0.78).

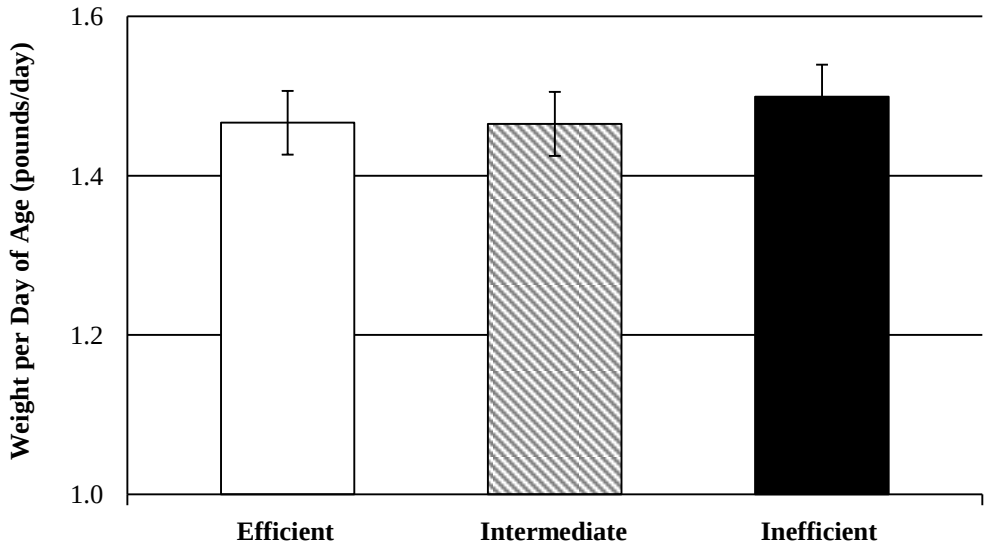

Figure 7. Weight per day of age at sexual maturity by residual feed intake (RFI) group. No differences among RFI groups (P = 0.53).

INFLUENCE OF NUTRITION DURING GESTATION ON CALVING DIFFICULTY FOR BONSMARA INFLUENCED FEMALES CALVING FIRST AT TWO YEARS OF AGE

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Introduction

Calving difficulty has long been known to have pervasive effects on the beef production process with large negative impacts on the economics of production (Laster, 1974). These effects have been shown to influence lifetime cow efficiency (Holloway et al. 2005). Most of the research performed to evaluate the influence of plane of nutrition during gestation on calving difficulty showed little relationship (Laster et al. 1973; Laster, 1974; Bellows and Short, 1978; Naazie et al., 1989). Some research has suggested a relationship between late gestational nutrition and calving difficulty (Preston and Willis, 1970; Holloway et al. 1980) although most research has shown either no or inconclusive relationships. As a result of these findings, most of the recent research into calving difficulty has focused on the impact of genetics (Basarab et al. 1993; Colburn et al. 1997; Eriksson et al. 2004a and b; Phocas and Laloe. 2003). Recent interest in Sanga breeds from southern Africa has resulted in new importations of tropically adapted breeds into the U.S. Sanga influenced cattle have been shown to distribute fat more to internal depots than British or continental breeds of cattle (Sprinkle et al., 1998). Because of this, high planes of nutrition during gestation may have greater impacts on calving difficulty than has been reported for British and continental breeds. Also, Sanga breeds of cattle originated in southern Africa where, because of nutritional limitations, the common practice is to calve heifers for the first time later than two years of age. This may have resulted in genetic selection over time that did not provide pressure for calving ease when the cattle are subjected to nutritional regimes conducive to first calving at two years of age. The purpose of this research was to evaluate the impact of plane of nutrition during the last trimester of pregnancy on calving difficulty and calving vigor of Bonsmara influenced heifers calving first at two years of age.

Materials and Methods

Experimental Samples

A total of 140 heifers of Bonsmara breeding (full bloods, 7/8 and ¾) were weighed, ultra-sounded for backfat, rectally palpated for pregnancy and scored for BCS (1 thin -9 fat) and Frame Score (1 short -9 tall) in December over 2 years (2007 and 2008). Within each year all heifers had been maintained as a single herd since weaning. Heifers were exposed to Bonsmara bulls from April 15 to July 15 of each year. Once pregnancy status had been determined, an expected calving date was predicted for each heifer. Heifers were stratified on expected calving date, and randomly allotted to 2 levels of nutrition for the remainder of gestation (Table1). In 2007, 31 heifers were allotted to range pasture (low nutrition-LOW) and 31 heifers to non-irrigated oat pasture (high nutrition-HIGH). In 2008, 31 heifers were placed onto the same range pasture as in 2007 (LOW) but due to dry weather there were no oats for grazing so 30 heifers were placed onto irrigated ryegrass pasture (HIGH). Heifers grazing range pastures were supplemented with 20% All Natural Crude Protein cubes at the rate of 2 lb/heifer/day from January 2 till calving while heifers grazing oats or ryegrass pastures were not supplemented. One week prior to expected calving date, heifers were placed in a dry lot and given access to free choice haygrazer (2007) or coastal Bermuda grass (2008) hay and supplemented with 20% All Natural Crude Protein cubes at the rate of 4 lb/heifer/day. As heifers approached the calving season (January 15-May 1), they were observed continuously every day during the daylight hours of 7:30 am to 4:30 pm. Heifers were not observed during the night, however, for any heifer exhibiting signs of imminent parturition, vigilance was maintained until calving occurred. Any heifers exhibiting signs of calving for more than 2 hours were placed into a working chute and assisted with the calving process (including, if needed, the use of a mechanical apparatus and Caesarean section by a licensed veterinarian). Within four hrs. of birth, calves were weighed, given Calf Vigor and Calving Difficulty Scores. Calf difficulty scores were: 1=No Difficulty, no assistance, 2=Minor difficulty, some assistance, 3=Major difficulty, usually mechanical assistance, 4=Caesarian section or surgery, 5=Abnormal presentation, BIF (2005). Calf vigor scores were: 0=dead, 1=weak, not alert, unable to stand, 2=weak, alert, able to stand, 3=healthy, alert, slow to nurse, 4=healthy, vigorous, nurse within 2hrs of birth. Heifers were weighed, ultra-sounded for backfat and fat in the udder, and udder measurements taken within 72 hours of parturition. Table 1 lists the number of heifers utilized in this experiment.

Data Analysis

Regression analysis was performed (PROC GLM, SAS, 2009) to produce least square means for treatment contrasts. The model was Y = calf birth date, dam birth date, calf sex, dam breed (full blood Bonsmara, 15/16, 7/8, 3/4 blood Bonsmara), year, treatment (high or low nutrition during last trimester of pregnancy), year x treatment, calf birth date x treatment, calf sex x treatment, and dam breed x treatment. When an *F*-test showed a significant difference for an effect ($P < 0.10$), least squares means were reported. Least squares means were separated using the standard errors from the PDIFF function (SAS Inst. Inc., Cary, NC). Two heifers from the HIGH treatment had late gestation abortions and 1 heifer from LOW treatment 1 had twins and all 3 were subsequently deleted from the analysis.

Results and Discussion

As intended, measurements made at the initiation of the trial were not different ($P > 0.5$) between heifers allotted to the two gestational nutrition treatments. All heifers met the management target for coming two year old heifers entering the last trimester of gestation (990 lb, BCS and Frame Score of 6.3, Table 2). Twice as many heifers on the HIGH treatment required major assistance at calving than those on the LOW level (Table 3). Twenty eight percent of heifers on the HIGH treatment had calves born dead as compared to 10% on the LOW treatment (Table 4). Almost twice as many calves born to heifers on the HIGH treatment were healthy and vigorous at birth than those born to the LOW treatment heifers (Table 4). Heifers on LOW prior to calving lost 33 lb during the trial including weight lost at calving whereas those on HIGH gained 107 lb. Level of nutrition prior to calving did not influence the size of the pelvic canal ($P > 0.2$, Table 5). After calving, cows on HIGH weighed 963 and 1090 lb respectively. Cows on the HIGH regime also had 0.29 in. more backfat at calving than those on LOW (Table 5). Table 2 shows the percent of heifers displaying calving difficulty. Heifer Calves born to heifers on HIGH weighed 8 lb more at birth than those born to heifers on LOW. These differences resulted in heifers that had been on HIGH prior to calving having considerably ($P = 0.005$) more calving difficulty than those on LOW (calving difficulty score of 2.3 for HIGH and 1.6 for LOW). Their calves also were less vigorous after birth (calf vigor score of 2.2 for HIGH and 3.3 for LOW). Apparently Bonsmara influenced cattle respond to HIGH during pregnancy by increasing nutrient supply to the calf at the same time as increasing overall fatness. This results in greater impacts on calving difficulty than would be expected from research results reported for British and European continental breeds.

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Table 1. Experimental design, number of females.

Variable	Yr=2007		Yr=2008		Total
Treatment	LOW=Range	HIGH=Oats	LOW=Range	HIGH=Ryegrass	
Declared Pregnant	31	31	31	30	123
Calved	30	29	30	28	117
Apparent Miscarries	1	2	2	1	6
Abortions	0	0	0	2	2
Died at calving	0	1	2	1	4

Table 2. Heifer traits at initiation of trial.

Variable	LOW	HIGH	Significance P > t	Residual standard error
Heifer weight, lb	996 ± 13.5	983 ± 13.1	0.50	72.6382
Heifer backfat, ultrasound, in.	0.28 ± 0.01	0.29 ± 0.01	0.53	0.2847
Body Condition Score (1-9)	6.2 ± 0.15	6.3 ± 0.15	0.51	0.8211
Frame Score (1-9)	6.3 ± 0.15	6.3 ± 0.15	0.98	0.8145
Heifer pelvic width, in	5.16 ± 0.07	5.20 ± 0.07	0.52	0.9242
Heifer pelvic height, in	6.29 ± 0.06	6.18 ± 0.06	0.29	0.8120
Heifer pelvic area, in^2	82.0 ± 1.46	81.9 ± 3.58	0.93	19.820

Table 3. Distribution of Calving Difficulty Score, % within treatment[1]

	Treatment[2]	
Calving Difficulty Score[3]	LOW	HIGH
1	65	47
2	14	7
3	21	42
4	0.00	4
5	0.00	0.00

[1]Two levels of nutritional grazing for last trimester of pregnancy.
[2]Treatment 1 = South Texas range, Treatment 2 = Oats (2007), ryegrass (2008).
[3]Calving Difficulty Scores: 1=No Difficulty, no assistance. 2=Minor difficulty, some assistance, 3=Major difficulty, usually mechanical assistance, 4=Caesarian section or surgery, 5=Abnormal presentation, BIF (2005).

Table 4. Distribution of Calf Vigor Score, %within treatment[1]

	Treatment[2]	
Calf Vigor Score[3]	LOW	HIGH
0	10	28
1	4	9
2	7	16
3	14	14
4	65	33

[1]Two levels of nutritional grazing for last trimester of pregnancy.
[2]Treatment LOW = South Texas range, HIGH = Oats (2007), Ryegrass (2008).
[3]Calf Vigor Scores: 0=dead, 1=weak, not alert, unable to stand, 2=weak, alert, able to stand, 3=healthy, alert, slow to nurse, 4=healthy, vigorous, nurse within 2 hr of birth.

Table 5. Influence of nutrition during gestation on measurements made at calving (heifer measurements made between 4-72 hours after calving).

Variable	LOW	HIGH	Significance P > t	Residual standard deviation
Heifer weight, lb	963 $\pm$ 15.5	1090 $\pm$ 14.9	< 0.0001	82.38
Heifer backfat, ultrasound, in	0.16 $\pm$ 0.013	0.45 $\pm$ 0.012	< 0.0001	0.0686
Calf birth weight, lb	72 $\pm$ 1.7	80 $\pm$ 1.6	0.001	9.123
Calving difficulty score	1.6 $\pm$ 0.16	2.3 $\pm$ 0.16	0.005	0.8708
Calf vigor score	3.3 $\pm$ 0.27	2.2 $\pm$ 0.26	0.005	1.4375

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