

Final Report
Texas Cattle Feeders Association
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- II. Institution:** Texas A&M University
- III. Project Title:** Relationships between net feed efficiency and performance, carcass and other physiological traits in growing and finishing Santa Gertrudis calves
- IV. Stated Objectives:**
1. Examine the relationships between feed efficiency measured in growing steers fed a roughage-based diet and feed efficiency measured in finishing steers fed a grain-based diet.
 2. Examine the relationships between growing and finishing feed efficiency traits and ultrasound estimates of carcass composition measured during the study and carcass composition, tenderness and other quality attributes measured at harvest.
 3. Examine the relationships between indicator traits (exit velocity and serum cortisol and IGF-I concentrations), and performance, carcass and feed efficiency traits.
 4. Compare actual measures of DMI and feed efficiency traits with estimates of dry matter required (**DMR**) and feed efficiency (DMR/ADG) generated by the CVDS model.
 5. Compare empty body fat (**EBF**) predicted by the CVDS model and that obtained based on ultrasound and carcass cooler data with EBF predicted by 9-11th rib chemical analysis.
 6. Conduct sensitivity analysis of the CVDS predictions based on diet composition, animal performance, and composition of the gain.
- V. Background information about the need for this research.**

Feed costs represent more than 60% of the cost of producing beef, and manure output is the primary contributor to the industry's adverse effect on the environment. Feed efficiency is therefore an important trait to consider in developing selection programs to identify cattle that are more economically and environmentally sustainable to produce. Yet, current genetic selection programs remain primarily focused on output traits (e.g., growth, carcass traits). Selection strategies are needed that will improve efficiency of feed utilization, but not alter performance traits or compromise carcass quality. Feed-to-gain or feed conversion ratio (**FCR**) has been the traditional trait used to assess feed efficiency in cattle. Although FCR is known to be moderately heritable, FCR is strongly correlated genetically in a negative manner with growth traits and mature size. As such, it is difficult to determine if variation in FCR represents inherent differences in energetic efficiency or differences in growth and(or) changes in maturity pattern. An alternative trait is needed that will quantify differences in feed efficiency independent of differences in growth traits. Moreover, while new technologies (e.g., GrowSafe[®] feed intake system) are now available to reduce the costs of measuring individual feed intakes in cattle, there is a need to develop alternative approaches to identifying efficient animals that do not require individual feed intake measurements.

Two recent developments have the potential to improve our ability to identify more efficient animals for use in selection programs:

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1. Development of an alternative feed efficiency trait (net feed intake; **NFI**) that identifies efficient cattle independent of growth traits. Net feed intake is calculated as actual feed consumed minus an animal's expected feed intake based on average daily gain (**ADG**) and body weight (**BW**). Thus, obtaining NFI data requires that individual feed intakes be measured.
2. Development of a mathematical model (Cornell Value Discovery System, **CVDS**) to estimate feed required for observed performance based on individual ADG, BW, and estimates of composition of gain for group-fed cattle. This CVDS model has been successfully used to allocate feed to individual calves fed in group pens and has potential to be used to select cattle for improved feed efficiency.

Net feed intake in beef cattle. As described above, NFI is calculated as the difference between actual DMI and the DMI an animal is expected to eat based on its size and growth rate. The expected DMI for each individual is computed from a regression equation derived from the group being evaluated. Cattle that are larger and grow faster would be expected to consume more feed than cattle that are smaller and grow slower. **Thus, cattle that eat less than expected for their BW and ADG have a negative or low NFI and are the most efficient, while calves that eat more than expected for their BW and ADG have positive or high NFI and are the least efficient.** We have examined phenotypic relationships between NFI and performance traits in growing crossbred steers (n = 169; Carstens et al., 2002), and found that NFI was positively correlated with DMI (r = 0.59) and FCR (r = 0.49), but not ADG or BW. In contrast, FCR was negatively correlated phenotypically with ADG (r = -0.72). In this study, the most efficient steers (steers with NFI < 0.5 SD from the mean; n = 54) consumed 17% less feed than the least efficient steers (steers with NFI > 0.5 SD from the mean; n = 51) even though final BW (715 vs 712 lb) and ADG (2.24 vs 2.24 lb/day) were similar for both groups.

Two recent studies have found that NFI is moderately heritable, and genetically independent of BW and ADG in growing bulls (Arthur et al., 2001b; Schenkel et al., 2004). In these studies, FCR was also found to be moderately heritable, however FCR was strongly correlated in a negative manner with ADG, indicating that direct selection for improved FCR would cause indirect increases in growth and mature size. Arthur et al. (2001c) found that calves born to parents selected for low NFI (more efficient) after almost two generations were similar in yearling BW (845 vs 838 lb) and ADG (3.17 vs 3.08 lb/day), but consumed 12% less feed and had lower FCR (6.6 vs 7.8) compared to calves born to parents selected for high NFI. *These studies demonstrate that NFI is a trait that will allow producers to select for improved feed efficiency without impacting genetic merit for growth or size.*

Archer et al. (1999) suggested that NFI is a trait that reflects variation in metabolic processes that impact key components of efficiency such as energy requirements for maintenance. Basarab et al. (2003) found that steers with high NFI produced 10% more total heat and had heavier liver and gastrointestinal tract weights than steers with low NFI even though BW and ADG were similar. Differences in digestibility may also account for some of the variation in NFI, though few studies have examined the relationship between NFI and digestibility. Oddy & Herd (2001) found that steers born to low-NFI parents (more efficient) tended to have higher digestibilities (79.5 vs 77.3) than steers born to high-NFI parents. *Additional studies are needed to determine the biological basis for within-breed variation in NFI in beef cattle.*

Differences in body composition may also contribute to variation in NFI. Positive, but low genetic correlations between NFI and ultrasound estimates of carcass fatness have been reported (Arthur et al., 2001; Herd & Bishop, 2000), suggesting that cattle with lower NFI are leaner. However, Crews et al. (2003) reported a negative genetic correlation between NFI and carcass backfat thickness. Positive phenotypic correlations have been reported between NFI and ultrasound estimates of backfat thickness (Carstens et al., 2002) and empty body fat (Basarab et al., 2003), but the magnitude of these relationships were small. Few studies have examined the relationships between

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NFI and carcass quality traits. McDonagh et al. (2001) examined carcass quality traits in steers produced from a single generation of divergent selection for low and high NFI. In this study, selection for NFI had no effect on marbling scores, meat or fat color, or LD muscle shear force. However, steers from the low NFI parents had a lower index of myofibril fragmentation in LD muscle and higher levels of calpastatin activity compared to steers from the high NFI parents. These later findings suggest the possibility that long-term selection for low NFI may be associated with a reduction in the rate of postmortem protein degradation, which could potentially have a negative impact on tenderness. *Additional studies are needed to examine relationships between NFI and carcass composition and quality.*

The primary limit to implementing selection programs to improve NFI is the difficulty and expense of measuring individual feed intake. Identification of physiological indicators (e.g., hormone) or other measurements that are predictive of NFI would be useful as early screening tests to reduce the number of animals that would need to be tested. For example, Petherick et al. (2002) reported that exit velocity (time to travel a defined distance exiting a working chute) was negatively correlated phenotypically with ADG and feed efficiency, indicating that less stress-responsive steers performed better. Moreover, Australian research has shown that exit velocity is negatively correlated genetically with carcass tenderness. Steers with low NFI had lower hemoglobin:red blood cell ratios and lower serum protein concentrations than steers with high NFI steers (Richardson et al., 1996). Theis et al. (2002) found that serum cortisol, hemoglobin concentrations, and RBC counts were negatively correlated with ADG and feed intake and positively correlated with FCR. Moore et al. (2005) reported that plasma IGF-I concentrations were positively correlated genetically with NFI ($r_g = 0.56$) in growing cattle, suggesting that IGF-I may be a useful physiological indicator of NFI. *Additional studies are warranted to identify and evaluate the use of physiological indicators as indirect selection criterion for NFI in beef cattle.*

While a number of studies have demonstrated that genetic variation in NFI exists in growing cattle, few studies have been conducted to determine if NFI measured in growing calves is comparable with NFI measured in finishing calves. In Charolais-crossbred steers, Crews et al. (2003) found that NFI measured during the growing phase while fed a barley-silage diet were positively correlated genetically ($r_g = 0.55$) to NFI measured during the subsequent finishing phase while fed a barley-grain diet. The authors suggested that although NFI measured in growing and finishing steers were favorably associated, the two traits may not be genetically equivalent. *Additional studies are needed to examine the relationships between NFI measured on roughage- vs grain-based diets. Moreover, as all NFI studies to date have been conducted with Bos taurus cattle, studies with Bos indicus-influenced cattle are warranted.*

There are currently two DNA tests for tenderness that are commercially available to use in selection for tenderness (polymorphisms related to calpain and calpastatin genes). Much of the research conducted to date has been based on using Warner-Bratzler shear force measurements to establish the efficacy of these DNA test for tenderness. However, there are other indicators of tenderness that are currently being used or being researched for use by the industry. One example is the CVS BeefCam[®] Tenderness Module (Vote et al., 2003). It is important to establish the relationships between DNA tests and these other measures of tenderness as it is unlikely that Warner-Bratzler shear force will be used routinely as an ongoing measure of tenderness by the industry. The more rapid measurements of tenderness, such as the CVS BeefCam[®] Tenderness Module, offer the opportunity for mass screening of meat products. *It will important for producers to know if these DNA tests for tenderness are predictive of the measures generated by these technologies that are likely to be used to screen and segregate meat products.*

Predicting feed efficiency of individual cattle fed in groups. Most progeny tests are conducted on farm, where calves are group fed in large pens. Growth rate is the most common trait measured, however, selection for this trait has led to an increase in mature size, and a reduction in carcass

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grade at desired finished BW (Fox et al., 2001a). A mathematical model has been developed to estimate feed required for observed performance based on individual ADG, BW, and estimates of composition of gain (Guiroy et al., 2001). The potential use of this model (Cornell Value Discovery System, **CVDS**) in selecting for feed efficiency has been explored (Fox et al., 2002), and has been successfully used to allocate feed to individuals fed in group pens and market them at their most profitable endpoints. When evaluated in commercial feedlots, the overall error in accounting for the feed actually fed was less than 1% (Guiroy et al., 2001). In evaluations of the model at Cornell since 1997, the overall prediction of DMR has typically been within 1 to 3% of the amount of feed fed for growing/finishing calves fed in group pens.

Recently, a dynamic, iterative and mechanistic growth model has been developed for the CVDS (Tedeschi et al., 2004). This growth model accounted for 74% of the variation in the observed DMI of 362 individually-fed steers with a 2% bias; the measured carcass composition and adequate diet characterization in this data allowed accurate accounting for differences in ration energy and composition of gain. In this CVDS model, an iterative process was developed to estimate partial efficiency of ME for growth based on composition of gain. *More information is required to evaluate the effect of composition of gain on determining feed efficiency in growing and finishing animals of different breeds.*

The evaluation of the CVDS model to estimate feed efficiency indicated high precision (r^2 of 84%) with low a bias of 1.94% using data from 362 individually-fed steers (Tedeschi et al., unpublished). Our evaluations indicated a good agreement in the ranking analysis between predicted and observed FCR, suggesting the CVDS model was able to rank the most efficient animals without individual DMI measurements. The model was able to identify 34 out of 50 most efficient animals (68% accuracy). *Additional research is needed to further evaluate the CVDS model with individually fed cattle, particularly with *Bos indicus* breed types.*

VI. Achievement of the specific objectives.

1. *Examine the relationships between feed efficiency measured in growing steers fed a roughage-based diet and feed efficiency measured in finishing steers fed a grain-based diet.* Three feed efficiency traits were characterized in *Bos indicus* type steers during growing and finishing phases. Average daily gain was strongly correlated with feed conversion ratio (**FCR**) and marginally correlated with partial efficiency of growth (**PEG**), but was not correlated with net feed intake (**NFI**), demonstrating that NFI will facilitate selection for improved feed efficiency independent of responses in growth or mature size. During both growing and finishing phases, steers with low NFI consumed 18-19% less feed and had 19-23% lower FCR than steers with high NFI. Of the three feed efficiency traits compared between growing and finishing phases, NFI had the strongest correlation, suggesting that NFI may be the most appropriate trait to use in evaluating feed efficiency across various production phases.
2. *Examine the relationships between growing and finishing feed efficiency traits and ultrasound estimates of carcass composition measured during the study and carcass composition, tenderness and other quality attributes measured at harvest.* To determine if carcass composition and(or) quality traits were unfavorably related to the feed efficiency traits, ultrasound traits were measured at the end of the growing and finishing phases, and 9-11th rib analysis, marbling, Warner-Bratzler shear force (**WBSF**) and calpastatin activity were measured at harvest. Feed efficiency traits measured during the growing phase were not correlated to ultrasound measurements of composition or marbling. Ultrasound backfat thickness and 9-11th rib fat content was correlated with PEG and NFI measured during the finishing phase, such that more efficient PEG and NFI phenotypes tended to be leaner than the inefficient phenotypes. During the finishing phase, correlations with carcass fatness traits were strongest for PEG, nonsignificant for FCR and intermediate for NFI. Likewise, marbling scores

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and quality grades were more correlated with PEG than FCR or NFI, such that the more efficient PEG phenotypes had slightly less intramuscular fat. Partial efficiency of growth, but not FCR or NFI was positively correlated with day-1 WBSF indicating that more efficient PEG phenotypes were slightly tougher. The results suggest that steers identified as having low NFI during the finishing phase were slightly leaner, but were not different in tenderness or marbling compared to steers with high NFI.

3. *Examine the relationships between indicator traits (exit velocity and serum cortisol and IGF-I concentrations), and performance, carcass and feed efficiency traits.* Discovery of indicator traits that are predictive of NFI would be useful as early screening test to reduce the cost of identifying efficient phenotypes. Serum IGF-I was correlated with NFI during the growing phase, but not the finishing phase, supporting previous research demonstrating the use of serum IGF-I as an indicator trait for NFI is most appropriate in newly weaned calves. Serum cortisol does not appear to have utility as an indicator trait for performance or feed efficiency traits. Evaluation of exit velocity relationships, revealed that this indicator trait was a better predictor of performance traits than feed efficiency traits. Exit velocity measured prior to harvest, but not at the start of the finishing phase, was correlated with WBSF, such that steers with calmer temperaments (faster exit velocities) were more tender.
4. *Compare actual measures of DMI and feed efficiency traits with estimates of dry matter required (DMR) and feed efficiency (DMR/ADG) generated by the CVDS model.* During the growing phase, DMR predictions were derived from ultrasound measurements (**DMR_{UL}**). DMR predictions were based on empty body fat estimates derived carcass cooler trait measurements (**DMR_{CC}**), and 9-11th rib chemical analysis (**DMR_{RIB}**), as well as from ultrasound measurements during the finishing phase. During the growing phase, strong correlations were found between actual DMI and FCR and DMR and FCR_{UL} (**DMR_{UL}/ADG**). Likewise, during the finishing phase, DMI was strongly correlated with **DMR_{UL}**, **DMR_{CC}** and **DMR_{RIB}**, and actual FCR strongly correlated with **FCR_{UL}**, **FCR_{CC}**, and **FCR_{RIB}** ($r = 0.79, 0.82,$ and 0.83 ; respectively). These results suggest that the use of carcass ultrasound and carcass cooler traits were equally effective in estimating composition of growth to predict DMR using the CVDS model. The use of the chemical analysis of the 9-11th rib to estimate actual empty body fat and BW at 28% empty body fat had little effect on improving the prediction **DMR_{RIB}** and **FCR_{RIB}** compared to using ultrasound measurements and carcass traits. These results indicate that further work is needed to enhance the ability of mathematical models to predict composition of gain in order to more accurately predict DMR in growing and finishing calves.
5. *Compare empty body fat (EBF) predicted by the CVDS model and that obtained based on ultrasound and carcass cooler data with EBF predicted by 9-11th rib chemical analysis.* Good estimates of EBF are critical to accurate prediction of DMR and feed efficiency. In this study, the correlations between empty body fat predicted from the 9-11th rib analysis (**EBF_{RIB}**) and empty body fat estimated from ultrasound measurements (**EBF_{UL}**) and carcass cooler traits (**EBF_{CC}**) were 0.62 and 0.69; respectively. These correlations were less than we had anticipated and illustrate that more work is needed to further develop ultrasound technologies to more accurately assess EBF in cattle.
6. *Conduct sensitivity analysis of the CVDS predictions based on diet composition, animal performance, and composition of the gain.* The impact of error in estimating diet metabolizable energy (**ME**) concentration or composition of gain (± 10 and $\pm 20\%$) on model precision and accuracy was examined. This analysis indicated the CVDS model had a high precision in prediction of DMR regardless the diet ME used, and that using ME values that are lower or higher than the real diet ME would have little or no effect on ranking the animal using

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predicted DMR. Similar to the sensitivity analysis on diet ME, changing the composition of gain had little effect on the ranking of animals using the model to predict DMR. Based on these analyses, we concluded that improvements in the accuracy and precision of mathematical models to estimate diet energy values and composition of gain can enhanced our ability to estimate animal performance and DMR. Future efforts will focus on the utility of using model predictions of DMR in combination with physiological indicator traits and(or) genetic markers of NFI to more accurately and cost effectively identify growing calves with superior genetic merit for feed efficiency.

VII. Materials and Methods.

Sire-identified Santa Gertrudis steers were weaned from one of five herds at the King Ranch (n = 120) and transported to the Animal Science Teaching Research and Extension Center in College Station. The steers were placed in one of 20 pens equipped with Calan gate feeders (six/pen) to measure individual feed intakes. Steers were blocked by sire-progeny groups within weaning-weight contemporary groups and assigned to pen. Wherever possible, at least two steers per sire were represented in each pen. Steers were adapted to a roughage-based diet and trained to eat from Calan gates for 21 d. At the end of this adaptation period, steers were individually fed for 77 d to determine growing-phase NFI. Steers were then be adapted to the high-grain diet for 21 d, and thereafter individually fed for 80 days to determine finishing-phase NFI. During both the growing and finishing measurement periods, BW were measured weekly, diets fed ad libitum twice daily and feed refusals measured weekly.

Ultrasound measures of 12th rib fat thickness (**BF**), ribeye area (**REA**) and intramuscular fat (**IMF**) was obtained at the start and end of the growing period, and on day 70 of the finishing period. Steers were assigned a subjective temperament score in the squeeze chute (1 = calm; 5 = continuous vigorous movement), and escape velocity from the chute measured by electronic timing. Temperament scores and escape velocities were measured at the start and end of the growing period, and on day 70 of the finishing period. Blood samples were collected from all steers at the start of the initial adaptation period at the King Ranch, at the start and end of the growing period, and on day 70 of the finishing period. Plasma was harvested from blood samples and assays conducted to determine cortisol and IGF-I concentrations.

Steers were transported to Sam Kane Beef Processors, Inc. and harvested at a common backfat thickness endpoint of 0.4 inches. Steers were harvested in two groups; on days 80 and 108 of the finishing phase. After a 24-h chill, a 50-g sample was collected from the *longissimus dorsi* (**LD**) muscle to determine calpastatin activity. After a 48-h chill, carcass characteristics (skeletal and muscle maturity, 12th rib fat thickness, LD muscle area, KPH fat, marbling score) were measured to determine yield and quality grades. The 6-12th rib section was removed, vacuumed packaged and transported to Rosenthal Meat Science Center. Two steaks were obtained from the 12th rib section, and randomly assigned to one- or 14-d aging periods to determine Warner-Bratzler shear force (**WBSF**). Warner-Bratzler shear force steaks were thawed to 2°C and cooked on an open hearth grill to an internal temperature of 70°C. Temperature was monitored using iron-constantan thermocouples inserted into the geometric center of each steak. Steaks were cooled to room temperature and 6-0.5 inch cores were removed. Total pounds of force required to segment each core was recorded using a Universal Testing machine. The average of the six cores were reported as the WBSF for each steak. The 9-11th rib section was dissected into separable fat, lean and bone tissue, and soft tissue subsequently analyzed for moisture, lipid and protein content to determine carcass and empty body composition.

NFI calculations and analyses. Linear regression of weekly BW on time was used to derive ADG, initial and final BW for each steer during the growing and finishing periods. To determine growing and finishing NFI, average daily DMI was regressed on ADG and mid-test BW^{0.75}, and individual NFI calculated as the actual DMI minus DMI predicted from the regression equation (Carstens et

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al., 2002). Feed conversion ratio was calculated as DMI divided by ADG. Partial efficiency of growth (**PEG**) was calculated as the ratio of ADG to DMI available for growth (Arthur et al. 2001a). Dry matter intake for growth was computed as actual DMI minus expected DMI for maintenance. The expected DMI to meet maintenance requirements was calculated as $0.077 \cdot \text{MBW} \div \text{NEm}$ concentrations of the test diets. Partial correlation coefficients were determined to examine phenotypic relationships between growing and finishing efficiency traits, as well as between efficiency traits and performance traits, physiological indicators, ultrasound measures of carcass composition, and carcass composition and quality measures obtained at harvest. To further characterize NFI, steers were ranked by NFI, separated into low, medium and high groups that are $< 0.5 \text{ SD}$, $\pm 0.5 \text{ SD}$, and $> 0.5 \text{ SD}$, respectively, from the mean NFI, and data analyzed using a model to determine if significant differences exist between low vs high NFI groups.

Procedures for CVDS analysis. Individual DMR was predicted from observed ADG, final BW adjusted to 28% empty body fat, diet chemical composition and weather data as described below. The predicted DMR and DMR/ADG were compared with actual DMI and FCR to evaluate the CVDS model. During the growing phase, DMR predictions were based on empty body fat (predictor of composition of gain) estimates derived from ultrasound measurements obtained at the end of the growing phase (**DMR_{UL}**). During the finishing phase, DMR predictions were based on empty body fat estimates derived from carcass cooler trait measurements (**DMR_{CC}**), and chemical analysis of 9-11th rib sections obtained at harvest (**DMR_{RIB}**), as well as from ultrasound measurements obtained on day 70 of the finishing phase.

1. Actual Average Daily Gain: The actual ADG will be derived from the linear regression of BW (measured at 14-d intervals) on days on feed.
2. Adjusted Final Body Weight: Predicted DMR computed by the CVDS model requires an estimate of final BW adjusted to a 28% empty body fat endpoint. Empty body fat derived from the chemical analysis of the 9-11th rib section was used to predict adjusted final BW (Guiroy et al., 2002). The ultrasound measurements obtained prior to slaughter was compared with empty body fat derived from the 9-11th rib chemical analysis, and a multiple regression equation developed to predict empty body fat from ultrasound measurements.
3. Ration Analysis: Accurate ration characterization is critical to determine metabolizable energy concentration, which is used in the CVDS model to partition feed required for maintenance and for growth. Individual ration ingredients were sampled weekly and composited at the end of each period. Samples were sent to the Dairy One Laboratory (Ithaca, NY) for chemical analysis (NDF, ADF, lignin, CP, protein solubility, ADF protein, fat, and ash).
4. Environmental Information: Because the CVDS model accounts for the effects of environment on intake and the energy requirement for maintenance due to heat and cold stress, weekly measurements of temperature, relative humidity and sunlight were recorded.

Santa Gertrudis steers and heifers (N = 451; contemporaries of the steers used in the College Station study) were also used in this study. Prior to being transported to the King Ranch Feedyard, exit velocities were measured, and a blood sample collected as described above. All steers and heifers were assigned to group pens and fed a receiving diet for 30 days prior to being fed a finishing diet. During the finishing period, calves were weighed at 28-d intervals. Ultrasound measurements were obtained prior to the calves being shipped for harvest. As in the College Station study, steers and heifers were transported to Sam Kane Beef Processors, Inc. and harvested at a common 0.4 inch backfat endpoint. After a 48-h chill, carcass cooler traits were measured to determine yield and quality grades. The 12th rib section was removed to provide steaks for 14-day WBSF determination. Complete carcass cooler data and WBSF were obtained on 442 carcasses. As carcasses were presented for grading, digital video images of the 12-13th rib interface were obtained using a CVS BeefCam camera, and data processed via proprietary software that was used

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to generate output variables to predict WBSF, BF, REA and yield and quality grades. Of the 451 carcasses submitted for CVS BeefCam analysis, data were obtained on only 325 carcasses, due to misidentification of carcasses at the plant and missing output data. The CVS BeefCam data for the steers from the College Station study were not obtained due to miscommunications.

VIII. Summary of Results and Discussion.

1. Examine relationships between feed efficiency measured in growing steers fed a roughage-based diet and feed efficiency measured in finishing steers fed a grain-based diet.

Feed efficiency and growth trait relationships during the growing phase. During the 77-day growing phase, overall ADG, DMI, and NFI were 2.78 (SD = 0.46), 22.2 (SD = 2.87), and 0.00 (SD = 1.96) lb/d, respectively. Phenotypic correlations between growth and efficiency traits for the growing and finishing phases are presented in Table 1. During the growing phase, DMI was strongly correlated in a positive manner ($r > 0.50$) with ADG, and initial and final BW, illustrating that larger and faster growing steers consume more feed. However, given that the correlation between DMI and ADG was considerably less than unity ($r = 0.59$), the results illustrate that considerable variation in the amount of DMI consumed by individual steers at a given growth rate exists. Similar phenotypic correlations have been reported in previous studies in growing calves (Arthur et al., 2001a; Carstens et al., 2002). ADG was not correlated with NFI as expected, but was strongly correlated with FCR ($r = -0.66$) and marginally correlated with PEG ($r = 0.23$). Thus selection for favorable NFI (low) and PEG (high) phenotypes would result in minimal growth responses, whereas, selection for favorable FCR (low) phenotypes would result in increases in growth and mature size. Initial BW was correlated with FCR ($r = 0.24$) and tended to be correlated with PEG ($r = -0.17$), such that favorable FCR and PEG phenotypes were those that were lighter at the start of the test. Initial BW was not correlated with NFI. Dry matter intake was strongly correlated with PEG ($r = -0.58$) and NFI ($r = 0.68$), such that the efficient phenotypes consumed less feed. Dry matter intake tended ($P < 0.10$) to be correlated with FCR. Net feed intake was strongly correlated with FCR ($r = 0.61$), and PEG ($r = -0.91$) in growing steers, indicating that the three feed efficiency traits examined in this study were strongly related.

Growth and feed efficiency results for steers with low, medium and high NFI during the growing and finishing phases are presented in Table 2. Growing steers with low NFI (< 0.5 SD below the mean) consumed 18% less feed than high NFI steers (> 0.5 SD above the mean). Consequently, steers with low NFI had a 19% lower ($P < 0.01$) FCR compared to steers with high NFI, as ADG was similar for steers with low and high NFI. Steers with low NFI were also more ($P < 0.01$) efficient as measured by PEG (0.32 vs 0.20 ± 0.004 ADG/DMI for growth) compared to steers with high NFI.

Table 1. Phenotypic correlations^a between growth, feed intake and feed efficiency traits in growing and finishing steers

Trait ^b	Final BW	ADG	DMI	FCR	PEG	NFI
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Growing Phase

Initial BW	0.91	0.17†	0.53	0.24	-0.17†	0.00
Final BW		0.56	0.69	-0.07	-0.05	0.00
ADG			0.59	-0.66	0.23	0.00
DMI				0.18†	-0.58	0.68
FCR					-0.80	0.61
PEG						-0.91

Finishing Phase

Initial BW	0.93	0.26	0.59	0.26	-0.38	0.00
Final BW		0.59	0.75	-0.02	-0.33	0.00
ADG			0.69	-0.63	0.03	0.00
DMI				0.07	-0.65	0.59
FCR					-0.64	0.54
PEG						-0.79

^aCorrelations in bold are different from zero at $P < 0.05$;

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

^bFCR = feed conversion ratio; PEG = partial efficiency of growth; NFI = net feed intake.

Feed efficiency and growth trait relationships during the finishing phase. During the 80-day finishing phase, overall ADG, DMI, and NFI were 2.26 (SD = 0.53), 20.0 (SD = 3.8), and 0.00 (SD = 2.2) lb/d, respectively. Reasons for the unexpected low performance of steers during the finishing period were not evident, but likely were related in part to climatic conditions as steers were fed over the summer months in College Station. Similar to that observed during the growing phase, DMI was strongly correlated ($r > 0.50$) with ADG, and initial and final BW during the finishing phase. Average daily gain during the finishing phase was strongly correlated with FCR ($r = -0.63$), but not with PEG or NFI. Significant correlations were found between initial BW and FCR and PEG indicating the favorable FCR and PEG phenotypes were those that were lighter weight at the start of the finishing phase. Initial and final BW were not correlated with NFI. Dry matter intake was not correlated with FCR, but was strongly correlated with PEG ($r = -0.65$) and NFI ($r = 0.59$). Net feed intake was strongly correlated to FCR ($r = 0.54$), and PEG ($r = -0.79$) during the finishing phase.

Finishing steers with low NFI consumed 19% less feed and had a 23% lower FCR than finishing steers with high NFI (Table 2). Steers with low NFI were also more efficient as measured by PEG (0.25 vs 0.16 ± 0.01) compared to high NFI steers. In summary, the phenotypic correlations between performance and feed efficiency traits were remarkably similar for growing steers fed a high-roughage diet and finishing steers fed a high-grain diet. These results suggest that for steers fed high-roughage or high-grain diets, selection for favorable NFI and PEG phenotypes would result in minimal growth responses, whereas, selection for favorable FCR phenotypes would result in large increases in growth and mature size.

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

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

^aLow, medium, and high NFI steers were < 0.5 SD, ± 0.5 SD, and > 0.05 SD from the mean NFI of 0.00 ± 0.82 and 0.00 ± 0.89 kg/d (mean ± SD) for experiment one and two, respectively.

^bPEG, ADG/DMI for growth.

Trait relationships between the growing and finishing phases. Average daily gain and DMI measured during the growing phase were positively correlated with ADG ($r = 0.27$) and DMI ($r = 0.51$) during the finishing phase (Data not shown in tabular form). Feed conversion ratio ($r = 0.22$) and PEG ($r = 0.29$) were marginally correlated between the growing and finishing phases, whereas, growing-phase NFI and was moderately correlated ($r = 0.48$) with finishing-phase NFI. These results indicate that NFI measured in steers fed roughage diet was moderately related to NFI measured in steers fed a grain-based diets, but that these two feed efficiency traits may not be biologically similar. The fact that NFI had the highest correlation between growing and finishing phases, suggests that this feed efficiency trait may be the most appropriate trait to use in evaluating feed efficiency across various production phases. However, these results also demonstrate that diet and(or) stage of maturity may influence genetic ranking of NFI in growing cattle.

2. Examine the relationships between growing and finishing feed efficiency traits and ultrasound estimates of carcass composition measured during the study and carcass composition, tenderness and other quality attributes measured at harvest.

Relationships between feed efficiency and ultrasound carcass traits. Ultrasound estimates of ribeye area and backfat thickness measured at the end of the growing phase were positively correlated ($P < 0.05$) with DMI, but not with ADG (Table 3). Ribeye area measured at the end of the growing phase was not correlated with either of the feed efficiency traits. The lack of a correlation between NFI and ribeye area is consistent with results from previous studies in both growing (Carstens et al., 2002; Fox et al., 2004; Nkrumah et al., 2004; Schenkel et al., 2004) and finishing (Basarab et al., 2003; Nkrumah et al., 2004) steers and bulls.

Backfat thickness measured at the end of the growing phase was not significantly correlated with the feed efficiency traits, although the correlation between backfat thickness and NFI ($r = 0.14$) was within the range of correlations (0.14 to 0.20) previously reported in studies with growing steers and bulls (Arthur et al., 2001a; Carstens et al., 2002; Fox et al., 2004; Schenkel et al., 2004). Steers with low NFI tended ($P = 0.12$) to have less backfat than high NFI steers (Table 4). Collectively, these studies indicate that growing calves with low NFI (more efficient) will be slightly leaner than steers with high NFI. Final intramuscular fat was not correlated with feed efficiency traits during the

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growing phase (Table 3). Schenkel et al. (2004) also found that intramuscular fat was not correlated with NFI in growing bulls. However, Fox et al. (2004) found that ultrasound estimates of intramuscular fat tended to be positively correlated with NFI in Bonsmara bulls, suggesting that intramuscular fat may be unfavorably related to NFI.

Table 3. Phenotypic correlations^a between final carcass ultrasound measurements and performance and feed efficiency traits in growing and finishing steers

Trait ^b	ADG	DMI	FCR	PEG	NFI
<i>Growing Phase</i>					
Ribeye area	0.18†	0.33	0.08	-0.05	-0.03
Backfat thickness	0.07	0.21	0.10	-0.14	0.14
Intramuscular fat	0.13	0.14	-0.05	-0.06	0.11
<i>Finishing Phase</i>					
Ribeye area	0.33	0.44	-0.02	-0.21	0.09
Backfat thickness	0.38	0.62	0.10	-0.46	0.30
Intramuscular fat	0.09	0.09	-0.08	-0.09	0.07

^aCorrelations in bold are different from zero at $P < 0.05$.

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

^bDMI = dry matter intake; FCR = feed conversion ratio; PEG = partial efficiency of growth; NFI = net feed intake.

At the end of the finishing phase, ultrasound estimates of ribeye area and backfat thickness were significantly correlated with ADG and DMI (Table 3). Final ribeye area was marginally correlated with PEG ($r = -0.21$), but not FCR or NFI, and final backfat thickness was moderately correlated with NFI ($r = 0.30$) and PEG ($r = -0.46$) during the finishing phase. However, ultrasound estimates of intramuscular fat were not significantly correlated with either of the feed efficiency traits. Steers with low NFI during the finishing phase tended ($P = 0.09$) to have less backfat than high NFI steers (Table 4). These results suggest that the more efficient steers, as measured by NFI and PEG, were leaner than the less efficient steers. Additionally, these results indicate that the relationship between ultrasound estimates of carcass backfat thickness and NFI and PEG were stronger during the finishing phase than the growing phase.

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Table 4. Least squares means for final carcass ultrasound measurements in steers with low, medium, and high NFI^a during the growing and finishing phases

Trait	Low NFI	Medium NFI	High NFI	SE	P-value
<i>Growing Phase</i>					
Number of steers	35	45	35	--	--
Final rib eye area, in ²	9.42	9.42	9.35	0.17	0.92
Final back fat, in	0.12	0.12	0.15	0.01	0.12
Final intramuscular fat, %	1.76	1.90	1.89	0.12	0.63
<i>Finishing Phase</i>					
Number of steers	40	38	37		
Final rib eye area, in ²	12.4	12.4	12.6	0.23	.84
Final back fat, in	0.32	0.35	0.38	0.02	.09
Final intramuscular fat, %	2.82	3.19	2.99	0.13	0.10

^aLow, medium, and high NFI steers were < 0.5 SD, ± 0.5 SD, and > 0.05 SD from the mean NFI of 0.00 ± 0.82 and 0.00 ± 0.89 kg/d (mean ± SD) for experiment one and two, respectively.

^{xyz}Within a row, means without a common superscript letter differ ($P < 0.05$)

Relationships between feed efficiency and carcass composition traits measured at harvest. Carcass backfat thickness measured at harvest was correlated with PEG ($r = -0.42$) and NFI ($r = 0.29$), but not FCR measured during the finishing phase (Table 5). Likewise, yield grade was correlated with PEG and NFI, but not FCR. Chemical analysis of 9-11th rib section confirmed these results. The fat content of the 9-11th rib section was also correlated with PEG ($r = -0.40$) and NFI ($r = 0.22$), but not FCR. Steers with low NFI had less ($P < 0.05$) backfat, and tended ($P = 0.10$) to have lower yield grades compared to steers with high NFI (Table 6). Although not significant, steers with low NFI had numerically less 9-11th rib fat than steers with high NFI. Carcass ribeye area was not correlated with growth or feed efficiency traits. Moreover, 9-11th rib protein content was not significantly correlated with FCR or NFI, although 9-11th rib protein content was correlated with PEG. These results indicate that selection for improved NFI in cattle fed high-grain diets will result in slightly leaner cattle, with minimal effects on ribeye area or carcass protein content.

Relationships between feed efficiency and carcass quality traits measured at harvest. Marbling score and quality grade were significantly correlated with PEG, and tended to be correlated with FCR, such that favorable PEG and FCR phenotypes had lower marbling scores and quality grades (Table 5). Net feed intake was not significantly correlated with either marbling score and quality grade, although these correlations were approaching significance, suggesting the possibility that steers with favorable NFI may potentially have slightly lower marbling fat. However, marbling score and quality grade were similar for steers with low and high NFI (Table 6). Of the three feed efficiency traits measured during the finishing phase, PEG was the most and NFI the least correlated with marbling score, with FCR being intermediate. A number of studies have found that NFI was not correlated with ultrasound estimates of marbling fat in growing (Arthur et al., 2001; Carstens et al., 2002) and finishing calves (Nkrumah et al., 2004). However, Fox et al. (2004) and Basarab et al. (2003) reported that NFI tended to be positively correlated with marbling fat in growing bulls and finishing steers, indicating that calves with low NFI (more efficient) tended to have lower marbling scores.

Dry matter intake during the finishing phase was negatively correlated with day-1 WBSF ($r = -0.22$), suggesting that steers that consumed more feed yielded more tender beef (Table 5), although DMI was also positively correlated with calpastatin activity ($r = 0.29$). Calpastatin activity also tended ($P < 0.10$) to be correlated with ADG. Day-14 WBSF were not correlated with either of the performance or feed efficiency traits. Feed conversion ratio was not correlated with day-1 WBSF or calpastatin

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activity. Partial efficiency of growth was positively correlated with day-1 WBSF, suggesting that favorable PEG phenotypes were tougher, although PEG tended ($P < 0.10$) to be negatively correlated with calpastatin activity. NFI was not correlated with day-1 WBSF, but tended ($P < 0.10$) to be positively correlated with calpastatin activity. Day-1 and -14 WBSF measurements and calpastatin activity did not differ ($P > 0.05$) between NFI groups. These results suggest that steers identified as having low NFI during the finishing phase were slightly leaner, but were not different in tenderness or marbling compared to steers with high NFI. In contrast to these results, McDonagh et al. (2001) found that steer progeny from parents selected for low NFI had a lower index of myofibril fragmentation in LD muscle and higher calpastatin activities compared to steer progeny from high-NFI parents.

Table 5. Phenotypic correlations^a between carcass traits obtained at slaughter, and performance and feed efficiency traits in finishing steers

Trait ^b	ADG	DMI	FCR	PEG	NFI
<i>Carcass cooler traits</i>					
Hot carcass weight	0.56	0.72	-0.03	-0.34	0.02
Ribeye area	0.15	0.10	-0.09	0.01	-0.10
Backfat thickness	0.34	0.55	0.06	-0.42	0.29
Marbling score	-0.04	0.11	0.17†	-0.30	0.13
Yield grade	0.37	0.58	0.04	-0.42	0.27
Quality grade	0.005	0.16†	0.17†	-0.36	0.12
<i>Tenderness traits</i>					
Day-1 WBSF	-0.15	-0.22	-0.05	0.23	0.04
Day-14 WBSF	-0.04	-0.10	-0.09	0.09	0.07
Calpastatin activity	0.16†	0.29	0.04	-0.16†	0.17†
<i>9-11th rib composition</i>					
Protein	-0.16†	-0.27	-0.02	0.29	-0.12
Lipid	0.30	0.42	0.01	-0.40	0.22
Ash	-0.27	-0.37	0.002	0.32	-0.16†

^aCorrelations in bold are different from zero at $P < 0.05$.

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

^bDMI = dry matter intake; FCR = feed conversion ratio; PEG = partial efficiency of growth; NFI = net feed intake; WBSF = Warner-Bratzler shear force.

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Table 6. Least squares means for carcass quality traits obtained at slaughter in steers with low, medium, and high NFI during the finishing phase^a

Trait	Low NFI	Medium NFI	High NFI	SEM	P-value
Number of steers	40	38	37	--	--
<i>Carcass cooler traits</i>					
Hot carcass weight, lb	713.4	702.2	706.5	11.3	0.75
Ribeye area, in ²	12.1	11.9	11.7	0.16	0.11
Backfat thickness, in	2.49 ^x	3.23 ^y	3.18 ^y	0.23	0.02
Marbling score ^b	472.9	508.8	483.3	15.1	0.18
Yield grade	2.81	3.13	3.17	0.13	0.10
Quality grade ^c	423.0	435.0	425.5	6.2	0.30
<i>Tenderness traits</i>					
Day-1 WBSF	2.79	2.73	3.16	0.15	0.07
Day-14 WBSF	2.17	2.15	2.40	0.10	0.10
Calpastatin activity	2.62	2.64	2.84	0.07	0.06
<i>9-11th rib composition</i>					
Protein, %	14.8	14.4	14.5	0.31	0.60
Lipid, %	32.1	34.8	34.3	1.1	0.16
Ash, %	0.69	0.66	0.67	0.01	0.29

^aSteers with low, medium & high NFI were < 0.5, ± 0.5, > 0.5 SD from the mean NFI of 0.0.

^b400 = Small; 500 = Modest.

^c400 = Choice.

^{xy}Means with unlike superscripts differ (P < 0.05).

3. Examine the relationships between indicator traits (exit velocity and serum cortisol and IGF-I concentrations), and performance, carcass and feed efficiency traits.

Australian researchers (Moore et al., 2005) reported positive genetic correlations between plasma IGF-I concentrations measured in wean calves and NFI ($r_g = 0.56$), suggesting that IGF-I may be a useful physiological indicator of NFI. Day-0 serum IGF-I concentrations were positively correlated ($P < 0.05$) with growing phase DMI ($r = 0.33$) and NFI ($r = 0.19$), and tended ($P < 0.10$) to be correlated with PEG ($r = -0.17$; Table 7). However, serum IGF-I was not correlated with ADG or FCR. Thus, steers with favorable NFI and PEG phenotypes tend to have lower concentrations of IGF-I. In contrast, serum IGF-I concentrations on day 0 of the finishing phase were not correlated with feed efficiency traits, even though serum IGF-I was correlated with DMI ($r = 0.18$) and ADG ($r = 0.23$). Results from the growing phase of this study support previous results from our laboratory. In both growing steers and bulls, Brown et al. (2004) found that serum IGF-I concentrations were positively correlated with DMI ($r = 0.17, 0.29$) and NFI ($r = 0.22, 0.38$), respectively. In general, the phenotypic correlations we have found between serum IGF-I and NFI have been lower than the genetic correlations reported by Australian researchers. In our TAMU studies the initial serum IGF-I concentrations were measured one to three months after weaning following a postweaning adaptation period, whereas, in the Australian studies initial serum IGF-I concentrations were measured at weaning. Collectively, these results demonstrate that serum IGF-I has considerable potential to be used as a physiological indicator trait for NFI, however to be effective, serum IGF-I will need to be measured in newly weaned calves.

Serum IGF-I concentrations measured on day 0 of the growing phase were correlated with ultrasound estimates of ribeye area ($r = 0.23$), backfat ($r = 0.25$), and intramuscular fat ($r = 0.25$) measured at the end of the growing phase (Table 8), suggesting that steers with low serum IGF-I concentrations will be leaner. Serum IGF-I measured on day 0 of the finishing phase was correlated with final ribeye area ($r = 0.32$), but not correlated with final backfat or intramuscular fat.

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Table 7. Phenotypic correlations^a between physiological indicator traits and performance and feed efficiency traits in growing and finishing steers

Trait ^b	ADG	DMI	FCR	PEG	NFI
<i>Growing Phase</i>					
Serum IGF-I	0.16	0.33	0.05	-0.17†	0.19
Serum cortisol	-0.18†	-0.11	0.13	-0.10	-0.02
Exit velocity	-0.26	-0.32	0.03	0.18†	-0.16†
<i>Finishing Phase</i>					
Serum IGF-I	0.23	0.18	-0.13	-0.01	-0.13
Serum cortisol	-0.03	-0.17	-0.11	0.10	-0.11
Exit velocity	0.03	-0.21	-0.23	0.20	-0.11

^aCorrelations in bold are different from zero at $P < 0.05$.

^bFCR = feed conversion ratio; PEG = partial efficiency of growth; NFI = net feed intake

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

Serum cortisol concentrations measured on day 0 of the growing phase tended ($P < 0.10$) to be negatively correlated with ADG ($r = -0.18$) during the growing phase, but were not correlated with DMI or either of the feed efficiency traits. Likewise, Brown et al. (2004) reported negative correlations between serum cortisol concentrations and ADG and DMI, but not NFI in growing steers. During the finishing phase, day-0 serum cortisol concentrations were not correlated with either of the performance or feed efficiency traits. Thus, although serum cortisol is a measure of stress responsiveness in calves, it does not appear to be a good physiological indicator of performance or feed efficiency in growing calves.

Exit velocity measured on day 0 of the growing phase was negatively correlated with ADG ($r = -0.26$) and DMI ($r = -0.32$) during the growing phase, indicating that steers with faster exit velocities (more stress responsive) ate less feed and grew slower compared to steers with slower exit velocities (less stress responsive). Exit velocity was not correlated with FCR but tended ($P < 0.10$) to be correlated with PEG and NFI, such that steers with faster exit velocities actually had favorable PEG and NFI phenotypes. Brown et al. (2004) found that exit velocity was negatively correlated with ADG and DMI, but not with FCR or NFI in growing bulls. Exit velocity measured on day 0 of the finishing phase was negatively correlated with DMI ($r = -0.21$), but not with ADG. Initial exit velocity was correlated with FCR ($r = -0.23$) and PEG ($r = 0.20$), but not NFI during the finishing phase. These results suggest that exit velocity may be a better indicator trait for prediction of performance traits than feed efficiency traits in growing calves.

Exit velocity measured on day 0 of the growing phase was not correlated with final carcass ultrasound traits in the growing phase. In the finishing phase, initial exit velocity was negatively correlated with backfat ($r = -0.29$) and tended ($P < 0.10$) to be correlated with ribeye area ($r = -0.18$), but was not correlated with intramuscular fat. These results suggest that steers with good temperaments (slower exit velocities) will tend to be leaner than then steers with poor temperaments (faster exit velocities).

Burrow (1997) suggested that temperament was correlated with tenderness in cattle. In this study, exit velocity measured on day 0 of the growing phase and day 0 of the finishing phase were not significantly correlated with day-1 or 14-WBSF (data not shown). However, exit velocity measured on day 70 of the finishing phase was correlated ($P < 0.01$) with day-1 ($r = 0.37$) and day-14 WBSF ($r = 0.27$). These results suggest that exit velocity measured prior to harvest may be an indicator trait for tenderness in finishing calves.

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Table 8. Phenotypic correlations^a between initial physiological indicator traits and carcass ultrasound traits in growing and finishing steers

Trait	Ribeye area	Backfat thickness	Intramuscular fat
<i>Growing Phase</i>			
Serum IGF-I	0.23	0.25	0.25
Serum cortisol	0.03	-0.17†	-0.09
Exit velocity	-0.08	-0.12	-0.09
<i>Finishing Phase</i>			
Serum IGF-I	0.32	0.10	-0.01
Serum cortisol	-0.21	-0.12	-0.09
Exit velocity	-0.18†	-0.29	-0.01

^aCorrelations in bold are different from zero at $P < 0.05$.

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

4. Compare actual measures of DMI and feed efficiency traits with estimates of DMR and feed efficiency (DMR/ADG) generated by the CVDS model.

Accurate predictions of dry matter required (**DMR**) of individual calves using the CVDS model requires good estimates of diet composition (energy concentration), management practices (e.g., growth implants), weather and animal performance such as growth and composition of gain. In this study, the relationships between actual DMI and DMR from model predictions were compared during both the growing and finishing phases. During the growing phase, DMR predictions were based on empty body fat (predictor of composition of gain) estimates that were derived from ultrasound measurements (**DMR_{UL}**). During the finishing phase, DMR predictions were based on empty body fat estimates derived carcass cooler trait measurements (**DMR_{CC}**), and 9-11th rib chemical analysis (**DMR_{RIB}**), as well as from ultrasound measurements.

Dry matter intake measured during the growing phase was strongly correlated ($r = 0.73$; Table 9) with **DMR_{UL}**. Additionally, actual FCR measured during the growing phase was strongly correlated ($r = 0.71$) with **FCR_{UL}** (**DMR_{UL}/ADG**). During the finishing phase, DMI was strongly correlated with **DMR_{UL}**, **DMR_{CC}** and **DMR_{RIB}**. Similarly, actual FCR measured during the finishing phase was strongly correlated with **FCR_{UL}**, **FCR_{CC}**, and **FCR_{RIB}** ($r = 0.79, 0.82, \text{ and } 0.83$; respectively). These results suggest that the use of carcass ultrasound and carcass cooler traits were equally effective in estimating composition of growth to predict DMR using the CVDS model. The use of the chemical analysis of the 9-11th rib section to estimate actual empty body fat and BW at 28% empty body fat had little effect on improving the prediction **DMR_{RIB}** and **FCR_{RIB}** compared to using ultrasound measurements and carcass traits. These results indicate that further work is needed to enhance the ability of mathematical models to predict composition of gain in order to more accurately predict DMR in growing and finishing calves.

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Table 9. Phenotypic correlations^a between actual dry matter intakes and feed conversion ratios and predicted dry matter intake required (DMR) and feed conversion ratios from the CVDS model in growing and finishing steers.

Model Trait ^b	Growing Phase	Finishing Phase
DMR _{UL}	0.73	0.79
DMR _{CC}	----	0.80
DMR _{RIB}	----	0.78
FCR _{UL}	0.71	0.79
FCR _{CC}	----	0.82
FCR _{RIB}	----	0.83

^aCorrelations in bold are different from zero at $P < 0.05$.

^bDMR_{UL} = predicted DMR using carcass ultrasound traits; DMR_{CC} = predicted DMR using carcass cooler traits; DMR_{RIB} = predicted DMR using 9-11th rib analysis; FCR_{UL} = DMR_{UL}/ADG; FCR_{CC} = DMR_{CC}/ADG.

5. Compare empty body fat (EBF) predicted by the CVDS model and that obtained based on ultrasound and carcass cooler data with EBF predicted by 9-11th rib chemical analysis.

Carcass traits have been successfully used to determine body composition of steers to allocate feed to individual animals fed in groups (Guiroy et al., 2001). However, more information is needed to accurately predict dry matter required (DMR) based on ultrasound information. In this study, the correlations between empty body fat predicted from the 9-11th rib analysis (EBF_{RIB}) and empty body fat estimated from ultrasound measurements (EBF_{UL}) and carcass cooler traits (EBF_{CC}) were 0.62 and 0.69; respectively. Baker et al. (2005) estimated the individual DMR for the observed performance of 118 yearling bulls using ultrasound measurements, including ultrasound backfat, rump fat, and ribeye area. Carcass data (HCW, backfat thickness at the 12th rib, marbling score, and ribeye area) was collected for comparison with ultrasound data. The 9-11th rib section was removed and dissected into edible and non-edible portions, and chemical fat content of the edible portion of the 9-11th rib section determined by ether extraction. The chemical fat content of the 9-11th rib section was used to estimate empty body fat, which averaged 23.7%. Baker et al. (2005) reported that ultrasound measurements accounted for 63% of the variation in empty body fat, whereas, carcass cooler traits accounted for 73% of the variation in the empty body fat. These results are in agreement with our findings and suggested that carcass cooler traits were slightly better in predicting empty body fat (estimated from 9-11th rib analysis) than ultrasound measurements. However, more work is needed to understand the impact of other factors (e.g. breed and nutrition) on estimating empty body fat from carcass and ultrasound measurements.

6. Conduct sensitivity analysis of the CVDS predictions based on diet composition, animal performance, and composition of the gain.

A sensitivity analysis of diet composition was performed on the database of empty body fat estimated using the 9-11th rib analysis of this study to evaluate the effects of animal performance and composition of the gain on the prediction of DMR. The impact of error in estimating diet metabolizable energy (ME) concentration (± 10 and $\pm 20\%$) on model precision and accuracy are presented in Table 10. This analysis indicated the CVDS model had a high precision in prediction of DMR (little change in the correlation coefficient) regardless the diet ME used. As expected, the accuracy decreased when diet ME used was lower or higher than the real value. The rank correlation was similar among these runs. These findings indicated that using ME values that are lower or higher than the real diet ME would have little or no effect on ranking the animal using predicted DMR.

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We tested the effect of composition of the gain on the prediction of DMR using two methods reported by Tedeschi et al. (2004) to estimate composition of gain. These methods are based on equations to estimate composition of gain by the NRC (2000) and a decay equation as developed by Tedeschi et al. (2004), which is based on retained energy as protein. Similar to the sensitivity analysis on diet ME, changing the composition of gain using these two methods had little effect on the correlation ($r = 0.78$ and 0.80 ; respectively for NRC and decay equations). However, as expected, the bias increased and the accuracy decreased. These findings are in agreement with results generated by Tedeschi et al. (2004), who demonstrated that the ranking of animals was not affected by errors in diet composition or composition of the gain. Based on these analyses, we concluded that improvements in the accuracy and precision of mathematical models to estimate diet energy values and composition of gain can enhance our ability to estimate animal performance and DMR, which in turn can be used as a first step in identifying the best combination of factors to improve production efficiency.

Table 10. Sensitivity analysis of diet composition for the prediction of dry matter required (DMR) using the Cornell CVDS model

% Diet ME from Base ME	r	Bias, % ^a	Accuracy ^b
-20%	0.74	-18.1	0.62
-10%	0.76	-0.20	0.99
0%	0.78	16.6	0.70
10%	0.79	32.6	0.41
20%	0.80	47.9	0.27

^aA negative bias means over prediction.

^bAccuracy varies from 0 to 1, the higher the more accurate.

IX. Publications, abstracts, manuscripts in progress, thesis or presentations that resulted from this work.

- Carstens, G.E. and M.S. Kerley. Invited presentation entitled "Residual feed intake: an alternative measure of feed efficiency for beef cattle". Presented at the Beef Species: Enhancing Energetic Efficiency Symposium at the joint annual meeting of ADSA/ASAS/PSA in July, 2004. Preliminary results from the growing phase of current study presented.
- Carstens, G.E. Presentation entitled "Commercialization of net feed intake in growing bulls". Presented at the 50th Beef Cattle Short Course as part of the Beef Cattle Research in Texas Update. Preliminary results from the growing phase of current study presented.
- Carstens, G.E. Presentation entitled "Commercialization of technologies to measure feed efficiency in growing bulls". Presented at the field day for the Beef Development Center of Texas in June, 2004. Preliminary results from the growing phase of current study presented.
- Brown, E.G., G.E. Carstens, J.T. Fox, S.A. Woods, D.T. Dean, S. Moore, and P.C. Genho. 2005. Feed efficiency in growing and finishing steers: I. Relationships between feed efficiency and carcass ultrasound traits. Beef Cattle Research in Texas.
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Brown, E.G., G.E. Carstens, J.T. Fox, S.A. Woods, D.T. Dean, S. Moore, and P.C. Genho. 2005. Relationships between feed efficiency and real-time ultrasound traits in growing and finishing steers. *J. Anim. Sci.* (Abstract; Submitted).

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