RESIDUAL FEED INTAKE, BREED OF SIRE AND DAM, AND INDIVIDUAL SIRE AFFECT PERFORMANCE AND CARCASS CHARACTERISTICS AND RATES OF BACK FAT AND INTRAMUSCULAR FAT OF FEEDLOT STEERS

BY

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DISSERTATION

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Abstract

RESIDUAL FEED INTAKE, BREED OF SIRE AND DAM, AND INDIVIDUAL SIRE AFFECT PERFORMANCE AND CARCASS CHARACTERISTICS AND RATES OF BACK FAT AND INTRAMUSCULAR FAT OF FEEDLOT STEERS

One hundred and fifty eight Angus (A), Simmental (S), Angus-Simmental, and Simmental-Angus steers across two years across were classified into high (H), medium (M), and low (L) residual feed intake (RFI) groups. Steers in the H RFI group ate 1 kg more of DMI ($P < 0.05$) per day than steers in the L and M RFI group. Steers in the L RFI group had the highest feed efficiency by gaining 15% and 22% more per kg of feed than steers in the M and H RFI groups, respectively. Steers in the L RFI group had a phenotypic advantage for growth rate of 0.20 kg/d more ($P < 0.05$) than steers in the M and H RFI groups. Steers in the H RFI group had carcasses with more kidney, pelvic, and heart fat than carcasses of steers in the L and M RFI group. No differences were observed ($P = 0.89$) among RFI groups for meat tenderness using the Warner Bratzler shear force method. Breed of dam exhibited some differences for initial ($P < 0.0001$), final weight ($P = 0.01$), and G:F ($P = 0.02$). The interaction between breed of sire and dam had no significant ($P > 0.05$) effect on any of the performance characteristics analyzed. Steers from Angus sires had 23% (0.33 cm, $P < 0.0001$) higher carcass back fat (BF) than steers from Simmental sires. Steers from Angus sires had higher ($P = 0.0002$) marbling score (MS) than steers from Simmental sires. Meat tenderness was similar ($P = 0.98$) between the steers from Angus or Simmental sires. Steers from Simmental dams had heavier hot carcass weight (HCW) ($P = 0.01$) than steers from Angus dams. Steers from Angus dams had carcasses with 21% more ($P = 0.001$) of BF and 85 units more ($P = 0.001$) MS than carcasses of steers from

Angus dams. Our findings confirmed that management practices such as crossbreeding, and selection for RFI will reduce intake requirements of feedlot steers without affecting growth rate.

Six hundred and four steers from Angus (A), Simmental (S), Simmental-Angus (SA), 75% Simmental (75S) breeds was used across four different years from four separate ranches. Dietary treatments were: 75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG); all replicated during the four years. Steers fed 40DDGS had the heaviest carcass ($P < 0.05$) with 16 kg more of HCW than steers fed the other diets. Carcasses of steers fed co-products had 0.21 cm more ($P < 0.05$) of BF than carcasses of steers fed 75 DRC. Carcasses of steers fed 75DRC diet had the lowest ($P < 0.05$) calculated yield grade (CYG). Steers fed 40DDGS exhibited the highest rate ($P < 0.05$) of intramuscular fat (IM) deposition. Differences ($P < 0.05$) among RFI class were noted for BF, rib eye area (REA), and CYG. The carcasses of H RFI steers had the highest ($P < 0.05$) amount of BF with an average of 1.47 cm. Steers classified L RFI had the largest ($P < 0.05$) REA. Steers in the L RFI group had the lowest CYG ($P < 0.05$) and steers in the medium (M) RFI group had the highest ($P < 0.05$) carcass CYG. Residual feed intake influenced the rate of ultrasonic BF ($P < 0.05$). Angus sired steers had carcasses with the highest amount of BF ($P < 0.05$). Carcasses of steers from A and SA had higher MS ($P < 0.05$) than carcasses of steers from 75S and S. Progeny of A had carcasses with the highest CYG which averaged 3.33 and S steers had carcasses with the lowest CYG which averaged 2.94. Rates of ultrasonic BF and IM deposition differed significantly among breed of sires. Steers sired by A deposited back fat 14% higher ($P < 0.05$) than steers sired by SA and 75S. Steers sired by A bulls had the highest ($P < 0.05$) rate of IM deposition. The rate of marbling over back fat was similar

(P > 0.05) among breed of sires. This study confirms that there is no unique feature in the feedlot sector that could address the many biological and market challenges.

Progeny from sires with breed composition of Angus (n = 4 sires, A), Simmental (n = 8 sires. S), Simmental-Angus (n = 5 sires, SA), and 75% Simmental (n = 3 sires, QS) were used. Sires were assigned a random number followed by a letter indicating breed composition for identification purposes. High RFI (H RFI) group consisted of two A sires and one S sire. Low RFI (L RFI) group consisted of four S and two SA sires. For the medium RFI (M RFI) group, three S sires, three SA sires, three QS sires, and two A sires classified within this group. In average, sires RFI was 0.44 kg/d, -0.06 kg/d, and -0.48 kg/d for H RFI, M RFI, and L RFI group; respectively. Sire "3-S" had the highest estimated RFI value of 0.50 kg/d. Sire "15-S" exhibited the lowest RFI value. Initial weight differed (P = 0.0044) among RFI group of sires. Medium RFI Sire "4-QS" had the heaviest initial weight whereas, H RFI Sire "2-A" had the lightest initial weight with a difference of 58 kg (P < 0.05). The rate of ultrasonic marbling deposition was influenced (P < 0.0001) by sire and RFI classification. Sires classified as M RFI had slower rates than H and L RFI sires. Average rates of ultrasonic marbling ($1/100*d^{-1}$) were 1.22 for H RFI sires and 1.23 for L RFI sires. Medium RFI sires had an average rate of 1.19 ($1/100*d^{-1}$). Sire and RFI classification did not influence (P = 0.0948) the rate of marbling over a standard back fat endpoint of 1 cm. These suggest that selection for high rates of marbling deposition relative to back fat should maintain acceptable quality while allowing a high retail yield. Results from this study indicate that individual sire RFI is a potential selection tool to improve profitability by improving feed efficiency in the beef cattle industry.

Dedication

In memory of Manuel Trejo my loving father.

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List of Abbreviations

ADG – Average Daily Gain

BF – Back fat Thickness

CYG – Calculated Yield Grade

DMI – Dry Matter Intake

G:F – Feed Efficiency, Gain to Feed

HCW – Hot Carcass Weight

KPH – Kidney, Pelvic and Heart Fat

REA – Longissimus Muscle Area

RFI – Residual Feed Intake

MS – Marbling Score

QG – Quality Grade

CHAPTER I

LITERATURE REVIEW

Introduction

The most expensive input within any livestock production system is feed. In the beef cattle industry the cost of feeding is more important than in other species due to the fact that 70 to 75% of the total dietary energy cost in beef production is used for maintenance (Ferrell and Jenkins, 1985). Thus, improving feed efficiency for beef cattle industry has become increasingly important as feed cost continue to rise. Feed cost is the largest cost variable over which a producer has control in the profitability equation. Only by reducing cost of production (via reduced feed intake) will U.S. beef producers be able to remain competitive and sustainable in a global marketplace. To improve the economic and environmental sustainability of the enterprise, cattle that are more efficient at utilizing feed resources must be identified. Traditionally, feed conversion efficiency was expressed as the ratio of feed intake to body weight gain, but selection for this trait may be confounded with maturity patterns and body size, thus contributing to greater maintenance energy requirements and a greater environmental impact of the breeding or feedlot herd (Kelly et al., 2010). An alternative measure to reduce feed cost has been proposed, residual feed intake (RFI) is being utilized as a measure of efficiency in beef cattle production in Australia and is being implemented in Canada (Bohach, 2008).

Early investigations by Koch et al. (1963) started understanding the differences among animals in converting feed into body tissue are important in determining net income from beef cattle operations. However, measuring individual feed intake is costly because of increased equipment and labor requirement. Hence, the heritability of efficiency of feed use and its genetic relationship with other measureable traits need to be examined carefully before recommendations concerning individual feeding can be made (Koch et al., 1963).

The work on growth, intake, and feed conversion was the base for developing the concept of RFI. Efficiency, expressed as gain adjusted and body weight ($BW^{0.75}$) for differences in feed consumption, was considered the most accurate mathematical description of the cause and effect relationships. This measurement also had the highest heritability among the measures studied. Furthermore, feed intake can be partitioned into 2 components: (a) the feed intake expected for the given level of production and, maintenance, and (b) a residual portion. The residual portion of feed intake could be used to identify animals that deviate from their expected level of feed intake and was moderately heritable, with efficient animals having less or negative RFI.

Definition and Calculation

Residual feed intake is defined as the difference between the actual feed intake of an animal and its expected feed requirements for maintenance and growth (Basarab et al., 2003). In addition, RFI is by definition phenotypically independent of the production traits used to calculate expected feed intake, and so allows comparison between individual's differing in the level of production (Archer et al., 1999). The RFI is an individual measurement; therefore, animals must be fed individually or in groups using electronic devices that measure each animal's intake individually (Sainz and Paulino, 2004).

Although RFI has been proven to be independent of production, some authors (Kennedy et al., 1993) have concluded that when RFI is calculated by phenotypic regression of production on feed intake, the resulting measure of efficiency is not necessarily genetically independent of production. Hence, genetic variation in RFI may include genetic variation in production traits as well as variation in inherent relationships between feed intake and production. In order to account for this genetic variation Kennedy et al. (1993) suggested obtaining a measure of efficiency that is genetically independent of production, genotypic RFI could be calculated using genetic co-variances rather than the phenotypic co-variances used in the phenotypic regression approach. More precisely, Robinson and Oddy (2004) explained that the phenotypic calculation is done as the error term when fitting the equation:

$$\text{Intake} = \mu + \beta_w \text{ x mean metabolic weight} + \beta_g \text{ x weight gain} + \text{error}$$

Where intake is daily feed intake (kg, as fed), μ is a constant; mean metabolic weight is mean $(\text{weight})^{0.75}$ of the animal for the fed intake test period; and weight gain is live weight gain (kg/d) over the feed intake test period. One of the problems discussed by the authors is that the standard least squares regression equations to estimate β_w and β_g produce unbiased results only if the independent variables (mean metabolic weight and weight gain) are free from measurement error. In contrast, if measurement errors are large compared with the inherent variation between animals, biases may be substantial.

Measurements of feed intake represent one of the most critical components of measuring RFI, thus Archer et al. (1997) suggests that feed intake can be measured with moderate repeatability over a period as short as 5 weeks. In addition, mean metabolic weight can be measured with high accuracy over the same period because the errors in each individual weight measurement are averaged out by taking the mean of several weight measurements (i.e. weekly). However, unless measured over a relatively long interval of time, accuracy of weight gain may be low. For data sets in which weight and weight gain are highly correlated, it is likely to produce a substantial downward bias in the estimate of β_g and upward bias in the estimate of β_w (Robinson and Oddy, 2004).

Physiological and Molecular Basis

Residual feed intake measures whether an animal eats more or less feed than predicted by published feeding standards or by comparison with measured feed intakes or like-type animals (e.g., same breed, sex, age) eating the same feed in contemporary groups (Herd and Arthur, 2009). Five major processes have been described by Herd et al. (2004) by which variation in efficiency can arise. These processes are associated with variation in feed consumption, feed digestion and its associated energy costs, metabolism, activity, and thermoregulation. A brief summary comprising each of the 5 major processes will be discussed below.

Feed consumption - variation in feed intake per se is associated with variation in maintenance requirements of ruminant. As feed intake increases, the amount of energy expended to digest the feed increases, in part because of an increase in size of the digestive organs and increase in energy expended within the tissues themselves. Given that selection for RFI is associated with differences in intake, then those animals that eat les for the same performance could be expected to have less energy expended as heat increment of feeding, which in ruminants is approximately 9% of ME intake. The rate of ingestion, duration of the meal, feeding time, and number of eating sessions (excluding eating rate) also had been linked with RFI (Herd and Arthur, 2008). Feed digestion - it is known that as level of feed intake relative to maintenance increases, the digestion of feed tends to decrease. Some research (Richardson et al., 1996; Richardson and Herd, 2004) have indicated that in their ability to digest DM by about 1% unit when tested on a specific ration with a calculated DM digestibility of 68%. This difference in DM digestibility accounted for 14% of the difference in intake between the 2 groups of cattle. In addition, digestibility was correlated (r = -0.44) with RFI. The direction of the correlation indicated that less RFI (greater efficiency) was associated with greater digestibility. Together, these results indicate that differences in the processes of digestion and in substrate availability do occur and provide a possible mechanism to explain variation in efficiency of feed utilization, without the need to include variation in nutrient utilization per se.

Body composition and metabolism – the deposition of the same weight of lean tissue and fat has different energy costs. There is more variation in the efficiency in depositing lean gain than fat gain. In theory, partial efficiencies of nutrient use for fat gain are in the range 70 to 95%, and for lean gain approximately 40 to 50%. However, there is more variation in efficiency of lean (protein) gain due to greater variation in protein turnover than in fat. Moreover, protein turnover varies to a much greater extent between organs than does fat turnover. Accordingly, any variation in composition of gain, and in body composition, can influence the apparent efficiency of nutrient utilization (Herd and Arthur, 2008). In a study of Richardson et al. (2001) beef steers divergently selected for RFI showed that chemical composition was correlated with genetic variation in RFI, with steer progeny of low RFI parents having less whole body chemical fat and more whole body chemical protein than progeny of high RFI parents. The differences in energy retained in the body accounted for only 5% of the differences in feed intake, with the remainder 95% due to heat production. In addition, Richardson et al. (2001) concluded that the weight of the highly active tissues of the gastro intestinal tract and the internal organs were not related to genetic variation in RFI. The difference in ME intake following a single generation of divergent selection for RFI was due to metabolic processes rather than to changes in body composition. Huntington et al. (1988) reported that oxygen consumption by the portal drained viscera is directly associated with the feed intake in beef cattle. Thus, given the strong correlation between feed intake and RFI, it is possible there are associated decreases in oxygen consumption of these tissues after selection for improved RFI. Variation in metabolism can affect heat production.

Many of these processes contribute to the maintenance energy requirement of an animal (Herd and Arthur, 2008). Herd and Bishop (2000) stated that there is evidence that maintenance energy requirement per unit metabolic body weight was closely associated with genetic variation in RFI.

Activity – variation in heat production and energy available for maintenance and growth occurs as a result of differences in energy expenditure associated with activity. Difference in activity can be associated with variation in RFI in cattle (Herd and Arthur, 2008). A phenotypic correlation of 0.32 for RFI was reported by Richardson et al. (1999) with daily pedometer count that would indicate that about 10% of the observed variation in RFI was explained by this measure of activity. In addition, mechanisms associated with variation in activity include the work needed for feeding, ruminating, and locomotion at various speeds.

Thermoregulation – in ruminants the principal route for energy loss is evaporative heat loss, specifically through heat exchange in the lungs and nasal turbinates (Blaxter, 1962). This is regulated by rate of respiration; however, Herd and Arthur (2008) specify that there is limited to no literature regarding the relationship between respiration rate and RFI.

A quantification of the contribution of biological mechanisms to variation in RFI has been discussed by Richardson and Herd (2004). These results were observed on Angus steers progeny following a single generation of divergent selection for RFI. For instance, differences in energy retained in protein and fat accounted for only 5% of the difference in RFI following divergent selection. Differences in digestion contributed conservatively 10% and feeding patterns 2% to the variation in RFI. The heat increment of fermentation contributed 9% and activity contributed 10%. Indirect measures of protein turnover indicate that protein turnover, tissue metabolism, and stress response contributed to at least 37% of the variation in RFI. Other processes such as ion transport can account approximately 27%. Although, the research of RFI has become of more interest in the beef cattle industry, further research is required to better understand the mechanisms responsible for the variation in RFI in target populations. We also need to integrate the physiological information with molecular genetics information that will become the basis for commercial tests for genetically superior animals (Herd and Arthur, 2008).

Performance and Residual Feed Intake

Various attempts have been made by many animal geneticists and breeders to identify efficient animals using a new concept known as RFI rather than by feed:gain ratios. Feed-to gain ratio is highly correlated with growth and are confounded with growth rate and maturity patterns (Okine et al., 2001). However, RFI is an index that can be used to calculate the efficiency of an animal and describes the divergence in intake from that needed for maintenance and growth. Maintenance and growth requirements are not accounted for by gain to feed ratio, making RFI comparisons between animals a better measure of efficiency (Kolath et al., 2006). Because RFI is moderately heritable (h^2 = 0.16 to 0.43), it offers a genetic selection method to improve beef cattle efficiency without also increasing growth rate and mature size. Selection for efficiency using the RFI trait could potentially improve feed efficiency in cattle through reduced feed intake (Baker et al., 2006).

Recent research confirms the independence of RFI in relation to some production traits. For instance, Kelly et al. (2010) examined the effect of divergence in RFI of 86 Limousin x Holstein-Freisan growing heifers. The results indicated that low RFI heifers consumed 8.5 and 15.9 % less feed than their counterparts ranked as either medium or high RFI, respectively. Furthermore, average daily gain (ADG), initial body weight, and final body weight did not differ ($P > 0.10$) between the high, medium, and low RFI groups. Relative growth rate did not differ between the RFI groups. Residual feed intake was not phenotypically correlated with ADG, but was correlated with DMI (r = 0.47). In a study by Cruz et al. (2010), it is reported that as expected the correlation between ADG and RFI was zero. In addition, the authors concluded that RFI was positively correlated with DMI and cost of gain, and negatively correlated with gain to feed ratio (G:F). Cost of gain was correlated moderately and positively with DMI and RFI, and strongly and negatively correlated with G:F and ADG. Kolath et al. (2006) observed no differences (P=0.80) in final body weight or ADG between the low and high RFI groups. In agreement, Baker et al., 2006) reported no differences detected in ADG, initial body weight, and d 71 body weight among the high, mid, and low RFI steers. However, the authors observed a greater dry matter intake (DMI, P=0.004) and feed conversion ratio for the high RFI steers when compared to the low RFI steers. Herd et al. (2003) stated that no differences were detected between the progeny of parents of Angus steers selected for low RFI or high RFI in ADG and body weight. Basarab et al. (2003) observed no differences in ADG among the high, medium, and low RFI groups. However, low RFI (efficient) steers consumed 6.4% less feed than medium RFI steers and 10.4% less feed than high RFI. In this study RFI was adjusted for gain in ultrasound back fat thickness and gain in ultrasound marbling.

The opportunity to improve whole-herd production efficiency through exploitation of genetic variation in RFI is dependent not only on the existence of genetic variation in young cattle but also on the magnitude of the genetic correlations with other key production traits. These traits include growth and feed intake during finishing, carcass and meat quality traits at harvest, and cow traits, such as mature size, feed intake, milk production, and lifetime reproductive performance (Herd et al., 2003). In agreement, Herd and Bishop (2000) concluded that selection against RFI has the potential to increase the efficiency of beef production by reducing feed intake without changing the growth rate of the young animal, or increasing mature cow size.

Carcass and Residual Feed Intake

Current genetic selection programs are focused primarily on growth and carcass traits, which are easily and inexpensively measured (Archer et al., 1999). However, it is important that any process of selection for efficiency does not adversely impact improvements made in end-product quality. Nevertheless, Baker et al. (2006) reported genetic correlations between RFI and carcass traits in U.S. cattle have not been reported. According to Richardson et al. (1998) there is some indication that lower RFI steers are leaner than higher RFI steers, indicating an association of genetic selection for RFI and maturity patterns . Other authors (Tedeschi et al., 2006) have supported the previous finding by observing a significant coefficient for empty body fat and the Pearson correlation between RFI and empty body fat was significantly different (r = 0.43). This indicated that on average dry matter intake would be higher for fatter animals at the same body weight and ADG; which would be expected because of a higher energy requirement for gain.

The relationship among RFI, fat thickness, and intramuscular fat may not be the same in purebred or crossbred groups of cattle, as there is some inconsistencies in the data reported to date (Baker et al., 2006). In addition, the authors observed no differences (P>0.05) in hot carcass weight (HCW), *Longissimus* muscle area (LM), fat thickness; kidney, pelvic, and heart fat (KPH), yield grade or quality grade among the low, medium, and high groups. Castro Bulle et al. (2007) reported no differences (P>0.20) for dressing percent, HCW, KPH, LM, marbling score, and yield grade between high and low RFI class of beef steers.

Although there is some evidence of a genetic relationship between RFI and subcutaneous fat, reports on the relationship between RFI and intramuscular fat are not conclusive. Robinson and Oddy (2004) estimated genetic correlations of RFI with rump and rib fat of 0.72 and 0.48, respectively. For RFI and % of intramuscular fat a genetic correlation of 0.22 was reported. In addition, the authors estimated the environmental correlations of RFI with rib fat and intramuscular fat % being 0.01 and 0.09, respectively. Thus, selection for lower RFI is likely to reduce subcutaneous fat. Intramuscular fat may also be reduced, though the evidence is not quite as strong as for subcutaneous fat (Robinson and Oddy, 2004). McDonagh et al. (2001) found no differences in visual marbling scores or objectively measured intramuscular fat for carcasses of a group of Angus, Angus x Hereford, Angus x Polled Hereford, and Angus x Shorthorn steers, which were the progeny of high and low RFI selection lines. In contrast, Richardson et al. (2001) concluded that progeny from Angus cattle selected for low RFI had 13.2% less subcutaneous and intramuscular fat than progeny from those selected for high RFI. Baker et al. (2006) suggested that the variation in RFI does not correlate with visual marbling scores and intramuscular fat in Angus steers. In addition, it may be that less efficient steers (high RFI) have a greater propensity to deposit fat than protein. It is important to note, as stated by Baker et al. (2006), the difference between studies may be attributed to differences in age and maturity of animals when traits were measured or may suggest that other unidentified variables may be influencing composition in these populations.

It has been previously discussed the genetic association between RFI and carcass traits. However, if antagonisms between improved RFI and meat tenderness traits exist, they need to be identified as they could reduce the economic benefit achieved from breeding to reduce the cost of feeding cattle (McDonagh et al., 2001). An increment in tenderness during post mortem aging of meat is thought to be due to several processes including the disassembly of muscle myofibers by the proteolytic activity of μ-calpain and the specific inhibition of calpain by calpastatin. Higher rates of myofibers disassembly may also be indicative of higher rates of protein breakdown in muscle in the living animal (McDonagh et al., 1999). McDonagh et al. (2001) proposed that selection for RFI may produce changes in the calpain system, due to its association with efficiency of energy use in muscle and may therefore affect the tenderness of meat. The authors concluded that following just a single generation of divergent selection there were correlated responses in carcass fatness and in calpastatin and myofibril fragmentation. On-going selection for low RFI may affect market suitability and meat tenderness respectively. In contrast, some research has reported no differences between RFI classes. For instance, Castro Bulle et al. (2007) reported no differences ($P>0.10$) between high and low RFI groups when carcass characteristics were related to myofibrillar protein metabolism. Baker et al. (2006) concluded that no differences were detected between high and low RFI groups for LM calpastatin activity. Furthermore, Warner-Bratzler shear force was similar across RFI groups. All steaks over the aging periods tested from high and low RFI groups sheared ≤ 3.7 kg, falling within the industry standard range (< 4.1 kg) for acceptable eating quality. Steaks from high RFI steers had lower ($P = 0.04$) off-flavor scores than those from low RFI steers. Using sensory panel evaluation, there were no differences in tenderness or flavor scores among steaks form high, mid, or low RFI steers. The authors concluded that their data support the hypothesis that meat quality and palatability are not different between inefficient (high RFI) and efficient (low RFI) steers.

Ultrasonic Carcass Measurements and Residual Feed Intake

Net returns of integrated beef cattle production systems are heavily dependent on the costs of feed inputs relative to the value of outputs. Given that feed inputs are the largest variable costs associated with producing beef, selection programs to improve profitability of beef production systems should focus on reducing feed inputs without compromising economically relevant output traits. Considerable genetic variation for feed efficiency exists in beef cattle, yet limited genetic progress has been achieved due to the costs of labor and equipment to acquire feed intake data compared to output traits (Lancaster et al., 2009).

Ultrasound technology provides an opportunity to quickly and economically estimate carcass attributes on the live animal (Brethour, 2000). Although correlations between RFI and ultrasound measurements of subcutaneous fat, intramuscular fat, rump fat, and carcass fat measurements have been proposed (Arthur et al., 2001; Basarab et al., 2003; Crews et al., 2003), they are also inconclusive. For instance, Arthur et al. (2001) observed low phenotypic (r = 0.14) and genotypic (r = 0.17) correlations between RFI and ultrasound fat thickness and ultrasound *Longissimus* muscle area. Ultrasound marbling has been reported to have a tendency (P = 0.11) to be correlated with RFI, but no relationship was detected between RFI and marbling score (Basarab et al., 2003). Furthermore, Crews et al. (2003) reported negative correlations between RFI and fat thickness and between RFI and marbling scores; and Carstens et al., 2002) concluded that high RFI cattle had greater rump fat thickness, but similar fat thickness and intramuscular fat compared with low RFI steers. Recently, Lancaster et al. (2009) reported phenotypic correlations between ultrasound traits and RFI. However, these values were weak for both final back fat (0.12) and gain in back fat (0.22). In the previous study, heifers with low RFI had similar final back fat, but gained more back fat (P<0.001) during the trial than heifers with high RFI as initial back fat tended to be higher (P = 0.08) for low RFI. The moderate genetic correlation between RFI and final back fat (0.36) indicates that selection for favorable RFI will reduce subcutaneous fat depots. It is important to take into consideration that due to the stronger relationships between RFI and carcass composition traits found in cattle fed high-grain diets, inclusion of live carcass compositions traits to compute RFI may be useful to reduce the potential impact of selection for RFI on carcass quality grade of progeny (Lancaster et al., 2009).

Current Developments in Residual Feed Intake

The main inhibitor to adoption of RFI remains the cost and technical difficulty in measuring the trait. This situation makes RFI a prime candidate for marker assisted selection because the trait is moderately heritable such that DNA or other predictive markers could be used in selection schemes. Currently, molecular tools such as insulin-like growth factor-I (IGF-I) tests and a commercial gene test are being utilized to augment phenotypic RFI data in Australia (Moore et al., 2009). Insulin-like growth factor-I, a hormone that regulates growth and cellular metabolism, have been shown to be associated with increased feed efficiency. Davis and Simmen (2006) used IGF-I as an indirect selection criterion for RFI and concluded that its correlation with some growth traits and carcass measures. Furthermore, improved efficiency has been observed with a decrease in IGF-I concentrations as well a significant relationship between RFI and IGF-I (Moore et al., 2005). However, the extent of the relationship between RFI and IGF-I has been difficult to quantify because conflicting results have been obtained from different studies (Moore et al., 2009). More research is being focused in determining the genetic basis of RFI.

Recent interest in gene mapping of cattle to identify genetic markers associated with production traits suggests that possibility of using genetic markers in breeding program to aid selection for feed efficiency (Herd et al., 2003). Barendse et al. (2007) conducted a whole-genome association study, in which the MegAllele Genotyping Bovine 10K SNO panel was assessed. The marker spacing on this chip averaged 325 kbp. The chip was used to genotype 189 cattle of different breeds, including Angus, Brahman, Santa Gertrudis, and Shorthorn. These breeds represented animals with extreme RFI values and it belonged to a subset from a total population of 1,472 animals. The authors found 161 SNP to be associated (P<0.01) with RFI when tested individually. The amount of RFI explained by the 20 most significant SNP was 76%, whereas subsequent sets of 20 SNP form the 161 progressively explained less variance. In addition, the authors analyzed SNP locations and showed that the significant SNP for RFI were proportionally represented in micro-RNA motifs, promoter sequences, or mRNA sequences compared with the SNP evaluated. However, there was a difference in the type of micro-RNA motifs that were in the flanking SNP sequence compared with the rest of the SNP. This was not due to different sequences composition because the types of promoter elements did not differ between RFI SNP and other SNP. In addition, these findings suggest a signature of regulation unique to RFI. Of the 161 SNP, 90 contained micro-RNA motifs and 86 contained promoter elements in the sequence flanking the SNP (Barendse et al., 2007). At the Univeristy of Alberta Bovine Genomics unit a primary genome scan to identify putative QTL for RFI was done as reported by Nkrumah et al. (2007). The authors looked at 400 beef cattle steers that were offspring of 20 Angus, Charolais or Alberta Hybrid bulls. The markers used were 100 microsatellites and 355 SNP spanning the 29 bovine autosomes. Eight QTL for RFI were identified across the families with a chromosome-wise $P < 0.05$ threshold on *Bos taurus* autosome 1, 5, 7, 8, 12, 16, 17, and 26. Suggestive QTL for RFI with a chromosome-wise $P<0.10$ threshold were also identified on *Bos taurus* autosome 2, 14, 18, 19, 20, 21, 24, 28, and 29. The study also reported for genetic and phenotypic RFI. Concordance of QTL between phenotypic and genetic RFI was high, 14 of the RFI QTL were detected in both types of RFI. Only 1 of the suggestive genetic RFI QTL and 2 suggestive phenotypic RFI QTL were not detected in the other RFI measure. It is important to point out that one of the issues with QTL interval mapping is the large QTL intervals. As it is explained by Moore et al. (2009) the previous study was a primary genome scan with a low marker density, it is not surprising that the QTL intervals span over an average of 30 cM. To address this, future studies need to fine map QTL on specific parts of the *Bos taurus* autosome. In a more recent study, Sherman et al. (2010), analyzed a total of 2, 633 SNP across 29 bovine autosomes in 464 steers sired by Angus, Charolais, or Alberta Hybrid bulls for association with RFI. A total of 150 SNP were associated with RFI ($P < 0.05$) if which 23 were significant ($P < 0.01$). Two methods were used to create a panel of SNP that were maximally informative for RFI based on the data. In conclusion, one panel was created from a multivariate model with 32 SNP and account for 36.5% of the phenotypic variation in RFI. The other panel created from the sequential molecular breeding value method identified 79 SNP, which explain 37.3% of the phenotypic variation in RFI. Twenty-seven of the SNP are common to the 2 panels. These markers represent an important step toward future application in marker assisted selection for improved feed efficiency in cattle (Sherman et al., 2010).

Results from data validating markers for RFI can be considered optimistic. However, Moore et al. (2009) stated that two main barriers remain before fully adoption of markers can be implemented. First, the genetic interaction of genes affecting RFI on other traits is, as yet, not fully understood. Second, the number of animals with high quality estimates of RFI remains small. In addition, it can be difficult due to the environmental conditions and genetic background of the animals varying greatly, ranging from Australia to Canada and across breeds including *Bos taurus* and *Bos indicus* cattle.

Residual Feed Intake and Environmental Impact

All food production systems have an impact upon the environment, regardless of how and where the food is produced. The environmental impacts of agricultural practices are increasingly well-known, not only to food producers but also to policy makers, retailers and consumers. Increased public awareness of these issues underlines the critical need to adopt livestock production systems that reduce the environmental impact of agricultural production. This can be achieved through the use of management practices and technologies that encourage environmental stewardship at the farm level (Capper, 2009).

In ruminant livestock, Crutzen et al. (1986) reported that methane from enteric fermentation contributes approximately 12% of anthropogenic greenhouse gas emissions globally. Furthermore, methane production is dependent upon the quantity of feed consumed, although this effect is moderated by feed digestibility and other feed and animal characteristics. In a study with 76 Angus steers selected from breeding lines divergently selected for RFI, Hegarty et al. (2007) reported that across the 70 d feeding period there were positive associations between methane production and feed intake ($R^2 = 0.26$, $P = 0.001$). However, methane production rate was not associated ($P = 0.88$) with the expected breeding value of RFI. This unexpected result was explained due to a reduction in feed intake during the process of measuring methane emissions. The change in intake during methane production rate measurement may have confounded the test for association between the expected breeding value of RFI and methane production rate. To overcome this problem, the authors re-calculated RFI for a shorter period (15 d) when steers were being prepared and measured for methane production rate. Over this period there was a positive association between methane production and RFI (R^2 = 0.12, P = 0.002). In addition, a reduction in methane emission of 13.38 g/d was calculated to be associated with a 1 kg/d reduction in RFI. To further evaluate the association between methane and RFI over the methane measurement period, the methane production rate and intake characteristic of the 10 steers with the lowest and the 10 steers with the highest RFI. Steers with lowest RFI emitted 25% less methane daily than steers with the highest RFI, and their growth had a lower methane cost of 24% less methane per unit ADG (Hegarty et al., 2007).

In an earlier study by Nkrumah et al. (2006), they looked at the relationship of feedlot feed efficiency with methane production of 27 steers selected from a total of 306 animals based on their RFI. Residual feed intake was correlated with daily methane production and energy lost as methane ($r = 0.44$, $P < 0.05$). Methane production was 28 and 24% less in low RFI animals compared with high and medium RFI animals, respectively. The authors stated that any inherent differences in animals that may lead to ecological changes in the ruminal microbial ecosystem may translate into differences in methane production. Increased methane production by high RFI animals not only represents significant decreases in energetic efficiency, but it also has implications for the environmental sustainability of beef cattle production because of the significant contributions to atmospheric methane emissions. In addition, the study identified differences in daily fecal dry matter production per unit of DMI. In agreement with the previous findings, Hegarty et al. (2007) stated that reduced DMI of low RFI cattle can also be expected to reduce the amount of manure produced an also the potential quantity of nitrous oxide liberated from manures. Furthermore, this advantage can be attributed to the simple reduction in total nitrogen intake and also a greater efficiency of capture of dietary N within the body, because low RFI cattle continue to accrete body tissue at the same rate as high RFI cattle and may have reduced protein turnover. In conclusion, although the reduction in greenhouse gas emission from livestock industries is seen as a high priority, strategies for reducing emissions should not reduce the economic viability of enterprises if they are to find industry acceptance. The reduction of enteric methane emissions from livestock by selection for more feed efficient animals based on their estimated breeding value offers a novel way of reducing the feed costs, the methane production, and potentially the nitrous oxide emissions of cattle without compromise in their growth rate (Hegarty et al., 2007).

Summary

Feeding in beef cattle production represents the highest cost of the operation. Feed represents 75% of the total feed cost used for maintenance in breeding cows. Therefore, profitability partially depends on the efficient and productive use of feed for maintenance and growth with minimal excesses and losses. One way to achieve this goal is to select breeding bulls that are naturally feed efficient, since 80 to 90% of the genetic improvement in a herd comes through the sires. An efficient bull will pass on superior genetics for feed efficiency to his progeny, which will be realized as feed saving for calves in the feedlot and for replacement heifers entering the cowherd. If translated into the economic effect, a 5% improvement in feed efficiency could have an economic effect four times greater than a 5% improvement in ADG.

Residual feed intake or net feed efficiency is defined as the difference between the actual DMI and the expected DMI. Residual feed intake involves the variation in feed intake that remains after the requirements for maintenance and growth have been met. Efficient animals eat less than expected and they will have negative or low RFI value. However, inefficient animals will eat more than expected and their RFI value will be positive or high. Considerable variation in RFI exists among individual animals within breeds or genetic strains. This variation suggests that substantial progress can be made in RFI due to its heritability which is approximately 40%.

The economic potential of RFI is evident. Some projections estimate that after 15 to 25 years of selection for RFI the feeder cattle industry and cow-calf producers could reach more than $100 million annually. In addition to the improvement in productivity, selection by RFI could have a positive impact in the environment. It is expected to reduce methane and manure emissions from cattle with lower RFI by 15 to 20%, which may result in new agriculture investment due to greenhouse gas reductions.

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CHAPTER II

INFLUENCE OF RESIDUAL FEED INTAKE, BREED OF SIRE AND DAM ON THE PERFORMANCE AND CARCASS CHARACTERISTICS OF EARLY WEANED STEERS DURING THE FEEDLOT PHASE

Abstract

Improving feed efficiency through management practices is a major goal of the beef industry. The objectives of this study were: (1) to calculate individual residual feed intake (RFI) and evaluate its effect on the performance and carcass characteristics of early weaned steers during the feedlot phase; (2) to evaluate the effect of breed of sire and dam and crossbreeding influences on performance and carcass characteristics; and (3) to evaluate the effect of residual feed intake, breed of sire and dam on meat tenderness of early weaned steers. One hundred and fifty eight Angus (A), Simmental (S), Angus-Simmental, and Simmental-Angus steers across two years were considered. Animals were early weaned at approximately 56 d of age and after entering the feedlot, animals were allotted to pens by weight and fed a common diet. Steers were classified into high (H), medium (M), and low (L) RFI groups. Twenty eight % (n = 44) of the steers in this study were classified in the H RFI group, 38% (n = 60) in the M RFI and 34% (n = 54) in the L RFI group. No differences ($P > 0.05$) among RFI groups were detected for initial and final weight. Steers in the H RFI group ate 1 kg more of DMI ($P < 0.05$) per day than steers in the L and M RFI group. Steers in the L RFI group had the highest feed efficiency by gaining 15% and 22% more per kg of feed than steers in the M and H RFI groups, respectively. Steers in the L RFI group had an advantage in their growth rate of 0.20 kg/d more ($P < 0.05$) than steers in the M and H RFI groups. No differences among RFI groups were observed ($P > 0.05$) for hot carcass

weight (HCW), back fat (BF), marbling score (MS), calculated yield grade (CYG), and rib eye area (REA). Carcasses averaged 394.3 kg, 1.28 cm, 632 (Choice^0), 3.08, and 90.07 cm^2, respectively. Steers in the H RFI group had carcasses with more kidney, pelvic, and heart fat than carcasses of steers in the L and M RFI group. No differences were observed (P = 0.89) among RFI groups for meat tenderness using the Warner Bratzer shear force method. Breed of sire had no effect (P > 0.05) on the performance characteristics. Breed of dam exhibited some differences for initial (P < 0.0001), final weight (P = 0.01), and G:F (P = 0.02). No differences (P > 0.05) between breed of dam were detected for dry matter intake, average daily gain, and RFI. The interaction between breed of sire and dam had no significant (P > 0.05) effect on any of the performance characteristics analyzed. Breed of sire had no effect (P =0.64) in HCW. However, steers from Angus sires had 23% (0.33 cm, P < 0.0001) higher carcass BF than steers from Simmental sires. Steers from Angus sires had higher (P = 0.0002) MS than steers from Simmental sires. Meat tenderness was similar (P = 0.98) between the steers from Angus or Simmental sires. Breed of dam effects were observed for most of the carcass characteristics evaluated with the exception of REA (P = 0.10), KPH % (P = 0.98) and WBSF (P = 0.56). Steers from Simmental dams had heavier HCW (P = 0.01) than steers from Angus dams. Steers from Angus dams had carcasses with 21% more (P = 0.001) BF and 85 units more (P = 0.001) MS than carcasses of steers from Angus dams. Our findings confirmed that practice management such as crossbreeding and selection for RFI will reduce intake requirements of feedlot steers without affecting growth rate.

Introduction

In a typical beef cattle operation, weaning occurs at approximately 205 d of age. However, conventional management practices are being questioned as the beef industry progresses away from isolated production segments toward vertically coordinated beef production systems (Barker-Neef et al., 2001). The practice of early weaning consists in starting the calves with a grain diet at approximately 100 d of age and reducing any lactation. Early weaning may enhance production efficiency and may have the potential to increase returns in a vertically coordinated system of production. The search for management practices to improve feed efficiency has become of more importance to the industry. On average, 75% of the total feed costs for production of a beef carcass are used for maintenance of the breeding cow herd. Hence, factors that can help ameliorate these costs in order to improve efficiency of production and to increase profit need to be considered and evaluated. Some of these factors to be considered include choice of breed, crossbreeding and selection within breeds.

Residual feed intake (RFI) is defined as the difference between the actual feed intake of an animal and its expected feed requirements for maintenance and growth (Basarab et al., 2003). In addition, RFI is by definition phenotypically independent of the production traits used to calculate expected feed intake. This features allows comparison between animals differing in level of production during the measurement period (Archer et al., 1999). Considerable variation in RFI exists among individual animals within breeds or genetic strains. This variation suggests that substantial progress can be made in RFI since the heritability of the trait is about 0.2 - 0.40 in feedlot cattle (Basarab et al., 2006). Understanding the potential of RFI in beef cattle is of importance to evaluate the influence of this trait, along with crossbreeding effects, during the feedlot phase. Thus, the objectives of this study were: (1) to calculate individual residual feed intake and evaluate its effect on the performance and carcass characteristics of early weaned steers during the feedlot phase; (2) to evaluate the effect of breed of sire and dam and crossbreeding influences on the performance and carcass characteristics of early weaned steers during the feedlot phase; and (3) to evaluate the effect of residual feed intake, breed of sire and dam on meat tenderness of early weaned steers.

Materials and Methods

Animals and Management

One hundred and fifty eight Angus, Simmental, and Angus-Simmental steers from eleven identified sires were used across two different years. The same sires were used in purebred and crossbred production of steers. Steers originated from two sources: Orr Beef Research Center (Perry, IL.) and Urbana Beef Research Center (Urbana, IL). Animals were early weaned at approximately 56 d of age and back-grounded on a high-energy diet prior to starting the trial. Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* (Consortium, 1988). Experimental protocols were submitted and approved by the University of Illinois Institutional Animal Care and Use Committee. Steers were vaccinated for Bovine Respiratory Syncytial Virus, IBR, BVD, PI3, and Pasteurella. The implant strategy utilized for year one was Component E-S® (200 mg progesterone USP and estradiol benzoate 20 mg; VetLife, Overland Park, KS) at the initiation of the growing phase and re-implanted with Component TE-IS® (80 mg trenbolone acetate, 16 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) at the initiation of the finishing phase (112 d of age), and Component TE-S® (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) after 76 days on feed of the finishing period. The implant strategy for year two was Component E-S® (200 mg progesterone USP and estradiol benzoate 20 mg; VetLife, Overland Park, KS) at the initiation of the growing phase and re-implanted with Component TE-S® (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) at the beginning of the finishing phase (112 d of age). Animals were allotted to pens by weight and fed one common diet. The diet was formulated to meet or exceed the minimum NRC (1996) requirements for maintenance and gain (Table 1).

Performance Data Collection

Measurements were recorded every 50 d throughout the feeding period to evaluate live animal performance and steer weight. On average, the finishing phase included 106 d on feed. Two d prior to harvesting, individual weights were measured and used as the final weight value. This value was used to calculate final individual-animal average daily gain and feed efficiency (gain to feed).

Carcass Data Collection

Steers were harvested at a commercial processing facility. Animals were stunned via captive bolt pistol and exsanguinated. On the day of harvest individual carcass measurements were taken for hot carcass weight. After undergoing a 24 h chill at -4ºC measurements for back fat thickness (**BF**), kidney, pelvic and heart fat (**KPH**) percentage, and marbling score (**MS**) were collected by trained university personnel. Chromatography paper was used to take an image of the *longissimus dorsi* and measurements for the *longissimus* muscle area **(REA)** were recorded using a planometer. University of Illinois (**UI**) measurements were used to determine quality grade (**QG**) and calculate yield grade (**CYG**). Yield grade was calculated using the equation [2.5 + (2.5*inches of BF) + (0.20*KPH%) + (0.0038*lb. of HCW) – (0.32*square inches of LD muscle)] (Taylor, 1994).

Shear Force Data

A rib sample was collected from the right side of each steer between the 11th and 12th ribs. Ribs were stored at 2ºC for 14 d postmortem in individually vacuum-packaged bags (27 mm Hg). After the 14 d aging period, rib samples were frozen at -29ºC until Warner-Bratzler Shear Force (WBSF) was conducted. Frozen steaks were faced and fabricated into a 2.54-cm thick *longissimus dorsi* muscle steaks. Frozen steaks were thawed for 24 h at 2ºC. All steaks were cooked to an internal temperature of 70ºC in a Blodgett dual-air-flow gas convection oven (model DFG-201; G. S. Blodgett Co., Inc. Burlington, VA). Steak temperature was monitored by 30-gauge, type-T thermocouples (inserted into the geometric center of each steak) attached to a Doric temperature recorder (model 205; Vas Engineering, San Francisco, CA). After cooking, steaks were stored for approximately 12 hours at 2ºC in a McCall refrigerator (Kolpak Industries Inc., Parsons, TN). After storage, eight 1.27-cm diameter cores were taken parallel to muscle fibers and sheared perpendicular to muscle fibers with an Instron universal testing machine (model 4201; Instron Corp., Canton, MA) with a WBSF attachment with a V-shaped blade. A 50-kg compression load cell with a crosshead speed of 250mm/min was used.

Statistical Analyses and Residual Feed Intake Calculation

Response variables included live animal performance, carcass, and tenderness parameters. Data were analyzed using the GLM procedure of SAS (SAS Institute, 2003). The model included the fixed effects of: Residual Feed Intake Classification, Breed of Sire, and Breed of Dam as fixed effect. The random effects were pen and year. Interactions evaluated were: residual feed intake classification and breed of sire, residual feed intake classification and breed of dam, breed of sire and breed of dam. However, only significant interactions ($P < 0.05$) will be discussed. Main effect means for all analyses were separated using the LSD procedure when the respective F-tests were significant ($P \leq 0.05$).

Residual feed intake value was calculated as the difference of the actual dry matter intake (DMI) and the expected DMI. The expected DMI was calculated as a linear regression of dry matter intake, average daily gain (ADG), and metabolic body weight ($BW^{0.75}$) using the REG procedure of SAS (SAS Institute, 2003).

$$\textit{Expected DMI } (Y_i) = \beta_o + \beta_1 \text{ADG} + \beta_2(\text{BW})$$

$$\text{RFI} = \text{Actual DMI (kg)} - \text{Expected DMI (kg)}$$

Where β_o is the intercept and β_1 *and* $\beta 2$ denote the regression coefficients. Steers with RFI values greater than 0.5 SD were classified as high (H) RFI. Steers with RFI values ± 0.5 SD classified as medium RFI (M) and steers with less than 0.5 SD were classified as low (L) RFI.

Results and Discussion

Residual Feed Intake effect

Twenty eight % (n = 44) of the steers in this study were classified in the H RFI group, 38% (n = 60) in the M RFI and 34% (n = 54) had calculated RFI values to be classified in the L RFI group. No differences ($P > 0.05$) were detected for initial and final weight (Table 2). On average, steers had an initial weight of 363.5 kg and a final weight of 631.5 kg. However, for daily DMI steers in the H RFI group ate 1 kg more ($P < 0.05$) than steers in the L and M RFI group. Steers in the L and M RFI group had a DMI of 8.70 kg which was similar ($P > 0.05$) between both groups. Feed efficiency expressed by the gain to feed ratio (G:F) exhibited differences ($P < 0.0001$) among all RFI groups. Steers in the L RFI group had the highest feed efficiency by gaining 15% and 22% more per kg of feed than steers in the M and H RFI groups, respectively. In this study, differences (P = 0.002) were observed among RFI groups for ADG. Steer in the L RFI group had an advantage in their growth rate of 0.20 kg/d more (P < 0.05) than steers in the M and H RFI groups. However, steers in the H and M RFI groups had similar (P > 0.05) ADG. On average, these steers gained 1.44 kg/d. Rutherford (2010) reported that although ADG was similar across L, M, and H RFI classifications there was a significant difference among the three RFI classes for total gain on test. Low RFI steers gained more over the entire test than H RFI steers. In agreement with some of our finding, Kelly et al. (2010) examined the effect of divergence in RFI of 86 Limousin x Holstein-Freisan growing heifers and reported that low RFI heifers consumed 8.5 and 15.9 % less feed than their counterparts ranked as either medium or high RFI, respectively. Furthermore, the initial body weight, and final body weight did not differ (P > 0.10) between the high, medium, and low RFI groups. However, the authors did not observed differences for ADG and relative growth rate between the RFI groups. Similar, Kolath et al. (2006) observed no differences (P=0.80) in final body weight or ADG between the low and high RFI groups. Baker et al. (2006) reported no differences detected in ADG, initial body weight, and d 71 body weight among the high, mid, and low RFI steers. However, the authors observed a greater dry matter intake (DMI, P=0.004) and feed conversion ratio for the high RFI steers when compared to the low RFI steers.

As expected, differences (P = 0.0004) observed among steers in the H, M, and L RFI groups shows the existing correlation between DMI and RFI. In this study, the correlation between DMI and RFI was 0.56 (P < 0.0001). Although our results indicate differences for ADG among RFI groups, correlation results between RFI and ADG showed no relationship (r = 0.001, P = 0.999). In agreement with our correlation results, Cruz et al. (2010) reported a correlation of zero between ADG and RFI. In addition, the authors concluded that RFI was positively correlated with DMI and cost of gain, and negatively correlated with gain to feed ratio (G:F). Cost of gain was correlated moderately and positively with DMI and RFI, and strongly and negatively correlated with G:F and ADG. Lancaster et al. (2009) reported a phenotypic and genotypic correlation for ADG in Brangus heifers of 0.00 and 0.04, respectively. In addition, phenotypic and genotypic correlations for DMI were 0.70 and 0.85, respectively. The authors concluded that compared with the other feed efficiency traits examined; RFI has considerable potential for use in selection programs because it is less affected by differences in rate and composition of growth. In addition, RFI can easily be computed to be phenotypically independent of carcass composition traits.

Carcass characteristics analyzed for the effect of RFI are presented in Table 3. No differences were observed ($P > 0.05$) among RFI groups for HCW, BF, MS, CYG, and REA. Carcasses averaged 394.3 kg, 1.28 cm, 632 (Choice^0), 3.08, and 90.07 cm^2, respectively. However, KPH fat differed ($P = 0.0389$) among RFI groups. Steers in the H RFI group had carcasses with KPH fat than carcasses of steers in the L and M RFI group. On average, steers in the H RFI group had 2.53% of carcass KPH fat whereas steers in the L and M RFI group averaged 2.31% of carcass KPH fat. We attribute this difference to a positive correlation ($r = 0.33$, $P < 0.0001$) observed between RFI and KPH fat. Castro Bulle et al. (2007) reported no differences ($P>0.20$) for dressing percent, HCW, KPH, LM, marbling score, and yield grade between high and low RFI class of beef steers. Similar, Baker et al. (2006) observed no differences ($P>0.05$) in HCW, LM, BF; KPH, CYG or QG among the low, medium, and high groups. Some researches (Richardson et al., 1998) have reported lower RFI steers are leaner than higher RFI steers, thus establishing an association of genetic selection for RFI and maturity patterns. However, in his study no differences in BF deposition or intramuscular fat (MS) were detected between carcasses of H and L RFI groups.

Steers from H, M, and L RFI groups were analyzed for meat tenderness using the WBSF method. No differences were observed ($P = 0.8908$) among RFI groups. On average, steers in the H, M, and L RFI group had a WBSF value of 3.25 kg, 3.15 kg, and 3.16 kg, respectively. Interestingly, a correlation analysis detected a negative correlation ($r = -0.25$, $P = 0.0016$) between RFI and WBSF. This result can explain why steers in the H RFI group had a numerically higher WBSF value than steers in the M and L RFI group and suggests that steers classified as H RFI will decrease meat tenderness, whereas steers classified as L RFI will have more tender meat. In this study, both groups were within the standards of the industry for meat tenderness and quality. Baker et al. (2006) discussed the strong genetic association between RFI and carcass traits. However, if antagonisms between improved RFI and meat tenderness traits exist, they need to be identified as they could reduce the economic benefit achieved from breeding to reduce the cost of feeding cattle (McDonagh et al., 2001). Castro-Bulle et al. (2007) reported no differences ($P>0.10$) between high and low RFI groups when carcass characteristics were related to myofibrillar protein metabolism. Baker et al. (2006) concluded that no differences were detected between high and low RFI groups for LM calpastatin activity. Furthermore, the authors reported similar ($P > 0.05$) Warner-Bratzler shear force across RFI groups. All steaks over the aging periods tested from high and low RFI groups sheared ≤ 3.7 kg, falling within the industry standard range (< 4.1 kg) for acceptable eating quality. Although in the current study differences for some performance characteristics were found, no negative impact in carcass quality and yield grade can be confirmed.

Breed of Sire and Dam Effect

With a population of cross bred steers with known sires and dam, it was of interest to evaluate the effect of breed of sire and breed of dam and crossbreeding on performance (Table 4) and carcass characteristics (Table 5). Two breeds were represented for the sire and dam, Angus (A) and Simmental (S). A total of four breed compositions were represented within the steer population, 34% (n = 53) A/A, 13% (n = 21) A/S, 14% (n = 22) S/A, and 39% (n = 62) S/S. Breed of sire had no effect ($P > 0.05$) on the performance characteristics of the early weaned steers. Steers from the Angus breed averaged 356 kg of initial weight, 629.5 kg final weight, 9.14 kg/d DMI, 1.49 kg ADG, 0.16 G:F, and 0.16 kg/d RFI. Similar, steers from the Simmental breed averaged 365 kg initial weight, 634 kg final weight, 9.18 kg/d DMI, 1.48 kg ADG, 0.16 G:F, and -0.15 kg/d RFI. Interestingly, breed of dam exhibited some differences for initial ($P < 0.0001$), final weight ($P = 0.0096$), and G:F ($P = 0.0235$). Steers from Angus dams were 34.5 kg lighter than steers from Simmental dams at the beginning of the trial. In contrast, steers from Simmental dams were 40 kg heavier at final weight than steers from Angus dams. This difference can be partly explained by higher milk production levels reported in the literature for Simmental or Simmental cross-bred cows than other beef breeds cows. For instance, Kress et al. (1990) reported lower milk production for Hereford dams than 50% and 75% Simmental dams. In addition, calves from 50% and 75% Simmental dams had the highest growth traits. Marston et al. (1992) reported higher total milk yield based on a 205 d lactation period for Simmental cows than for Angus cows. Total milk yields were 1, 724 kg for Simmental cows and 1,454 kg for Angus cows. Furthermore, calves from Simmental dams were 57 kg heavier than calves from Angus dams when weaned.

Steers from Angus dams had a 4% advantage in feed efficiency than steers from Simmental dams. These differences could be attributed solely to the existing differences between breeds rather than a maternal direct effect. No differences between breed of dam ($P > 0.05$) were detected for DMI, ADG, and RFI. The progeny of Angus dams averaged 9.07 kg/d DMI, 1.47 kg ADG, and 0.19 kg/d RFI. In addition, progeny of Simmental dams averaged 9.25 kg/d DMI, 1.50 kg ADG, and -0.12 RFI. Although significant differences were not detected between dam breeds, an advantage in the RFI of steers with Simmental dams was observed. Steers from Simmental dams ate 0.31 kg/d less of the expected DMI than steers from Angus dams. Contrary to our findings, Archer et al. (1999) stated that under usual conditions, Continental-bred cattle may be less efficient at converting feed to live weight gain than British-bred cattle partly due to higher maintenance requirements. Furthermore, maintenance efficiency differs across breeds and these differences are related to productive potential of those breeds. Barker-Neef et al. (2001) stated that crossbred calves likely had more growth potential than Angus calves due to hybrid vigor and the influence of Continental genetics. In a review by Gregory and Cundiff (1980), maternal heterosis was estimated for five breeding groups of backcross and eight breeding groups of three breed cross females involving the Angus, Brahman, Charolais, and Hereford breeds. Maternal heterosis was of major importance for reproductive traits and was relatively small for pre-weaning growth rate.

Sire and dam breed interaction was not significant ($P > 0.05$) in any of the performance characteristics analyzed. Massey and Benyshek (1981) reported a significant sire by breed of dam interaction for all performance traits except ADG. Furthermore, the authors concluded that the sire by breed of dam component of variance and the genetic correlations for post-weaning characteristics indicated sizable interaction effects for all measures of growth except ADG. The non-significant interaction and the large correlation of sire breeding values for ADG would be possible if the significant interaction found for pre-weaning performance is indeed a genotype by environment or maternal environment interaction (Massey and Benyshek, 1981).

Opposite to the effects observed on the performance characteristics of early weaned steers, differences were detected among carcass characteristics (Table 5) influenced by the breed of sire and dam effect. Breed of sire had no effect (P =0.6422) in HCW of the early weaned steers. However, steers from Angus sires had 23% (0.33 cm, P < 0.0001) more carcass BF than steers from Simmental sires. In addition, the progeny of Angus sires reported a higher (P = 0.0002) MS than the progeny of Simmental sires. Carcasses from Angus sired steers showed an increase of 75 units of MS. This represented an improvement in carcass quality grade. Carcasses of Angus sired steers were classified as an "Average Choice" whereas, carcasses of Simmental sired steers classified as "Low Choice". Other carcass characteristics favored steers from Simmental sires. For instance, carcasses of Simmental sires progeny had a lower CYG (P < 0.0001) than carcasses of steers with Angus sires. Carcasses were improved by 0.5 points which represented an average CYG value of 2.81. Rib eye area of Simmental sired steers were larger (P = 0.0232) than REA of Angus sired steers. *Longissimus* muscle in carcasses of steers with Simmental sires was 4 cm^2 larger than in carcasses with Angus sires. Steers from Angus sires exhibited higher (P = 0.05) KPH % than steers from of Simmental sires. As expected, steers sired by a British breed (i.e. Angus) had higher back fat and intramuscular fat deposition, opposite to steers sired by a Continental breed like Simmental in which carcasses were leaner. Meat tenderness was similar (P = 0.98) between the progeny of Angus or Simmental sires. Steers had in average WBSF of 3.22 kg. This value meets the industry requirements for meat tenderness and consumers acceptance.

In a study by Barker-Neef et al. (2001), Angus sired steers offspring of Angus and Angus cross-bred cows reported lighter HCW for the Angus sired steers. The authors attribute the outcome as part of the genotype which predisposed them to light HCW. Although MS were similar for carcasses, high quality grades were observed in carcasses of Angus sired steers. The authors concluded that the major economic penalty for early weaned steers was a result of their early physiological maturity and reduced carcass weight. This phenomenon may be breed-type dependent. Similarly, Myers et al. (1999) reported an interaction between weaning age and genotype for harvest weight in ¾ Angus and ¾ Simmental steers. Therefore, the economic consequences of using early weaning in an accelerated system may be influenced by the cattle's breed type and associated rate of physiological maturity (Barker-Neef et al., 2001).

Breed of dam effects were observed for most of the carcass characteristics evaluated with the exception of REA ($P = 0.1016$), KPH % ($P = 0.9768$) and WBSF ($P = 0.5634$). On average, carcasses for Angus and Simmental dam breed had 89.64 cm^2, 2.42 %, and 3.21 kg for REA, KPH and WBSF, respectively. However, steers from Simmental dams had heavier HCW ($P = 0.0096$) than steers from Angus dams. Carcass weight of steers from Simmental dams was 25 kg heavier than that of steers from Angus dams. Similar to the results reported for sire breed, BF and MS was higher in carcasses of steers from Angus dams. The progeny of Angus dams had carcasses with 21% higher ($P = 0.0006$) BF and 85 units more ($P = 0.0003$) MS than carcasses of steers from Simmental dams. These MS differences allowed carcasses of steers from Angus dams to classify as an "Average Choice" (MS = 669) and steers from Simmental dams to classify as "Low Choice" (MS = 584). Opposite to the behavior observed for the dam effect of the Angus breed, steers from Simmental dams had carcasses with lower CYG (2.94, $P = 0.05$) than carcasses of steers from Angus dams whose CYG averaged 3.22. Our data suggests a direct influence of the maternal effect in carcass characteristics and composition, different than the influence reported for the performance characteristics. Urick et al. (1991) found differences due to breed of dam for HCW and REA and approached significance (P = 0.07) for KPH %. For HCW, heifers from Angus dams were lighter than heifers from Simmental dams. Carcass back fat thickness was above average for heifers from Angus dams. Breed group differences for marbling scores were small, but heifers from Angus dams had higher marbling scores than those from dams of other breed groups (Urick et al.,1991).

The interaction between breed of sire and dam did not have a significant (P > 0.05) effect on most of the carcass characteristics. However there was a tendency for this interaction (P = 0.09) to influence MS. Pure bred Angus steers had the higher MS (728) than the rest of steers. However, similar MS were observed among carcasses of steers with Angus-Simmental, Simmental-Angus, and pure bred Simmental composition. Carcasses of steers from these breed composition averaged MS of 600, 610, and 567; respectively. The use of Angus breed either through sire or dam improved the ability to deposit more intramuscular fat than what we would expect from a pure bred Simmental steer. Angus-Simmental and Simmental-Angus steers had carcasses that averaged an “Average Choice” quality grade while pure bred Simmental steers had carcasses that averaged “Low Choice” quality grade. These results confirm breed complementarities and heterosis expression in feedlot steers. Gregory and Cundiff (1980) stated that crossbreeding systems can be used in beef cattle production to provide for heterosis and to use breed differences in additive genetic merit for specific characters to synchronize more effectively performance characteristics and adaptability of genetic resources for climatic environment, nutritive environment, and other resource that are most economical to provide, consistent with market requirements.

Implications

Our findings confirmed that practice management such crossbreeding and selection for RFI will reduce intake requirements of feedlot steers without affecting growth rate. Furthermore, low RFI steers had no alterations in carcass composition which could have lead to a compromise in quality and value. In addition, meat tenderness was not affected by RFI selection. However, it is important to consider breed selection when utilizing cross-breeding programs. As previously discussed, breed of sire did not had an effect in performance characteristics and small effect in carcass characteristics. In contrast, breed of dam played an important role in enhancing performance and carcass characteristics. Future research should address the effects of RFI and breed of sire and dam in feedlot profitability when using early weaned steers or heifers.

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Table 2-1. Ingredient composition of early weaned steers finishing diet (% dry matter basis, DMB)

Ingredient (% DMB)	Finishing Diet	
	Year 1	Year 2
Dry Rolled Corn	53	50
Dry Distillers Grains	24	25
Corn Silage	13	15
By-product Supplement[#]	10	10

[#]By-product supplement: ground corn, urea, limestone, Thiamine Promix®, Rumensin®, Tylan 40®, trace mineral salt, copper chloride, vitamin ADE, and liquid fat.

Table 2-2. Residual Feed Intake (RFI) effect on the performance characteristics of early weaned steers

Item	Residual Feed Intake Classification*			SEM	P-Value
	High	Medium	Low		
N	44	60	54	-	-
Initial Weight, kg	358	369	355	6	0.1436
Final Weight, kg	624	628	654	11	0.1654
Average Daily Dry Matter Intake, kg/d	9.74[a]	8.76[b]	8.63[b]	0.19	0.0004
Average Daily Gain, kg/d	1.45[a]	1.42[a]	1.63[b]	0.04	0.002
Gain:Feed	0.149[a]	0.161[b]	0.190[c]	0.003	<.0001
RFI, kg/d	1.09[a]	0.02[b]	-0.91[c]	0.38	<.0001

[*] High: RFI > 0.5 SD; Medium: RFI ± 0.5 SD; Low: RFI < 0.5 SD

Table 2-3. Residual Feed Intake (RFI) effect on carcass characteristics of early weaned steers

Item	Residual Feed Intake Classification*			SEM	P-Value
	High	Medium	Low		
N	44	60	54	-	-
Hot Carcass Weight, kg	387	390	406	7	0.1654
Back Fat, cm	1.26	1.28	1.32	0.07	0.8322
Marbling Score#	617	639	640	18	0.6533
Calculated Yield Grade	3.05	3.12	3.06	0.11	0.8767
Rib Eye Area, cm^2	89.46	87.88	92.88	1.59	0.0558
KPH@, %	2.53[a]	2.33[b]	2.32[b]	0.06	0.0389
Shear Force, kg	3.25	3.15	3.16	0.15	0.8908

* High: RFI > 0.5 SD; Medium: RFI ± 0.5 SD; Low: RFI < 0.5 SD
# 500 = Small, 600 = Moderate, 700 = Modest
@ Kidney, Pelvic, and Heart Fat

Table 2-4. Breed of sire and dam effect on the performance characteristics of early weaned steers

Sire Breed[&]	A	A	S	S	SEM	Sire Breed P-Value	Dam Breed P-Value	Sire*Dam Breed P-Value
Dam Breed	A	S	A	S				
N	53	21	22	62	-	-	-	-
IW[+], kg	345	367	342	388	7	0.382	<.0001	0.3694
FW[+], kg	613	646	610	658	12	0.6422	0.0096	0.763
ADDMI[+], kg/d	9.08	9.20	9.06	9.30	0.20	0.9421	0.2773	0.8854
ADG[+], kg/d	1.45	1.52	1.48	1.47	0.05	0.8685	0.653	0.6813
Gain:Feed	0.168	0.163	0.170	0.161	0.003	0.9913	0.0235	0.4865
RFI[+], kg/d	0.40	-0.42	-0.02	-0.19	0.79	0.4063	0.4799	0.4037

[&]Angus (A), Simmental (S)

Table 2-5. Breed of sire and dam effect on the carcass characteristics of early weaned steers

Sire Breed[&]	A	A	S	S	SEM	Sire Breed P-Value	Dam Breed P-Value	Sire*Dam Breed P-Value
Dam Breed	A	S	A	S				
N	53	21	22	62	-	-	-	-
Hot Carcass Weight, kg	380	401	379	408	8	0.6422	0.0096	0.763
Back Fat, cm	1.63	1.27	1.23	1.01	0.08	<.0001	0.0006	0.6282
Marbling Score[#]	728	600	610	567	20	0.0003	0.0003	0.0991
Calculated Yield Grade	3.55	3.15	2.90	2.73	0.12	<.0001	0.0553	0.3962
Rib Eye Area, cm^2	85.57	89.65	89.66	93.66	1.78	0.012	0.1016	0.6146
KPH[@], %	2.50	2.47	2.34	2.37	0.06	0.0548	0.9811	0.7792
Shear Force, kg	3.11	3.33	3.22	3.19	0.17	0.98	0.7014	0.6355

[&] Angus (A), Simmental (S)
[#] 500 = Small, 600 = Moderate, 700 = Modest
[@] Kidney, Pelvic, and Heart Fat

CHAPTER III

THE EFFECT OF DIETARY TREATMENT, RESIDUAL FEED INTAKE, AND BREED OF SIRE ON CARCASS CHARACTERISTICS AND RATES OF BACK FAT AND INTRAMUSCULAR FAT DEPOSITION OF FEEDLOT STEERS

Abstract

In addition to improving quality grade in the final product, producers are seeking management practices that can reduce major costs in a feedlot operation. The objectives in this study were: (1) to evaluate rates of ultrasonic back fat (BF) and intramuscular fat (IM) deposition of feedlot steers, (2) to determine the relationship between RFI and rates of ultrasonic BF and IM deposition of feedlot steers; and (3) to evaluate the effect of dietary treatment and breed of sire on carcass characteristics and rates of ultrasonic BF and IM deposition of feedlot steers. Six hundred and four steers were used across four different years from four separate ranches. From this previous population, 589 steers had identified sires from the breed compositions: Angus (A), Simmental (S), 50% Simmental-50% Angus (SA), 75% Simmental (75S). All dietary treatments were replicated during the four years: 75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG). Steers fed 40DDGS had the heaviest carcass ($P < 0.05$) with 16 kg more of hot carcass weight (HCW) than steers fed the other diets. Carcasses of steers fed co-products had 0.21 cm more ($P < 0.05$) of BFt than carcasses of steers fed 75 DRC. Carcasses of steers fed 75DRC diet had the lowest ($P < 0.05$) calculated yield grade (CYG). Differences in marbling score (MS) and kidney, pelvic and heart fat (KPH) among diets were not detected. Steers fed diets 25DDGS, 40DDGS, 40FWDG had similar ($P > 0.05$) rates of ultrasonic BF deposition. The

rates of ultrasonic IM deposition were similar (P > 0.05) among steers fed 75DRC, 25DDGS, and 40FWDG and steers fed 40DDGS exhibited the highest rate (P < 0.05) of IM deposition. Differences (P < 0.05) among RFI class were noted for BF, REA, and CYG. Steers were classified as high (H), medium (M) or low (L) RFI. The carcasses of H RFI steers had the highest (P < 0.05) amount of BF with an average of 1.47 cm. Steers classified as low (L) RFI had the largest (P < 0.05) REA. Steers in the L RFI group had the lowest CYG (P < 0.05) and steers in the medium (M) RFI group had the highest (P < 0.05) CYG. Residual feed intake was related to the rate of ultrasonic BF (P < 0.05). No differences (P > 0.05) for the rates of ultrasonic IM deposition and marbling over back fat deposition were detected among RFI groups. No differences were detected (P > 0.05) among breed of sire for HCW and kidney, pelvic, and heart fat %. Angus sired steers had carcasses with the highest amount of BF (P < 0.05). No differences were observed (P > 0.05) in the amount of carcass back fat among steers sired by S, SA, and 75S. Carcasses of steers from A and SA had higher MS (P < 0.05) than carcasses of steers from 75S and S. Progeny of 75S and A had carcasses with similar (P > 0.05) REA. Progeny of A had carcasses with the highest CYG which averaged 3.33 and S steers had carcasses with the lowest CYG which averaged 2.94. Rates of ultrasonic BF and IM deposition differed significantly among breed of sires. Progeny of 75S and S had similar (P > 0.05) rates of ultrasonic BF deposition. Steers sired by A deposited back fat 14% faster (P < 0.05) than steers sired by SA and 75S. Steers sired by A bulls had the highest (P < 0.05) rate of IM deposition. The rate of marbling over back fat was similar (P > 0.05) among breed of sires. This study confirms that there is no unique breed of sire or diet could address all the biological and market challenges in feedlots.

Introduction

The beef industry is seeking to manage beef cattle to meet consumer demands while maintaining a profitable and sustainable industry. Since the publication of USDA standards for beef carcass quality in 1928, the United States cattle industry has had a system of grades to classify their products. Over the years, modification and additions have been implemented to update and improve the applications of those standards. However, these carcass characteristics (i.e. marbling, lean texture and color, and physiological age) have controlled the quality grading standards. Specifically, marbling and muscle characteristics have been the major factors in quality grade separation.

In addition to improve quality grade in the final product, producers are seeking for practice managements that can reduce the major cost in a feedlot operation. The current incorporation of residual feed intake (RFI) as a potential tool for selection provides an opportunity to decrease feed costs and maintain final products quality. Residual feed intake measures whether an animal eats more or less feed than predicted by published feeding standards or by comparison with measured feed intakes or like-type animals (e.g., same breed, sex, age) eating the same feed (Herd and Arthur, 2009). Limited literature can be found on the association between RFI values and rates of back fat and marbling deposition in individual animals. Richardson et al. (2001) concluded that progeny from Angus cattle selected for low RFI had 13.2% less subcutaneous and intramuscular fat than progeny from those selected for high RFI. Baker et al. (2006) suggested that the variation in RFI does not correlate with visual marbling scores and intramuscular fat in Angus steers. In addition, it may be that less efficient steers (high RFI) have a greater propensity to deposit fat than protein. It is important to note that, as stated by Baker et al. (2006), the difference between studies may be attributed to differences in age and maturity of animals when traits were measured or may suggest that other unidentified variables may be influencing composition in these populations.

The objectives in this study were: (1) to evaluate rates of ultrasonic back fat and intramuscular fat deposition of feedlot steers, (2) to determine the relationship between residual feed intake and rates of ultrasonic back fat and intramuscular fat deposition of feedlot steers; and (3) to evaluate the effect of dietary treatment and breed of sire on carcass characteristics and rates of ultrasonic back fat and intramuscular fat deposition of feedlot steers.

Materials and Methods

Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* Consortium, 1988. Experimental protocols were submitted and approved by the University of Illinois Institutional Animal Care and Use Committee.

Animals and Management

Six hundred and four steers were used across four different years from four separate ranches; and three ranches were replicated in each year. From the previous population, 589 steers had identified sires from the following breed compositions: Angus (n=19 sires, 107 steers), Simmental (n=47 sires, 302 steers), Simmental-Angus (n=23 sires, 134 steers), 75% Simmental (n=5 sires, 49 steers). Prior to shipping to the University of Illinois, steers were vaccinated for Bovine Respiratory Syncytial Virus, IBR, BVD, PI3, and Pasteurella. The implant strategy utilized during the first, third, and fourth year was Component TE-IS (80 mg trenbolone acetate, 16 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) at the initiation of the trial, and re-implanted with Component TE-S (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) after 84 days on feed. In year 2, steers were implanted with Revalor-G® (40 mg trenbolone acetate and 8 mg estradiol; Intervet, Millsboro, DE) at the initiation of the trial, and re-implanted with at forty-two days on feed with Component TE-S (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) after 84 days on feed. Animals were randomly assigned to a dietary treatment by breed of sire across the four years. Four diets were represented in the compiled data. Dietary treatments were replicated during the four years (Table 1) and their composition was: 75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG). Diets were formulated to meet or exceed the minimum NRC (1996) requirements for maintenance and gain (Table 2).

Performance and Ultrasound Data Collection

To evaluate live animal performance, steer weight, and ultrasonic measurements of back fat thickness and marbling score were recorded at 28, 56, 84 and 112 days on feed during year 1; for years 2, 3, and 4 measurements were taken at 42, 84, and 126 days on feed. Ultrasound measurements were taken with an Aloka 500V (Wallingford, CT) B-mode instrument equipped with a 3.5-MHz general purpose transducer array. Back fat and marbling measurements were taken in a transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline. Marbling image analysis was performed according to Brethour (1994). Daily feed intake was recorded using the GrowSafe® automated feeding system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada). Final individual-animal average daily gain and feed efficiency (gain to feed) were calculated based on carcass adjusted final weights. Adjusted final weight was calculated by dividing hot carcass weight (HCW) by the average dressing percent of the slaughter group. Harvest groups were sorted on ultrasound back fat and weight. Steers had minimum of 8.89 mm of back fat and 545.5 kg lbs of live weight. For year 1, groups were harvested after 121 (80 head), 147 (194), and 168 (75 head) days on feed. For year 2, groups were harvested after 146 (27 head), 169 (202 head), and 195 (206 head) days on feed. Groups for year 3 were harvested after 145 (154 head) and 170 (321 head) days on feed. In year 4, steers were harvested after 141 (38 head) and 171 (73 head) days on feed.

Carcass Data Collection

Steers were harvested at a commercial processing facility. Animals were stunned via captive bolt pistol and exsanguinated. On the day of harvest individual carcass measurements were taken for HCW. After undergoing a 24 h chill at -4ºC measurements for back fat thickness (BF), kidney, pelvic and heart fat (KPH) percentage, and marbling score (MS) were collected by trained university personnel. Chromatography paper was used to take an image of the *longissimus dorsi* (LD) and measurements for the *longissimus* muscle area (LMA) were recorded using a planometer. University of Illinois (UI) measurements were used to determine quality grade (QG) and calculate yield grade (YG). Yield grade was calculated using the equation [2.5 + (2.5*inches of BF) + (0.20*KPH%) + (0.0038*lb. of HCW) – (0.32*square inches of LD muscle)] (Taylor, 1994).

Statistical Analyses and Residual Feed Intake Calculation

Response variables studied included live animal performance, carcass, and ultrasound parameters. Data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003). Fixed effects in the model included Diet, Breed of sire, Ranch, and RFI classification. The random effects in the model included pen and year. Two-way interactions were analyzed between: diet and breed of sire, diet and ranch, diet and RFI classification, breed of sire and ranch, breed of sire and RFI classification, ranch and RFI classification. Only significant interactions will be discussed. In order to account for unequal replication within treatments and its effect on the degrees of freedom, the Kenward-Rogers method was used for the adjustment.

Residual feed intake value was calculated as the difference of the actual dry matter intake (DMI) and the expected DMI (Basarab et al., 2001). The expected DMI was calculated as a linear regression of dry matter intake, average daily gain (ADG), and metabolic body weight ($BW^{0.75}$) using the REG procedure of SAS (SAS Institute, 2003).

$$\textit{Expected DMI } (Y_i) = \beta_o + \beta_1\text{ADG} + \beta_2\text{(BW)}$$

$$\text{RFI} = \text{Actual DMI (kg)} - \text{Expected DMI (kg)}$$

Where β_o is the intercept and β_1 and $\beta 2$ denote the regression coefficients. Steers with RFI values greater than 0.5 standard deviation (SD) were classified as high (H) RFI. Steers with RFI values equal to 0.5 SD were classified as medium (M) RFI and steers with RFI values less than to 0.5 SD were classified as low (L) RFI.

A simple linear regression model using the REG procedure of SAS was used to obtain a slope and intercept for each steer for rates of back fat and marbling over days of feed, and rates of marbling over back fat deposition. Main effect means for all analyses were separated using the LSD procedure when the respective F-tests were significant ($P \leq 0.05$).

Results and Discussion

Dietary Treatment and Residual Feed Intake

Dietary treatment means of performance characteristics and descriptive statistics for RFI by dietary treatment are presented in Table 3 and Table 4, respectively. Steers averaged 329 kg for initial weight, 593 kg for adjusted final weight, 10.18 kg /d for DMI, 1.58 kg/d for ADG, and

0.16 gain to feed ratio. In average steers had RFI values of 0.06 ± 0.41 (75DRC), -0.03 ± 0.32 (25DDGS), 0.11 ± 0.39 (40DDGS), and 0.04 ± 0.45 (40FWDG) kg/d. In the population of steers evaluated, 29% (n = 175) were classified as H RFI, 38% (n = 227) as M RFI, and 33% (n = 202) as L RFI.

Carcass characteristics were influenced ($P < 0.05$) by the main effects dietary treatment (Table 5). For instance, steers fed 40DDGS had the heaviest carcass ($P < 0.05$) with 16 kg more of HCW than steers fed the other diets. Steers fed 75DRC or a traditional feedlot diet had the lightest ($P < 0.05$) HCW. Carcass back fat differed ($P < 0.05$) among dietary treatments, with carcasses of steers fed co-products having 0.21 cm more of BF than carcasses of steers fed 75 DRC. In average carcass back fat for co-product diets and 75DRC diet was 1.36 cm and 1.15 cm, respectively. Rib eye area increased 2.6 cm^2 more ($P < 0.05$) in carcasses of steers fed 40DDGS and 40FWDG diets. No differences were detected in REA of steers fed 75DRC and 25DDGS diets, carcasses averaged 85.8 cm^2. For CYG, carcasses of steers fed 75DRC diet had the lowest CYG (2.84). In average, CYG was 3.25, 3.18, and 3.07 for carcasses of steers fed 25DDGS, 40DDGS, and 40FWDG; respectively. No differences in MS and KPH were detected. Across diets, carcasses had an average MS of 567 ($Choice^-$ = 500), and KPH of 2.38%. Dietary factors that have been proposed to affect marbling include provision of lipid in the diet, different methods of processing grain to influence the amount of starch escaping rumen digestion (to increase supply of glucose precursors to the animal), and differing levels of amino acid supply relative to energy. Oddy et al. (2000) concluded that grain based diets containing different amounts of protein relative to estimated requirements have no significant effect on the rate of fattening in the body (fat thickness) or on intramuscular fat content. However, there was a trend for high protein diets to produce less marbling and low protein diets more marbling than control.

Distillers grains with soluble are a good source of protein and energy, values from the NRC, 1996 reports 30% CP and 10% fat. In a recent study by Uwituze et al. (2010) observed no differences (P = 0.96) in marbling score when fed 25% DDGS compared to a high corn diet. In agreement, VanderPol et al. (2006b) reported no significant differences for any carcass characteristic in yearlings fed wet distillers grains. However, Gunn et al. (2009) concluded that marbling scores and quality grades were negatively affected when DDGS increased from 25% to 50% of the diet in a DM basis. The authors attributed these responses to a combination of elevated concentrations of CP and fat within these diets which could have diminished rumen efficiency. Pethick et al. (2004) stated that dietary differences between feedlot cattle and pasture-finished animals include more net energy available for fat synthesis in the feedlot-finished animals. Dietary induced differences in net energy availability include greater total net intake per day in the feedlot, decreased relative gastro-intestinal tract size in feedlot animals leading to a reduced maintenance energy and thus higher net energy for gain compared with pasture-fed animals, and a different pattern of energy substrates available to animals in feedlots compared with pasture diets. A key conclusion from this review is that the final level of intramuscular fat after finishing is determined to a large extent by the pre-feedlot level established in the pasture or back-grounding phase of the production system.

Nutritional management has been proven to enhance BF and IM fat deposition in feedlot cattle (Bindon, 2004; Oddy et al., 2000; Pethick et al., 2004). Bruns et al. (2004) reported that in a similar population of calf-fed steers, MS and to a large degree BF increased linearly when analyzed as a component of growth over time. Our results indicate a significant effect of dietary treatment on the rates of ultrasonic back fat and marbling deposition (Table 6). Steers fed diets 25DDGS, 40DDGS, 40FWDG had similar (P > 0.05) rates of ultrasonic BF deposition. On average, steers deposited back fat at a rate of 0.06 mm/d, which corresponded to a 33% increase of back fat deposition ($P < 0.05$) when compared to steers fed 75DRC which is considered a traditional high corn finishing. This result indicates that diets with corn co-products could enhance back fat deposition and at the same time help reduce feed cost due to their lower price in comparison to the higher prices of corn. The rates of ultrasonic marbling deposition were similar ($P > 0.05$) among steers fed 75DRC, 25DDGS, and 40FWDG. Steers fed 40DDGS exhibited the highest rate ($P < 0.05$) of intramuscular fat deposition. Steers showed an advantage of 0.20 of one hundredth marbling score per day more than steers fed the other dietary treatments. This difference represents a potential improvement of 16% in the carcass MS. However, as shown in carcass characteristics results, the range of MS was narrow across diets and numerically carcasses of steers fed 25DDGS had the highest MS with a score of 577. In addition, it was of interest to evaluate ultrasonic marbling deposition based on a standard endpoint for back fat. Thus, we calculated intramuscular fat deposition per 1 cm of back fat. No differences ($P > 0.05$) on ultrasonic marbling deposition based on a standard increase for back fat were detected among dietary treatments. On average, steers deposited 168.75 units of 100 MS for 1 cm of back fat. The range of rates among dietary treatments was narrow. This suggests that independent of the diet being fed to feedlot steers, animals will have a similar increase in marbling score per 1 cm increase in back fat.

The factors by which grain diets stimulate adipose tissue growth are not well understood and likely differ between subcutaneous and intramuscular fat depots. Smith and Crouse (1984) stated that a decrease in marbling may be due to reduced dietary starch content. Additionally, ruminants fed grain-based diets have greater concentration of propionate than those fed a forage-based diet (Owens and Goetsch, 1988;Okine and Arthur, 1997). Increasing propionate, a gluconeogenic precursor, may lead to greater glucose availability and hence greater marbling deposition. In addition, Ham et al. (1994) reported an increase in propionate concentrations when 20% thin stillage was infused or when 15% condensed distillers solubles was fed to finishing steers. The authors suggest an alteration of microbial populations, specifically a reduction of the protozoa populations may have caused the increased propionate. Similarly, Vander Pol et al. (2009) observed greater propionate molar proportion and decreased acetate:propionate ratio in cattle fed 40% wet distillers grains when compared to those fed a DRC diet. Opposite to the previous findings, Uwituze et al. (2010) reported lower concentrations of propionate in steers fed DDGS with corn silage as the roughage source than those fed DDGS with alfalfa hay as the roughage source.

An interaction ($P = 0.0276$) between RFI and dietary treatment was detected for carcass back fat. It was evident that carcasses of steers fed 25DDGS and classified as H RFI had the highest ($P < 0.05$) back fat. In addition, carcass back fat decreased within all RFI groups when steers fed 40FWDG. Medium and L RFI steers had similar results in which carcasses had the highest back fat when steers were fed 25DDGS diet. Although this outcome could be influenced by DMI, steers fed 25DDGS consumed in average 9.72 kg of DM which was 1.15 kg less than the highest intake in steers fed 40DDGS diet.

Differences ($P < 0.05$) among RFI classes were noted for BF, REA, and CYG (Table 5). However, HCW, MS and KPH was similar ($P > 0.05$) across RFI groups. Hot carcass weight for H RFI, M RFI, and L RFI steers averaged 371 kg, 372 kg, and 386 kg, respectively. Marbling score for H RFI, M RFI, and L RFI steers averaged 583, 570, and 549, respectively. In addition, KPH % for H RFI, M RFI, and L RFI steers averaged 2.41%, 2.32%, 2.42%; respectively. Differences for back fat among RFI group demonstrated that carcasses of H RFI steers had the highest ($P < 0.05$) amount of back fat with an average of 1.47 cm. In addition, these carcasses had 0.18 cm and 0.30 cm more of back fat than carcasses of M and L RFI steers; respectively. For REA, steers classified as L RFI had the largest ($P < 0.05$) area with an average REA of 90 cm^2. Steers in the L RFI group had the lowest CYG ($P < 0.05$) and steers in the M RFI group had the highest ($P < 0.05$) carcass CYG value. On average, carcasses of steers classified as H, M, and L RFI had a CYG of 3.35, 3.04, and 2.85; respectively.

Baker et al. (2006) reported genetic correlations between RFI and carcass traits in U.S. cattle have not been reported. According to Richardson et al. (1998) there is some indication that lower RFI steers are leaner than higher RFI steers, indicating an association of genetic selection for RFI and maturity patterns. In agreement with our findings, Baker et al. (2006) observed no differences ($P>0.05$) in hot carcass weight (HCW), *Longissimus* muscle area (LM), fat thickness; kidney, pelvic, and heart fat (KPH), yield grade or quality grade among the low, medium, and high groups. Castro Bulle et al. (2007) reported no differences ($P>0.20$) for dressing percent, HCW, KPH, LM, marbling score, and yield grade between high and low RFI class of beef steers. In a recent study by Cruz et al. (2010), the authors reported no significant differences between low and high RFI groups for slaughter weight, HCW, REA, BF, KPH, quality grade, yield grade, and carcass weight at slaughter.

Residual feed intake influenced the rate of ultrasonic back fat (Table 6). No differences were detected ($P > 0.05$) among RFI groups for the rates of ultrasonic marbling deposition and marbling over back fat deposition. On average steers had a rate of ultrasonic marbling deposition of 1.16 of a hundredth of MS per day and an average rate of marbling over back fat of 168 (100 / 1 cm of back fat). Steers classified as H RFI had the highest ($P < 0.05$) rate of ultrasonic back fat deposition with an advantage of 0.01 mm more per day than M RFI steers and 0.02 mm more per day than L RFI steers.

Our findings indicate a strong relationship between RFI and the rate of ultrasonic BF deposition whereas; a weak relationship could be detected between RFI and ultrasonic intramuscular fat deposition. There was no alteration in carcass quality for those steers classified as L RFI in which actual intake is significantly reduced from expected intake. This could have an impact in the industry by reducing feed cost thru the selection of L RFI steers and guaranteeing no negative effects on carcass characteristics that could compromise its value. Correlations between RFI and ultrasound measurements of subcutaneous fat, intramuscular fat, rump fat, and carcass fat measurements have been proposed (Arthur et al., 2001; Basarab et al., 2003; Crews et al., 2003), however they are also inconclusive. For instance, Arthur et al. (2001) observed low phenotypic (r = 0.14) and genotypic (r = 0.17) correlations between RFI and ultrasound fat thickness and ultrasound *Longissimus* muscle area. Ultrasound marbling has been reported to have a tendency (P = 0.11) to be correlated with RFI, but no relationship was detected between RFI and marbling score (Basarab et al., 2003). Furthermore, Crews et al. (2003) reported negative correlations between RFI and fat thickness and between RFI and marbling scores; and Carstens et al. (2002) concluded that high RFI cattle had greater rump fat thickness, but similar fat thickness and intramuscular fat compared with low RFI steers. Recently, Lancaster et al. (2009) reported phenotypic correlations between ultrasound traits and RFI. However, these values were weak for both final back fat (0.12) and gain in back fat (0.22). In the previous study, heifers with low RFI had similar final back fat, but gained more back fat (P<0.001) during the trial than heifers with high RFI as initial back fat tended to be higher (P = 0.08) for low RFI. The moderate genetic correlation between RFI and final back fat (0.36) indicates that selection for favorable RFI will slightly reduce subcutaneous fat depots. It is important to take into consideration that due to the stronger relationships between RFI and carcass composition traits found in cattle fed high-grain diets, inclusion of live carcass compositions traits to compute RFI may be useful to reduce the potential impact of selection for RFI on carcass quality grade of progeny (Lancaster et al., 2009).

A significant interaction was detected between RFI and dietary treatment for the rate of ultrasonic back fat. Steers fed 40DDGS and classified as H RFI had the highest ($P < 0.05$) rate, which represented an advantage of 28% more of back fat being deposited daily. However, steers fed 75DRC diet and classified as M RFI had the slowest ($P < 0.05$) rate of ultrasonic back fat. Across all RFI class an increase on the rate of back fat was observed as corn co-products were added to the diet. An explanation for this interaction can be based on the higher DMI in steers receiving 40DDGS relative to the other diets. Along with the higher expected intake of these animals (i.e. H RFI class), nutrient availability will increase and nutrient repartition will shift more toward fat deposition. Opposite to the intake results observed in steers fed 75DRC diet that had the lowest DMI. Thus, having M RFI will just upkeep adequate growth rate and fat deposition.

Breed of Sire and Residual Feed Intake

Carcass results by breed of sire and RFI classification are presented in Table 7. No differences were detected ($P > 0.05$) among breed of sire for HCW and KPH %. For carcass BF, Angus sired steers had carcasses with the highest amount of BF ($P < 0.05$). These carcasses had in average 0.16 cm more ($P < 0.05$) of BF than carcasses of Simmental, Simmental-Angus, and 75% Simmental breed of sire. No differences were observed ($P > 0.05$) in the amount of carcass BF among steers sired by Simmental, Simmental-Angus, and 75% Simmental breeds. Carcasses of Simmental, Simmental-Angus, and 75% Simmental sire breed averaged 1.30 cm of BF. Marbling score differed ($P < 0.05$) among breed of sires. For instance, carcasses of steers from Angus and Simmental-Angus sires had higher MS ($P < 0.05$) than carcasses of steers from 75% Simmental and Simmental sires. Marbling score in carcasses of Angus and Simmental-Angus sired steers averaged 613 and 550 in carcasses of 75% Simmental and Simmental sired steers, respectively. Although this difference was significant, quality grade was “Average Choice” for Angus carcasses and “Low Choice” for Simmental-Angus, Simmental, and 75% Simmental carcasses. These grades indicated acceptable carcass quality. The progeny of 75% Simmental and Angus sires had carcasses with similar ($P > 0.05$) REA and in addition, their REA were 4 cm^2 smaller than REA in carcasses of steers sired by Simmental-Angus and Simmental bulls. Calculated yield grade differed ($P < 0.05$) for carcasses of steers sired by Angus and Simmental bulls. Progeny of Angus sires had carcasses with the highest CYG which averaged 3.33 and Simmental sired steers had carcasses with the lowest CYG which averaged 2.94. Steers sired by 75% Simmental, Simmental-Angus and Simmental bulls had a CYG of 3.04 which did not differed ($P > 0.05$) among these sire breeds.

In agreement with our finding, previous research (Cundiff et al., 1993) has showed a higher relative difference for bio-economic traits that influence quantity and value of production; such as growth rates, mature size and lean to fat ratio of the Simmental breed. In addition, Greiner (2002) reported that British breeds produced progeny which were 88% Choice or higher, and 22.3% yield grades 1 and 2 when compared to Continental breeds were 60.9% graded Choice or higher and 57% of the produced progeny had yield grades 1 and 2. Rios-Utrera et al. (2006) reported absolute differences in hot carcass weight of steers sired by Simmental bulls when compared to Angus progeny. Furthermore, carcass back fat was significantly higher in steers sired by Angus bulls. Other studies (Smith et al., 1976; Cundiff et al., 1993; Marshall, 1994) have also shown similar results for carcass characteristics as those reported in this experiment. Marshall (1994) proposed that although carcass heterosis effects do not seem to improve carcass composition, crossbreeding could potentially benefit carcass composition through complementary blending of breed characteristics. On the contrary, Casas and Cundiff (2003) concluded that sire and maternal grandsire breed differences allowed for the optimization of post-weaning growth and carcass traits by incorporating selected breeds and crossbreeding schemes. In addition, Cundiff et al. (1993) concluded that genetic variation found between breeds is comparable in magnitude to that found within breeds for growth for most carcass and meat traits. Thus, significant genetic change can result from selection both between and within breeds.

Rates of ultrasonic back fat and marbling deposition differed significantly among breed of sires (Table 8). Progeny of 75% Simmental and Simmental sires had similar ($P > 0.05$) rates of ultrasonic back fat deposition. In average, steers were depositing 0.05 mm/d. However, steers sired by Angus bulls were depositing back fat 14% faster ($P < 0.05$) than Simmental-Angus and 75% Simmental sired steers. This difference is equivalent to 0.01 mm/d more of back fat. In addition, progeny of Simmental sires had a slower rate ($P < 0.05$) with a reduction of 29% when compared to Angus progeny. Similar to the previous findings, steers sired by Angus bulls had the fastest ($P < 0.05$) rate of ultrasonic marbling deposition. However, steers sired by Simmental-Angus bulls had similar ($P > 0.05$) rates. The rate of ultrasonic marbling deposition averaged 1.25 of one hundredth of MS per day. In agreement with the carcass data, steers sired by Simmental-Angus sires had the highest ($P < 0.05$) carcass MS. A slower rate of ultrasonic marbling deposition was observed for steers sired by Simmental and 75% Simmental. These steers deposited ultrasonically measured intramuscular fat 18% slower ($P < 0.05$) than steers sired by Angus and Simmental-Angus bulls. The rate of marbling over back fat was similar ($P > 0.05$) among breed of sires. On average, steers had 163 units of 100 MS for one cm of back fat deposition.

Many studies (Albrecht et al., 2006; Chambaza et al., 2002; Marshall, 1994) have described the influence of breeds on the quantity of stored lipids. For instance, Albrecht et al. (2006) reported that among breeds differences appeared in the quantity, structure, and distribution of the marbling flecks in *Longissimus* and *Semitendinosus* muscles. The authors utilized computerized image analysis in order to provide detailed marbling characteristics. Furthermore, results indicated that German Angus, Galloway, and Holstein-Freisan bulls at 24 mo of age had relatively greater amount of fat which led to fusion of single marbling flecks to larger fat streaks in both muscles. In addition, German Angus bulls exhibited larger marbling flecks already in young animals, but the number or marbling flecks was greater in Galloway and Holstein-Freisan bulls.

Opposite to the results from dietary treatment and RFI, no significant interaction was observed between RFI and breed of sire. Baker et al. (2006) stated that the relationship among RFI, fat thickness, and intramuscular fat may not be the same in purebred or crossbred groups of cattle, as there is some inconsistencies in the data reported to date. McDonagh et al. (2001) found no differences in visual marbling scores or objectively measured intramuscular fat for carcasses of a group of Angus, Angus x Hereford, Angus x Polled Hereford, and Angus x Shorthorn steers, which were the progeny of high and low RFI selection lines. In contrast, Richardson et al. (2001) concluded that progeny from Angus cattle selected for low RFI had 13.2% less subcutaneous and intramuscular fat than progeny from those selected for high RFI. Baker et al. (2006) suggested that the variation in RFI does not correlate with visual marbling scores and intramuscular fat in Angus steers. In addition, the less efficient steers (high RFI) may have a greater propensity to deposit fat than protein.

Implications

If the beef cattle industry continues to apply price discrimination based on quality and yield grades, selection of breeding stock based on carcass merit and efficient performance will provide an economic incentive. Our findings indicated that including up to 40% of corn co-products in finishing diets will not affect carcass quality. Contrary, faster rates of ultrasonic back fat and intramuscular fat were observed for the corn co-products diets. In addition, RFI and breed complementarity enhanced nutritional managements by increasing rates of ultrasonic intramuscular fat and back fat. However, when considering solely efficient animals (i.e. lower RFI values) the rates of ultrasonic back fat and intramuscular fat were compromise. This study confirms that there is no unique feature in the feedlot sector that could address all the biological and market challenges.

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Table 3-1. Diet composition in a dry matter basis fed to finishing feedlot steers

Ingredient (%)	Dietary Treatment			
	75DRC	25DDGS	40DDGS	40FWDG
Dry Rolled Corn	75	50	-	-
Dry Distillers Grains	-	25	40	-
Fresh Wet Distillers Grains	-	-	-	40
Soy Hulls	-	-	35	35
Corn Silage	15	15	15	15
Soy-based Supplement[+]	10	-	-	-
Co-product Supplement[++]	-	10	10	10

[+]Soy based supplement: soy bean meal, ground corn, urea, limestone, Rumensin®, Tylan 40®, trace mineral salt, copper sulfate, vitamin ADE, and liquid fat.
[+]Co-product supplement: ground corn, urea, limestone, Thiamine Promix®, Rumensin®, Tylan 40®, trace mineral salt, copper chloride, vitamin ADE, and liquid fat.

Table 3-2. Nutritional composition of dietary treatment fed to finishing feedlot steers

Item	Dietary Treatment			
	75DRC	25DDGS	40DDGS	40FWDG
Dry Matter, %	71	73	71	54
Crude Protein, %	13.2	14.6	18	18.1
Acid Detergent Fiber, %	7.1	7.3	23.1	24
Neutral Detergent Fiber, %	14.7	17.3	38.7	40.8
TDN, %	77	76	68	67
NE_m, Mcal/lb	0.86	0.84	0.71	0.7
NE_g, Mcal/lb	0.57	0.56	0.44	0.43
Calcium, %	0.4	0.55	0.66	0.66
Phosphorus, %	0.35	0.46	0.47	0.46
Magnesium, %	0.13	0.19	0.25	0.27
Potassium, %	0.6	0.67	1.09	1.08
Sodium, %	0.11	0.17	0.22	0.25
Iron (ppm)	84.33	127.78	243.67	298.78
Zinc (ppm)	48.22	67.56	69.56	72.78
Copper (ppm)	15.44	23.89	20.56	23.11
Manganese (ppm)	16	20.56	23.11	25
Molybdenum (ppm)	0.33	0.4	0.42	0.5

Table 3-3. Dietary treatment means and pooled standard deviations of performance characteristics of feedlot steers

Measurement	Dietary Treatment[+]				Pooled Standard Deviation
	75DRC	25DDGS	40DDGS	40FWDG	
N	*160*	*127*	*129*	*188*	-
Initial Weight, kg	332	328	327	329	46
Adjusted Final Weight[&], kg	578	588	608	599	50
Average Daily Dry Matter Intake, kg	9.61	9.72	10.87	10.50	1.28
Average Daily Gain[@], kg	1.46	1.54	1.68	1.65	0.23
Gain:Feed	0.15	0.16	0.15	0.16	0.02

[+]75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG).
[&] Calculated from hot carcass weight and dressing percentage.
[@] Calculated using the adjusted final weight

Table 3-4. Descriptive statistics for residual feed intake (RFI) by dietary treatment fed to feedlot steers

Treatment[+]	RFI[&]	N	Mean	Std. Deviation	Minimum	Maximum
75 DRC	High	32	1.21	0.60	0.49	2.84
	Medium	68	-0.02	0.26	-0.45	0.43
	Low	60	-1.00	0.36	-2.00	-0.50
25DDGS	High	20	0.89	0.34	0.46	1.59
	Medium	47	-0.02	0.28	-0.44	0.45
	Low	60	-0.97	0.34	-1.76	-0.47
40DDGS	High	60	1.15	0.56	0.48	2.78
	Medium	42	0.04	0.24	-0.39	0.45
	Low	27	-0.86	0.37	-1.76	-0.46
40FWDG	High	63	1.13	0.60	0.48	2.92
	Medium	70	0.04	0.26	-0.44	0.45
	Low	55	-1.05	0.50	-3.01	-0.47

[+]75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG).

[&] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD); Low (< 0.5 SD)

Table 3-5. Effect of residual feed intake classification (RFI) and dietary treatment on carcass characteristics of feedlot steers

RFI[&]	High				Medium				Low				SEM	P-Value*
Treatment[+]	75DRC	25DDGS	40DDGS	40FWDG	75DRC	25DDGS	40DDGS	40FWDG	75DRC	25DDGS	40DDGS	40FWDG		
N	*32*	*20*	*60*	*63*	*68*	*47*	*42*	*70*	*60*	*60*	*27*	*55*	-	-
HCW[bx], kg	362	366	380	376	361	370	387	372	372	385	400	386	12	0.9252
BF[abx], cm	1.33	1.58	1.50	1.47	1.08	1.44	1.39	1.26	1.04	1.12	1.29	1.24	0.10	0.0276
MS[x]	585	590	586	571	561	585	582	551	560	557	541	537	18	0.9318
REA[abx], cm^2	83.91	79.23	87.20	84.83	85.56	85.08	88.86	88.60	90.66	90.93	90.99	90.26	1.98	0.1909
KPH[x], %	2.32	2.45	2.48	2.40	2.28	2.34	2.28	2.37	2.39	2.40	2.53	2.38	0.09	0.5419
CYG[abx]	3.13	3.64	3.33	3.33	2.79	3.29	3.15	2.95	2.61	2.83	3.06	2.93	0.17	0.0595

[+]75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG).

[&] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD); Low (< 0.5 SD)

[x] Hot Carcass Weight (HCW); Back Fat (BF), Marbling Score (MS), Rib Eye Area (REA); Kidney, Pelvic and Heart fat percentage (KPH); Calculated Yield Grade (CYG)

[y] University of Illinois marbling score; 500 = Small, 600 = Moderate, 700 = Modest

[a] P-Value ≤ 0.05 main effect of RFI classification

[b] P-Value ≤ 0.05 main effect of dietary treatment

* P-Value corresponding to the interaction of RFI classification and dietary treatment

Table 3-6. Effect of residual feed intake (RFI) and dietary treatment on rates of ultrasonic back fat (BF), marbling (Marb), and marbling over back fat (MBF) deposition of feedlot steers

RFI Class[&].	High				Medium				Low				SEM	P-Value*
Treatment[+]	75DR	25DD	40DD	40WD	75DR	25DD	40DD	40WG	75DR	25DD	40DD	40WD		
N	*32*	*20*	*60*	*63*	*68*	*47*	*42*	*70*	*60*	*60*	*27*	*55*	-	-
MBF, 100/ 1 cm BF	162	121	173	147	210	148	184	166	177	190	183	160	27	0.45
BF[#@], mm/d	0.053[bc]	0.048[c]	0.079[a]	0.068[b]	0.047[e]	0.066[b]	0.054[bc]	0.062[b]	0.047[de]	0.052[c]	0.062[bc]	0.053[bc]	0.008	0.03
Marb[@]., 1/100*d^{-1}	1.23	0.99	1.25	1.22	1.04	1.12	1.32	1.05	1.03	1.24	1.34	1.08	0.12	0.57

[&] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD); Low (< 0.5 SD)
[+]75% dry rolled corn + 25% corn silage (75DR), 50% dry rolled corn + 25% dry distillers grains with soluble (25DD), 40% dry distillers grains with soluble + 35% soy hulls (40DD), and 40% fresh wet distillers grains + 35% soy hulls (40WD).
[#] P-Value ≤ 0.05 main effect of RFI classification
[@] P-Value ≤ 0.05 main effect of dietary treatment
* P-Value corresponding to the interaction of breed of sire and RFI classification
[abcde] Superscripts with different letters differ (P ≤ 0.05) among each item within rows

Table 3-7. Effect of sire breed and residual feed intake (RFI) on carcass characteristics of feedlot steers

Sire Breed[&]	75 Simm			Ang			Simm			Simm-Ang			SEM	P-Value[*]
RFI Class[+].	H	M	L	H	M	L	H	M	L	H	M	L		
N	*13*	*18*	*18*	*40*	*40*	*26*	*84*	*115*	*102*	*36*	*47*	*50*	-	-
HCW[x], kg	384	386	390	378	383	386	385	385	390	382	381	385	10	0.623
BF[abx], cm	1.47	1.18	1.27	1.64	1.40	1.34	1.34	1.26	1.11	1.47	1.34	1.22	0.07	0.604
MS[ax]	563	539	548	609	593	598	565	558	547	608	581	567	15	0.845
REA[abx], cm	82.76	90.08	88.44	82.06	87.98	88.64	88.04	90.09	91.88	89.34	90.10	93.00	1.46	0.2593
KPH[x], %	2.38	2.28	2.46	2.40	2.29	2.42	2.34	2.34	2.34	2.47	2.36	2.34	0.07	0.6348
CYG[abx]	3.53	2.86	3.11	3.69	3.17	3.12	3.14	2.95	2.75	3.22	3.00	2.78	0.13	0.3387

[&] 75% Simmental (75 Simm), Angus (Ang), Simmental (Simm), Simmental-Angus (Simm-Ang)
[+] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD); Low (< 0.5 SD)
[x] Hot Carcass Weight (HCW); Back Fat (BF), Marbling Score (MS), Rib Eye Area (REA); Kidney, Pelvic and Heart fat percentage (KPH); Calculated Yield Grade (CYG)
[y] University of Illinois marbling score; 500 = Small, 600 = Moderate, 700 = Modest
[a] P-Value ≤ 0.05 main effect of sire breed
[b] P-Value ≤ 0.05 main effect of RFI classification
* P-Value corresponding to the interaction of breed of sire and RFI classification

Table 3-8. Effect of residual feed intake (RFI) and breed of sire on rates of ultrasonic back fat (BF), marbling (Marb), and marbling over back fat (MBF) deposition of feedlot steers

Sire Breed[&]	75 Simm			Ang			Simm			Simm-Ang			SEM	P-Value*
RFI Classification[+]	H	M	L	H	M	L	H	M	L	H	M	L		
N	*13*	*18*	*18*	*40*	*40*	*26*	*84*	*115*	*102*	*36*	*47*	*50*	-	-
MBF, 100/ 1 cm BF	113	184	174	135	145	124	161	158	171	192	217	185	26	0.7812
BF[ab], mm/d	0.062	0.051	0.048	0.083	0.068	0.061	0.058	0.052	0.035	0.063	0.057	0.048	0.007	0.7477
Marb[b]., $1/100{*}d^{-1}$	1.00	0.97	1.10	1.36	1.25	1.14	1.13	1.03	0.99	1.32	1.32	1.13	0.11	0.8152

[&] 75% Simmental (75 Simm), Angus (Ang), Simmental (Simm), Simmental-Angus (Simm-Ang)
[+] Residual Feed Intake Classification: High (>0.5 SD, H); Medium (±0.5 SD, M); Low (< 0.5 SD, L)
[a] P-Value ≤ 0.05 main effect of RFI classification
[b] P-Value ≤ 0.05 main effect of sire breed
* P-Value corresponding to the interaction of breed of sire and RFI classification

CHAPTER IV

INFLUENCE OF SIRE RESIDUAL FEED INTAKE ON PERFORMANCE, CARCASS CHARACTERISTICS, AND RATES OF BACK FAT AND INTRAMUSCULAR FAT DEPOSITION OF FEEDLOT STEERS

Abstract

Breed associations have become interested in identifying variation in feed efficiency utilization within breeds. The existence of genetic variation in residual feed intake (RFI) offers the potential that selection for low RFI will produce progeny with lower DMI without compromising growth performance and/or carcass composition. The objectives of this study were: (1) to calculate RFI value of the sire and evaluate its effect on the performance and carcass characteristics of feedlot steers and (2) to evaluate the effect of estimated RFI of the sires on the rates of back fat and intramuscular fat deposition. Progeny from sires with breed composition of Angus (n = 4 sires, A), Simmental (n = 8 sires. S), Simmental-Angus (n = 5 sires, SA), and 75% Simmental (n = 3 sires, QS) were used. Records from 309 steers were included in the analysis and the minimum and maximum number of steers per sire was 10 and 53, respectively. Individual blood samples were sent to a laboratory of the University of Illinois for parental validation. Sires were assigned a random number followed by a letter indicating breed composition for identification purposes. Three sire groups were identified using the RFI value cutoff of 0.5 standard deviation from mean. High RFI (H RFI) group consisted of two A sires and one S sire. Low RFI (L RFI) group consisted of four S and two SA sires. For the medium RFI (M RFI) group, three S sires, three SA sires, three QS sires, and two A sires classified within this group. On average, sires RFI was 0.44 kg/d, -0.06 kg/d, and -0.48 kg/d for H RFI, L RFI, and M RFI group; respectively. Sire “3-S” had the highest estimated RFI value of 0.50 kg/d. Opposite, Sire “15-S” exhibited the lowest RFI value. No differences (P > 0.05) were observed between sire and RFI classification group for adjusted final weight, DMI, ADG, and G:F. Initial weight differed (P = 0.0044) among RFI group of sires. High Medium RFI Sire “4-QS” had the heaviest initial weight whereas, H RFI Sire “2-A” had the lightest initial weight with a difference of 58 kg (P < 0.05). Hot carcass weight and KPH% were similar (P > 0.05) among individual sire and its RFI groups. The rate of ultrasonic marbling deposition was influenced (P < 0.0001) by sire and RFI classification. Sires classified as M RFI had slower rates than H and L RFI sires. Average rates of ultrasonic marbling ($1/100*d^{-1}$) were 1.22 for H RFI sires and 1.23 for L RFI sires. Medium RFI sires had an average rate of 1.19 ($1/100*d^{-1}$). Sire and RFI classification did not influence (P = 0.0948) the rate of marbling over a standard back fat endpoint of 1 cm. These suggest that selection for high rates of marbling deposition relative to back fat should maintain acceptable quality while allowing a high retail yield. Results from this study indicate that individual sire RFI is a potential selection tool to improve profitability in the beef cattle industry.

Introduction

Breed associations have become more interested in identifying variation in feed utilization within breeds due to its economic impact. The existence of genetic variation in residual feed intake (RFI) offers the potential that selection for low RFI will produce progeny with lower consumption without compromising growth performance and/or carcass composition. Residual feed intake by definition is phenotypically independent of the production traits used to calculate expected feed intake, thus it allows comparison between individuals differing in level of production (Herd and Bishop, 2000). Currently, the level of usage of economic selection indices in the beef industry is low. Herd et al. (2003) explains that for the medium term, it is likely that a large proportion of bull breeders and bull purchasers will continue to base decisions on expected progeny difference (EPD) or expected breeding values (EBV) for individual traits. Furthermore, presentation of separate EPD or EBV for feed intake and growth, which are antagonistic and highly correlated, is likely to cause difficulty in interpretation as it is difficult to compare an animal with high intake and high growth rate with another with lower intake but lower growth also. Conceptually, an EPD or EBV for feed intake after adjustment for differences in growth performance (i.e., RFI) would be easier to interpret than an EPD or EBV for feed intake unadjusted for growth, as the correlation between growth EBV and the adjusted feed intake EBV would be lower and comparisons between feed intake of animals with different growth performance would be simplified (Herd et al., 2003). Considering RFI as a potential selection tool in the beef cattle industry it is important to analyze individual sire variation within breeds in addition limited literature has reported on individual sires basis. The objectives of this study were: (1) to calculate RFI value of the sire and evaluate its effect on the performance and carcass characteristics of feedlot steers and (2) to evaluate the effect of estimated RFI of the sires on the rates of back fat and intramuscular fat deposition.

Materials and Methods

Animals and Management

Progeny from identified sires with breed composition of Angus (n = 4 sires), Simmental (n = 8 sires), Simmental-Angus (n = 5 sires), and 75% Simmental (n = 3 sires) were used across four different years from four separate ranches and three of these ranches were replicated in each year. Records from 309 steers were included in the analysis and the minimum and maximum number of steers per sire was 10 and 53, respectively (Table 1). Individual blood samples were sent to a laboratory of the University of Illinois for parental validation. Confirmation of sire paternity was assessed by genotyping of 15 microsatellite markers including eight of the nine markers recommended by the ISAG Standing Committee on Cattle Molecular Markers and Parentage Testing (Sherman et al., 2004). Parentage exclusion analysis was conducted using CERVUS (Slate et al., 2000).

Animals used in this trial were managed according to the guidelines recommended in the *Guide for the Care and Use of Agriculture Animals in Agriculture Research and Teaching* Consortium, 1988. Experimental protocols were submitted and approved by the University of Illinois Institutional Animal Care and Use Committee. Prior to shipping to the University of Illinois, steers were vaccinated for Bovine Respiratory Syncytial Virus, IBR, BVD, PI3, and Pasteurella. The implant strategy utilized during the first, third, and fourth year was Component TE-IS (80 mg trenbolone acetate, 16 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) at the initiation of the trial, and re-implanted with Component TE-S (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) after 84 days on feed. In year 2, steers were implanted with Revalor-G® (40 mg trenbolone acetate and 8 mg estradiol; Intervet, Millsboro, DE) at the initiation of the trial, and re-implanted with at forty-two days on feed with Component TE-S (120 mg trenbolone acetate, 24 mg estradiol, 29 mg tylosin tartate; VetLife, Overland Park, KS) after 84 days on feed. Animals were randomly assigned to a dietary treatment by breed of sire across the four years. Four diets were represented in the compiled data and were replicated across years (Table 2). Diets were formulated to meet or exceed the minimum NRC (1996) requirements for maintenance and gain (Table 3).

Performance and Ultrasound Data Collection

Steer weight and ultrasonic measurements of back fat thickness and marbling score were recorded at 28, 56, 84 and 112 days on feed; for year two, three, and four measurements were taken at 42, 84, and 112 days on feed in order to evaluate live animal performance. Ultrasound measurements were taken with an Aloka 500V (Wallingford, CT) B-mode instrument equipped with a 3.5-MHz general purpose transducer array. Back fat and marbling measurements were taken in a transverse orientation between the 12th and 13th ribs approximately 10 cm distal from the midline. Marbling image analysis was performed according to Brethour (1994). Daily feed intake was recorded using the GrowSafe® automated feeding system (GrowSafe Systems Ltd., Airdrie, Alberta, Canada). Final individual-animal average daily gain (ADG) and feed efficiency (gain to feed, GF) were calculated based on carcass adjusted final weights. Adjusted final weight was calculated by dividing hot carcass weight (HCW) by the average dressing percent of the slaughter group. Harvest groups were sorted on ultrasound back fat and weight. Steers had minimum of 8.89 mm of back fat and 545.5 kg lbs of live weight. For year one groups were harvested after 121 (80 head), 147 (194 head), and 168 (75 head) days on feed. For year two groups were harvested after 146 (27 head), 169 (202 head), and 195 (206 head) days on feed. Groups for year three were harvested after 145 (154 head) and 170 (321 head) days on feed. In year four, steers were harvested after 141 (38 head) and 171 (73 head) days on feed.

Carcass Data Collection

Steers were harvested at a commercial processing facility. Animals were stunned via captive bolt pistol and exsanguinated. On the day of harvest individual carcass measurements were taken for HCW. After undergoing a 24 h chill at -4ºC measurements for back fat thickness (BF), kidney, pelvic and heart fat (KPH) percentage, and marbling score (MS) were collected by trained university personnel. Chromatography paper was used to take an image of the *longissimus dorsi* (LD) and measurements for the *longissimus* muscle area (REA) were recorded using a planometer. Yield grade was calculated using the equation [2.5 + (2.5*inches of BF) + (0.20*KPH%) + (0.0038*lb. of HCW) – (0.32*square inches of LD muscle)] following the equation presented by Taylor, 1994.

Statistical Analyses and Residual Feed Intake Calculation

Response variables studied included live animal performance, carcass, and ultrasound parameters. Data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003). Fixed effects in the model included Sire RFI classification, Sire nested within Breed of sire, Diet, and Ranch. The random effects in the model included pen and year.

Residual feed intake value was calculated as the difference of the actual dry matter intake (DMI) and the expected DMI (Basarab et al., 2001). The expected DMI was calculated as a linear regression of dry matter intake, average daily gain (ADG), and metabolic body weight ($BW^{0.75}$) using the REG procedure of SAS (SAS Institute, 2003).

$$\textit{Expected DMI } (Y_i) = \beta_o + \beta_1 \text{ADG} + \beta_2(\text{BW})$$

$$\text{RFI} = \text{Actual DMI (kg)} - \text{Expected DMI (kg)}$$

Where β_o is the intercept and β_1 and $\beta 2$ denote the regression coefficients. Sires with RFI values greater than 0.5 standard deviation (SD) were classified as high (H) RFI. Sires with RFI values equal to 0.5 SD were classified as medium (M) RFI and sires with RFI values less than to 0.5 SD were classified as low (L) RFI.

A simple linear regression model using the REG procedure of SAS was used to obtain a slope and intercept for each steer for rates of back fat and marbling over days of feed, and rates of marbling over back fat deposition. Main effect means for all analyses were separated using the LSD procedure when the respective F-tests were significant ($P \leq 0.05$).

Results and Discussion

Residual feed intake means and descriptive statistics are presented in Table 4 for individual sires. Sires were assigned a random number followed by a letter indicating breed composition for identification purposes. The high RFI group consisted of two Angus (A) sires and one Simmental (S) sire. The low RFI group consisted of four Simmental sires and two Simmental-Angus (SA) sires. The medium RFI group consisted of three Simmental sires, three Simmental-Angus sires, three 75% Simmental sires (QS), and two Angus sires. On average, sires RFI was 0.44 kg/d, -0.06 kg/d, and -0.48 kg/d for H RFI, M RFI, and L RFI group; respectively. Sire “3-S” had the highest RFI value of 0.50 kg/d. Opposite, Sire “15-S” exhibited the lowest RFI value. Interestingly, sires “15-S” and “3-S” are of the same breed composition and high variation in RFI behavior can be observed. Based on this population, progeny of Sire “15-S” would have a daily intake of 1.03 kg less than progeny of Sire “3-S”. In addition, progeny of Sire “3-S” would have a reduction of 0.5 kg/d when compared to M RFI sires where intakes are within expected values.

Performance

Results of performance characteristics are presented in Table 5. No differences ($P > 0.05$) were observed between sire and RFI classification group for adjusted final weight, DMI, ADG, and G:F. On average, H RFI sires had an adjusted final weight of 583 kg, 10.36 kg/d of DMI, 1.59 kg/d of ADG, and a G:F of 0.15. Furthermore, L RFI sires had in average 608 kg of adjusted final weight, 10.30 kg/d of DMI, 1.63 kg/d of ADG, and 0.16 of G:F. Sires within the L

RFI group averaged 607 kg of adjusted final weight, 10.58 kg/d of DMI, 1.65 kg/d of ADG, and 0.16 of G:F. Initial weight differed ($P = 0.0044$) among sire's RFI group. For instance, H RFI sires were lighter than L and M RFI sires. Medium RFI Sire "4-QS" had the heaviest initial weight whereas, H RFI Sire "2-A" had the lightest initial weight with a difference of 58 kg ($P < 0.05$). However, L RFI sires had similar weights than M RFI sires. Initial weight for H RFI sires was in average 317 kg, for L RFI sires 342 kg, and 344 kg for M RFI. Clearly, independent of RFI classification of the sire feed efficiency remained similar across sires

Limited literature is available in an individual sire basis. In a recent study by Rutherford (2010) evaluating RFI in centrally tested Angus and Simmental bulls and related steers; no differences between RFI classifications for the traits of initial weight, final weight, and ADG were reported when comparing L, M, and H RFI classes for central tested bulls. However, when incorporating age as a covariate the bulls within the intermediate RFI class had significantly heavier birth weights than bulls in the other two classes. Furthermore, yearling weight was significantly different between H and L RFI classes when adjusting for final weight on test. Sires with L RFI values had heavier adjusted yearling weights than bulls within the H RFI class. Average daily gain was similar across the three RFI classifications; however, there were significant differences among the three RFI classes for total gain on test. Low RFI steers gained more over the entire test than high RFI steers. Although no differences were detected in our study for performance characteristics, excluding initial weight, Arthur et al. (2001) stated that after using bulls divergently selected for RFI over five years progeny from these two lines differed in DMI. The low RFI line consumed, on average, 0.29 kg/d less than H RFI line. In addition, the authors concluded that an average $27 per head was saved on animals in the L RFI line over a 100 d feeding period.

Carcass

Results of carcass characteristics are presented in Table 6. Hot carcass weight and KPH% were similar ($P > 0.05$) among individual sire and its RFI groups. High RFI steers averaged 373 kg of HCW and 2.35 % of KPH. Low RFI sires averaged 389 kg of HCW and 2.32 % of KPH. Similarly, M RFI sires averaged 388 kg of HCW and 2.37 % of KPH. Carcass characteristics such as BF, MS, REA, and CYG were significantly different between sire and RFI classification. For BF, an increase could be observed in H RFI sires whereas; L RFI sires had the lowest amount of BF in their carcasses. Interestingly, sires with the same breed composition had the highest and lowest amount of carcass BF. Sire “17-S” classified as L RFI had an average BF of 1.04 cm and Sire “9-S” averaged 1.71 cm of BF. Similar to the outcome observed for BF, MS increased in H RFI sires and a reduction was observed in L and M RFI sires. However, sires within the same RFI group had the lowest and highest MS. Specifically, L RFI Sire “17-S” had the lowest MS with an average of 499 and L RFI Sire “20-SA” had the highest MS with an average of 629. In addition, H RFI Sire “1-A” and L RFI Sire “20-S” had similar ($P > 0.05$) MS. The difference between the highest and lowest MS placed carcasses on two different quality grades. Carcasses of steers sired by Sire “20-SA” on an Average Choice quality grade whereas, carcasses of steers sired by Sire “17-S”graded Select^{+}. In a market based on a quality grid, the difference in carcass value between Choice and Select quality grade can be of great importance maximizing profitability. Rib eye area exhibited an increase as sires were classified M and L RFI. In average, M and L RFI sires had a REA of 88 and 89 cm^2; respectively. Sires in the H RFI group had the smallest REA with an average of 86 cm^2. Sire “12-SA” from the M RFI group had the highest ($P < 0.05$) REA. Although, the smallest ($P < 0.05$) REA was also observed for M RFI Sire “6-QS” with an average REA of 83.25 cm^2; no differences were detected ($P > 0.05$) when compared to H RFI Sire "3-S". The L RFI sires exhibited a decrease in CYG whereas, an increase was seen for H and M RFI sires. On average, L RFI sires had a CYG of 3.00, 3.24 for H RFI, and 3.23 for M RFI. Two M RFI sires with different breed composition had the highest ($P < 0.05$) CYG. Sire "8-A" and Sire "9-S" averaged CYG of 3.74 and 3.71, respectively. Low RFI Sire "16-S" had the lowest CYG ($P < 0.05$) with an average of 2.81. Results from this study demonstrated the influence of the RFI of the sire on carcass characteristics. High and L RFI sires could potentially increase carcass quality grade as well the amount of boneless, closely trimmed retail cuts.

In a study by McDonagh et al. (2001), no differences were observed between H and L RFI groups for HCW, REA, dressing percentage, and marbling score in Angus and Angus cross steers from a single generation of divergent selection on RFI. Furthermore, the authors reported that H RFI steers exhibited more rib fat and tended to have more rump fat than L RFI steers. Rutherford (2010) found no differences across RFI classifications for CYG and BF. However, the author observed that steers with H and M RFI had higher CYG than their L RFI contemporaries. Richardson et al. (2001) found in yearling Angus steers from dams and sires tested and ranked as H and L RFI a smaller change in REA, more carcass fat, and tended to have less beef yield from carcass than steers form the L RFI group. Basarab et al. (2001) concluded that RFI in growing Angus steers was not correlated with composition of empty body tissue gain, as well as final empty body composition at slaughter. Furthermore, Richardson et al. (2001) reported that steer progeny from L RFI sires gained more empty body fat protein than steer progeny from H RFI sires. In addition, less than 5% of the variation in sire RFI could be explained by the variation found in the empty body composition of their steer progeny. Overall, the literature suggests that selection for L RFI may result in indirect selection for increase lean gain, but considering the impact of this effect may be small.

Rates of ultrasonic back fat and marbling deposition

Differences on carcass back fat and MS among sires and within RFI groups can be further explain with the results observed from rates of ultrasonic back fat and marbling deposition (Table 7). The rate of ultrasonic back fat increased ($P < 0.05$) in H RFI sires whereas; L and M RFI sires had lower rates with the exception of sire “8-A” that pertained to the M RFI groups but had the highest rate of ultrasonic back fat ($P < 0.05$). On average, this sire had a rate of 0.12 mm/d. In addition, L RFI sire “17-S” had the lowest rate of ultrasonic back fat deposition with an average of 0.043 mm/d. This outcome agrees with the results observed in carcass back fat in which Sire “8-A” had one of the highest carcass back fat and sire “17-S” had carcasses with the least amount of back fat. On average the rates of ultrasonic back fat were 0.071 mm/d for H RFI sires, 0.062 mm/d for M RFI sires, and 0.053 mm/d for L RFI sires. The rate of ultrasonic marbling deposition was influenced ($P < 0.0001$) by sire and RFI classification. Sires classified as M RFI had slower rates than H and L RFI sires. Rates of ultrasonic marbling ($1/100*d^{-1}$) averages were 1.22 for H RFI sires and 1.23 for L RFI sires. Medium RFI sires had an average rate of 1.19 ($1/100*d^{-1}$). The fastest rate ($P < 0.05$) of ultrasonic marbling was observed in L RFI sire “20-SA”; progeny had the potential to deposit up to 48% more of marbling score units than the progeny of other sires. Furthermore, H RFI sire “3-S” and L RFI sire “17-S” shared the slowest ($P < 0.05$) rate with an average of 0.90 hundredth of marbling score per day. In agreement with carcass results, sire “20-SA” had the highest carcass marbling score and sire “17-S’ had the lowest score.

Sire and RFI classification did not influence (P = 0.0948) the rate of marbling over a standard endpoint of 1 cm of back fat. However, sires had a wide range of rates independent of RFI classification. The average of rate marbling over back fat (100 MS/1 cm of BF) was 161 ± 46, 189 ± 46, and 190 ± 59 for H RFI, M RFI, and L RFI sires; respectively.

In the feedlot sector, cattle are fed to a level of external fat that provides a reasonable chance to achieve low choice marbling and desirable dressing percentage. Previous literature indicates that genetic correlation of marbling score and fat thickness or live growth traits is low (Vieselmeyer et al., 1996). Therefore, selection of sires with high rates of marbling deposition relative to back fat may result in progeny with lower amounts of subcutaneous and seam fat at a constant marbling endpoint or more marbling at a constant fat thickness or carcass weight (Gwartney et al., 1996). McPhee et al. (2006) reported that the heritability for marbling is approximately 35% indicating that management and environment account for 65% of the variability in marbling. The amount of intramuscular fat in the *longissimus* muscle has a phenotypic correlation with subcutaneous fat thickness; therefore, highly marbled carcasses generally also have increased fat trim losses.

A negative correlation between ultrasound measure of body composition (ultrasound measure of 12^{th} rib and rump fat thickness) and RFI has been reported (Carstens et al., 2002). In addition, the authors reported that ultrasound measures of REA and intramuscular fat percentage were not correlated with RFI. Rutherford (2010) concluded that no differences were detected between RFI classifications for ultrasound REA and ultrasound BF. Herd et al. (2003) found that H RFI steers tended to have more ultrasonic BF and ultrasonic REA than L RFI steers. Similar, Nkrumah et al. (2007) reported more ultrasonic BF gain per day in H RFI steers than M and L RFI steers. Although differences in the current study were not detected for rates of BF and marbling deposition, selection for high rates of marbling deposition relative to BF should maintain acceptable quality while allowing a high retail yield.

Implication

Results from this study indicate that individual sire RFI value is a potential selection tool for the beef cattle industry. However, effects on carcass characteristics should be taken into consideration. In addition, large variability was observed for performance characteristics, carcass characteristics, and rates of ultrasonic fat deposition within RFI classification groups and sire. Thus, when analyzing on an individual sire basis results should be closely monitored for extrapolation in a population of beef cattle.

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Table 4-1. Distribution of sire across years[+]

Year			
1	2	3	4
11-S	10-S	11-S	11-S
12-SA	11-S	13-SA	13-SA
14-SA	12-SA	1-A	
18-S	13-SA	2-A	
1-A	15-S	3-S	
20-SA	16-S	5-QS	
2-A	17-S		
3-S	18-S		
8-A	19-SA		
	1-A		
	4-QS		
	5-QS		
	6-QS		
	7-A		
	9-S		

[+] Sires were assigned a random number followed by a letter indicating breed composition for identification purposes: Angus (A), Simmental (S), Simmental-Angus (SA), and 75% Simmental (QS)

Table 4-2. Diet composition in a dry matter basis fed to finishing feedlot steers

Ingredient (%)	Dietary Treatment			
	75DRC	25DDGS	40DDGS	40FWDG
Dry Rolled Corn	75	50	-	-
Dry Distillers Grains	-	25	40	-
Fresh Wet Distillers Grains	-	-	-	40
Soy Hulls	-	-	35	35
Corn Silage	15	15	15	15
Soy-based Supplement[+]	10	-	-	-
Co-product Supplement[++]	-	10	10	10

[+]Soy based supplement: soy bean meal, ground corn, urea, limestone, Rumensin®, Tylan 40®, trace mineral salt, copper sulfate, vitamin ADE, and liquid fat.
[+]Co-product supplement: ground corn, urea, limestone, Thiamine Promix®, Rumensin®, Tylan 40®, trace mineral salt, copper chloride, vitamin ADE, and liquid fat.

Table 4-3. Nutritional composition of dietary treatment fed to finishing feedlot steers

Item	Dietary Treatment			
	75DRC	25DDGS	40DDGS	40FWDG
Dry Matter, %	71	73	71	54
Crude Protein, %	13.2	14.6	18	18.1
Acid Detergent Fiber, %	7.1	7.3	23.1	24
Neutral Detergent Fiber, %	14.7	17.3	38.7	40.8
TDN, %	77	76	68	67
NE_m, Mcal/lb	0.86	0.84	0.71	0.7
NE_g, Mcal/lb	0.57	0.56	0.44	0.43
Calcium, %	0.4	0.55	0.66	0.66
Phosphorus, %	0.35	0.46	0.47	0.46
Magnesium, %	0.13	0.19	0.25	0.27
Potassium, %	0.6	0.67	1.09	1.08
Sodium, %	0.11	0.17	0.22	0.25
Iron (ppm)	84.33	127.78	243.67	298.78
Zinc (ppm)	48.22	67.56	69.56	72.78
Copper (ppm)	15.44	23.89	20.56	23.11
Manganese (ppm)	16	20.56	23.11	25
Molybdenum (ppm)	0.33	0.4	0.42	0.5

Table 4-4. Descriptive statistics of individual sire's residual feed intake (RFI)

Sire[#]	RFI Class[+]	N[@]	Mean	Std. Dev	Minimum	Maximum
1-A	High	14	0.42	1.06	-1.17	2.17
2-A	High	12	0.38	1.49	-2.07	2.90
3-S	High	10	0.50	0.85	-0.77	1.54
10-S	Med	11	-0.17	0.78	-1.30	1.01
11-S	Med	53	0.18	0.82	-1.50	2.13
12-SA	Med	14	-0.05	0.54	-1.24	0.97
13-SA	Med	21	-0.08	0.85	-1.13	1.68
14-SA	Med	10	-0.28	0.90	-1.20	1.38
4-QS	Med	14	-0.34	0.71	-1.53	0.84
5-QS	Med	12	0.22	1.02	-1.90	2.38
6-QS	Med	14	-0.18	0.61	-1.08	1.24
7-A	Med	13	-0.24	0.53	-1.04	0.45
8-A	Med	17	0.23	0.91	-1.16	1.69
9-S	Med	11	0.08	0.76	-1.46	0.86
15-S	Low	11	-0.61	0.75	-1.60	0.56
16-S	Low	12	-0.56	0.76	-1.43	0.60
17-S	Low	11	-0.46	0.62	-1.44	0.73
18-S	Low	23	-0.47	0.76	-1.47	1.23
19-SA	Low	15	-0.38	0.72	-1.48	0.77
20-SA	Low	11	-0.42	1.26	-1.64	1.99

[#] Sires were assigned a random number followed by a letter indicating breed composition for identification purposes: Angus (A), Simmental (S), Simmental-Angus (SA), and 75% Simmental (QS)
[+] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD, Med); Low (< 0.5 SD)
[@] Number of steers

Table 4-5. Effect of sire and residual feed intake (RFI) classification on performance characteristics of feedlot steers.

Sire[#]	RFI Class[+]	N	Performance Characteristics[&]				
			IWT, kg	AFWT, kg	DMI, kg	ADG, kg/d	G:F
2-A	High	12	309	581	10.29	1.62	0.16
1-A	High	14	313	574	10.37	1.58	0.15
3-S	High	10	330	595	10.43	1.57	0.15
13-SA	Med	21	305	569	9.47	1.51	0.16
14-SA	Med	10	336	597	10.70	1.67	0.16
7-A	Med	13	341	597	10.34	1.61	0.16
12-SA	Med	14	342	593	10.39	1.60	0.15
5-QS	Med	12	342	598	10.55	1.63	0.15
11-S	Med	53	342	614	10.62	1.62	0.15
8-A	Med	17	344	627	11.33	1.75	0.15
6-QS	Med	14	344	591	10.58	1.64	0.16
9-S	Med	11	360	624	10.89	1.68	0.16
10-S	Med	11	360	629	10.78	1.73	0.16
4-QS	Med	14	367	640	10.69	1.72	0.16
17-S	Low	11	330	614	10.00	1.62	0.16
20-SA	Low	11	332	574	10.26	1.54	0.16
16-S	Low	12	342	594	9.85	1.54	0.16
18-S	Low	23	343	621	10.54	1.70	0.16
19-SA	Low	15	343	613	10.44	1.67	0.16
15-S	Low	11	362	634	10.71	1.71	0.16
SEM	-	-	15	18	0.62	0.10	0.01
P-Value	-	-	0.0044	0.108	0.1865	0.2101	0.6671

[#] Sires were assigned a random number followed by a letter indicating breed composition for identification purposes: Angus (A), Simmental (S), Simmental-Angus (SA), and 75% Simmental (QS)
[+] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD, Med); Low (< 0.5 SD)
[&]Initial weight (IWT), Adjusted final weight (AFWT), Dry matter intake (DMI), Average daily gain (ADG), and Gain to feed ratio (G:F)

Table 4-6. Effect of sire and residual feed intake (RFI) classification on carcass characteristics of feedlot steers.

Sire[#]	N	RFI Class[+]	Carcass Characteristics[&]					
			HCW, kg	BF, cm	MS[@]	REA, cm	KPH, %	CYG
1-A	14	High	367	1.44	625	86.70	2.25	3.19
2-A	12	High	372	1.45	606	87.22	2.36	3.25
3-S	10	High	381	1.35	558	85.43	2.41	3.29
12-SA	14	Med	379	1.24	548	96.01	2.24	2.62
13-SA	21	Med	364	1.26	554	89.74	2.34	2.80
11-S	53	Med	393	1.36	575	91.34	2.41	3.06
14-SA	10	Med	381	1.49	528	92.77	2.27	3.11
5-QS	12	Med	382	1.29	537	86.83	2.40	3.15
7-A	13	Med	386	1.15	501	83.46	2.32	3.20
6-QS	14	Med	380	1.19	537	83.25	2.36	3.21
10-S	11	Med	402	1.29	522	85.88	2.18	3.27
4-QS	14	Med	409	1.57	528	86.22	2.46	3.65
9-S	11	Med	398	1.71	600	85.88	2.46	3.71
8-A	17	Med	401	1.66	619	86.64	2.64	3.74
16-S	12	Low	380	1.18	570	90.58	2.24	2.81
17-S	11	Low	393	1.04	499	89.37	2.49	2.87
20-SA	11	Low	366	1.33	629	91.05	2.25	2.89
19-SA	15	Low	391	1.18	516	88.59	2.23	3.00
18-S	23	Low	397	1.34	551	89.34	2.31	3.21
15-S	11	Low	404	1.14	556	85.73	2.39	3.25
SEM	-	-	11	0.13	25	4.43	0.16	0.31
P-Value	-	-	0.1144	0.0037	<.0001	0.0492	0.1233	0.0045

[#] Sires were assigned a random number followed by a letter indicating breed composition for identification purposes: Angus (A), Simmental (S), Simmental-Angus (SA), and 75% Simmental (QS)
[+] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD, Med); Low (< 0.5 SD)
[&]Hot carcass weight (HCW), Back fat (BF), Rib eye area (REA); Kidney, pelvic, and heart fat percentage (KPH), and Calculated yield grade (CYG)
[@] Marbling score; 500 = Small, 600 = Moderate, 700 = Modest

Table 4-7. Effect of residual feed intake (RFI) classification and sire on rates of ultrasonic back fat (BF), ultrasonic marbling (MARB), and marbling over back fat (Marb/BF) deposition of feedlot steers.

Sire[#]	RFI Class[+]	N	Rate		
			BF, mm/d	Marb. 1/100*d	Marb./BF, 100 MS/1 cm BF
1-A	High	14	0.073	1.35	143
2-A	High	12	0.070	1.38	127
3-S	High	10	0.068	0.93	214
10-S	Med	11	0.050	1.27	274
11-S	Med	53	0.048	0.96	208
12-SA	Med	14	0.053	1.36	182
13-SA	Med	21	0.051	0.94	167
14-SA	Med	10	0.059	1.14	146
4-QS	Med	14	0.053	1.13	197
5-QS	Med	12	0.063	1.23	186
6-QS	Med	14	0.060	1.14	198
7-A	Med	13	0.063	1.00	90
8-A	Med	17	0.120	1.48	213
9-S	Med	11	0.067	1.48	215
15-S	Low	11	0.057	1.56	244
16-S	Low	12	0.054	0.97	108
17-S	Low	11	0.043	0.87	247
18-S	Low	23	0.051	1.18	215
19-SA	Low	15	0.059	1.07	130
20-SA	Low	11	0.054	1.72	198
SEM			0.028	0.23	71
P-Value			<.0001	<.0001	0.0948

[#] Sires were assigned a random number followed by a letter indicating breed composition for identification purposes: Angus (A), Simmental (S), Simmental-Angus (SA), and 75% Simmental (QS)
[+] Residual Feed Intake Classification: High (>0.5 SD); Medium (±0.5 SD, Med); Low (< 0.5 SD)

CHAPTER V

SUMMARY OF THESIS

Early weaned steers: residual feed intake, breed of sire and dam

Improving feed efficiency through management practices is a major goal of the beef industry. The objectives of this study were: (1) to calculate individual residual feed intake (RFI) and evaluate its effect on the performance and carcass characteristics of early weaned steers during the feedlot phase; (2) to evaluate the effect of breed of sire and dam and crossbreeding influences on the performance and carcass characteristics; and (3) to evaluate the effect of residual feed intake, breed of sire and dam on meat tenderness of early weaned steers. One hundred and fifty eight Angus (A), Simmental (S), Angus-Simmental, and Simmental-Angus steers across two years across were considered. Animals were early weaned at approximately 56 d of age and after entering the feedlot, animals were allotted to pens by weight and fed a common diet. Steers were classified into high (H), medium (M), and low (L) RFI groups. Twenty eight % (n = 44) of the steers in this study were classified in the H RFI group, 38% (n = 60) in the M RFI and 34% (n = 54) in the L RFI group. No differences ($P > 0.05$) among RFI groups were detected for initial and final weight. Steers in the H RFI group ate 1 kg more of DMI ($P< 0.05$) than steers in the L and M RFI group. Steers in the L RFI group had the poorest feed efficiency by gaining 15% and 22% more per kg of feed than steers in the M and H RFI groups, respectively. Steers in the L RFI group had an advantage in their growth rate of 0.20 kg/d more ($P < 0.05$) than steers in the M and H RFI groups. No differences among RFI groups were observed ($P > 0.05$) for HCW, BF, MS, CYG, and REA. Carcasses averaged 394.3 kg, 1.28 cm, 632 (Choice^0), 3.08, and 90.07 cm^2, respectively. Steers in the H RFI group had carcasses with more kidney, pelvic, and heart fat than carcasses of steers in the L and M RFI group. No differences were observed (P = 0.89) among RFI groups for meat tenderness using the WBSF method. Breed of sire had no effect (P > 0.05) on the performance characteristics. Breed of dam exhibited some differences for initial (P < 0.0001), final weight (P = 0.01), and G:F (P = 0.02). No differences (P > 0.05) between breed of dam were detected for DMI, ADG, and RFI. The interaction between breed of sire and dam had no significant (P > 0.05) effect on any of the performance characteristics analyzed. Breed of sire had no effect (P =0.64) in HCW. However, steers from Angus sires had 23% (0.33 cm, P < 0.0001) higher carcass BF than steers from Simmental sires. Steers from Angus sires had higher (P = 0.0002) MS than steers from Simmental sires. Meat tenderness was similar (P = 0.98) between the steers from Angus or Simmental sires. Breed of dam effects were observed for most of the carcass characteristics evaluated with the exception of REA (P = 0.10), KPH % (P = 0.98) and WBSF (P = 0.56). Steers from Simmental dams had heavier HCW (P = 0.01) than steers from Angus dams. Steers from Angus dams had carcasses with 21% more (P = 0.001) of BF and 85 units more (P = 0.001) of MS than carcasses of steers from Angus dams. Our findings confirmed that practice management such as early weaning, crossbreeding, and selection for RFI will reduce intake requirements of feedlot steers without affecting growth rate.

Carcass characteristics and rates of back fat and intramuscular fat deposition: dietary treatment, residual feed intake, and breed of sire

In addition to improving quality grade in the final product, producers are seeking for practice managements that can reduce the major cost in a feedlot operation. The objectives in this study were: (1) to evaluate rates of ultrasonic back fat (BF) and intramuscular fat (IM) deposition of feedlot steers, (2) to determine the relationship between RFI and rates of ultrasonic BF and IM deposition of feedlot steers; and (3) to evaluate the effect of dietary treatment and breed of sire on carcass characteristics and rates of ultrasonic BF and IM deposition of feedlot steers. Six hundred and four steers were used across four different years from four separate ranches. From the previous population, 589 steers had identified sires from the breed compositions: Angus (A), Simmental (S), Simmental-Angus (SA), 75% Simmental (75S). All dietary treatments were replicated during the four years: 75% dry rolled corn + 25% corn silage (75DRC), 50% dry rolled corn + 25% dry distillers grains with soluble (25DDGS), 40% dry distillers grains with soluble + 35% soy hulls (40DDGS), and 40% fresh wet distillers grains + 35% soy hulls (40FWDG). Steers fed 40DDGS had the heaviest carcass ($P < 0.05$) with 16 kg more of hot carcass weight (HCW) than steers fed the other diets. Carcasses of steers fed co-products had 0.21 cm more ($P < 0.05$) of back fat than carcasses of steers fed 75 DRC. Rib eye area (REA) had 2.6 cm^2 more ($P < 0.05$) than carcasses of steers fed 40DDGS and 40FWDG diets. Carcasses of steers fed 75DRC diet had the lowest ($P < 0.05$) calculated yield grade (CYG). Differences in marbling score (MS) and kidney, pelvic and heart fat (KPH) among diets were not detected. Steers fed diets 25DDGS, 40DDGS, 40FWDG had similar ($P > 0.05$) rate of ultrasonic BF deposition. The rates of ultrasonic IM deposition were similar ($P > 0.05$) among steers fed 75DRC, 25DDGS, and 40FWDG and steers fed 40DDGS exhibited the highest rate ($P < 0.05$) of IM deposition. Differences ($P < 0.05$) among RFI class were noted for BF, REA, and CYG. Steers were classified as high (H), medium (M) or low (L) RFI. The carcasses of H RFI steers had the highest ($P < 0.05$) amount of BF with an average of 1.47 cm. Steers classified as low (L) RFI had the largest ($P < 0.05$) REA. Steers in the L RFI group had the lowest CYG ($P < 0.05$) and steers in the medium (M) RFI group had the highest ($P < 0.05$) carcass CYG. Residual feed intake influenced only the rate of ultrasonic BF ($P < 0.05$). No differences ($P > 0.05$) for the rates of ultrasonic IM deposition and marbling over back fat deposition were detected among RFI groups. No differences were detected (P > 0.05) among breed of sire for HCW and KPH %. Angus sired steers had carcasses with the highest amount of back fat (P < 0.05). No differences were observed (P > 0.05) in the amount of carcass back fat among steers sired by S, SA, and 75S. Carcasses of steers from A and SA had higher MS (P < 0.05) than carcasses of steers from 75S and S. Progeny of 75S and A had carcasses with similar (P > 0.05) REA. Progeny of A had carcasses with the highest CYG which averaged 3.33 and S steers had carcasses with the lowest CYG which averaged 2.94. Rates of ultrasonic BF and IM deposition differed significantly among breed of sires. Progeny of 75S and S had similar (P > 0.05) rates of ultrasonic BF deposition. Steers sired by A deposited back fat 14% higher (P < 0.05) than steers sired by SA and 75S. Steers sired by A bulls had the highest (P < 0.05) rate of IM deposition. The rate of marbling over back fat was similar (P > 0.05) among breed of sires. This study confirms that there is no unique feature in the feedlot sector that could address all the biological and market challenges.

Sire residual feed intake: performance, carcass characteristics, and rates of back fat and intramuscular fat deposition

Breed associations have become interested in identifying variation in feed efficiency within breeds. The existence of genetic variation in residual feed intake (RFI) offers the potential that selection for low RFI will produce progeny with lower consumption without compromising growth performance and/or carcass composition. The objectives of this study were: (1) to calculate RFI value of the sire and evaluate its effect on the performance and carcass characteristics of feedlot steers and (2) to evaluate the effect of estimated RFI of the sires on the rates of back fat and intramuscular fat deposition. Progeny from sires with breed composition of Angus (n = 4 sires, A), Simmental (n = 8 sires. S), Simmental-Angus (n = 5 sires, SA), and 75%

Simmental (n = 3 sires, QS) were used. Records from 309 steers were included in the analysis and the minimum and maximum number of steers per sire was 10 and 53, respectively. Individual blood samples were sent to a laboratory of the University of Illinois for parental validation. Sires were assigned a random number followed by a letter indicating breed composition for identification purposes. Three sire groups were identified using the RFI value cutoff of 0.5 standard deviation. High RFI (H RFI) group consisted of two A sires and one S sire. Low RFI (L RFI) group consisted of four S and two SA sires. For the medium RFI (M RFI) group, three S sires, three SA sires, three QS sires, and two A sires classified within this group. On average, sires RFI was 0.44 kg/d, -0.06 kg/d, and -0.48 kg/d for H RFI, L RFI, and M RFI group; respectively. Sire "3-S" had the highest estimated RFI value of 0.50 kg/d. Opposite, Sire "15-S" exhibited the lowest RFI value. No differences ($P > 0.05$) were observed between sire and RFI classification group for adjusted final weight, DMI, ADG, and G:F. Initial weight differed ($P = 0.0044$) among RFI group of sires. High Medium RFI Sire "4-QS" had the heaviest initial weight whereas, H RFI Sire "2-A" had the lightest initial weight with a difference of 58 kg ($P < 0.05$). Hot carcass weight and KPH% were similar ($P > 0.05$) among individual sire and its RFI groups. The rate of ultrasonic marbling deposition was influenced ($P < 0.0001$) by sire and RFI classification. Sires classified as M RFI had slower rates than H and L RFI sires. Average rates of ultrasonic marbling ($1/100*d^{-1}$) were 1.22 for H RFI sires and 1.23 for L RFI sires. Medium RFI sires had an average rate of 1.19 ($1/100*d^{-1}$). Sire and RFI classification did not influence ($P = 0.0948$) the rate of marbling over a standard back fat endpoint of 1 cm. These suggest that selection for high rates of marbling deposition relative to back fat should maintain acceptable quality while allowing a high retail yield. Results from this study indicate that individual sire RFI is a potential selection tool to improve profitability in the beef cattle industry.

AUTHOR'S BIOGRAPHY

Celia Odila Trejo was born to Manuel and Marta Trejo on October 8, 1982 in Tegucigalpa, Honduras. She graduated from La Estancia School in May of 1999. Upon completion of her high school studies, she attended Zamorano Pan-American School of Agriculture where she graduated with a Bachelor of Science in Agricultural Science with a major of Animal Science in December 2003. After completing college she started working for a couple of years as a Beef Cattle Field Instructor and Extension Assistant at Zamorano University. In 2005 she attended University of Illinois where she obtained a Master of Science degree in Animal Science under the direction of Dr. Larry L. Berger. After completion of her Master's degree she continued to pursue her Doctorate of Philosophy in Ruminant Nutrition under the direction of Dr. Larry Berger and Dr. Dan B. Faulkner at the University of Illinois. Upon completion of her doctoral degree she accepted the position of Associate Professor for the Zamorano Pan-American School of Agriculture in Honduras.