EVALUATION OF CORRESPONDENCE OF FEED EFFICIENCY, ULTRASOUND CARCASS, AND MATERNAL TRAITS IN PUREBRED BEEFMASTER CATTLE

A Dissertation

by

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ABSTRACT

The goal of this study was to assess the correspondence between feed efficiency and maternal traits, feed efficiency and carcass traits, and carcass traits and maternal traits. Two sets of data from Beefmaster Breeders United (BBU) were used. Efficiency traits included residual feed intake (RFI), average daily gain (ADG), dry matter intake (DMI) and gain to feed ratio (G:F). Ultrasound carcass traits included longissimus area (LA), intramuscular fat (IMF), and rib fat. Maternal traits included age at first calving (AFC), calving interval (CI), and disposal age. The first set of data included females that had been tested for feed efficiency (n = 277). The second set had ultrasound carcass measures, calving records, and records of disposal (n = 3,756 cows). There was a negative regression of AFC on RFI (–7.04 ± 3.36; $P < 0.05$), but otherwise no relationships ($P > 0.12$). Heifers in the upper quartiles had rib fat estimates of 0.7 ± 0.05 cm and differed from the very low quartile (0.60 ± 0.05 cm; $P < 0.05$). The regression coefficients ($P < 0.001$) of IMF on RFI and rib fat were 0.20 ± 0.06 and 0.067 ± 0.017, respectively. The regression coefficients ($P < 0.01$) of IMF, rib fat, and LA on DMI were 0.12 + 0.04, 0.079 ± 0.011, and 2.60 ± 0.35, respectively. The regression of LA on ADG was 4.47 ± 1.76 ($P < 0.05$). The regressions ($P < 0.05$) of IMF and rib fat on G:F were –3.66 ± 1.53, and –1.85 ± 0.44, respectively. Heritability estimates ranged from 0.2 ± 0.03 to 0.38 ± 0.03 for IMF, rib fat, and LA. Estimates of heritability for maternal traits were less than 0.1. Estimates of genetic correlations for carcass traits were greater than 0.23, and for AFC and CI was –0.90 ± 0.15. The regression coefficients ($P < 0.05$)

of AFC on IMF and LA were –2.58 ± 1.06 and –0.50 ± 0.11). Minimal correspondence between feed efficiency, carcass, and fertility was detected in this work, and results in Beefmaster cattle appearing to be consistent with other breeds.

DEDICATION

I would like to thank everyone throughout this process that believed in me and pushed me to complete the process. My parents who never gave up on me during this time and continue to be two of my biggest supporters. They instilled in me a desire to finish what I started from a young age. My mother was always the one with the inquisitive mind and always encouraged me to ask questions and use my resources to find the answers and taught me the value of research from a young age. My father always kept me on track and encouraged my exploration of my areas of interest, but also kept me grounded to make sure that I knew what I was doing would have a practical application and be helpful in whatever profession I pursued. My younger sister also always encouraged me to follow my dreams. Mom, Dad and Leah, I will always be thankful for your support.

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This work was supervised by a dissertation committee consisting of Professors James Sanders, Chair of committee, David Riley, Co-Chair of committee, and Andy Herring of the Department of Animal Science and Professor Jason Sawyer of the East Foundation.

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NOMENCLATURE

ADG	Average daily gain
AFC	Age at first calving
BBU	Beefmaster Breeders United
CI	Calving interval
DMI	Dry matter intake
G:F	Gain to feed ratio
IMF	Intramuscular fat
LA	Longissimus area
RFI	Residual feed intake
WHR	Whole Herd Reporting

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1. INTRODUCTION

The cattle industry across the United States is moving forward into a future where there is more urbanization of traditionally rural areas that have been used for production. This means that to maintain the level of performance that the industry has worked for years to achieve cattle will need to be able to do more with less and be more efficient on a systems wide basis. This means that animals should be efficient feed converters and maternally and reproductively efficient as well, while still maintaining the quality of carcass that has come to be expected by consumers. This demand for beef is increasing worldwide in developed and developing countries (Smith et al., 2018). As the world population grows, the beef demand increases, and the land in agricultural production decreases, it is important to evaluate how to make the production of beef cattle more efficient from an entire system perspective. This includes feed efficiency, maternal efficiency, and carcass traits, as well as the traditional growth traits.

The goal of this work is to assess the correspondence between the traits measured in different components of a typical United States beef production system. This means correspondence between performance measures which are taken while animals are in a setting being fed high concentrate diets in a typical U.S. feedlot and female fertility and other traits. The cattle used for the study will be from animals that are recorded in the Beefmaster Breeders United (BBU) database. There are two subsets of cattle that will be used to analyze different traits, one subset of cows with that have been tested for feed efficiency and another subset of cows that are enrolled in the BBU Whole Herd Reporting program. The objectives of this proposed study will be to evaluate and assess the correspondence of:

1. measures of feed efficiency in typical U.S. feedlot conditions with fertility traits of females,
2. measures of feed efficiency in typical U.S. feedlot conditions with ultrasound carcass measures.
3. ultrasound carcass measures with fertility traits of females.

2. LITERATURE REVIEW

2.1. History of the Beefmaster Breed

The Beefmaster breed was developed in Falfurrias, Texas by Tom Lasater (BBU, 2022). It is a breed that was developed out of the necessity to make profit in economically hard times. The breed was developed in the 1930s with the systematic crossing of three breed types: Shorthorn, Hereford, and *Bos indicus*. In 1932 Lasater began with four sources of cattle: a "Brahma herd" (American Brahman), a registered Hereford herd, registered Shorthorn bulls, and one polled Hereford bull. Brahman were crossed with cattle from the other herds and became what he termed the "cross-bred" herd. This "cross-bred herd" was subsequently managed as a purebred herd, that is, no outside animals from the other sources were used for breeding. The foundation herd of Beefmaster cattle has remained a closed herd since the beginning of the breed. This herd has moved from Falfurrias, Texas to Matheson, Colorado to Julesburg, Colorado, and now back to Falfurrias, Texas.

Lasater developed the breed on attributes that he called the six essentials for beef production. These traits are weight, conformation, milk production, fertility, hardiness, and disposition, and were economically relevant at the time, as well as today. They are more accurately measured today with the exception of hardiness, which is a subjective term. However, the adaptability of the breed is evident, as cattle perform very well from reproduction and survival perspectives across the diverse environments of the Southern United States, from the humid Southeastern states as well as in the high desert areas in the West.

The breed was recognized by the United States Department of Agriculture (USDA) as a pure breed in 1954, and today Beefmaster cattle are found across the United States as well as in many tropical and subtropical climates. The breed registers 15,000 to 16,000 head of cattle annually and has been on an upward trend over the past five years (BBU, 2022). There has been a noticeable increase in demand for Beefmaster bulls in the recent years and this has resulted in increased value of females as well.

2.2. Cattle Industry

Efficient beef production will be required because of the growing world population and the need for more high-quality protein. As the world population and the overall standard of living increase, the demand for beef and other sources of protein will correspondingly increase. Bongaarts (2009) projected a world population of 9.2 billion by 2050. Public perception with respect to management of carbon emissions necessitates a research emphasis on efficiency in beef production and agriculture in general. Accelerated urbanization will require that more beef be produced with less resources. The percentage of U.S. land in agriculture in 1949 was 63%, but in 2007 that estimate was 51% (USDA, 2012). A systems perspective of efficiency not only includes feed conversion, but maternal efficiency, that is, the ability of a female to produce a calf every year. Animals that are feed efficient, grow efficiently, and are reproductively efficient are more sustainable. Sustainability is defined as the avoidance of the depletion of natural resources in order to maintain an ecological balance.

Since the domestication of cattle there has been selection for traits related to the intended purpose of the animal, whether that is for food or draft. In the past producers have selected to improve cattle largely on traits that are relatively simple to measure, like growth, carcass, and reproductive traits. Efficiency traits are more difficult and costly to measure, so historically selection has not been accomplished on these types of traits as compared to others. Advances in technology have facilitated collection, storage, and analyses of these data; this may facilitate effective selection programs for efficiency traits.

2.3. Efficiency

There are several different measures of feed efficiency.   These include Residual Feed Intake (RFI), feed conversion ratio, and residual gain. Residual feed intake is the difference between the actual intake and the predicted intake of an animal relative to growth (Koch et al., 1963). The average residual is, by definition, zero within a contemporary group. Negative values of RFI value are favorable, meaning that the animal's intake was less than expected for a given level of production; positive values indicate less favorable efficiency. Feed conversion is calculated as the ratio of dry matter intake to live weight gain. Lower values of feed conversion are more favorable and indicate that the animal consumed less feed for every unit increase of gain. Gain to feed ratio (G:F) is another measure used to assess feed efficiency in animals and is the inverse of the feed conversion ratio, meaning that the larger or closer to 1 the value is the more an animal gained per kg of intake. Novo et al. (2021) reported that G:F had a low estimate of heritability (0.08) in Senepol heifers in Brazil.

Dry matter intake (DMI) is a component of several efficiency traits. Rolfe et al. (2011) reported estimates of heritability of 0.4 and 0.52 for DMI and RFI, respectively, in steers that were cross bred and comprised of Angus, Hereford, Simmental, Charolais, Limousin, Gelbvieh, Red Angus and MARC III composites.   These values indicate that these traits are moderately to highly heritable and good candidates for selection programs. The BBU currently uses estimates of heritability of 0.38 and 0.41 for RFI and DMI, respectively, in the models for Expected Progeny Differences (BBU, 2022).

Average daily gain (ADG) is the weight gain across a given interval divided by the length of the interval. Kelley (1994) reported that ½ Beefmaster steers under typical U.S. feeding conditions had ADG of 1.31 kg/d; those with more than ½ Beefmaster had an ADG of 1.28 kg/d in Texas. More recently, ADG for Beefmaster steers in Mississippi was 1.42 kg/d (Parish et al, 2014). Retallick et al. (2017) reported that Beefmaster had one of the best feed efficiencies in a feedlot setting, based on an on test average daily feed intake and on test average daily gain index, when compared to other breeds that are used heavily in the U.S. cattle industry at the U.S. Meat Animal Research Center at Clay Center, Nebraska. Cattle and other ruminants will never be as efficient in conversion of feed on a dry matter basis as monogastric animals, but they can be selectively improved.

2.4. Maternal

The profitability of a cow starts with the ability to conceive and give birth and raise a calf every year. Boyer et al. (2020) estimated that if a cow fails to wean a calf in one year in a productive lifetime of 11 years the profitability of the cow decreases by $472 for spring calving cows and $483 for fall calving cows. They also demonstrated that an animal that a cow that fails to calve once is still profitable. This indicates that heifers or cows that miss a calf earlier in their productive lifetime take longer to become profitable. Age at first calf or parturition (AFC) is an important trait to analyze, because most beef cattle producers aim for heifers to calve at 24 months of age or approximately 720 days of age. Maternal traits are typically characterized as being lowly heritable and therefore harder to make genetic progress with selection. Frazier et al. (1999) reported an average AFC in Angus cattle of 740 days and a heritability of AFC of 0.22. The same study reported an average calving interval between the first and second calf of 370 days with a heritability of 0.01 to 0.02.

Reproductive traits constitute part of maternal efficiency of an animal and therefore the correspondence with other efficiency and growth traits needs to be characterized. Schmidt et al. (2019) reported a heritability for AFC of 0.20, similar to what was reported by Frazier et al. (1999). In a study of Angus, Blanco Orejinegro, and Zebu cattle in Colombia, Vergara et al. (2009) reported estimates of heritability of AFC as 0.15 and the calving interval (CI) between the first and second calf at 0.11. Genetic correlations of fertility traits were reported from this same study and there was a 0.33 genetic correlation between AFC and the first calving interval. Pardo et al. (2020) reported that in Angus, Hereford, and Angus-Hereford cross animals the heritability of AFC was 0.08, which is lower than previously reported by Frazier et al. (1999). Olson et al. (2020) evaluated feed efficiency traits and reproductive traits in crossbred beef cattle and found that there was a negative phenotypic correlation between calving interval (over four parities) and the duration and frequency of an animal feeding. There is anecdotal evidence that animals that efficiently convert feed in feedlot conditions have difficulty maintaining body condition and are not as fertile as animals that are not as feed efficient. Behrouzi et al. (2022) reported that selecting for favorable (lower) RFI (which they adjusted for backfat thickness) may have a negative impact on fertility in heifers. This may be because fat acts as an energy store; animals that are predisposed to deposit fat may be more maternally efficient.

2.5. Carcass

Cattle carcasses are predominately marketed and sold in arrangements where discounts and premiums are applied to the base price of the carcass based on different factors. Two of the major factors that affect the unit price of the carcass are the USDA quality grade and yield grade (Hale et al., 2013). Quality grade is based on the amount of intramuscular fat and the age of the animal. Prime, Choice, Select and Standard are the quality grades used, with Prime having the highest percentage of intramuscular fat, followed by Choice, then Select and then Standard having the least. Yield grade is a measure that helps estimate the amount of boneless, closely trimmed retail cuts from a carcass, with values ranging from 1 to 5. An animal with a yield grade 1 is expected to have a high percentage of these boneless, closely trimmed retail cuts, while a yield grade of 5 is expected to have a small percentage, driven by a higher fat content. These premiums for yield grade and quality grade fluctuate throughout the year based on supply and demand. The difference in value of a carcass with a choice quality grade compared to one with a select quality grade for 2021 through 2022 ranged from $3.88 per hundred pounds of weight to $32.48 per hundred weight (USDA, 2022). Carcasses with a yield grade of 4 or 5 receive a discount while carcasses with a yield grade of 1 or 2 receive a premium. Results from the National Beef Quality Audit in 2016 indicated that the percentage of carcasses that grade USDA Choice or better has increased from 51% to 71% from the year 2000 to 2016 (BQA, 2016). That same National Beef Quality Audit results indicated that the mean USDA Yield Grade increased from 2.9 in 2011 to 3.1 in 2016 (BQA, 2016). Kelley (1994) reported an average ribeye (longissimus muscle) area measured between the 12^{th} and 13^{th} ribs in ½ Beefmaster cattle to be 83.1 cm^2 and in cattle with greater than ½ Beefmaster influence to be 82.7 cm^2. Parish et al. (2014) found average longissimus area for Beefmaster steers to be 81.6 cm^2. When investigated as part of the Germplasm Evaluation Program at the U.S. Meat Animal Research Center at Clay Center, Nebraska, Beefmaster sired animals had an average longissimus area of 80.8 cm^2 (Wheeler et al., 2010). Correspondence of carcass characteristics with other economically important traits is of great research and practical value, because of the reward system for carcass merit.

Ultrasound carcass measurements have been used for years to help estimate the economically relevant traits or rib fat, rump fat, IMF percentage and longissimus area (LA) in live animals. Ultrasound carcass traits have been recorded as moderately heritable. Miar et al. (2013) reported moderate estimates of heritability of ultrasound carcass traits in crossbred cattle, with Angus or Charolais sires mated to composite cows, to be 0.31 for fat deposition, 0.17 for longissimus area, and 0.37 for marbling score. Phenotypic and genetic correlations were also reported for the ultrasound carcass traits and there was a positive correlation between fat and marbling both phenotypically and genetically. Marestone et al. (2022) reported heritability and genetic correlations of ultrasound carcass traits in Nellore cattle and found the heritability of LA to be 0.31, rib fat 0.17, and IMF 0.41. The genetic correlations between LA and rib fat, LA and IMF, and IMF and rib fat were 0.14, 0.12, and 0.41, respectively.

2.6. Maternal and Efficiency

Certain measures of feed efficiency appear to have unfavorable correspondence with maternal traits. Age at puberty was negatively correlated with RFI in British crossbred heifers; that is, heifers that had positive RFI were less feed efficient, and reached puberty earlier (Shaffer et al., 2011). Shaffer et al. (2011) also concluded that although the heifers with unfavorable (high) RFI reached puberty earlier, they had similar pregnancy rates to heifers with favorable RFI values. The less efficient heifers (high RFI values) reached puberty 16 days earlier than the moderate RFI heifers and 14 days earlier than the more efficient heifers. When considered as either favorable or not favorable (positive and negative) RFI groups, the positive RFI heifers reached puberty 13 days earlier than the negative RFI heifers. Basarab et al. (2011) reported that heifers with negative RFI (more feed efficient) had delayed onset of puberty compared to the positive RFI heifers. Heifers with negative RFI also had lower pregnancy rates (9.4% lower) and calving rates (11.6% lower) than the heifers with numerically positive RFI. Mu et al. (2016) reported a negative correlation between ADG and days to calving in heifers from two multibreed herds that were composed mainly of Angus, Simmental, Piedmontese and Charolais, meaning that heifers that grew faster calved earlier. From the same work, a negative correlation was reported for RFI with days to calving, meaning that animals with a lower, or better, RFI calved later, there was also a negative correlation between DMI and age ate first calving, meaning that animals that consumed more feed calved earlier. Basarab et al. (2007) reported that cows with calves that had negative RFI (more feed efficient) gave birth 5 to 6 days later in the calving season than the cows that had calves with positive RFI values. This same study indicated that although there was a difference in calving date, there was no difference in calving interval. Callum et al. (2019) reported that there was no significant phenotypic correlation between RFI and reproductive traits. Morris et al. (2014) reported no difference in pregnancy rates, or calf birth dates between high and low RFI Angus heifers. Najera et al. (2020) reported that in Lowline Angus heifers there was no difference in first service conception rate, pregnancy rate or response to estrous synchronization between high RFI and low RFI cattle. It was also found in the same study that the same reproductive traits did not have a significant correlation to average daily gain or dry matter intake (Najera et al., 2020). However, Ferreira Júnior et al. (2018) considered two categories of heifers with respect to RFI, positive and negative RFI, and evaluated days to calving, calving interval between the first and second calf and cow longevity. The only trait that differed between RFI classes was calving interval: the females with negative (favorable) RFI had average calving interval 45 days shorter than the females with positive RFI average value. There was, however, a negative correlation for days to calving with RFI, indicating that the higher RFI (less efficient) cows calved earlier. Gunn et al. (2017) reported no difference in heifer pregnancy rates between more feed efficient animals and less efficient Angus animals; however, there the more efficient animals had a higher pregnancy rate after their first calving. Schmidt et al. (2019) reported that in Nellore cattle there was no genetic correlation between gain from birth to weaning or from weaning to yearling with AFC. O'Daniel et al. (2018) reported that in Brahman heifers, differences in RFI were not associated with differences in AFC or CI.

2.7. Carcass and Efficiency

Documented relationships of carcass and efficiency traits in cattle have not been consistently favorable or unfavorable. Steers with low RFI (efficient) had less fat and IMF than those with a higher RFI (Basarab et al., 2003). Angus steers sired by low RFI bulls had less rump and rib fat than steers sired by high RFI bulls (Richardson et al., 2001). Nkrumah et al. (2007) reported positive phenotypic and genetic correlations for DMI with ultrasound carcass traits. DMI had a phenotypic correlation with ultrasound fat of 0.41, ultrasound IMF of 0.20 and loin muscle eye area of 0.35. The genetic correlations were 0.29 for DMI with rib fat, and 0.53 with IMF, and 0.44with loin muscle area. Nkrumah et al. (2004) found that animals there was a 0.19 correlation of RFI with backfat thickness and also a negative correlation between RFI and lean muscle yield. This indicates that the more efficient animals put on less fat and are higher yielding. Unfavorable genetic correlations of RFI with 12th rib fat and rump fat in Nellore steers were 0.53 and 0.37 respectively (Ferreira Júnior et al., 2018). No difference in ribeye area (LA) or IMF between efficient and inefficient Angus heifers (Gunn et al., 2017). Crowley et al. (2011) found a positive correlation between fat depth and RFI in Angus, Charolais, Hereford, Limousin and Simmental bulls, meaning that the more efficient bulls had less fat deposition. Crowley et al. (2011) reported a negative correlation between RFI and muscle area, indicating that the more efficient animals put on more muscle. Novo et al. (2021) also reported in Senepol heifers in Brazil that there was correspondence between the G:F, RFI, and DMI with ultrasound carcass traits.

2.8. Carcass and Maternal

Several studies have indicated that animals that visually have more fat may be more reproductively efficient. There was a negative correlation between body condition score (BCS) and age at first calving in Nellore cows, indicating that animals that had higher BCS, on a scale of 1 to 5 with one being thin and 5 being obese, calved earlier (Lacerda et al., 2018). In the same study it was found that animals with a higher BCS had a shorter calving interval in repeated calvings. Results from another study, utilizing a 1 to 9 scale with 1 being emaciated and 9 being obese, indicated that females with lower BCS at the time of calving returned to estrus slower and subsequently returned to pregnancy slower (Richards et al., 1986). This may be in part because fat is high in energy and extra fat acts as an energy reserve and allows cattle to return to estrus more quickly after parturition. There is anecdotal evidence that suggests that animals that have higher IMF percentage measured by ultrasound are more successful in reproduction. This has been observed in certain herds in the Beefmaster breed that have selected strictly on fertility, that is, where any female that failed to wean a calf for any reason (after a short 27-day breeding season) was removed from the herd (Dr. Watt Casey, Casey Beefmasters, personal communication).

No substantial genetic relationship of carcass quality traits with heifer pregnancy was detected in Red Angus females (McAllister et al., 2011). This suggests that selection for improvement of carcass traits is not antagonistic to fertility in heifers. Meyer and Johnson (2003) reported that Hereford cows with a propensity to deposit fat tended to have shorter days to calving (Meyer and Johnson, 2003). Evans et. al (2004) studied heifers that were synchronized for estrus and ultrasound carcass measures were taken. There was no significant difference in the amount of intramuscular fat (IMF) in the pregnant vs non pregnant cycling heifers; however, pregnant heifers had higher IMF than non-cycling heifers. Paula et al. (2015) reported no significant genetic correlations between fat measured between the 12^{th} and 13^{th} rib and age at first calving or the length of the first calving interval in Nellore cows in Brazil. Boldt et. al. (2018) reported genetic correlations between the ultrasound measured carcass traits of LA and rib fat with heifer pregnancy of 0.16 and 0.14 respectively, while there was no genetic correlation of ultrasound measured IMF with Heifer pregnancy. It was also reported in this same study that there were genetic correlations of 0.19 and 0.37 for stayability with LA and rib fat, respectively, but there was no genetic correlation between stayability and IMF.

2.9. Summary

It is important to evaluate the beef cattle industry from a system wide perspective in order to make selection and progress towards a more efficient system. There are indications that selecting cattle on certain feed efficiency traits may adversely affect maternal traits. There are also indicators that selection on RFI and G:F may have antagonistic effects on carcass quality. Several studies indicate that selection of carcass traits can be done independently of maternal traits, while others indicate that there is a relationship of fat with maternal traits. The correspondence of these different traits is important because efficiency at one level of beef production must be achieved without adversely affecting another level of production.

3. MATERIALS AND METHODS

Two subsets of data from BBU were utilized in these analyses. The first subset of data included feed efficiency measures, ultrasound carcass measures, and reproductive records. All females in this subset had at least one recorded calf and many had a second recorded calf. The second subset of data came from the BBU WHR program and had measures of ultrasound carcass traits and reproductive traits. All females in this subset of data had at least one calf, many had a second calf, and some had a disposal recorded with BBU.

Cattle with records were all registered with BBU. A subset of females (n = 277) was evaluated in a structured system (Vytelle, L.L.C., Calgary, AB, Canada) and have calving records, age adjusted ultrasound carcass data, as well as feed intake and efficiency data. RFI was calculated be regression of DMI on body weight and DMI within pens on a feed test, there were no other adjustments to RFI. The ultrasound carcass traits were adjusted to 380 days of age by BBU, the ultrasound carcass traits are not measures of carcass traits at harvest but are indicators of what is expected at harvest. Age at first calf and calving interval were both calculated using calving data from the BBU database. These females represent a subset of animals from across the Beefmaster breed, with several of the larger herds being present in this data. The cattle were tested on a Vytelle system in at three commercial evaluation locations from the year 2016 to 2020: PX Feeders in Evant, Texas, The Genetic Development Center in Navasota, Texas, and NextGen Cattle Company in Allen, Kansas. The unadjusted means for this data set are reported in Table 1. In the analyses of AFC, LA, IMF, and rib fat there were 69 sires represented and 16 contemporary groups. In the analysis of CI there were 49 sires represented and 12 contemporary groups.

These data were used to estimate relationships as regression coefficients between feed efficiency and reproductive performance, carcass and reproductive performance, and feed efficiency and carcass traits. The regression coefficients were used to analyze the magnitude and direction of correspondence between two traits. The data were analyzed by fitting a linear mixed model using the lme4 package in R statistical software (Bates et al., 2015). In all models, sire and contemporary group were fitted as random effects. Contemporary group accounted for the test pen, date, location, date of birth, and breeder (ranch of origin). The same base linear model was used in all analyses. For the evaluation of RFI categories the data were categorized as very low (–3.30 to –0.499 kg/d), low (–0.50 to 0.00 kg/d), high (0.01 to 0.499 kg/day), and very high (0.5 kg/d or greater). These categories were based on the RFI quartiles of the heifers. All other traits analyzed as covariates were continuous and modeled with respect to their unit of measure. In separate analyses, RFI was also investigated as a continuous variable.

After the initial model was constructed for each trait with the random effects of sire and contemporary group, the dependent variable was regressed on each independent variable individually. AFC was regressed on each efficiency trait individually, and each ultrasound carcass trait individually. The analysis of CI was performed in the same manner. The ultrasound carcass traits were regressed on the efficiency traits individually.

The other subset of data is represented by females that are recorded in the BBU Whole Herd Reporting (WHR) program and have all weights and ultrasound measures. There were 3,756 individuals represented in this data set born in the years 2005 to 2019. The BBU WHR is based on active females in a producer's herd and all active females must have a weaned or disposed calf recorded for a year or have a disposal code and date. The animals represented had at least one calf and had records for weight traits and ultrasound carcass traits.

The BBU whole herd data were analyzed using ASReml (Gilmour et al., 2015), with an animal model, that is, a mixed effects model with animal as a random effect. To create contemporary groups for these animals the birth year and breeder were used. These contemporary groups were used in all models as a random effect. The minimum contemporary group size was 4. This set of data included records of LA, FAT, IMF, AFC, CI, Disposal Codes and Disposal Age. Ultrasound carcass data were previously adjusted for age by BBU. The disposal age is the age in days at which an animal was removed from the population or died. The same adjustments for ultrasound carcass traits in the first subset were made for this subset of data as well. The AFC, CI, and disposal age were calculated using the calving data from BBU.

Ultrasound carcass traits (LA, IMF, and FAT) and the correspondence with the fertility traits of AFC, CI and disposal age were assessed using this set of data. Two-trait analyses of each pair of traits were performed to determine phenotypic and genetic correlations between the pairs. The unadjusted means and standard deviations for these traits are presented in Table 2. A base model for AFC was built using AFC as the dependent variable, breeder and birthyear as a random contemporary group effect variable and the pedigree of the animal as a random variable to construct an animal model. Individual variables were then added to the model as linear covariates to determine their effect on AFC, and regression coefficients were estimated. This process was repeated for CI and for cow age at disposal.

Table 1. Unadjusted means (SD) for evaluated traits in females with efficiency records

	N	Mean (SD)	Minimum	Maximum
Feedlot efficiency				
Average daily gain, kg	277	1.19 (0.34)	0.23	2.22
Dry matter intake, kg/d	277	8.99 (1.77)	4.27	14.86
Residual feed intake, kg/d	277	–0.02 (0.789)	–3.30	2.08
Gain:Feed kg gain/kg intake	277	0.13 (0.04)	0.02	0.27
Ultrasound traits				
Longissimus area, cm^2	275	62.13 (11.00)	39.29	113.55
Rib fat, cm	275	0.70 (0.275)	0.025	1.42
Intramuscular fat, %	276	3.69 (0.962)	0.04	7.56
Reproductive traits				
Age a first parturition, d	277	748.3 (64.20)	649	963
Calving interval, d	169	400.1 (65.73)	326	605

Table 2. Unadjusted means (SD) for evaluated traits in Beefmaster Breeders United Whole Herd Reporting females

	n	Mean (SD)	Minimum	Maximum
Ultrasound traits				
Longissimus area, cm^2	3,754	60.53 (11.40)	27.93	104.48
Rib fat, cm	3,749	0.51 (0.274)	0.023	1.59
Intramuscular fat, %	3,753	3.38 (1.02)	0.041	7.40
Reproductive traits				
Age at first parturition, d	3,339	759.6 (68.52)	646	999
Calving interval, d	1,113	372.2 (23.40)	297	471
Age at disposal, yr	712	5.52 (2.58)	2	16

4. RESULTS AND DISCUSSION

4.1. Correspondence of Feed Efficiency Traits with Female Fertility Traits

The data used to evaluate the correspondence of feed efficiency traits were the subset of BBU data that included females that had been tested on a Vytelle system at one of three locations throughout the United States from the years 2016 to 2020. There were 297 females in this data set and all of them had at least one calf recorded with BBU. These females all had recorded measures for RFI, ADG, and DMI as well as a recorded AFC, and some females had CI between the first and second calf. They were in contemporary groups defined by BBU which includes the ranch of origin (breeder), year, and season of birth.

There were insufficient records for tested females to efficiently employ an animal model, therefore, a sire model was constructed to model fertility traits. Sire and contemporary group were both included as random effects in linear mixed models. There were 69 sires and 16 contemporary groups in the model for AFC, and 49 sires and 12 contemporary groups in the model for CI. There was an average of 17 females per contemporary group and an average of 4 females per sire. The estimated variances are presented in Table 3. Contemporary group had a large variance with AFC and CI, while there was a small sire variance for AFC and larger sire variance for CI.

After the initial model was created, subsequent models were implemented to evaluate the fixed effect of RFI quartile (Very low: $-3.30 < RFI < -0.499$, Low: $-0.50 < RFI < 0.00$, High: $0.01 < RFI < 0.499$, Very High $RFI > 0.5$) in analyses of AFC and CI. Regression of AFC or CI on the variables, RFI, DMI, ADG, or G:F were assessed in distinct models.

When fertility traits were evaluated including RFI quartile as a fixed effect, there were no significant differences in least squares means for AFC or CI with respect to any of the RFI quartiles (Table 4). However, there was a tendency for females in the low, high, and very high quartiles to calve earlier than those in the very low quartile. Animals in the low quartile calved 19 days earlier ($P = 0.06$) than those in the very low quartile, animals in the high quartile calved 16 days earlier ($P = 0.13$) than those in the very low quartile, and animals in the very high quartile calved 18 days earlier ($P = 0.09$) than those in the very low quartile.

The correspondence between the fertility traits of AFC and CI with DMI, ADG, RFI and G:F was assessed using regression coefficients. Estimated regression coefficients are reported in Table 5. There was a negative regression coefficient found between AFC and RFI ($P < 0.05$), when RFI was evaluated as a continuous variable. The significant regression coefficient of AFC regressed on RFI indicates that for every kg/day decrease in RFI there is an increase of 7 days for AFC. There were no other regression coefficients different than 0 ($P > 0.12$)

The relationship of feedlot efficiency with female reproductive traits in other breeds has not been conclusive. Results from the present study were not consistent with those of Mu et al. (2016), who reported a negative correlation between ADG and CI in crossbred *Bos taurus* cattle in Ontario, Canada. Similarly, Ferreira Júnior et al. (2018) reported a negative correlation for days to calving (defined as when in the calving season a cow calves) with RFI in Nellore cows in Brazil, meaning that the more feed efficient animals calved later in the calving season. However, the results of the present study were consistent with those of Morris et al. (2014), who reported no differences of pregnancy rates or calf birth dates in high or low RFI Angus heifers in Australia. The present results were also consistent with those of Callum et al. (2019), who also noted no phenotypic correlation of RFI and AFC in Angus, Charolais, and Hereford females located in Canada. Najera et al. (2020) found no significant correlations of fertility traits to RFI, ADG or DMI in Lowline Angus cattle evaluated in California. O'Daniel et al. (2018) reported similar results in Brahman heifers in Texas, concluding that RFI did not have a significant influence on AFC or CI. Shaffer et al. (2011) reported that RFI did not have an effect on pregnancy rates in British crossbred heifers in West Virginia.

Table 3. Estimated variances for fertility traits in feed efficiency tested females

	Sire	Contemporary group	Residual
Trait			
Age at first calving, d^2	7.37	3754.5	1,805.6
Calving interval, d^2	1,561.2	171.8	2,846.8

Table 4. Least squares means ± SE for RFI quartile and fertility traits

RFI quartile	Very low[1]	Low[2]	High[3]	Very high[4]
Trait				
Age at first calving, d	771 ± 16.8	752 ± 16.8	755 ± 16.9	753 ± 16.8
Calving Interval, d	392 ± 11.7	409 ± 12.5	400 ± 12.2	417 ± 12.2

[1]Very low: RFI < –0.499

[2]Low: –0.50 < RFI < 0.00

[3]High: 0.01 < RFI < 0.499

[4]Very high: RFI > 0.50

Table 5. Estimates of regression coefficients ± SE for fertility traits and feed efficiency[1]

Trait	Age at first calving, d	Calving interval, d
Covariate		
Dry matter intake, kg/d	1.55 ± 2.24	0.73 ± 3.53
Average daily gain, kg	12.78 ± 9.98	–0.24 ± 15.76
Residual feed intake, kg DM/d	–7.04 ± 3.36*	9.12 ± 5.78
Gain:Feed kg gain/ kg intake	86.32 ± 88.23	–58.02 ± 134.4

[1]Analyzed traits are in column headings. Covariates are in row labels.

*$P < 0.05$

4.2. Correspondence of Feed Efficiency Traits with Carcass Traits Measured by Ultrasound

The correspondence of feed efficiency traits and ultrasound measured carcass traits was assessed using records of the same females from BBU, that is, those that had been tested on a Vytelle system in one of three locations. The females in this analysis had RFI, DMI, and ADG measures, as well as age adjusted ultrasound carcass measures of IMF percentage, rib fat, and LA. The age adjusted ultrasound carcass measurements were provided by BBU. The contemporary groups utilized were the same as in the analysis of the correspondence of feed efficiency and fertility traits and were defined by BBU to include the ranch of origin (breeder), year, and season of birth. An effect of age was also partially accounted for by age adjustments to carcass traits performed by BBU.

Random effects included sire and contemporary group in linear mixed models. Estimated variances are presented in Table 6. After confirmation of the appropriateness of this initial model, RFI quartile, RFI, DMI, and ADG and G:F were evaluated in distinct models for the ultrasound carcass traits of IMF, rib fat, or LA.

The results for the evaluation of the correspondence of RFI quartile and ultrasound measured carcass traits are presented as least squares means in Table 7. Females in the very high quartile had a higher percentage of IMF than those in the very low quartile ($P < 0.05$). Heifers in the high and very high RFI quartile groups deposited more rib fat than heifers in the very low group ($P < 0.05$). There were no differences ($P > 0.22$) between the low, high, and very high RFI quartiles for rib fat deposition. There were no differences in LA ($P > 0.68$) for the different RFI groups.

Table 6. Estimated variances for carcass traits in feed efficiency tested animals

	Sire variance	Contemporary group variance	Residual variance
Trait			
Intramuscular fat, %	0.215	0.255	0.521
Rib fat, cm^2	0.008	0.020	0.046
Longissimus area, cm^2	25.30	42.42	47.99

Table 7. Least squares means ± SE for carcass traits by RFI quartile

RFI Quartile	Very low[1]	Low[2]	High[3]	Very high[4]
Trait				
Intramuscular fat, %	3.49 ± 0.18[b]	3.72 ± 0.18[ab]	3.70 ± 0.18[ab]	3.83 ± 0.18[a]
Rib fat, cm	0.60 ± 0.05[b]	0.66 ± 0.05[ab]	0.71 ± 0.05[a]	0.74 ± 0.05[a]
Longissimus area, cm^2	60.5 ± 2.09	60.2 ± 2.10	60.7 ± 2.10	61.7 ± 2.09

[1]Very low: RFI < –0.499

[2]Low: –0.50 < RFI < 0.00

[3]High: 0.01 < RFI < 0.499

[4]Very high: RFI > 0.50

[a,b] Means within rows that do not share a superscript are different ($P < 0.05$).

The correspondence of IMF, rib fat, and LA with DMI, ADG, and RFI was evaluated by estimating regression coefficients (Table 8). IMF percentage was regressed on DMI and there was a positive regression coefficient ($P < 0.05$) indicating that for every 1 kg increase in DMI there was a corresponding 0.1% increase in IMF. DMI also had positive regression coefficients with rib fat ($P < 0.001$) and LA ($P < 0.001$) indicating that for each kg increase in DMI there were increases in rib fat deposition and LA. Ultrasound carcass traits were regressed on ADG and the only significant coefficient was positive ($P < 0.01$) for LA and ADG, indicating that as gain increased so did the deposition of muscle. Ultrasound carcass traits were regressed on RFI as a continuous variable, and both IMF percentage and rib fat had positive regression coefficients ($P < 0.01$ and $P < 0.001$ respectively), indicating that higher RFI values were associated with higher values of percent IMF and rib fat. For every unit increase in RFI there was an increase of 0.061 cm of rib fat deposited and 0.165 percent of IMF. The regression coefficient of RFI on LA did not differ from 0 ($P > 0.17$). The gain to feed ratio had negative regression coefficients with IMF ($P < 0.05$) and rib fat ($P < 0.001$), indicating that the more weight an animal gained per kg of feed consumed the lower the IMF and rib fat were. The regression coefficient between G:F and LA was not different than 0 ($P > 0.06$)

The results of this study are consistent with what has been previously reported by others. Richardson et al. (2001) reported that Angus steers in Australia, with feed efficient, or low RFI sires deposited less rib fat than those with less feed efficient sires. Basarab et al. (2003) also reported that steers with a more favorable (lower) RFI, had less IMF and less rib fat than those with an unfavorable (higher) RFI. A positive genetic correlation of rib fat and RFI was reported in Nellore steers by Ferreira Júnior et al. (2018), meaning that larger breeding values for DMI were associated with larger breeding values of IMF percent, rib fat, and LA. In 2011 Crowley et al. reported a positive genetic correlation between RFI and fat depth in Angus, Charolais, Hereford, Limousin and Simmental bulls in Ireland. Nkrumah et al. (2007) reported positive phenotypic and genetic correlations of RFI with ultrasound measured carcass traits. The results are consistent with Novo et al. (2021) report in Senepol heifers in Brazil, where G:F and RFI both had unfavorable correspondence with IMF. Novo et al. (2021) also reported that animals with higher G:F and lower RFI had less rib fat.

Table 8. Estimates of regression coefficients ± SE for carcass traits from analyses of efficiency traits[1]

Trait	Intramuscular fat, %	Rib fat, cm	Longissimus area, cm^2
Covariate			
Dry matter intake, kg/d	0.12 ± 0.04**	0.079 ± 0.011***	2.60 ± 0.35***
Average daily gain, kg	–0.053 ± 0.181	0.022 ± 0.052	4.47 ± 1.76*
Residual feed intake, kg DM/day	0.200 ± 0.06***	0.067 ± 0.017***	0.800 ± 0.584
Gain:Feed kg gain/kg feed	–3.66 ± 1.53*	–1.85 ± 0.44***	–29.01 ± 15.14

[1]Analyzed traits are in the column headings. Covariates are in the row labels.

**P* < 0.05

***P* < 0.01

****P* < 0.001

4.3. Correspondence of Carcass Traits Measured by Ultrasound with Female Fertility Traits

In the evaluation of the correspondence of ultrasound measured carcass traits and female fertility trait two sets of data were used independently of one another. The first set of data used included the 297 females that were tested on Vytelle systems from 2016 to 2020. These females all had age adjusted IMF, rib fat, and LA as well as AFC and CI recorded. The contemporary groups used for this analysis the BBU reported contemporary groups that include season and year of birth, and breeder. There were 69 sires and 16 contemporary groups in the analysis of all ultrasound carcass traits, with an average of 17 females per contemporary group with a minimum of 2 and a maximum of 38. Age was also accounted for with the preadjusted ultrasound carcass traits. These animals were young; the fertility traits evaluated were the AFC and CI between the first and second calving.

The second set of data were from the BBU Whole Herd Reporting system and included 3,756 females born from 2005 to 2019. All animals had age adjusted IMF, rib fat, and LA recorded, as well as AFC, CI, and disposal age, the age in years at which a cow was recorded as removed from the breeding herd. The contemporary groups for this analysis were created using the birth year and season of the cow as well as the herd of origin, age of the animal is accounted for partially through contemporary group and partly by the age adjustments to the carcass traits done previously by BBU.

For the first set of feed efficiency tested females the same initial sire model was used from the evaluation of the correspondence of feed efficiency and fertility traits. The variance estimates from this analysis are found in Table 3.

The second set of females that were from the BBU WHR system were evaluated using an animal model. The basic mixed model included the contemporary group and additive genetic values as random effects. The variance estimates from these models are presented in Table 9. Contemporary group variances were 0.62 ± 0.02, 0.15 ± 0.03, and 0.38 ± 0.05 as proportions of phenotypic variance for AFC, CI, and disposal age. The variances were also used in the estimation of heritability (h^2) (Table 10). Estimates of h^2 were from single trait analyses; these were moderate for IMF, rib fat and LA, and low for AFC and CI. Equations for analysis of disposal age failed to converge. The estimates of heritability of the AFC and CI were both low and are similar to the findings of Pardo et al. (2020) in a population of Angus, Hereford and Angus-Hereford cross heifers. In a study of Angus, Blanco Orejinegro, and Zebu cattle in Colombia Vergara et al. (2009) reported h^2 estimates of 0.15 and 0.11 for AFC and CI respectively, slightly higher than the findings from this analysis. Frazier et al. (1999) reported a higher estimate of h^2 for AFC at 0.22 and a lower estimate of 0.01 to 0.02 h^2 estimate for CI than what was found in this analysis. Estimates of h^2 for ultrasound carcass were similar to the moderate estimates in Nellore cattle in Brazil by Marestone et al. (2022). The estimates also correspond to what was reported by Miar et al. (2013) in crossbred cattle in Canada.

Table 9. Estimated variances ± SE for fertility traits in Beefmaster Breeders United Whole Herd Reporting females

Trait	Additive genetic	Contemporary group	Residual
Age at first calving, d^2	439.39 ± 107.69	3,189.08 ± 304.88	1,528.66 ± 98.75
Calving interval, d^2	36.67 ± 35.26	84.63 ± 20.29	432.70 ± 37.53
Disposal age, yr^2	0	2.54 ± 0.47	4.23 ± 0.24

Table 10. Estimates of heritability, genotypic and phenotypic correlations ± SE for ultrasound carcass and fertility traits in Beefmaster Breeders United Whole Herd Reporting[1]

	Intramuscular fat, %	Rib fat, cm	Longissimus area, cm^2	Age at first calving, d	Calving interval, d	Disposal age, yr
Intramuscular fat, %	**0.38 ± 0.03**	0.51 ± 0.06	0.24 ± 0.07	0.06 ± 0.11	0.30 ± 0.26	–0.98 ± 1.15
Rib fat, cm	0.21 0.01	**0.20 ± 0.03**	0.50 ± 0.06	–0.01 ± 0.12	0.12 ± 0.29	0.25 ± 1.02
Longissimus area, cm^2	0.07 ± 0.01	0.17 ± 0.01	**0.23 ± 0.03**	–0.25 ± 0.12	0.07 ± 0.25	-0.94 ± 2.76
Age at first calving, d	–0.02 ± 0.01	0.004 ± 0.01	–0.04 ± 0.01	**0.09 ± 0.02**	–0.90 ± 0.15	--
Calving interval, d	–0.001 ± 0.02	–0.03 ± 0.02	–0.006 ± 0.02	–0.31 ± 0.02	**0.07 ± 0.06**	–0.17 ± 4.38
Disposal age, yr	0.01 ± 0.03	0.01 ± 0.02	–0.02 ± 0.02	--[2]	–0.01 ± 0.05	**0.00 ± 0.00**

[1]Estimates of heritability are from single-trait analyses and are presented in the leading diagonal elements. Estimates of genetic and phenotypic correlations are above and below the leading diagonal, respectively.

[2]Two-trait analyses of age at first parturition and disposal age failed to converge.

4.3.1 Females Tested on Vytelle System

The regression coefficients for the correspondence of ultrasound measured carcass traits and fertility from the analysis of the feed efficiency tested females are presented in Table 11. Intramuscular fat percentage, rib fat, and LA had no significant effect on either AFC or CI in this analysis ($P > 0.15$)

The results from this set of data are consistent with what has previously been reported in other breeds of cattle. Evans et al. (2004) reported that in Angus in Mississippi, heifers with ultrasound carcass measures there was no difference in the amount of IMF in pregnant versus non-pregnant females. In Red Angus females with data recorded at the Red Angus Association of America. McAllister et al. (2011) reported no genetic relationship between carcass and female fertility. Paula et al. (2015) reported similar results in Nellore cattle in Brazil. However, Meyer and Johnson (2003) reported that animals that deposited more fat had shorter days to calving in Hereford cattle in Australia.

4.3.2 Females from BBU WHR Program

Results for the regression coefficients in the analysis of the females recorded in the BBU WHR system are reported in Table 12. Estimated regression coefficients for the covariate rib fat did not differ from 0 ($P > 0.05$) for AFC, CI, or disposal age. The significant association of IMF percentage with AFC indicated that a one percentage increase of IMF would decrease AFC by 2.58 days ($P < 0.05$). The covariate LA was not significant in the analysis of CI or disposal age ($P > 0.43$). The regression of LA on AFC was negative ($P < 0.001$).

A two-trait analysis was performed on the subset of females with records in the BBU WHR system to determine genetic correlations (r_g) and phenotypic correlations (r_p) between all traits in this analysis. The r_g and r_p for the ultrasound measured carcass traits of IMF, rib fat and LA as well as the fertility traits of AFC, CI, and disposal age are presented in Table 10. Estimates of genetic correlations were moderately large for fat deposition traits and large for LA with either rib fat or IMF. Estimates of genetic correlations between the ultrasound measured carcass traits and the fertility traits did not differ from 0. The large SE of these estimates are a consequence of smaller sample sizes for some traits. These results may suggest that selection for ultrasound measured carcass traits can be done independently of fertility traits.

The results of this study are similar to what has been reported in both Red Angus and Nellore cattle. McAllister et al (2011) reported that there were no genetic correlations between carcass traits and fertility traits in Red Angus. Paula et al. (2015) also reported that in Nellore heifers in Brazil that the genetic correlation between carcass traits and AFC or the calving interval between the first two calves did not differ from zero. While Boldt et al. (2018) did not report on AFC or disposal age there were genetic correlations found between heifer pregnancy and stayability, or the ability of an animal's daughters to remain productive in the herd until 6 years of age, and the ultrasound carcass traits, indicating that the selection on ultrasound carcass traits would affect heifer pregnancy and stayability in Red Angus females registered with the Red Angus Association of America. The negative genetic correlation between AFC and CI is different from positive genetic correlation was reported by Vergara et al. (2009) in multibreed cattle in Colombia.

Table 11. Estimates of regression coefficients ± SE for fertility traits and ultrasound carcass traits in feed efficiency tested females (n = 297)[1,2]

Trait	Age at first calving, d	Calving interval, d
Covariate		
Intramuscular fat, %	4.64 ± 3.217	3.87 ± 5.79
Rib fat, cm	–8.04 ± 11.61	5.73 ± 21.18
Longissimus area, cm^2	–0.12 ± 0.32	0.71 ± 0.55

[1]Analyzed traits are in the column headings and covariates are in the row labels.

[2]No values were different than 0 ($P > 0.05$)

Table 12. Estimates of regression coefficients ± SE for ultrasound carcass traits in analyses of fertility traits of Beefmaster Breeders United Whole Herd Reporting females (n =3,756)[1]

Trait	Age at first calving, d	Calving interval, d	Disposal age, yr
Covariate			
Intramuscular fat, %	–2.58 ± 1.06*	–1.13 ± 0.82	0.024 ± 0.10
Rib fat, cm	4.80 ± 4.27	–5.44 ± 3.23	–0.030 ± 0.41
Longissimus area, cm^2	–0.50 ± 0.11***	0.041 ± 0.078	–0.007 ± 0.009

[1]Analyzed traits are in the column headings and covariates are in the row labels

*$P < 0.05$

***$P < 0.001$

5. CONCLUSIONS

There will be an increasing demand for production of beef in the United States and worldwide to be more efficient. The amount of land that is available for production is decreasing and the population is continually increasing. The beef industry is focused on becoming more efficient from a system wide perspective, to include feed efficiency and maternal efficiency (including reproductive performance) while continuing to maintain or increase the quality of the beef that is produced. This study was designed to evaluate the correspondence between feed efficiency and fertility, feed efficiency and carcass traits, and carcass traits and fertility traits. The carcass traits that were evaluated were ultrasound measures, since all animals in the analysis are reproducing females, of LA, rib fat, and IMF. The feed efficiency traits evaluated were RFI, ADG and DMI, and the fertility traits were AFC, CI, and disposal age.

Reports from previous studies in the correspondence of feed efficiency and fertility indicated negative or no correspondence between these suites of traits. The females evaluated in this study came from multiple herds in the BBU database and were tested at several locations on Vytelle systems. Evaluation of the correspondence of AFC and CI with relation to the RFI quartile found that there were no differences, however there was a slight trend for the three upper quartiles to calve earlier than the lowest RFI quartile. There was no other correspondence found in the analysis of feed efficiency and fertility traits. The negative regression coefficient for AFC and RFI indicates that the lower RFI or more efficient heifers calve later than the less feed efficient heifers. There were no other reported correspondences between feed efficiency traits and fertility traits. The results indicate that the utilization of RFI for feed efficiency selection in Beefmaster heifers could be detrimental to the age at which they have their first calf. Utilizing G:F would be a more favorable trait to utilize for feed efficiency as there was no noted correspondence between it and the fertility traits.

Carcass traits are important for the final value of the product that is produced by the beef industry. The United States beef industry markets based on quality grade and yield grade, and quality grade has continually increased over the years. The majority of cattle in the United States are also fed in a feedlot setting and feed efficiency is important in that aspect of production. Not surprisingly, it was found that the more feed efficient, or negative RFI, heifers deposited less fat than their less efficient, or positive RFI, contemporaries. The DMI of the heifers also affected all ultrasound carcass traits. Animals that ate more deposited more rib fat and IMF while also having larger LA. The RFI of an animal as measured was associated with both rib fat and IMF with the less efficient animals depositing more of both types of fat. An animal's ADG only affected the LA. These results indicate that while feed efficiency may be beneficial for the yield grade of the carcass, they may be of detriment to the quality grade. This should be considered by Beefmaster breeders when they are making selection decisions to avoid carcass value losses. This should also be considered by the breed association when creating selection indices that are carcass focused. The cattle in this study were all females and ultrasound carcass data were used to estimate actual carcass values, it would be beneficial to have data on steers fed through an entire feedlot system and actual carcass data measured at harvest.

The data for the analysis of the correspondence between ultrasound carcass and fertility traits came from two data sets. The first set of data were used to estimate regression coefficients of fertility traits on ultrasound measured carcass traits. The second set was larger and was used to determine estimates of heritability of all traits and both genetic and phenotypic correlation estimates between traits as well as regression coefficients. In the WHR data set in which regression coefficients were estimated there was an association of LA with AFC, and IMF with AFC. The heifers with a larger LA calved earlier and those with more IMF also calved earlier. This result supports the anecdotal evidence found in the Casey Beefmaster herd in Albany, Texas (http://caseybeefmasters.com) that higher IMF cattle may be more reproductively efficient. Intramuscular fat percentage is a measure of fat and fat is a source of energy for cattle.

The heritability estimates of all ultrasound carcass traits were moderate, and the fertility traits were low in heritability. This is what was expected of these traits for heritability. The genetic correlations that were found were what would be expected and were between the carcass traits and other carcass traits. One estimate of genetic correlation that was different from 0 existed between AFC and CI. However, there were no detected genetic correlations between the carcass traits and the fertility traits that differed from 0. This is important because these results indicate that selection can be made on carcass without adversely affecting fertility.

The results of this study may be positive indicators for the industry since there was low correspondence found between feed efficiency and fertility and carcass and fertility. These results indicate that there is little to no correspondence between feed efficiency in a feedlot setting and fertility traits in Beefmaster cattle, and that carcass and fertility can be improved simultaneously. There were some noted antagonistic effects of RFI on the traits that affect the quality of the carcass but could be positive for yield grade. It should be noted that due to the nature of the calculation of RFI, the selection based on RFI can lead to the selection of animals that eat less and perform at a lower level than desired. These results can be used by BBU in the development of new selection indices for different goals of breeders.

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