Twenty Angus bulls from three purebred herds in Georgia were acquired to determine the impact of selecting sires based on phenotypic yearling ultrasound intramuscular fat % (UIMF) or UIMF expected progeny difference (EPD) on marbling score of steer progeny managed for commercial slaughter. Each year in each herd, pairs of bulls were selected to create large differences based on their age adjusted phenotypic yearling UIMF measurements. The average UIMF, weighted by number of progeny per sire, was 3.75% (SD = 1.10%) and 1.70% (SD = 0.53%) for high UIMF (HU) and low UIMF (LU) bulls, respectively. All available ultrasound measurements collected in the purebred cooperator herds were combined with other ultrasound records collected by the American Angus Association for the computation of genetic values for ultrasound fat thickness, ribeye area, and intramuscular fat %. Bulls were randomly mated to between 14 and 30 commercial Angus females for 1 to 5 yr. Carcass weight, fat thickness at the 12th rib, ribeye area at the 12th rib, marbling score, yield grade, and quality grade measurements were taken on 188 steer progeny. Carcass data were linearly adjusted to 480 d of age at slaughter. Steer progeny sired by HU bulls had higher age adjusted marbling score and quality grade (P < 0.05), and smaller age adjusted ribeye area (P < 0.05) than progeny sired by LU bulls. The regression of age adjusted carcass marbling score of steer progeny on ultrasound intramuscular fat % EPD of sires produced a highly significant regression coefficient of 90.50. Age adjusted carcass quality grade of steer progeny regressed on ultrasound intramuscular fat % EPD of sires produced a highly significant regression coefficient of 49.20. Yearling Angus bulls selected for high
phenotypic UIMF or UIMF EPD can be expected to produce steers with significantly higher amounts of marbling and quality grade. It also appears that marbling can be increased without corresponding increases in external fat thickness and yield grade.

**INDEX WORDS:**  Beef Cattle, Ultrasound, Intramuscular Fat, Selection Responses
EFFECTS OF SELECTION FOR ULTRASOUND INTRAMUSCULAR FAT PERCENT IN ANGUS BULLS

by

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CHAPTER I

INTRODUCTION

Due to the increase in marketing of cattle on pricing grids and in retained ownership due to the growth of alliances, more emphasis has been placed on the development and use of genetic values by the beef industry to improve carcass traits. Traditionally, the information used to predict carcass merit was collected through structured carcass sire progeny tests. Carcass sire progeny tests are time consuming, expensive, and subject to selection bias. Many breed associations have recently developed or are developing genetic values in the form of expected progeny differences (EPD) for carcass traits using live-animal ultrasound measurements.

Some of the advantages of ultrasound for predicting carcass merit is that ultrasound is relatively inexpensive, has a shorter generation interval when compared to carcass sire progeny testing programs, and the data provided via ultrasound may be subject to less selection bias then data collected via carcass sire progeny testing program. However, in order to obtain equivalent genetic change per year using real-time ultrasound may require testing of more sires compared to the traditional carcass sire progeny testing program. Perhaps the most important advantage of using ultrasound measurements collected from young breeding stock is that the data can be used to calculate non-parent ultrasound carcass EPD, allowing for selection of animals to occur at an earlier age.

Studies have shown that ultrasound measurements of fat thickness, ribeye area, and intramuscular fat percent are moderate to high in heritability, which indicates that
ultrasound has the potential to improve carcass traits. Also, studies have shown that ultrasound measures of fat thickness, longissimus muscle area, and intramuscular fat percent are accurate predictors of their corresponding carcass traits. Likewise, studies have shown a strong and favorable relationship between live-animal ultrasound measurements of yearling seedstock animals and corresponding carcass measurements of fed slaughter cattle. However, there is little information available in the literature to assess the consequences of actual selection of sires based on ultrasound measures on the carcass measures of their resulting slaughter progeny. The objective of this study was to determine the impact of selecting sires based on phenotypic yearling ultrasound intramuscular fat percent or ultrasound intramuscular fat percent EPD on marbling score of steer progeny managed for commercial slaughter.
CHAPTER II

REVIEW OF LITERATURE

Johnson et al. (1993) noted that real-time ultrasound technology offers a practical, nondestructive, and relatively inexpensive means of collecting indicators of carcass traits from live animals. In the past decade, there has been a rush to collect as many ultrasound records as possible, potentially for developing ultrasound carcass expected progeny differences and for making breeding and management decisions. The scope in which ultrasound technology can be used in the beef cattle industry is dependent on the heritability of ultrasound measures and the relationship between live-animal ultrasound measures of carcass traits and the corresponding carcass traits in fed slaughter cattle.

Overview of Carcass Traits

As a result of consumer demands for a leaner, healthier product without sacrificing tenderness, juiciness, and flavor, producers began to place more emphasis on carcass traits as part of their breeding plan than they had in the past. Genetic improvement of carcass traits is possible only if carcass traits are heritable. Koch et al. (1982) summarized heritabilities for fat thickness, longissimus muscle area, and marbling score from seven literature sources published prior to 1982. Heritability estimates ranged (average) from 0.24 to 0.68 (0.48), 0.25 to 0.73 (0.40), and 0.17 to 0.73 (0.42) for fat thickness, longissimus muscle area, and marbling score, respectively. In addition to reporting heritability estimates from published literature, Koch et al. (1982) estimated the heritability of fat thickness, longissimus muscle area, and marbling score in 2,453 crossbred steers representing 16 different breed types. Heritability estimates were 0.41,
0.56, and 0.40 for fat thickness, longissimus muscle area, and marbling score, respectively. The authors concluded that the estimated heritabilities were reasonably similar to the average heritabilities reported from the literature.

In contrast, Bertrand et al. (2001) summarized heritability estimates for selected carcass traits from eighteen literature sources published since 1980. Ranges (average) in reported heritability estimates for fat thickness, longissimus muscle area, and marbling score were 0.18 to 0.56 (0.34), 0.22 to 0.97 (0.47), and 0.15 to 0.93 (0.46), across eleven, twelve, and sixteen studies, respectively. Published literature since 1980 suggested that the average heritability for fat thickness has decreased, whereas, the average heritabilities for longissimus muscle area and marbling score have increased.

Despite the inconsistency in the reported heritabilities, carcass traits are moderate to highly heritable. The inconsistency in reported heritabilities may be due to small sample groups, sex of the animals sampled, method of estimation, high standard errors, and the varying breeds of cattle used to obtain the estimate. However, the moderate to high average heritabilities of fat thickness, longissimus muscle area, and marbling score reported by Koch et al. (1982) and Bertrand et al. (2001) suggested that selection for these traits has the potential to improve carcass traits.

**Ultrasonic Measurements of Carcass Characteristics**

Wilson (1992) reported on literature related to the use of ultrasound in livestock species, with an emphasis on the potential for genetic improvement programs in beef cattle. Ultrasonics in meat animals are used to record live animal anatomical measurements that will allow the prediction of genetic differences between individual animals for carcass merit, when used in conjunction with other measurements, such as
progeny data. Ultrasound has been used for more than four decades. However, technological advances in ultrasonics, such as real-time imagery and portable equipment, have renewed interest in the livestock industry for the use of this technology for genetic improvement. The swine papers reviewed by the author showed that ultrasound scans of fat (in all instances) and muscle (in some instances) improved the prediction of percent lean. The sheep papers that were reviewed by the author showed that ultrasound scans of fat and muscle, in some instances, improved prediction accuracy of sheep carcass composition after live weight adjustments. Similar results were found for beef cattle. The author concluded that additional research and development is needed before the beef and sheep industry will be able to incorporate ultrasound measurements of live animals into large-scale genetic improvement programs.

Several studies have noted the importance of equipment and technicians for obtaining accurate measurements utilizing real-time ultrasound. Results from a two part study by Smith et al. (1992) suggested that ultrasound measurements prior to slaughter were useful in estimating carcass fat thickness and imprecise in predicting carcass longissimus muscle area for measurements taken with an Aloka 210DX machine. The authors noted that fat thickness was underestimated on fatter cattle, whereas, longissimus muscle area was underestimated in heavily muscled cattle. In contrast, Herring et al. (1994) found that real-time ultrasound can be used to accurately predict fat thickness and longissimus muscle area with qualified trained personnel. The authors also noted that significant differences in accuracy and precision of measurements for longissimus muscle area exist between technicians when measurements were made with an Aloka 500V machine compared with the Aloka 210DX machine. However, little difference in the
accuracy of fat thickness was observed between technicians and the Aloka 500V and the Aloka 210DX machines. The authors suggested that before ultrasound measurements are accepted for use in national cattle evaluations, technicians must undergo rigorous training and be tested for proficiency.

Perkins et al. (1992) scanned yearling feedlot steers and heifers 24 hours prior to slaughter to evaluate the accuracy of ultrasonic measurements of fat thickness and longissimus muscle area for prediction of actual carcass measures. Animals were scanned by two technicians on alternating days using an Aloka 210DX machine. The technicians had equal but limited experience using ultrasound technology. The authors found no significant differences to exist between technicians for absolute differences between ultrasonic and carcass measurements. Unlike Smith et al. (1992), the accuracy of predicting ultrasonic measures did not change as the level of experience increased. Perkins et al. (1992) concluded that ultrasound measurements of fat thickness and longissimus muscle area may accurately predict final carcass fat thickness and longissimus muscle area in beef cattle.

Equipment and technician are important in order to obtain accurate and precise ultrasound measurements of live beef cattle. But, if ultrasound measurements of breeding cattle are going to be incorporated into cattle evaluations, then an ‘ideal’ age for obtaining these measurements needs to be determined along with adjustment equations. Waldner et al. (1992) investigated real-time ultrasound equipment and technicians for accuracy, precision, and to determine the most accurate age to measure fat thickness and longissimus muscle area. Real-time ultrasound measurements of longissimus muscle area and 12th rib fat thickness on a total of sixty Brangus bulls were taken every 4 months
beginning at 4 and 12 months of age, respectively until 24 months of age. Bulls were scanned with an Aloka 210DX and Equisonics LS-300A machines by four technicians with various levels of experience. Ten bulls were slaughtered at each evaluation period to determine actual longissimus muscle area and fat thickness. Results suggested that estimation of ultrasound fat thickness was most accurate when measured at either 12 or 16 months of age. The authors concluded that as fat thickness increased, accuracy of the measurement decreased, significant differences between the four technicians were present, an increase in technician skill did not improve the accuracy of the estimates for ultrasound fat thickness, and no significant difference was found for the two machines for measurements of fat thickness. The data further suggested that accurate estimation of longissimus muscle area only occurs at 12 months of age, increased level of skill did not improve the accuracy of longissimus muscle area estimates, no significant differences between the four technicians were present for longissimus muscle area measurements, and the Equisonics LS-300A unit was more accurate than the Aloka 210DX unit for measuring longissimus muscle area. The authors also found that smaller longissimus muscle areas were underestimated, whereas larger longissimus muscle areas were overestimated.

Bergen et al. (1996) assessed the accuracy and repeatability of ultrasound fat thickness and ultrasound longissimus muscle area in young performance-tested bulls. At the completion of the performance test, weights and ultrasound measurements were taken on 617 bulls using an Aloka 500V unit prior to slaughter. The authors found high correlations for ultrasound fat thickness (0.95) and ultrasound longissimus muscle area (0.94) between successive measurements on the same animal. Accuracy was determined
by comparing ultrasonic measurements of fat thickness and longissimus muscle area to the corresponding carcass measurements. Correlations between ultrasound and carcass fat thickness and ultrasound and carcass longissimus muscle area were 0.84 and 0.80, respectively. Therefore, the authors concluded that experienced ultrasound technicians could obtain repeatable and accurate measurements of ultrasound fat thickness and longissimus muscle area in yearling performance-tested bulls.

The combination of a value-based marketing system and ultrasound technology has increased the importance of live-animal measurements of carcass traits, especially intramuscular fat or marbling. Before live-animal measurements of intramuscular fat can be used as selection criteria or in national cattle evaluations, there must be a means for accurately predicting intramuscular fat from ultrasound measurements. Whittaker et al. (1992) reported on the basic engineering concepts of ultrasound technology with implications for ultrasound technology in beef cattle, specifically for measuring intramuscular fat. Preliminary results show that intramuscular fat may be predicted using an A-mode transducer coupled with frequency analysis. The authors noted that ultrasound has the potential for determining marbling in the live animal.

Herring et al. (1998) reported on the precision of four commercially available ultrasound systems that predict intramuscular fat in live beef cattle. Eighty-one steers were scanned 8 to 14 days prior to slaughter with one scanning session each day. Steers averaged 14.5 months of age and had been on feed for 170 days. The four software systems (and number of sonographers) used were Animal Ultrasound Services, Inc. (two sonographers), CPEC (four sonographers), Critical Vision, Inc. (one sonographer), and Classic Ultrasound Equipment (one sonographer). Authors found the CPEC and Critical
Vision, Inc. systems to be the most precise for predicting intramuscular fat in finished steers.

Wilson et al. (1995) reported on improvements in image processing and prediction models for intramuscular fat percentage. Seven hundred and twenty bulls and steers were scanned using an Aloka 500 machine. After slaughter, a rib slice of the longissimus muscle was collected to measure actual intramuscular fat percentage. The first of two models developed to predict intramuscular fat was based on the image processing parameters; the second model included ultrasound measured fat thickness at the 12th and 13th rib along with the image processing parameters used in the first model. The residual distribution for the first model indicated that intramuscular fat percentage was predicted with an error <1% in 53%, and <1.5% in 73% of the animals. The authors concluded that the validation of the model showed the usefulness of real-time ultrasound and image processing algorithms to predict intramuscular fat percentage in live cattle.

Hassen et al. (2001) scanned over five hundred steers prior to slaughter to develop models for predicting intramuscular fat percentage in live beef cattle. Steers averaged 455 days in age and were on feed an average of 248 days. Each steer was scanned across the 11th and 13th ribs using Aloka 500V and Classic Scanner 200 machines. Four to five images were collected per steer per machine. After slaughter, chemical extraction of a cross-sectional slice of the longissimus muscle was used to determine actual carcass intramuscular fat percentage. Four prediction models were developed separately for each of the two machines. The authors found that both the Aloka 500V and the Classic Scanner 200 machines could be used to accurately predict intramuscular fat percentage in live beef cattle. In comparing the ultrasound equipment, authors found no significant
difference in the accuracy for predicting intramuscular fat percentage for the Aloka 500V and the Classic Scanner 200 machines, when algorithms developed at Iowa State University were used.

Hassen et al. (1999) scanned 144 bulls, heifers, and steers to determine the repeatability of ultrasound intramuscular fat percentage and the effect of multiple measurements on the precision of prediction. Animals were scanned at an average age of 433 days by a certified technician; five to six images were taken on each animal by two Aloka 500V machines, and intramuscular fat percentage was predicted from two regions of interest within an image. The overall repeatability of ultrasound predicted intramuscular fat percentage was 0.63. No significant difference in repeatability was found between the two machines and between the two regions of interest. Ultrasound predicted intramuscular fat percentage was found to be more repeatable in steers (P < .05) when compared to bulls and heifers; repeatability in bulls and heifers were not significantly different. However, the authors found that bulls had the lowest standard deviation (0.82%) for ultrasound predicted intramuscular fat percentage when compared to steers (0.97%) and heifers (1.02%). They also noted that the standard error of animal mean measures decreased by 50% when the number of images per animal increased to four. Animals with mean ultrasound predicted intramuscular fat percentage < 4.79% were found to have less repeatable measures than animals with a mean > 4.79%. Therefore, the authors concluded that increasing the number of images per animal should be done solely for improving the precision of ultrasound marbling values, and multiple images per animal brings a faster reduction in the standard error of prediction than multiple measures within a single image.
Genetic Parameters of Ultrasound Measurements

Heritability of Ultrasound Measurements in Fed Cattle

Genetic parameters of ultrasound measurements vary depending on technician, technician experience, and equipment. Several studies have calculated heritabilities and genetic correlations for carcass traits based on live-animal ultrasound measurements. In general, estimates for heritability are slightly lower for ultrasound measurements than for the corresponding carcass measurements of fed cattle. However, Rouse et al. (1996) found preliminary heritability estimates for ultrasound fat thickness and ultrasound intramuscular fat percentage in more than 1,000 Angus and Simmental sired bull and steer progeny to be nearly double the heritability estimates for carcass fat thickness and chemical (ether extract) fat percentage. Final scans on all progeny were obtained at least 5 days prior to slaughter. Average age at slaughter was 440 days. Preliminary heritability estimates for ultrasound fat thickness, carcass fat thickness, ultrasound intramuscular fat percentage, and chemical or actual fat percentage in bulls (steers) were 0.73 (0.65), 0.31 (0.41), 0.40 (0.02), and 0.23 (0.44), respectively, and overall preliminary heritabilities for the same traits were 0.67, 0.39, 0.53, and 0.36, respectively, when adjusted to an age end point. The authors concluded from the preliminary data that more variation is present within steers than bulls for ultrasound measured traits, and that ultrasound intramuscular fat percentage measures can be used to classify high and low expected progeny difference sires for actual or chemical percentage fat.

Baud et al. (1998) analyzed ultrasound measurements of rump fat at the P8 site and longissimus muscle area in 489 steers recorded with an Aloka 210DX11 or an Aloka 500V machine. Ultrasound measurements were taken 30 days after feedlot entry and
again at the time of exit from the feedlot (within 14 days prior to slaughter). Heritability estimates for ultrasound rump fat and ultrasound longissimus muscle area for the first scan (second scan) were 0.29 (0.30) and 0.25 (0.15), respectively. The authors concluded that scans taken at feedlot entry could be useful in predicting mean carcass fat depths and longissimus muscle areas of lines of steers from vendors and, possibly, of sire lines. The authors hypothesized that there will be considerable re-ranking of individual steers between corresponding measurements taken on the live animal and their carcasses.

**Heritability of Ultrasound Measurements in Breeding Cattle**

Turner et al. (1990) analyzed ultrasound measurements of fat thickness and longissimus muscle area from 385 yearling Hereford bulls. Heritability estimates for ultrasound fat thickness and ultrasound longissimus muscle area were 0.04 and 0.12, respectively. The authors noted that ultrasound measures of fat thickness and longissimus muscle area in yearling Hereford bulls are less heritable than reported carcass fat thickness and carcass longissimus muscle area. The authors suggested that ultrasound longissimus muscle area measurements should be adjusted for age, weaning weight, and fat thickness effects.

Johnson et al. (1993) analyzed ultrasound measurements of fat thickness and longissimus muscle area from 2,101 Brangus calves from the Brink’s Brangus Ranch in Eureka, Kansas. Heritability estimates for age-constant (weight-constant) ultrasound fat thickness and ultrasound longissimus muscle area were 0.14 (0.11) and 0.40 (0.39), respectively. The authors concluded that the moderate heritabilities for longissimus muscle area indicated that selection to change these traits should be effective. However, the small reported heritability estimates for fat thickness would make it very difficult to
change the genetic ability of animals to fatten through selection based on this measurement.

Some studies are beginning to look at heifer ultrasound data along with bull data. It is not known what effect the inclusion of heifer ultrasound data with bull ultrasound data will have on the heritability of carcass traits. Arnold et al. (1991) estimated genetic parameters from ultrasound measurements taken on 3,482 registered Hereford bulls and heifers at 320 to 410 days of age. Heritability estimates for ultrasound measures of fat thickness and longissimus muscle area, adjusted to a constant age (adjusted to a constant yearling weight), were 0.26 (0.26) and 0.28 (0.25), respectively. Similarly, Moser et al. (1998) found heritability estimates from 3,583 yearling Brangus bulls and heifers for ultrasound fat thickness and ultrasound longissimus muscle were 0.11 and 0.29, respectively, when age at measurement was included as a covariate. In contrast, Evans et al. (1995) found a higher heritability for ultrasound longissimus muscle area than the heritability for ultrasound longissimus muscle area reported by Arnold et al. (1991) and Moser et al. (1998) when data were adjusted to a constant age. Evans et al. (1995) calculated heritability estimates from over 2,000 Red Angus yearling heifer and bull ultrasound data. Heritability estimates for ultrasound measures of fat thickness and longissimus muscle area were 0.50 and 0.46, respectively, when data were adjusted to a constant age.

Shepard et al. (1996) obtained ultrasound measurements from 1,557 Angus bulls and heifers. Images were taken by one of two trained technicians using an Aloka 500V machine. Animals ranged from 250 to 550 days in age at the time of scanning. Heritability estimates for ultrasound fat thickness and ultrasound longissimus muscle area
were 0.56 and 0.11, respectively. The authors noted that both ultrasonic fat thickness and ultrasonic longissimus muscle area are under some degree of genetic control, allowing selection to make genetic change in these traits. The authors suggested that more research was needed to determine the genetic correlations between ultrasound measurements of fat thickness and longissimus muscle area and other economically important traits so that producers can avoid potentially detrimental overall effects on their herds.

Robinson et al. (1993) estimated genetic parameters from 9,232 Angus, Hereford, and Polled Hereford steers, heifers, and bulls. Age at the time of scanning ranged from 300 to 600 days. Pooled heritability estimates were 0.30, 0.21, and 0.37 for ultrasound fat thickness, ultrasound longissimus muscle area, and ultrasound rump fat at the P8 site, respectively. Genetic correlations between ultrasound fat thickness and ultrasound rump fat, ultrasound fat thickness and ultrasound longissimus muscle area, and ultrasound rump fat and ultrasound longissimus muscle area were 0.86, 0.05, and 0.00, respectively. However, when ultrasound longissimus muscle area was adjusted to a constant weight of 400 kg, correlations for ultrasound fat thickness and ultrasound longissimus muscle area and ultrasound rump fat and ultrasound longissimus muscle area reduced to -0.07 and -0.10, respectively. The authors also noted that genetic evaluation of young breeding animals by mixed-model analysis could result in genetic progress for fat thickness, longissimus muscle area, and rump fat without the delay and cost of progeny testing.

Wilson et al. (2000) estimated genetic parameters from ultrasound measurements of fat thickness, rump fat, longissimus muscle area, and intramuscular fat percentage in 8,630 developing Angus heifers from 851 sires. Ultrasound measurements were adjusted
to a common age of 390 days. Heritability estimates for ultrasound measures of fat thickness, rump fat, longissimus muscle area, and intramuscular fat percentage were 0.48, 0.56, 0.40, and 0.42, respectively. Sire expected progeny differences (EPD) based on ultrasound measured traits were compared to EPD based upon carcass measured traits of steer progeny. Of the 851 sires with ultrasound EPD, 309 sires also had carcass EPD. Comparisons were made between EPD from the two sources of data using sire rank correlations. The rank correlations were 0.72, 0.76, and 0.69 for fat thickness, longissimus muscle area, and ultrasound intramuscular fat and marbling score, respectively, for ultrasound based EPD and carcass based EPD accuracy levels of 0.85 and higher. The authors concluded that producers could use EPD based upon ultrasound measures from developing Angus heifers to predict the same genetic differences observed from steer progeny carcass measures.

**Relationships between Carcass and Ultrasound Measurements**

Baud et al. (1998) noted that an important factor influencing the successful genetic improvement of carcass merit is the genetic relationship between the live-animal measurements made on breeding cattle and the corresponding carcass measurements of their progeny. Bertrand et al. (2001) noted that with genetic correlations between seedstock ultrasound measures and slaughter cattle carcass measures ≥ 0.70, carcass genetic evaluation programs may be able to rely mainly on ultrasound measures for the computation of genetic values while achieving similar or greater genetic progress at the same cost of a typical sire carcass progeny testing program. However, there are few reports on the genetic relationship between ultrasound measurements of breeding cattle
and the corresponding carcass measurements of progeny. This genetic relationship needs
to be better understood before using ultrasound measurements in beef cattle selection.

In addition to estimating heritabilities for ultrasound fat thickness and ultrasound
longissimus muscle area in breeding cattle, Arnold et al. (1991) compared the
relationship between ultrasound measurements of breeding cattle and steer carcass
measurements from two different data sets. The genetic correlation for data adjusted to a
constant weight between fat thickness and longissimus muscle area was 0.39 for breeding
cattle ultrasound data and -0.37 for steer carcass data. However, the genetic correlation
was higher (0.48) for ultrasound fat thickness and ultrasound longissimus muscle area
when data were adjusted to a constant age. Ultrasound fat thickness was positively
correlated to the growth traits (205 day adjusted weaning weight, postweaning average
daily gain, and measurement weight) on an age constant basis and negatively correlated
on a weight constant basis, i.e. fat thickness in the breeding animals did not appear to be
an indication of maturity, but of growth. The authors questioned whether selection for
increased longissimus muscle area would increase fat thickness in progeny, or whether
this relationship is limited to yearling breeding cattle on which it was observed.

Similarly, Evans et al. (1995) investigated over 2,000 Red Angus yearling heifer
and bull ultrasound measurements for fat thickness and longissimus muscle area. The
genetic correlation between ultrasound fat thickness and ultrasound longissimus muscle
area was 0.38, slightly less than the 0.48 that Arnold et al. (1991) reported. In contrast,
Johnson et al. (1993) reported a genetic correlation between ultrasound fat thickness and
ultrasound longissimus muscle area of 0.19, when data were adjusted to a constant age.
Like Arnold et al. (1991), Johnson et al. (1993) found that ultrasound fat thickness was
positively correlated with the growth traits (205 day adjusted weaning weight, postweaning average daily gain, and yearling scan weight). Evans et al. (1995) concluded that before ultrasound measurements of fat thickness and longissimus muscle area of yearling breeding cattle are used in genetic prediction of carcass merit more research was needed.

Smith et al. (1992) investigated the correlations between ultrasound and carcass measurements of fat thickness and longissimus muscle area from a total of 452 feedlot steers of various breed types. The first of two experiments consisted of 315 yearling steers used in a feeding trial conducted to determine the effect of virginiamycin, a feed-grade antibiotic, on performance and carcass characteristics of feedlot steers. The second experiment consisted of 137 yearling steers that were obtained from a trial conducted to determine the effect of anabolic implants on performance and carcass characteristics of feedlot steers fed a high-concentrate diet. All steers were scanned 5 days prior to slaughter with an Aloka 210DX machine. The correlations between ultrasound and carcass fat thickness and ultrasound and carcass longissimus muscle area were 0.81 (0.82) and 0.40 (0.63) for experiment 1 (experiment 2), respectively. The authors concluded that ultrasound measurements of fat thickness are precise predictors of carcass fat thickness. However, they suggested that improvements in equipment and technician expertise must be made before breeding and management decisions could be made from longissimus muscle area estimates generated from ultrasound technology.

In contrast, Rouse et al. (1996) analyzed ultrasound data from 282 crossbred steers. Steers were scanned on one of four dates with approximately 70 animals per scanning date. Animals were measured four to five days prior to slaughter with an Aloka
500V machine. The genetic correlations between ultrasound fat thickness and carcass fat thickness and ultrasound longissimus muscle area and carcass longissimus muscle area were 0.93 and 0.91, respectively. The authors found that ultrasound measured traits had less variation than the same traits measured on the carcass. The authors further concluded that the low standard errors of prediction from experienced technicians reflected the ability to accurately rank animals when ultrasound measures were compared to carcass data.

In addition to estimating heritabilities, Moser et al. (1998) also investigated the relationship between the carcass and ultrasound measurements in Brangus cattle. The authors found the genetic correlations between ultrasound fat thickness and carcass fat thickness and ultrasound longissimus muscle area and carcass longissimus muscle area to be 0.69 and 0.66, respectively. Because of the strong, favorable relationship between yearling breeding cattle ultrasound measurements and progeny carcass measurements, the authors concluded that selection of breeding animals using ultrasound measurements should lead to predictable genetic improvement in carcass characteristics of slaughter progeny.

Devitt and Wilton (2000) analyzed ultrasound measurements on 5,564 purebred yearling bulls of 11 breeds for fat thickness and longissimus muscle area, 3,450 bulls for ultrasound intramuscular fat percentage, and carcass measurements on 843 crossbred steers. Heritability estimates for all traits were moderate to high. The additive genetic correlations between ultrasound fat thickness and carcass fat thickness, ultrasound longissimus muscle area and carcass longissimus muscle area, and ultrasound intramuscular fat percentage and marbling score were 0.80, 0.66, and 0.88, respectively.
These strong, positive correlation estimates between yearling bull ultrasound measurements and corresponding steer carcass measurements suggested that genetic improvement of steer carcass traits could be achieved by using yearling bull ultrasound measurements as selection criteria.

Reverter et al. (2000) utilized Australian Angus and Hereford data to estimate within breed genetic correlations between ultrasound measurements of heifers and bulls at 15 months of age and carcass measurements from heifers and steers. The genetic correlations between ultrasound measurements for Angus bulls (heifers) and Angus carcass measures, adjusted to a constant carcass weight endpoint, were 0.79 (0.99), 0.29 (0.16), 0.82 (0.96), and 0.47 (0.46) for fat thickness, longissimus muscle area, rump fat at the P8 site, and intramuscular fat percentage, respectively. The same genetic correlations between ultrasound measurements for Hereford bulls (heifers) and Hereford carcass measures, adjusted to a constant carcass weight endpoint, were 0.87 (0.02), 0.94 (0.46), 0.82 (0.34), and 0.28 (0.93), respectively. The authors hypothesized that the genetic correlation between ultrasound longissimus muscle area in breeding cattle and carcass longissimus muscle area may be lower than other reported values since these data were adjusted to a constant carcass weight endpoint. The authors also found that intramuscular fat percentage could be predicted from live-animal ultrasound in yearling seedstock animals with the current ultrasound technology (Aloka 500V and Iowa State University software) using experience technicians. However, the authors cautioned the use of genetic correlation estimates when combining ultrasound and carcass data because they are not always consistent across breeds and across sexes within breeds. The authors
hypothesized that selection utilizing yearling ultrasound measurements of breeding cattle
should result in predictable genetic improvement of carcass characteristics.

The majority of the estimates in the literature reported genetic correlations
between ultrasound measurements in breeding cattle and carcass measurements of fed
cattle for fat thickness, longissimus muscle area, and intramuscular fat percentage to be
positive and variable in magnitude. This suggests that selection of breeding animals
using ultrasound measurements should lead to genetic improvement in carcass
characteristics of slaughter cattle.

In summary, carcass traits are moderately to highly heritable, but direct selection
of carcass traits require progeny tests which are time consuming, expensive, and subject
to selection bias. Experienced ultrasound technicians can accurately measure fat
thickness, longissimus muscle area, and intramuscular fat percentage in live animals. In
general, heritability estimates for ultrasound measurements of fat thickness, longissimus
muscle area and intramuscular fat percentage in breeding cattle are lower than reported
heritabilities for carcass traits of fed cattle. Even though there are only a few literature
reports on the genetic relationship between ultrasound measurements of breeding cattle
and carcass measurements of finished cattle, there appears to be a favorable relationship
between ultrasound and carcass measurements. Therefore, ultrasound measures of
yearling seedstock animals appear to be useful selection criteria for genetic improvement
of carcass traits in slaughter progeny. However, before producers can utilize ultrasound
measurements of seedstock cattle for breeding and management decisions, a better
understanding is needed of how actual selection for phenotypic ultrasound measurements
affects progeny carcass traits.
LITERATURE CITED IN THE LITERATURE REVIEW


CHAPTER III

EFFECTS OF SELECTION FOR ULTRASOUND INTRAMUSCULAR FAT PERCENT IN ANGUS BULLS ON CARCASS TRAITS OF PROGENY

ABSTRACT

Twenty Angus bulls from three purebred herds in Georgia were acquired to determine the impact of selecting sires based on phenotypic yearling ultrasound intramuscular fat % (UIMF) or UIMF EPD on marbling score of steer progeny managed for commercial slaughter. Each year in each herd, pairs of bulls were selected to create large differences based on their age adjusted phenotypic yearling UIMF measurements. The average UIMF, weighted by number of progeny per sire, was 3.75% (SD = 1.10%) and 1.70% (SD = 0.53%) for high UIMF (HU) and low UIMF (LU) bulls, respectively. All available ultrasound measurements collected in the purebred cooperator herds were combined with other ultrasound records collected by the American Angus Association for the computation of genetic values for ultrasound fat thickness, ribeye area, and intramuscular fat %. Bulls were randomly mated to between 14 and 30 commercial Angus females for 1 to 5 yr. Carcass weight, fat thickness at the 12th rib, ribeye area at the 12th rib, marbling score, yield grade, and quality grade measurements were taken on 188 steer progeny. Carcass data were linearly adjusted to 480 d of age at slaughter. Steer progeny sired by HU bulls had higher age adjusted marbling score and quality grade (P < 0.05), and smaller age adjusted ribeye area (P < 0.05) than steer progeny sired by LU bulls. The regression of age adjusted carcass marbling score of the steer progeny on ultrasound intramuscular fat % EPD of the sires produced a highly significant regression coefficient of 90.50. Age adjusted carcass quality grade of the steer progeny regressed on ultrasound intramuscular fat % EPD of the sires produced a highly significant regression coefficient of 49.20. Yearling Angus bulls selected for high phenotypic UIMF and UIMF EPD can be expected to produce steers with significantly higher amounts of marbling and
quality grade. It also appears that marbling can be increased without corresponding increases in external fat thickness and yield grade.

Key Words: Beef Cattle, Ultrasound, Intramuscular Fat, Selection Responses

Introduction

Due to the increase in marketing of cattle on pricing grids and in retained ownership due to the growth of alliances, more emphasis has been placed on the development and use of genetic values by the beef industry to improve carcass traits. Many breed associations have recently developed or are developing EPD for carcass traits using live-animal ultrasound measurements. Ultrasound as a means for predicting carcass merit is relatively inexpensive, has a shorter generation interval when compared to carcass sire progeny testing programs, and the data provided via ultrasound may be subject to less selection bias then data collected via carcass sire progeny testing program. Average heritability estimates of seedstock cattle summarized from published literature for ultrasound measurements of fat thickness, ribeye area, and intramuscular fat % are moderate to high (Bertrand et al., 2001). These moderate to high average heritabilities indicate that ultrasound has the potential to improve carcass traits.

An important issue affecting the ultimate usefulness of live-animal ultrasound information as a tool for carcass genetic improvement is the genetic relationship between the live animal measurements of seedstock cattle and the corresponding carcass measurements of their progeny (Baud et al., 1998). Researchers have shown the genetic correlation between ultrasound measurements of seedstock cattle and the corresponding carcass measurements of fed cattle to be positive, but variable in magnitude (Moser et al.,
There is little information available in the literature to assess the consequences of actual selection of sires based on ultrasound measures on the carcass measures of their resulting slaughter progeny. The objective of this study was to determine the impact of selecting sires based on phenotypic yearling ultrasound intramuscular fat % (UIMF) or UIMF EPD on marbling score of steer progeny managed for commercial slaughter.

Materials and Methods

General

Over five years, 422 Angus bulls born between 1992 and 1997 from three purebred herds in Georgia were scanned via real-time ultrasound at approximately one year of age. Each year, either a Beef Improvement Federation certified or an American Association of Ultrasound Practitioners certified technician collected images using an Aloka 500V (Corometrics Medical Systems, Wallingford, CT) machine with a 17.2-cm linear probe. Three different sonographers were used during the project. Each year, the sonographer that collected the images also interpreted the images of ultrasound fat thickness and UIMF measurements that were obtained. Ultrasound ribeye area measurements during yr 2 to 5 were also collected and interpreted by the same sonographer; however, ultrasound ribeye area measurements were not obtained during the first year of the project. The images taken to assess UIMF were interpreted using software developed by researchers at Iowa State University, Ames, Iowa. The ultrasound measurements for all traits were then linearly adjusted to 365 d according to regression coefficients proposed by Wilson et al. (1999) for yearling Angus bulls. Each year in
each herd, pairs of bulls were selected to create large differences based on their adjusted phenotypic yearling UIMF measurements. Selection of bulls was based solely on adjusted phenotypic yearling UIMF measurements.

In each of 5 yr, bulls were individually mated to between 14 and 30 commercial Angus females at the Northwest Georgia Branch Experiment Station, Calhoun. Females were randomly assigned to sires. Four bulls were used in the yr 1 of the project. Four new bulls entered the project in yr 2 and 4 of the project. Two and six new bulls entered the project in yr 3 and 5, respectively. Bulls were used for only one year, except for two of the original four bulls, one high and one low line bull, that remained throughout the entire project. Females were exposed to bulls in early April each year for approximately 90 d. Progeny were born in 1995 to 1999.

Actual birth and weaning weights were recorded on all calves. Bull calves were castrated at birth and implanted with 36 mg of zeranol (Ralgo, Schering-Plough Animal Health Corporation, Terre Haute, IN). Cows were grazed on Fescue pasture and were fed minerals ad libitum while the calves were at their sides. Calves remained with their dams until weaning. Steer calves were implanted with 100 mg of progesterone and 10 mg of estradiol benzoate (Synovex C, Syntex Animal Health Inc., Des Moines, IA) at 3 to 4 mo of age and again at weaning. After weaning, steer calves were developed on FESC pasture and received additional supplementation of approximately 50% rolled barley, 35% rolled corn, and 15% whole rolled soybeans at 1% of the steer’s body weight daily (as-fed basis). Steers also consumed fescue hay on an ad libitum basis. Steer calves were shipped to the feed yard at approximately 12 to 15 mo of age. Steers were implanted with 200 mg of trenbolone acetate and 28 mg of estradiol benzoate (Synovex Plus,
Syntex Animal Health Inc., Des Moines, IA) at the start of the finishing period. In the first year of the project, steer progeny were fed and slaughtered at University of Georgia facilities. After the first year, steer progeny were shipped to a commercial feedlot for finishing and slaughtered in a commercial slaughterhouse. Average age at slaughter was 392 d for yr 1 and a range of 514 to 576 d for yr 2 to 5. Carcasses during yr 1 were evaluated for USDA yield and quality grade factors by trained University of Georgia personnel; during yr 2 to 5 the same factors were evaluated on carcasses by USDA graders in the slaughter plants. The final data used in the analysis included 188 steer carcass records. Traits analyzed were carcass weight, fat thickness, ribeye area, marbling score, yield grade, and quality grade. The numerical marbling score was a subjective scoring system related to the amount of observable fat in the ribeye.

**Statistical Analyses**

Phenotypic UIMF measurements adjusted to 365 d were used to group bulls into high UIMF (HU) and low UIMF (LU) lines. The average UIMF, weighted by number of progeny per sire, was 3.75% (SD = 1.10 %) and 1.70% (SD = 0.53 %) for HU and LU line bulls, respectively. Carcass weight, fat thickness, ribeye area, and marbling score were linearly adjusted to 480 d of age at slaughter using the adjustment factors published for the Angus breed in the American Angus Association (AAA) Fall 2001 carcass evaluation (Wilson, 2001b). Age adjusted ribeye area, fat thickness, and carcass weight were used to calculate age adjusted yield grade, and age adjusted marbling score was used in the computation of age adjusted quality grade. The adjusted carcass traits were analyzed using the MIXED procedure of SAS, version 6.12 (SAS Inst. Inc., Cary, NC). The model used for analyses of all carcass traits measured in the progeny included fixed
effects for birth year of calf, phenotypic UIMF line of sire, and interaction between year and line. Sire, nested within year and line, was included as a random effect.

The available ultrasound measures of all yearling bulls that were collected in the purebred cooperator herds during the five years of the project were combined with other ultrasound records collected by the AAA. This data was then used to compute genetic values for ultrasound fat thickness, ribeye area, and intramuscular fat % during June 2001. The analysis procedures for the computation of ultrasound genetic values were outlined by Wilson (2001a). The current genetic evaluation of ultrasound traits by the AAA adjusts fat thickness and ribeye area for weight and age. Because a large proportion of the bulls had missing scan weights, we elected to conduct the genetic evaluation adjusting all ultrasound traits for age only. All bull ultrasound measurements were adjusted to 365 d and heifer ultrasound measurements were adjusted to 390 d and to a bull equivalent. The phenotypic UIMF line weighted average EPD and adjusted UIMF measurements are listed in Table 1.

The regression of steer carcass data on ultrasound EPD of sires was used to determine the impact of ultrasound EPD on progeny carcass measures. The carcass data were analyzed using the GLM procedure of SAS, version 6.12 (SAS Inst. Inc., Cary, NC). The model used for the regression of age adjusted carcass traits on ultrasound EPD of sires included fixed effect for birth year of calf and the covariate of ultrasound EPD of sire; where the carcass traits were adjusted to 480 d of age at slaughter using the adjustment factors published for the Angus breed in the AAA Fall 2001 carcass evaluation (Wilson, 2001b).
Results and Discussion

Overall means for 188 steer progeny by phenotypic UIMF line are listed in Table 2. Year of birth was highly significant for carcass weight, ribeye area, marbling score, and quality grade and significant for yield grade. Year x line interaction was significant for ribeye area.

Analyses by Phenotypic Ultrasound Intramuscular Fat % Lines

Least squares means for progeny carcass traits of the 20 bulls are listed by line in Table 3. Marbling score and quality grade were higher (P < 0.05) for HU calves than LU calves. In the steer progeny, ribeye areas of LU line were larger than HU line in four of the five years, and the effect of line was significant for ribeye area with HU having smaller ribeye area compared to LU. The genetic correlation between ultrasound intramuscular fat % and ultrasound ribeye area, summarized from published literature, averaged –0.07 (Bertrand et al., 2001). Bertrand et al. (2001) also reported an average genetic correlation of –0.01 between carcass ribeye area and marbling score from ten published literature reports. The fact that ribeye area was significantly larger for progeny sired by LU bulls compared to progeny sired by HU bulls may suggest that the correlation between ribeye area and marbling is more antagonistic than the literature suggests. Similarly, Gwartney et al. (1996) reported a tendency for ribeye areas to be larger in heifers and steers sired by bulls in a low marbling score EPD group compared to heifers and steers sired by bulls in a high marbling score EPD group when carcass traits were adjusted for days on feed, carcass weight, fat thickness, and marbling score.

Differences between phenotypic UIMF lines for fat thickness and yield grade in the steer progeny were found to be non-significant. The summarized genetic correlation
from published literature between ultrasound intramuscular fat % and ultrasound fat thickness averaged 0.08 and between carcass fat thickness and marbling score was 0.10 (Bertrand et al., 2001). The magnitude of these correlations suggests that you can select for marbling without increasing external fat. The results of this study also indicate that intramuscular fat % can be increased without increasing external fat. Our finding that neither fat thickness or yield grade was significantly different when selecting for increased marbling concurs with Gwartney et al. (1996) and Vieselmeyer et al. (1996). Both studies found that when sires were selected based on marbling score EPD fat thickness and yield grade in heifer and steer progeny were similar across the two marbling score EPD lines.

Analyses Using Ultrasound Expected Progeny Difference

The regression of carcass marbling score of steer progeny on ultrasound intramuscular fat % EPD of sires produced a highly significant regression coefficient of 90.50. The regression of carcass quality grade of steer progeny on ultrasound intramuscular fat % EPD of sires produced a highly significant regression coefficient of 49.20.

The effectiveness of direct selection using EPD has been demonstrated to improve growth traits (Hough et al., 1985; Mahrt et al., 1990), birth weight (Arnold et al., 1990; Lykins et al., 2000), and carcass traits (Gwartney et al., 1996; Vieselmeyer et al., 1996; Bertrand et al., 1997) in beef cattle. Traditional carcass evaluation programs have utilized carcass data produced from a structured sire progeny testing program. As elucidated by Wilson (1992), carcass progeny testing programs are costly in time and expense. Therefore, Wilson (1992) proposed that yearling live-animal ultrasound
measurements of carcass traits in seedstock cattle be included in national cattle evaluation programs to decrease cost and generation interval. However, the usefulness of ultrasound for improving carcass merit will be dependent on the magnitude of the genetic relationship between ultrasound measures of carcass traits in seedstock cattle and the corresponding carcass measures in fed slaughter cattle. Reports by Bertrand et al. (2001) and Devitt and Wilton (2000) reported genetic correlations between ultrasound intramuscular fat % in seedstock cattle and marbling score in fed slaughter cattle of 0.70 and 0.88, respectively. Reverter et al. (2000) used data from Australian Angus and Hereford cattle to estimate within breed genetic parameters between carcass measures from steers and heifers and 15 mo ultrasound measures from bulls and heifers. Near-infrared spectroscopy was used to measure intramuscular fat % in slaughter cattle in the abattoir. The genetic correlation for Angus slaughter carcass and ultrasound bull measures for intramuscular fat % was 0.47, and the same correlation involving Hereford slaughter carcass and ultrasound bull measures for intramuscular fat % was 0.28. The same genetic correlation involving slaughter carcass and seedstock ultrasound measures for intramuscular fat % within the same breed was 0.46 for Angus heifers and 0.93 for Hereford heifers.

To our knowledge, no previous report has shown that actual selection of yearling bulls based on phenotypic intramuscular fat % produces marbling score differences in their slaughter steer progeny. Our findings indicate that for every 1% difference between the intramuscular fat % EPD of bulls results in a 90.50 marbling score difference in the progeny. The range in ultrasound intramuscular fat % EPD for all animals was –0.59% to 0.78% in the AAA Fall 2001 body composition evaluation (Wilson, 2001a). This
range in intramuscular fat % EPD would equate to a possible range of 124 marbling score unit difference in the resulting progeny. It is interesting to note that the range in marbling score EPD (–0.66 to 0.77) of sires in the AAA Fall 2001 carcass evaluation program (Wilson, 2001b) would equate to a possible range of 143 marbling score unit difference in the resulting progeny. This may imply that ultrasound intramuscular fat % EPD predicted from yearling seedstock data provides similar genetic potential for changing marbling score in slaughter progeny when compared to marbling score EPD predicted from actual slaughter cattle.

The regression of carcass fat thickness of steer progeny on ultrasound fat thickness EPD of sires produced a regression coefficient of 1.19 with a p-value of 0.13. Yield grade of steer progeny regressed on ultrasound fat thickness EPD of sires produced a significant regression coefficient of 2.70. The regression of fat thickness of steer progeny on ultrasound fat thickness EPD of sires was close to 1.0. Bertrand et al. (1997) expressed concerns that small differences in ultrasound fat thickness EPD could translate to far larger external fat differences in steer progeny. The regression estimate in the current study does not support this concern. However, this concern could be still be valid for breeds that have lower amounts of external fat thickness in yearling bulls compared to Angus. The range in fat thickness EPD of sires in the AAA Fall 2001 carcass evaluation (Wilson, 2001b) was 0.46 cm. The range in ultrasound fat thickness EPD of all animals from the AAA Fall 2001 body composition evaluation (Wilson, 2001a) was also 0.46 cm. Again, this may imply that fat thickness EPD predicted from yearling seedstock data provides similar genetic potential for changing external fat in
slaughter progeny when compared to fat thickness EPD predicted from actual slaughter cattle.

Carcass ribeye area of steer progeny regressed on ultrasound ribeye area EPD of sires produced a regression coefficient of 0.40. However, it may be difficult to draw definite conclusions from this result because bulls measured in yr 1 had no ultrasound ribeye area measurements. This resulted in four bulls, including the two bulls that were used each year of the project, which had a pedigree only ultrasound ribeye area estimate. It is encouraging that the regression coefficient is positive; thus suggesting that ultrasound ribeye area EPD would improve ribeye area in slaughter progeny.

**Implications**

Yearling Angus bulls selected for high phenotypic ultrasound intramuscular fat % or phenotypic ultrasound intramuscular fat % expected progeny difference can be expected to produce steers with significantly higher amounts of marbling and quality grade. It also appears that marbling can be increased without corresponding increases in external fat thickness and yield grade. This implies that ultrasound intramuscular fat % should be included in genetic evaluation programs to allow producers to select animals that can influence degree of marbling in slaughter progeny at a younger age.

**Literature Cited**


Table 1. Phenotypic ultrasound intramuscular fat % (UIMF) line weighted average EPD, adjusted UIMF measurements, and standard deviations (SD)

<table>
<thead>
<tr>
<th>Phenotypic UIMF Line</th>
<th>High SD</th>
<th>Low SD</th>
<th>BA&lt;sup&gt;a&lt;/sup&gt; SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. sires</td>
<td>9</td>
<td>11</td>
<td>__</td>
</tr>
<tr>
<td>UIMF EPD, %</td>
<td>0.18</td>
<td>-0.22</td>
<td>0.01 0.11</td>
</tr>
<tr>
<td>UIMF, %</td>
<td>3.75</td>
<td>1.70</td>
<td>3.49 0.82</td>
</tr>
</tbody>
</table>

<sup>a</sup>Breed average, breed average for Angus cattle evaluated in the AAA Fall 2001 body composition evaluation (Wilson, 2001a).
Table 2. Phenotypic means and standard deviations (SD) by phenotypic ultrasound intramuscular fat % (UIMF) line

<table>
<thead>
<tr>
<th>Phenotypic UIMF Line</th>
<th>High</th>
<th>SD</th>
<th>Low</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. progeny</td>
<td>96</td>
<td></td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>CW(^1), kg</td>
<td>344.58</td>
<td>41.30</td>
<td>341.28</td>
<td>38.56</td>
</tr>
<tr>
<td>FAT, cm</td>
<td>1.55</td>
<td>0.41</td>
<td>1.55</td>
<td>0.43</td>
</tr>
<tr>
<td>REA, cm(^2)</td>
<td>75.90</td>
<td>7.06</td>
<td>78.43</td>
<td>9.15</td>
</tr>
<tr>
<td>MS(^b)</td>
<td>430.89</td>
<td>86.40</td>
<td>400.41</td>
<td>75.02</td>
</tr>
<tr>
<td>YG, %</td>
<td>3.55</td>
<td>0.64</td>
<td>3.40</td>
<td>0.72</td>
</tr>
<tr>
<td>QG(^c)</td>
<td>598.19</td>
<td>43.78</td>
<td>580.91</td>
<td>46.61</td>
</tr>
</tbody>
</table>

\(^1\)CW = carcass weight; FAT = fat thickness; REA = ribeye area; MS = marbling score; YG = yield grade; QG = quality grade; where the carcass traits were linearly adjusted to 480 d of age at slaughter.

\(^b\)300 – 399 = slight, 400 – 499 = small, 500 – 599 = modest.

\(^c\)500 – 599 = Select, 600 – 699 = Choice.
Table 3. Least squares means for carcass traits of progeny by phenotypic ultrasound intramuscular fat % (UIMF) line

<table>
<thead>
<tr>
<th>Phenotypic UIMF Line</th>
<th>High</th>
<th>Low</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CW&lt;sup&gt;a&lt;/sup&gt;, kg</td>
<td>335.58 ± 5.08</td>
<td>337.90 ± 4.36</td>
<td>-2.32 ± 6.70</td>
</tr>
<tr>
<td>FAT, cm</td>
<td>1.54 ± 0.06</td>
<td>1.53 ± 0.05</td>
<td>0.02 ± 0.08</td>
</tr>
<tr>
<td>REA, cm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>74.89 ± 0.85</td>
<td>77.86 ± 0.72</td>
<td>-2.97 ± 1.11*</td>
</tr>
<tr>
<td>MS&lt;sup&gt;b&lt;/sup&gt;</td>
<td>452.36 ± 11.76</td>
<td>408.16 ± 10.15</td>
<td>44.19 ± 15.53*</td>
</tr>
<tr>
<td>YG, %</td>
<td>3.50 ± 0.09</td>
<td>3.38 ± 0.08</td>
<td>0.12 ± 0.12</td>
</tr>
<tr>
<td>QG&lt;sup&gt;c&lt;/sup&gt;</td>
<td>607.97 ± 6.25</td>
<td>585.09 ± 5.39</td>
<td>22.87 ± 8.26*</td>
</tr>
</tbody>
</table>

<sup>a</sup>CW = carcass weight; FAT = fat thickness; REA = ribeye area; MS = marbling score; YG = yield grade; QG = quality grade; where the carcass traits were linearly adjusted to 480 d of age at slaughter.

<sup>b</sup>300 – 399 = slight, 400 – 499 = small, 500 – 599 = modest.

<sup>c</sup>500 – 599 = Select, 600 – 699 = Choice.

*(P < 0.05).*
CHAPTER IV

CONCLUSIONS

Carcass traits are moderately to highly heritable, but direct selection of carcass traits require progeny tests which are time consuming, expensive, and subject to selection bias. In general, heritability estimates for ultrasound measurements of fat thickness, longissimus muscle area and intramuscular fat percentage in breeding cattle are lower than reported heritabilities for carcass traits of fed cattle. Even though there are only a few literature reports on the genetic relationship between ultrasound measurements of breeding cattle and carcass measurements of finished cattle, there appears to be a favorable relationship between ultrasound and carcass measurements. Selecting yearling Angus bulls based on high phenotypic ultrasound intramuscular fat percentage or ultrasound intramuscular fat percentage expected progeny difference can be expected to produce steers with significantly higher amounts of marbling and quality grade. It also appears that marbling can be increased without corresponding increases in external fat thickness and yield grade. This implies that ultrasound intramuscular fat percentage should be included in genetic evaluation programs, allowing producers to select animals that can influence degree of marbling in slaughter progeny at a younger age.