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Evaluating the Relationship between Ultrasound-derived Carcass Characteristics and Production Traits in Angus Cattle

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I am submitting herewith a thesis written by William Michael Mayfield entitled "Evaluating the Relationship between Ultrasound-derived Carcass Characteristics and Production Traits in Angus Cattle." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

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Evaluating the Relationship between Ultrasound-derived Carcass Characteristics and Production Traits in Angus Cattle

A Thesis

Presented for the

Master of Science Degree

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William Michael Mayfield

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Dedication

This thesis is dedicated to my family as they have made me who I am today and it is they that have given me the tools to accomplish the milestones I have thus far. To my grandparents, parents, sister, and brother, thank you for your help as this would not have been accomplished without your love and support.

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Abstract

Profitability in the beef industry is a crucial aspect of management schemes. The overall aim of this study was to determine if carcass ultrasonography in replacement heifers could explain variation in traits such as reproduction, a major factor in beef cattle efficiency and profitability. During a 10-year period, data were obtained from 906 yearling heifers through the use of carcass ultrasonography. The measurements collected included adjusted values for ribeye area (REA), percent intramuscular fat (%IMF), rib fat (RF), and rump fat. A retrospective analysis was performed on data collected and variables were separated into the extreme high and low 25% and the median 50%. Analysis examined whether a relationship existed between reproductive traits (percentage calving at two years of age, age at first calving, first calving interval, lifetime calving interval) and carcass measurements determined by ultrasonography.

Age at first calving increased as ribeye area increased (Low REA 731.7±3.1 d; High REA 743.5±3.3 d; P=0.002). Rib fat was also related to age at first calving as heifers in the high grouping were approximately 9 days older at calving (Low RF, 734.5±3.1 d; High RF, 743.7±3.2 d; P=0.008). Expected progeny differences (EPD) for carcass traits such as REA also indicated differences between all three groups for age at first calving (Low REA EPD, 727.4±3.1 d; Med, 736.3±3.2 d; High, 746.2±3.2 d; P<0.0001). Observation of marbling EPD's resulted in a difference of 10 days for age at first calving between the high and low groups (Low MARB EPD, 734.4±3.1 d; High, 744.0±3.2 d; P=0.002). Interval from first to second calving (Low RF, 374.3±3.2 d; High RF, 361.7±3.5 d; P=0.014) and average lifetime calving interval (Low RF, 369.9±1.8 d;

High RF, 362.8±2.1d; P=0.048) were both correlated with adjusted rib fat. Evaluation of longevity (birth date to date of last calving) established that heifers with a higher carcass EPD for REA remained in the herd for an additional 7.2 months (Low REA EPD, 39.8±4.2 mo.; High REA EPD, 47.0±4.2 mo.; P=0.023). Ultrasonography-derived carcass measurements and calculated carcass EPDs may be used as potential tools to predict reproductive soundness of a replacement heifer before being retained in the herd.

Keywords: carcass, ultrasonography, ribeye area, intramuscular fat

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Chapter 1
Introduction

As the population of the world is projected to exceed 9 billion people in the year 2050 (Bureau, 2008), will agriculture be able to feed this ever-increasing population? Can beef producers feed 2 billion more people with only 38 calf crops as a window of opportunity for advancement? Is new technology in place for the improved efficiency needed by current and future producers to meet this demand? These are just a few of the many questions that are being directed toward animal agriculture and future research directions.

Two events must take place for the feasibility of carcass improvement to be adopted into production systems. First, seedstock producers must be provided an economic incentive to justify the use of carcass ultrasonography. Secondly, the process must be cost-effective and accurate (Wilson, 1992). With this in mind, the use of carcass ultrasonography must identify beneficial attributes for whole herd improvement, such as carcass quality, productivity, and performance. Arnold and co-workers (1991) reported that measures of longissimus muscle area, rib fat thickness, and marbling are currently received from carcass ultrasonography. This information, along with the knowledge that the livestock industry is moving closer to the value-based system adopted in the early 1990s, has become of great importance for carcass trait predictability (Houghton and Turlington, 1992). Heritability predictions for these traits (ribeye area, rib fat, and marbling) will be essential before ultrasound technology can be incorporated into national genetic program utilized for assisted selection. Of even more importance will be the understanding of how phenotypic, genetic, and environmental relationships among a variety of production types are related to carcass measurements. Without this knowledge, selection for carcass merit in breeding stock using ultrasonography may have unforeseen consequences on other traits of importance including growth, and reproduction (Arnold et al., 1991).

Studies have reported half-sibling data to evaluate growth traits for seedstock (Arnold et al., 1991; Perkins et al., 1992), while others have used ultrasound data to produce groups of cows fed to compositional similarity then harvested as a means to measure energy stores (Bullock et al., 1991). However, the use of live animal ultrasonography and utilization of lifetime production records have not been evaluated for fertility and longevity. The current question in this thesis is whether data from carcass ultrasonography obtained from yearling heifers relate to future fertility and production.

Past reports have indicated that use of half-sib carcass data for young breeding animals may have different relationships with growth and muscling than the steers from which the measures were taking (Arnold et al., 1991). The hypothesis for this thesis is that relationships exist between ultrasound measures of carcass characteristics and longevity (performance/reproduction). If relationships between ultrasound measured carcass traits and reproductive parameters exist, these relationships may aid in selection of replacement animals. An additional value of this study will be the initiation of complete data compilation from multiple research and education centers for future genomic studies.

Chapter 2
Literature Review

From the time cattle were introduced to North America, the beef cattle industry has changed immensely due to necessity and selection for efficiency. It has developed into an expansive $74 billion dollar industry as reported in 2010 that has decreased to 91 million head of cattle as of January 1, 2012, from 130 million head in 1975 (United States Department of Agriculture, 2011). As this economically beneficial industry has multiplied in value over time, cattle numbers are continuing to diminish and added efficiency is needed to meet consumer demand. An ever-increasing world population, expected to exceed 9 billion in the year 2050 (Bureau, 2008), has placed an added emphasis for rapid improvement in livestock production. Technological advances have made this possible as research allowed for the identification of numerical genetic rank to aid in selection.

2.1 Expected Progeny Differences

These numerical ranks are known today as Expected Progeny Differences (EPDs) and were first introduced in the 1960s; however, it was not until the 1970s that computational devices were sufficient enough to evaluate the massive data needed for accuracy and confidence (Pfizer, 2011). As reviewed by Greiner (2009), EPDs are calculated using performance data, pedigree information, information from collateral animals (siblings), and progeny data. Expected Progeny Differences offer beef producers an opportunity to improve genetics within their herds through sire selection (Greiner, 2009). The use of an EPD for any given trait to advance accuracy of sire selection for dam mating is a tool that can be invaluable in production. Use of EPDs provide an advantage for a producer who may desire to select for specific traits needed to improve their individual operation or fit their specific environment. Given this more efficient means of selection, genetic progress and improvement may be made in a shorter period of time allowing a production system to thrive into the future.

2.2 Breeding Values

Breeding values (BV) encompass a wide range of traits in several species of livestock. They are offered for swine, sheep, as well as several breeds of dairy and beef cattle. In swine, indices exist such as, terminal sire index (TSI), sow production index (SPI), and maternal line index (MLI). These indices allow a producer to fit a marketing and production scheme with the swine type necessary for a certain scenarios. These indices are primarily revenue or output driven; whereas, $value indices are produced as an output-based derivative for production. These indices are geared towards commercial producers as an economically-relevant selection tool for determining sires for a producer's production system. While these values have much potential for improving means of selection for many livestock species and breeds of cattle one must still take into account the components used in developing an index as well as the assumptions involved (Northcutt, 2006).

While, EPDs and breeding values are in use today, the beef industry must look forward toward the future. The possibility is there just as Arnold and co-workers stated in 1991 "we have the carcass values, but will they relate to something unseen." Can these productive genetic indicators (EPD and BV) be related to reproduction and longevity? This possibility for a new method of selection will provide greater efficiency and improve profitability for producers in the future.

2.3 Artificial Insemination

As selection processes are evolving, the techniques for improved efficiency are growing and advancing themselves. Among these techniques is artificial insemination (AI) which was first successfully performed by Lazzaro Spallanzani in 1784 when he successfully inseminated a dog (Foote, 2002). Walter Heape followed Spallanzani after the passing of a century using AI in many species including rabbits, dogs, and horses (Foote, 2002). Following this, a development from Russia in 1899 led to Ily Ivanoff's first use of AI in a study involving domesticated farm animals (Foote, 2002). This technology has now been commercially available for approximately 85 years and remains one of the most important assisted reproductive technologies due to its simplicity and success (Vishwanath, 2003). Artificial Insemination has given producers a way for advanced genetic improvement and the growth of 70 million inseminations from 1980 to 1995 is an indicator of that desire for improved genetics (Vishwanath, 2003). While being a cornerstone for genetic improvement, AI has been challenged as the optimal assisted reproductive technology since embryo transfer will allow for a faster rate of genetic progress.

2.4 Embryo Transfer

Walter Heape, along with his influences on the development of artificial insemination, is also known as the 'patron saint' of embryo transfer (ET; Betteridge, 1981). This title is given to Heape due to his success for the first recorded ET in 1890 of two Angora rabbit embryos in to a Belgian doe (Heape, 1890; 1897). Even with Heape's success, it was not until the 1930s that ET was utilized in food animals (Rowson and Moor, 1966). This assisted reproductive technology is widely used today and has improved efficiency for proliferation of quality genetics. Over a lifetime of super stimulation and embryo collections, a donor can ovulate hundreds of her potential 150,000 ova, resulting in potentially hundreds of calves compared to a non-stimulated cow producing only 8-10 calves in a lifetime (Selk, 2002). The proficiency of this process has aided producers economically by improving the genetic worth of their cattle.

2.5 Sexed Semen

Sex of the offspring; is a major economic factor in livestock production systems. Whether it is a dairy trying to produce females for milk or a beef producer trying to put pounds of calf on the ground, optimizing selection of the desired sex of the offspring is important. The technology of sex semen is one that can make production schemes extremely more efficient. This technology was discovered by accident when the Lawrence Livermore National Laboratory (LLNL) was studying the health effects of radiation on humans using mouse sperm as a model to indicate the damage to the germ-line DNA. However, in the initial phase of the study, their results were not able to be interpreted because of the flattening of sperm heads during this process (Gledhill et al., 1976; Van Dilla et al., 1977; Garner and Seidel, 2008). A solution to this problem was development of a flow cytometer that would orient sperm so that a measurement could be taken with these deceased or damaged sperm (Pinkel et al., 1982; Garner and

Seidel, 2008). This development also allowed the potential use of the flow cytometer for identifying X- and Y- sperm populations based on their differing DNA contents. In 1989, Johnson and co-workers first reported the sorting by sex of live sperm with Hoechst 33342, a fluorescent dye (Johnson et al., 1989; Garner and Seidel, 2008). These dyed sperm then are sorted with laser technology by their relative fluorescence with a 90% accuracy in sex determination of the sperm (Seidel, 2003). As efficiency of semen sorting improves, this assisted reproductive technology will be utilized heavily in the future in numerous production systems.

2.6 Carcass Evaluation

The evaluation of beef carcasses was first performed with grids and calipers for gauging the different sections of the carcass such as ribeye area (REA), rib fat (RF), marbling (MARB), and rump fat. These measurements were collected as an estimate of carcass quality and yield, measurements that determine value. Producers and researchers have utilized a variety of means to obtain carcass information. The use of actual carcass measures from progeny was initially analyzed through a genetic evaluation program to produce EPDs for seedstock. These measures were too expensive from an economical ($5,000-10,000) as well as time standpoint (4-7 years). Because of these constraints, few bulls were tested; thus, leading to low accuracies and few meaningful EPDs (Hicks, 2011). This opened the door for a new technology, carcass ultrasonography.

2.7 Carcass Ultrasonography

Carcass composition is a very important factor when determining value in the beef industry and the process of carcass ultrasonography has revolutionized the collection of carcass values. The use of ultrasonography in the livestock industry for estimating compositional differences was first noted in 1958 and has now been used in the beef industry for more than 50 years (Houghton and Turlington, 1992). The use of ultrasound technology was developed as an alternative to the telescoping probe developed for measuring carcass composition in livestock animals as review by Soberon (2010). In 1969, Stouffer made this thought a reality when he patented the Scanogram, a carcass transducer capable of measuring key carcass traits used in determining carcass value such as ribeye area (REA), percent intramuscular fat (%IMF), rib fat (RF), and rump fat (Soberon, 2010). The measurement for REA, in square inches, is collected between the 12th and 13th rib and is used to estimate the amount of muscle and lean product in the animal. Rib fat and rump fat are determined between the 12th and 13th rib and from hooks to pins, respectively; and represent external fat and actual cutability (red meat yield) of the animal. Hicks (2011) reported that marbling (%IMF) was an objective measure of internal fat in the longissimus dorsi muscle and provided an indication of palatability and estimate of USDA quality grade.

Comparatively, the use of live animal ultrasound is a more efficient process that allows producers a means to select for optimal carcass traits in seedstock for future genetic development. The use of ultrasonography evades problems associated with attaining actual carcass measurements listed by Wilson (1992). Carcass ultrasound eliminated necessity of the expensive and timely process of progeny testing and allowed for easier data collection without the logistical issues of a processing facility (Wilson, 1992). However, limitations for this technology include the precision of carcass measures. The accuracy of the longissimus muscle area (LMA), RF, and rump fat collected with live animal ultrasound has been evaluated (Robinson et al.; 1992). The results of this study indicate that measurements of fat depth can be measured as accurately with ultrasound as on the carcass and that the best technicians are only marginally less accurate for LMA; whereas, carcass rump fat depths were about 85% of scan measurements (Robinson et al., 1992). These data support the industry acceptance of carcass ultrasonography and its usefulness in selection.

2.8 Indications of Efficiency

Efficiency is not only indicated by production performance, but also by economics in the beef industry. An improvement in efficiency can be gained with the use of live animal carcass ultrasound.

In 2002, Crews and Kemp, reported on the supplemental use of ultrasound-derived carcass data and the accuracy it added to carcass breeding values. Utilizing live weights and ultrasound measures for fat thickness and REA on 404 yearling bulls, 514 heifers, and 235 steers, helped increase accuracy of carcass trait breeding values for carcass weight, REA, and fat thickness by 91, 75, and 51%, respectively (Crews and Kemp, 2002) . Thus, allowing seedstock and commercial producers alike a greater degree of selection for carcass based traits.

Using 2,411 Hereford steers to determine growth traits in beef cattle, Arnold and co-workers (1991) reported heritability estimates for RF, REA, and MARB to be 0.49, 0.46, and 0.35, respectively. Furthermore, high correlations were observed between %IMF and total post weaning average daily gain (ADG; 0.54) and feedlot relative growth rate (0.62; Arnold et al., 1991). This information allows producers to select for genetic lines of highly marbled animals to increase their rate of gain and growth. However, the results also indicated that carcass fat on slaughter steers and ultrasound measures of rib fat on young breeding heifers may potentially have different relationships with growth and muscling. Arnold and co-workers (1991) expressed the need for caution and more knowledge of carcass merit for breeding stock through ultrasonography as it may have unforeseen consequences in other traits such as growth, carcass, and reproduction.

Through personal communication, Dr. Rhinehart (2012), labeled whole herd efficiency as pounds of calves' weaned as a percentage of pounds of cows exposed. This definition is very economical as well, since the more pounds that are weaned per pound of cow would generate more income. With this definition in mind, one must determine how it can be achieved and how carcass ultrasonography could supplement this process. Thus, the objective of this thesis is to examine the relationship of live animal ultrasonography to fertility and longevity in seedstock production systems.

Chapter 3
Materials and Methods

3.1 General

During a 10-year period, 906 yearling Angus heifers were utilized for ultrasonic carcass measurements as required by best management practices of the University of Tennessee Institute of Agriculture Research and Education Centers. A portion of these animals were deleted from analysis due to incomplete (lacking in records, death, sold bred, etc.) data collection or entry. Of these heifers, 741 were utilized in the current study, obtained from the East Tennessee Research and Education Center (ETREC; n=500) and the Plateau Research and Education Center (PREC; n=241). Management practices at these two research and education centers were similar with spring calving herds (January 1- March 15); calves weaned at 6 -8 months of age, vaccinated according to the standard operating procedure and provided feed, mineral and water ad libitum. Following weaning, heifers were placed on endophyte infected tall fescue pastures with clover and supplemented (corn silage, 12% crude protein supplement, and hay) as determined by personnel at each research and education center. Carcass traits such as ribeye area (REA), % intramuscular fat (%IMF), rib fat (RF), and rump fat (Arnold et al., 1991) were determined for each heifer at 11-13 months of age using ultrasonography by a CUP certified ultrasound technician.

Prior to breeding at 13-15 months of age, heifers were supplemented as discussed in the previous section with cottonseed meal (ETREC) or corn silage and available protein (PREC). Heifers were bred utilizing a timed artificial insemination (TAI) protocol (7-day Co-Sync). Within 14 to 21days after TAI, heifers were placed with a calving ease bull for approximately 50-days, resulting in a 65-day breeding season. Initial pregnancy determination was performed at approximately 30-35 days following TAI with a 7.5 MHz linear transducer (Aloka 500). At approximately 6 months of gestation, heifers were checked by rectal palpation using trained individuals as a final pregnancy diagnosis.

With similar management practices, differences observed in the initial evaluation of independent variables were widespread over the period of data collection. As illustrated in Figures 3.1, 3.2, and 3.3, considerable variation is apparent between the two research and education centers during the 10-year period of data collection for REA, %IMF, and RF, respectively. Differences demonstrate the wide range of conformational and biological types in these two Angus herds.

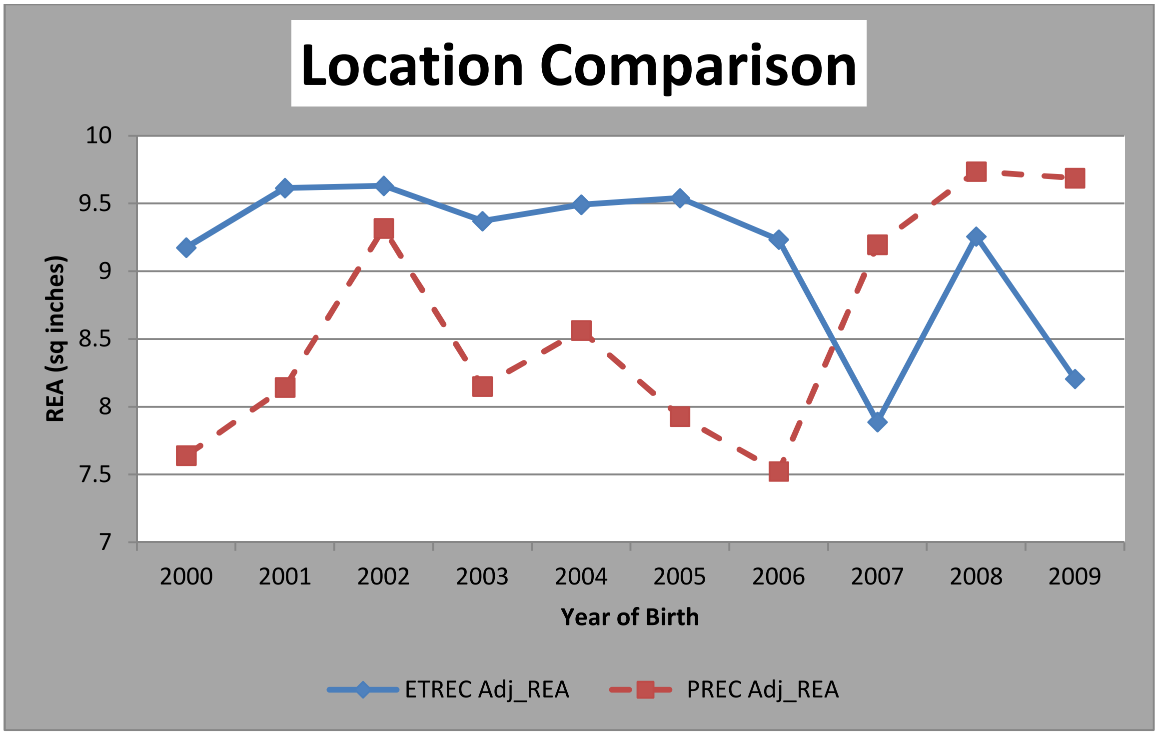

Figure 3.1. Location Comparison for mean Adj_REA.

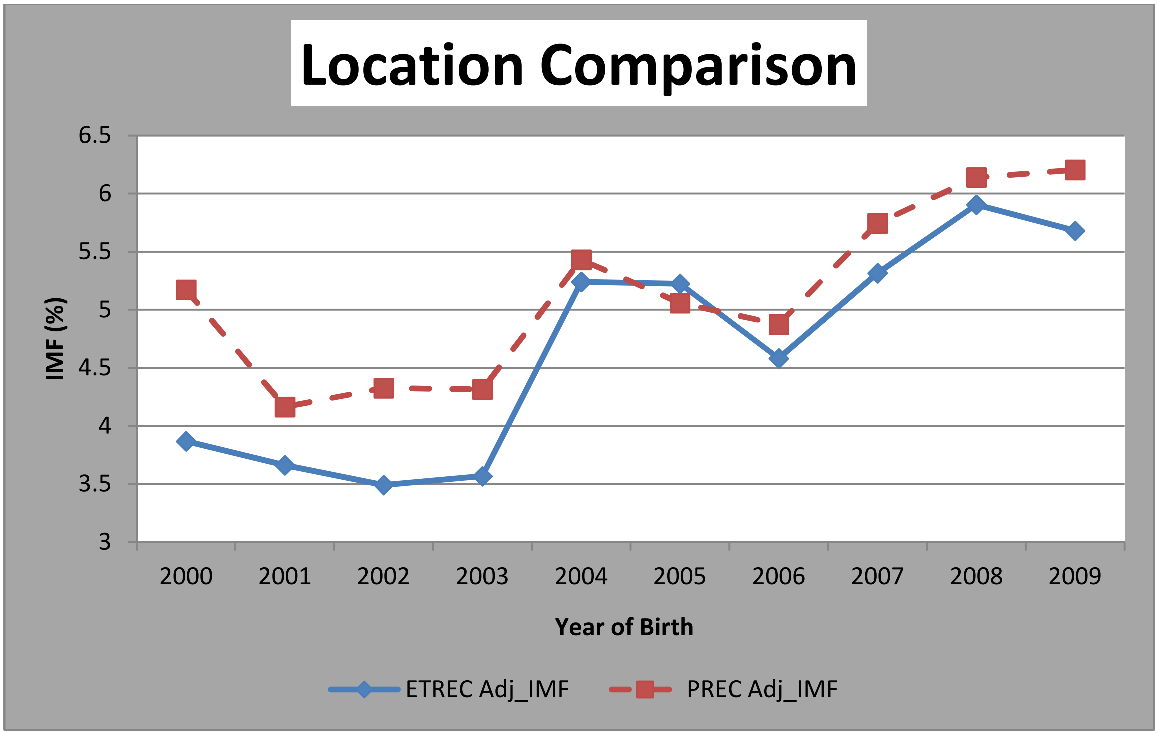

Figure 3.2. Location Comparison for mean Adj_IMF.

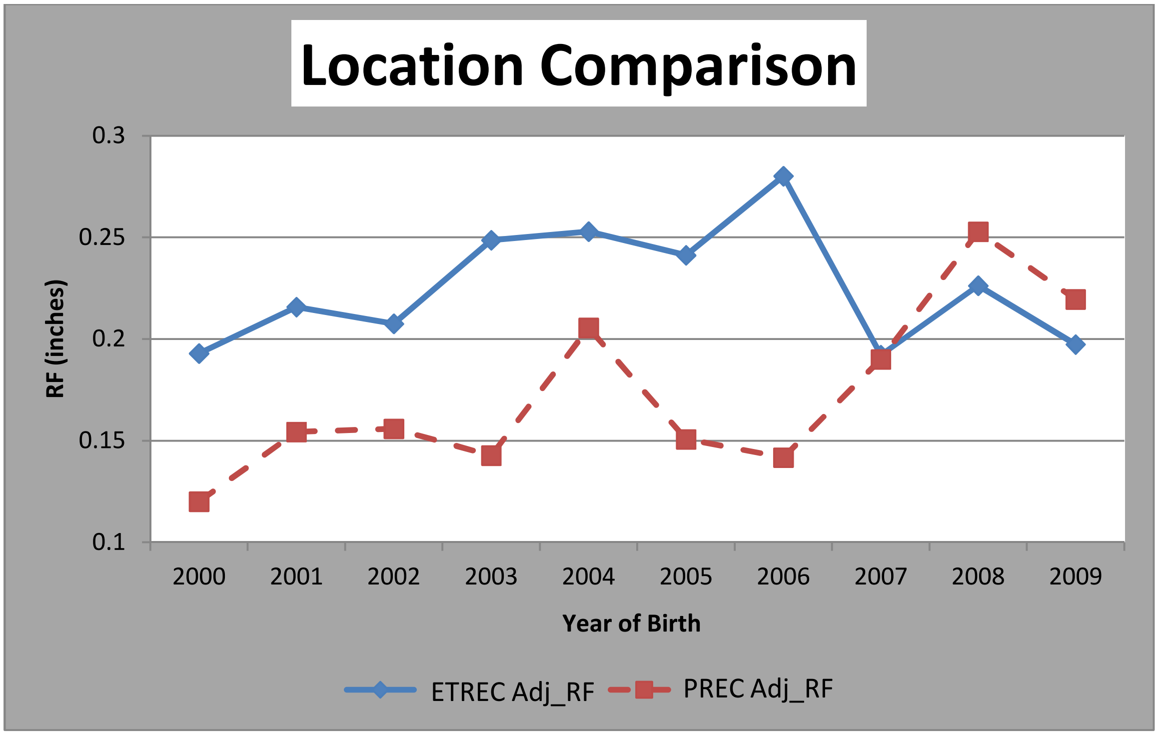

Figure 3.3. Location Comparison for mean Adj_RF.

3.2 Carcass Ultrasonography

Through the use of carcass ultrasonography performed by a certified technician from the Centralized Ultrasound Processing (CUP) laboratory and the utilization of Iowa State University's CUP software, actual measurements of ribeye area (REA), intramuscular fat (%IMF), rib fat (RF), and rump fat were obtained. These measures were achieved through images collected utilizing an Aloka 500 ultrasonography unit with a 3.5 MHz transducer with a carcass stand-off. The images were collected at distinct locations on the animal's body as the measure for REA (in square inches) and RF (in inches) were recorded over the 12th and 13th rib. Percent intramuscular fat was measured in a similar area, but in a horizontal rather than vertical fashion. Rump fat was then measured in the area between the hooks and pins. (See Figure 3.4)

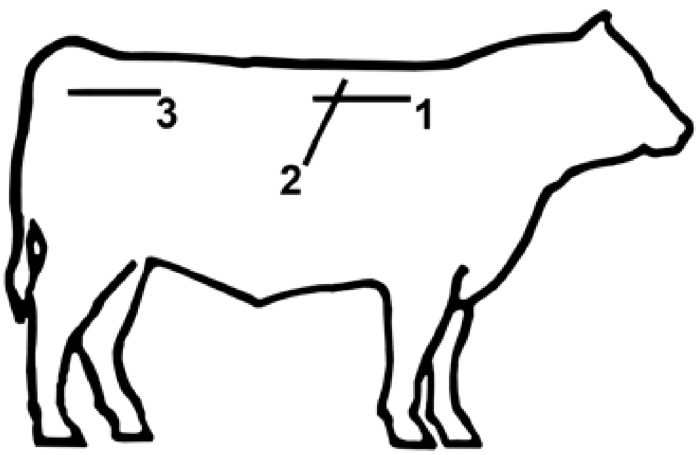

Figure 3.4 Ultrasound measuremetns are collected at three points on the animal (Hicks, 2011).
1 - Percent intramuscular fat
2 - Ribeye area and backfat
3 - Rump fat

After images were recorded by the CUP certified technicians, image files were sent to the CUP laboratory to be measured and adjusted for the animal's age and weight.

3.3 Data Collection and Statistical Analysis

Data pertaining to annual performance were collected from the American Angus Association (AAA) database, the Angus Information Management Software (AIMS), or derived from recorded values in the project datasheets maintained at each research and education center.

A retrospective analysis was performed using independent variables for analysis which are defined in sections B and C of Table 3.1. The ranges of HIGH 25%, MED 50%, and LOW 25% were produced in SAS using a proc univariate to establish the ranges for the new variables, then ranges were placed into 'if then' statements for the creation of the new variables. Adjustments were also made to birth weight, weaning weight, and yearling weights of the calves for age of dam and sex of the calf.

Ranges of high, medium, and low allowed for supplementary explanation of statistical means. These ranges allowed for the evaluation of the extreme values both low and high, as well as the medium values that helped exhibit the nature of the relationship to average means.

In general, data were analyzed as a randomized block design (RBD) with fixed effects of location and the carcass or EPD treatment groups, and random blocking effects of year using the mixed model procedure (SAS 9.3, SAS Inst., Inc., Cary, NC, USA). Data were tested for normality (Shapiro-Wilk $W \geq 0.90$), and treatment differences were determined using Tukey's highly significant difference protected least significant differences, reported as least square means ± standard error of means (SEM). Variables utilized are listed in table 3.1, with the addition of sire, year, and location. The use of adjusted carcass data for analysis was preferred and presented over actual carcass data since adjusted carcass data are most commonly used in the beef industry. Sire was subsequently dropped from analysis, as it gave a skewed distribution of the number of cows per sire. Adjusted Rump Fat was also removed from the model as a very high correlation (r=0.74) was observed with Adjusted rib fat, which indicated they would be likely to explain the same dependent variables. Following adjustments to the model, all dependent variables were again performed using a general linear model (GLM) with location and year as fixed variables allowing for R-squared values for reporting purposes.

Table 3.1 Variables and Ranges (Upper 25%, Med 50%, Lower 25%)

A. Descriptive Variables					Data Source
	Low	Medium	High	Mean	
Weight (kg)	578-740	741-847	848-1005	340.86	AAA, AIMS
B. Adjusted Values for Carcass Ultrasound					
REA (sq. in)	5.6-8.2	8.3-9.8	9.9-12.1	9.0	AAA, AIMS
IMF (%)	2.03-3.99	4.00-5.71	5.72-9.14	4.88	AAA, AIMS
Rib_Fat (in)	0.07-0.16	0.17-0.25	0.26-0.47	0.21	AAA, AIMS
Rump_Fat (in)	0.09-0.22	0.23-0.33	0.34-0.62	0.28	AAA, AIMS
C. Carcass EPDs					
REA_EPD	(-0.56)-0	0.01-0.25	0.26-0.71	0.13	AAA, AIMS
Marb_EPD	(-0.21)-0.14	0.15-0.41	0.42-0.91	0.28	AAA, AIMS
Fat_EPD	(-0.056)-(-0.014)	(-0.013)-0.012	0.0124-0.075	(-0.00047)	AAA, AIMS
D. Dependent Variables					
Calved (Y/N; %)	-	-	-	76.11	AAA, AIMS
Totalcalves	0-1	2-3	4-10	2.16	AAA, AIMS
Age at First Calving (d)	661-721	722-755	756-819	741.66	Derived
First Calving Interval (d)	307-348	349-387	388-440	368.46	Derived
Lifetime Calving Interval (d)	307-359	359.33-374	374.2-430	366.71	Derived
Longevity (mo.)	19-23	24-50	51-72	41.70	Derived
BW (kg)	21-31	32-36	37-50	33.58	Derived
WW (kg)	172-267	268-302	303-455	285.22	Derived
YW (kg)	324-352	408-446	478-974	417.39	Derived

Chapter 4
Results and Discussion

4.1 Percentage of Heifers Calving at Two Years of Age

Evaluation of adjusted carcass measurements obtained with ultrasonography indicated no difference in the percentage of Angus heifers that calved at approximately two years of age (Table 4.1). Regardless of grouping (High 25, Med 50, Low 25), neither adjusted REA, %IMF, nor rib fat significantly impacted percentage of heifers calving at 2 years of age (Table 4.1). Furthermore, analysis of carcass EPD values for REA, marbling (MARB), and fat also showed non-significance as related to the percentage of heifers calving at two years of age (Table 4.1).

Numerous studies have reported estimates of genetic or phenotypic parameters for reproductive, growth, or carcass data, but few have reported estimates of relationships among these groups of traits as stated by Splan and co-workers (1998). Splan and co-workers (1998) detailed in their study that the genetic relationship between RATE (Heifer calving rate) and the actual carcass values of their half-sibling steers to be low. These correlations between RATE and REA, adjusted fat thickness (AFAT), and marbling score (MARB) were 0.15, 0.19, and -0.05, respectively; thus, establishing a small relationship between carcass data and heifer calving rate. Information presented by Splan et al. (1998) agrees with results in the present study indicating that ultrasound-derived carcass measurements, collected at approximately a year of age, was not related to the percentage of heifers calving at two years of age.

Present results also suggest the lack of warranty for using carcass EPD information as a selection tools for subsequent heifer pregnancy/calving rate.

Table 4.1 Effect of adjusted carcass ultrasound measurements and carcass expected progeny differences on percentage calving at 2 years of age[1]

Variable	Low 25%	Medium 50%	High 25%	P value
		Adjusted Carcass Variables		
REA	77.5 (3.8) A	77.9 (3.2) A	74.5 (4.1) A	0.669
IMF	71.9 (4.9) A	80.0 (3.2) A	76.6 (4.2) A	0.167
RF	76.9 (3.9) A	76.6 (3.3) A	77.9 (4.0) A	0.946
		Carcass EPDs		
REA EPD	75.6 (4.1) A	75.7 (3.4) A	80.1 (3.7) A	0.500
Marb EPD	75.3 (4.1) A	75.8 (3.4) A	80.3 (3.7) A	0.468
Fat EPD	77.4 (4.0) A	74.4 (3.5) A	81.4 (3.5) A	0.183

[1] **Values presented as percentage (%) with least squared means (standard error)**
A, B, C LS means with different letters within row differ (P<.05)

Carcass measurements have been associated with age at puberty (Hall, 1995). However, these Angus heifers were of age and weight such that indication of puberty was visually occurring or had already occurred. Furthermore, all heifers were placed into a ~65 day breeding season (TAI and clean-up bull); thus, having ample opportunity for breeding success.

4.2 Age at First Calving

Analysis of ultrasound-derived carcass characteristics expressed that heifers in the high category for adjusted REA were older at first calving when compared to the low and medium group of which no differences were observed (Table 4.2; P=0.002). With grouping aside, %IMF lacked the expression of any significant difference (Table 4.2). Even still, evaluation of ultrasound measured RF revealed that those heifers in the high group showed a longer period to first calving compared to heifers categorized as Low RF (Table 4.2; P=0.008).

Evaluation of carcass EPD for REA conveyed that that there were significant differences between groups showing an ascending pattern from low to high (Table 4.2). Marbling EPD analysis exhibited significant differences as the high range did show difference which was larger than the means from the low and medium groups. Furthermore, Fat EPD with near significance was void of differences among all groupings related to age at first calving. As significance was seen in areas that could be viewed as indicators of mature weight and subsequent age the adjusted values for these carcass variables have been used which adjust for age and sex.

The relationship seen with the adjusted carcass variables suggests that those heifers in the top 25% for REA (54% of those also the top 25% for weight) were seen to be later maturing which would suggest that heifers would come into puberty later and consequently, calve at a later date. These results are substantiated by Owens and co-worker's (1993) who suggested that heifers with a heavier mature weight require more energy for maintenance and reach puberty later in life. Another variable suggesting a later onset of puberty would be adjusted rib fat as those in the high group were seen to take longer reaching their first calving date. These data are conflicting with most scientific information surrounding this topic in domesticated animals as well in humans.

The human studies reviewed display a shift towards an earlier onset of puberty and suggest very strong evidence that the increasing rate of childhood obesity is the cause (Kaplowitz, 2008). This result was also reported by Hall et al. (1995) evaluating body composition and metabolic processes in heifers to determine how they relate to puberty. The high gaining heifers in this study (also the fatter heifers) were younger, heavier, taller, and more muscular than heifers in the moderately-fed grouping that subsequently had less fat as a result. Keeping these results in mind, Splan and coworkers (1998) reported a very low correlation between age at puberty of the female and the different fat variables (Fat %, Adjusted fat thickness, %Kidney, pelvic, heart fat; -0.01, -0.01, -0.12, respectively) of the heifers' paternal half-sibling steers. Furthermore, increased levels of subcutaneous fat and its relationship with early onset of puberty would insinuate these females would breed earlier and consequently calve earlier. However, increased subcutaneous fat are believed by many (Marshall and Peel, 1910;

Parkes and Drummond, 1928) to have adverse effects on later fertility, which could offer an explanation of the delayed age to first calving.

Evaluation of the relationships with carcass EPD variables indicated differences for both REA and Marbling (Table 4.2). Carcass EPD for REA should have a similar relationship to adjusted REA collected during ultrasonography for carcass measurements, as those heifers selected for larger REA should consistently be heavier, later maturing, require higher level of maintenance energy, and consequently have a later onset of puberty. Differences between the high group for marbling EPD and the lower two could be attributed to alteration in usage of maintenance energy. These alterations could include storage as intramuscular fat rather than being utilized for development of reproductive function, consequently causing a longer period to first calving. Fat EPD tended to indicate a later age at first calving for heifers in the high 25% grouping: however, Tukey analysis of data prevents the usage of the significance terminology. Outcomes of this initial analysis assist in describing the relationship of carcass variables during early reproduction; however, the goal of this study was to further selection capabilities for lifetime production which will follow.

Table 4.2 Effect of adjusted carcass ultrasound measurements and carcass expected progeny differences on age at first calving[1]

Variables	Low 25%	Medium 50%	High 25%	P value
Adjusted Carcass Variables				
REA	731.7 (3.1) B	736.8 (2.8) B	743.5 (3.3) A	0.002
IMF	736.7 (3.5) A	736.1 (2.8) A	740.2 (3.3) A	0.371
RF	734.5 (3.1) B	735.7 (2.7) B	743.7 (3.2) A	0.008
Carcass EPDs				
REA EPD	727.7 (3.2) C	736.3 (2.8) B	746.2 (3.2) A	<0.0001
Marb EPD	734.4 (3.1) B	733.9 (2.7) B	744.0 (3.2) A	0.002
Fat EPD	735.1 (3.1) A	735.2 (2.6) A	741.5 (3.1) A	0.051

[1] Values presented in days with least squared means (standard error)
A, B, C LS Means with different letters within row differ ($P<.05$)

4.3 Calving Interval following First Calving

Assessment of adjusted carcass measurements obtained with carcass ultrasonography indicated no differences in calving interval following first calving for REA and %IMF measurements. Analysis of carcass RF showed high and low groups differ between each other with a spread of 13 days for a heifer's initial calving interval (Table 4.3; P=0.014). Evaluation of first calving interval utilizing carcass EPD's (REA, Marb, Fat) resulted in no differences between any variable or grouping within variable (Table 4.3).

Rib fat as an influence on calving interval relates well to the knowledge of reproductive philosophy many producers practice. In the present study, it was observed that heifers that were thinner, or were categorized in the bottom 25%, even as yearlings had longer initial calving intervals. This would suggest that heifers in the low group did not return to estrus as quickly after their initial calving and therefore calved later in the subsequent calving season, which is further explained by (Wiltbank et al., 1962) who stated that when nutrient intake is inadequate and body energy reserves are depleted that interval from calving to first estrus is extended. Data reported by Pryce et al. (2000) would agree, observation of body condition score (BCS) and calving interval (CI) were in fact inversely genetically related (r= -0.40) and stated simply that thinner cows would have a longer CI. Spitzer et al. (1995) observed that those first-calf cows with higher BCS values returned to estrus faster following calving. These differences observed in the current study between high or low rib fat could be directly related to body condition at calving.

Table 4.3 Effects of adjusted carcass ultrasound measurements and carcass measurements and carcass expected progeny differences on calving interval following first calving[1]

Variables	Low 25%	Medium 50%	High 25%	P value
Adjusted Carcass Variables				
REA	372.6 (3.3) A	366.2 (2.5) A	366.1 (3.3) A	0.192
IMF	365.4 (3.6) A	368.4 (2.6) A	368.0 (3.6) A	0.729
RF	374.3 (3.2) A	365.8 (2.7) AB	361.7 (3.5) B	0.014
Carcass EPDs				
REA EPD	372.3 (3.3) A	365.8 (2.6) A	367.3 (3.3) A	0.123
Marb EPD	368.8 (3.2) A	367.7 (2.6) A	367.2 (3.2) A	0.920
Fat EPD	368.0 (3.1) A	365.6 (2.5) A	372.0 (3.2) A	0.186

[1] Values presented in days with least squared means (standard error)
A, B, C LS Means with different letters within row differ (P<.05)

4.4 Lifetime Calving Interval

Evaluation of adjusted carcass measurements acquired with ultrasonography indicated no differences in lifetime calving intervals of Angus heifers when observing REA and %IMF (Table 4.4). However, observation of the adjusted value for RF indicated a difference of 7 days in calving interval between low and high groups (High 25, Low 25; Table 4.4; P=0.048). Analysis of carcass EPD variables for REA, Marb, and Fat showed no significant differences on lifetime calving interval (Table 4.4).

The explanation of lifetime calving interval (LCI) was an essential objective in the present study and the utilization of carcass ultrasonography allowed the tool necessary for a prediction of this lifetime reproductive variable. Adjusted rib fat in this study was established as an indicator of LCI for similar reasons as its association with calving interval following initial calving. Richards et al. (1986) reported a study that compared postpartum nutrition (PN), BCS, and their effect on reproductive performance. One objective in the study evaluated PN and BCS at calving to estrus and pregnancy intervals. The results for this study observed that any animal with a BCS greater than or equal to a five (scale of 1, emaciated to 9, obese) consistently had a shorter anestrous period after calving (Richards et al., 1986). These results for reproductive efficiency compared to BCS agree in theory with the present study as heifers categorized in the high rib fat group had shorter LCI's.

Table 4.4 Effect of adjusted carcass ultrasound measurements and carcass expected progeny differences on lifetime calving interval[1]

Variables	Low 25%	Medium 50%	High 25%	P value
Adjusted Carcass Variables				
REA	369.5 (1.9) A	366.1 (1.3) A	362.9 (1.9) A	0.069
IMF	364.2 (2.3) A	367.3 (1.3) A	365.3 (2.2) A	0.432
RF	369.9 (1.8) A	365.1 (1.4) AB	362.8 (2.1) B	0.048
Carcass EPDs				
REA EPD	367.9 (1.9) A	365.9 (1.3) A	365.6 (1.9) A	0.625
Marb EPD	367.3 (1.8) A	367.1 (1.4) A	363.9 (1.9) A	0.358
Fat EPD	365.9 (1.8) A	365.4 (1.3) A	368.4 (1.8) A	0.385

[1] Value presented in days with least squared means (standard error)

A, B, C LS Means with different letters within row differ (P<.05)

4.5 Longevity

Evaluation of ultrasonography-derived carcass variables indicated no differences in the number of months an Angus heifer stayed in production. Regardless of grouping, neither analysis of REA, %IMF, nor RF resulted in differences that would support the reasoning of longevity (Table 4.5).

However, evaluation for carcass EPD for REA, Marb, and Fat resulted in significant differences being seen between the high and low groups for REA EPD. This determination indicated that heifers in the high REA EPD group had a likelihood of remaining in production for an additional 7.2 months. Regardless of grouping for Marb and Fat EPDs, no differences were observed that would affect the lifetime production length of these Angus heifers.

Nonetheless, an observation of longevity from 2000-2006 showed a wide diversity of values (Figure 4.1). Results from Saxton et al. (1999) research that heifers in the upper 25% for REA EPD should be maintained additional 5.4 months within the herd and could possibly produce an additional calf. These results were supplemented by personal communication with both of the managers who expressed that breeding strategies of both research and education centers were focusing on the improvement of carcass quality in the herds, (Personal communication, Beavers, 2012; Hitch, 2012), which may explain the added expression of tenured females in the herd possessing higher REA EPD values.

Table 4.5 Longevity as influenced by carcass ultrasound measurements of carcass expected progeny differences[1]

Variables	Low 25%	Medium 50%	High 25%	P Value
Adjusted Carcass Variables				
REA	41.4 (3.5) A	44.3 (3.7) A	45.5 (3.8) A	0.258
IMF	39.6 (3.3) A	44.4 (3.7) A	46.7 (3.9) A	0.077
RF	43.8 (3.7) A	43.7 (3.6) A	43.7 (3.7) A	0.999
Carcass EPDs				
REA EPD	39.8 (4.2) B	44.1 (4.0) AB	47.0 (4.2) A	0.023
Marb EPD	43.0 (4.1) A	42.7 (3.9) A	46.4 (4.1) A	0.245
Fat EPD	42.7 (4.0) A	43.6 (3.8) A	45.1 (4.0) A	0.619

[1] Values presented in months with least squared means (standard error)
A, B, C LS Means with different letters within row differ (P<.05)

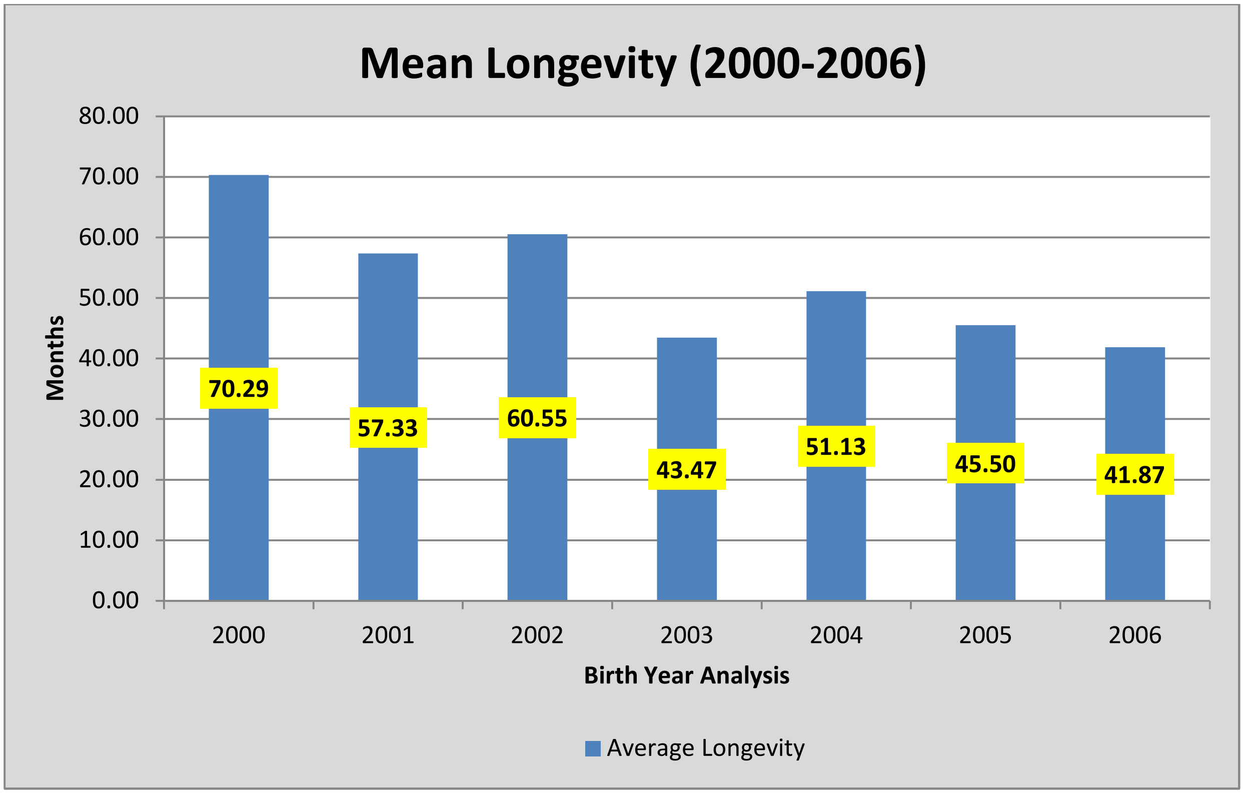

Figure 4.1 Lifetime production of calves and time remaining in the herd (months) for cows between 2000-2006

4.6 Production Values

Evaluation of adjusted carcass measurements obtained with ultrasonography at approximately 12 months of age indicated no differences in birth weights of calves from the group of Angus heifers. Regardless of grouping (High 25, Med 50, Low 25), neither adjusted REA, %IMF, nor RF resulted in significant differences (Table 4.6). Analysis of carcass EPD variables for REA, Marb, and Fat also showed no significance difference related to calf birth weights.

Ribeye area and rib fat had no effect on weaning weight comparison when observing REA and RF. However, %IMF resulted in a significant difference between the low and medium group showing a ~9 kilogram increased gain for those calves located in the intermediate 50% (Table 4.6, Section II; P=0.012). Carcass EPD variables resulted in no significant differences being apparent related to calf weaning weights.

Observation of ultrasound-derived carcass characteristics for REA, %IMF, and RF resulted in no significant differences for yearling weights of calves being observed, regardless of grouping (Table 4.6). Assessment of carcass EPD variables for REA, Marb, and Fat regardless of grouping did not show differences for yearling weights of calves.

During evaluation of the results, the determination was made that while birth weight (BW) and yearling weight (YW) could not be accurately predicted utilizing ultrasound-derived carcass data; adjusted IMF was established to be an indicator of weaning weight (WW). A study performed by Lamb et al. (1990), reported a high correlation between WW and adjusted IMF(r=0.71). This phenomenon was explained in 1998 as Splan and co-workers suggested this relationship was indicative that heavier females had steer sibs with relatively larger amounts of lean muscle as well as fat, presumably because of their own increased size (Splan et al., 1998). Results of the current study indicate heifers grouped into the intermediate 50% for IMF produced calves that were 9 kilograms heavier than those calves from the low 25%. One proposed theory of this relationship could be due to physiological factors of animals that reach a heavier threshold weight at weaning would alter the use of maintenance energy and thus would begin to store this energy as adipose tissue intramuscularly, consequently causing the highly correlated relationship with WW and adjusted IMF. This physiological description combined with a predisposed genetic phenotype was another means of explanation why adjusted IMF and WW were highly correlative. As a result, this relationship should prove that the concomitant selection for both increased IMF and WW is possible and could result in a very efficient tool that allows producers to meet market demand of a highly marbled and palatable carcass.

Table 4.6 Values of production traits as influenced by carcass ultrasonography measurements of carcass expected progeny differences[1]

Variables	Low 25%	Medium 50%	High 25%	P value
I. Adjusted Birth Weight of Calves (Kilograms)				
A. Adjusted Carcass Variables				
REA	35.3 (0.4) A	36.1 (0.4) A	35.6 (0.5) A	0.203
IMF	35.2 (0.4) A	36.0 (0.3) A	35.7 (0.4) A	0.123
RF	35.7 (0.4) A	35.8 (0.4) A	35.3 (0.5) A	0.388
B. Carcass EPDs				
REA EPD	35.4 (0.4) A	35.8 (0.4) A	35.8 (0.4) A	0.395
Marb EPD	35.7 (0.4) A	35.6 (0.4) A	35.8 (0.4) A	0.728
Fat EPD	36.0 (0.4) A	35.7 (0.4) A	35.4 (0.4) A	0.494
II. Adjusted Weaning Weight of Calves (Kilograms)				
A. Adjusted Carcass Variables				
REA	294.7 (3.7) A	301.1 (3.2) A	300.7 (3.6) A	0.117
IMF	293.5 (3.5) B	302.4 (2.7) A	299.1 (3.4) AB	0.012
RF	302.5 (3.5) A	301.9 (3.1) A	296.5 (3.5) A	0.267
B. Carcass EPDs				
REA EPD	297.9 (3.5) A	298.0 (3.0) A	303.3 (3.4) A	0.201
Marb EPD	298.4 (3.4) A	298.7 (3.1) A	301.4 (3.5) A	0.651
Fat EPD	296.8 (3.5) A	299.4 (3.0) A	301.5 (3.4) A	0.418
III. Adjusted Yearling Weight of Calves (Kilograms)				
A. Adjusted Carcass Variables				
REA	586.1 (5.7) A	591.2 (4.6) A	603.1 (5.9) A	0.054
IMF	597.0 (6.2) A	586.8 (4.4) A	600.2 (6.3) A	0.209
RF	592.1 (5.5) A	592.0 (4.6) A	594.3 (5.95) A	0.889
B. Carcass EPDs				
REA EPD	589.8 (5.5) A	588.4 (4.4) A	602.1 (5.5) A	0.112
Marb EPD	591.0 (5.5) AB	587.0 (4.4) B	602.9 (5.6) A	0.077
Fat EPD	592.4 (5.6) A	5901.0 (4.4) A	595.2 (5.5) A	0.600

[1] Values presented in kilograms with least squared means (standard error)
A, B, C LS Means with different letters within row differ (P<.05)

Chapter 5
Summary

The aim of this study was to determine possible relationships involved between carcass-derived ultrasound characteristics and variables associated with reproduction and fertility (Table 5.1). The results show that significant progress has been made in the area of selection and observations of the data exhibited that heifers in the high range for REA were older at first calving (P=0.002). Additionally, rib fat influenced length of first calving interval (P=0.014) and lifetime calving interval (P=0.048) in a positive manner, as with added RF came a shorter calving interval in both scenarios. Longevity was observed to be affected by REA EPD, which may be associated with added selection for carcass value resulting in a, difference of 7.2 months from the low to high groupings (P=0.023). Furthermore, the evaluation of production values suggest that females in the intermediate 50% for IMF will produce progeny that possess an increased WW of 9 kilo (P=0.012) compared to the Low or High grouping. This study likewise indicated that concomitant selection may be used to optimize both the value of reproduction in a beef herd while also increasing carcass quality to meet consumer demand. The results of this study also indicated that the use of carcass variables obtained through ultrasonography may be utilized for indication of subsequent growth of offspring. These relationships produced through the outcome of this study should greatly simplify the selection process and through this greatly increase the quality of reproductive value of beef seedstock in production.

Table 5.1 Differences and trends of variables as indicators of carcass and EPD increase[1]

	Carcass				EPDs		
Variables	REA	IMF	RF		REA	Marb	Fat
Calving	0	0	0		0	0	0
Age	-	0	-		-	-	-
CI 1st	0	0	+		0	0	0
LCI	+	0	+		0	0	0
Long	0	+	0		+	0	0
BW	0	0	0		0	0	0
WW	0	mid +	0		0	0	0
YW	0	0	0		0	0	0

[1] (0)-no differences; (+)-positive effect with increase, (mid +) - positive effect in middle 50%; (-) – negative effect with increase

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Vita

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