THE USE OF SERIAL ULTRASOUND EVALUATION OF BODY COMPOSITION TRAITS TO PREDICT PERFORMANCE ENDPOINTS IN COMMERCIAL BEEF CATTLE

A Dissertation

by

SORREL ANN CLEMENT

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2009

Major Subject: Animal Science

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Approved by:

Chair of Committee, Andy D. Herring
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ABSTRACT

The Use of Serial Ultrasound Evaluation of Body Composition Traits to Predict Performance Endpoints in Commercial Beef Cattle. (August 2009)

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Bos indicus influenced primiparous heifers (n = 300) and yearling Beefmaster heifers (n = 172) were evaluated to determine relationships between serial carcass ultrasound traits and ability to breed in short (45 to 90 d) breeding seasons. Data collected included carcass ultrasound traits: ribeye area (REA), intramuscular fat (IMF), rump fat (UFAT), ribfat, weight, and body condition score taken at yearling age, pregnancy determination, before breeding, and after the breeding season when pregnancy status was recorded. A logistic regression analysis was used to determine the influence of ultrasound traits and body condition on pregnancy status. Odds ratios suggested the likelihood of primiparous cattle rebreeding would have been increased by 93% if IMF would have averaged 3.5% instead of 2.5% as yearlings, or an increase in the average ribfat as yearlings from 0.287 to 0.387 cm would have increased the odds of rebreeding by 88%. Increased average body condition score of 6.5 rather than 5.5 at 30 days postpartum in primiparous cows was estimated to have increased rebreeding 367%. The odds of yearling Beefmaster heifers successfully breeding during a 45-day season would have been increased by 73% (year 1) or

274% (year 2) by increasing REA 6.4 to 6.5 cm^2 at a year of age. Steers were serially scanned beginning at approximately 265 kg of body weight through harvest in 56 day ± 6 intervals. Data collected included ultrasound measurements (ribeye area (REA), 12^{th} rib fat thickness (RibFat), percent intramuscular fat (IMF), and rump fat (UFAT)), weight, and carcass data. Days to choice was calculated for each steer based on a linear regression. The IMF deposition was quantified as quadratic from scans 1-6 and linear when cattle were on full feed. Prediction models at scans 1, 2, 3, 4, 5, and 6 yielded R-square values of 0.20, 0.25, 0.41, 0.48, 0.59, and 0.49, respectively for days to choice. Odds ratios suggested that if steers in this study had averaged 3.78% at day 0 rather than 2.78, the odds of cattle grading premium choice or greater would have been increased by 300%.

ACKNOWLEDGEMENTS

I would not have been blessed so abundantly with the opportunities, sustenance, or the courage to finish had it not been for the grace of God. Through Him all things are possible and to Him all praise belongs.

I owe my deepest gratitude to my parents and brothers for their unwavering support during every step of this project. They organized every data collection event, managed all the cattle, and funded 100% of this research project.

The pursuit of this degree and completion of this dissertation would not have been possible without the sponsorship and guidance of Dr. Andy Herring who served as my major professor and chair. Additionally, without the constant support of Drs. Jason Sawyer and Tryon Wickersham this dissertation would not be possible. These three gentlemen always selflessly invested their personal best when asked for assistance in all aspects of this dissertation as well as my academic career. Their generosity, vested interest, and support will never be forgotten and they are personal heroes of mine. I want to acknowledge Dr. Jeff Savell and Dr. Dan Hale for serving on my committee as members. I would also like to recognize Dr. Michael Speed for his generous statistical counsel.

I would also like to express my appreciation to Texas A&M University and the Department of Animal Science to study at a prestigious university and for the opportunity to complete a doctoral degree.

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INTRODUCTION

The value of carcass ultrasound, or any tool used to make predictions, is the ability to identify and adjust management strategies early in the production phase to optimize an animal's performance. This study is divided into two experiments which explore serial ultrasound as a means to make predictions about reproductive performance and feedlot performance of commercial cattle.

Experiment 1

Maternal productivity (*defined for the purpose of this paper as the ability of a primiparous heifer to calve as a two year old, breed back in less than 80 days post partum so as to maintain a 365 day calving interval, and wean a healthy calf*) is extremely influential upon profit, but is hard to predict as it is influenced by many factors. In commercial heifers, visual characteristics are the primary assessment of maternal productivity potential as a result of lack of records in most cases. If maternal productivity could be predicted at a younger age, heifers could be sorted into groups based on predicted maternal abilities and managed or culled accordingly. Thus, one of the purposes of this study is to explore ultrasound measures of body composition as a means to evaluate potential maternal productivity in yearling heifers.

The research objectives that defined Experiment 1 were to 1) study relationships between maternal productivity and ultrasound body composition

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This dissertation follows the style and format of the Journal of Animal Science.

measures in commercial females, and 2) establish ultrasound carcass data thresholds which accurately predict maternal performance in yearling heifers.

Experiment 2

With pressure from rising input costs and increased cost of gain, the implementation of tools that boost efficiency within feeding programs for beef cattle are prevalent, and should continue to be explored in depth. Real time ultrasound has the ability to increase efficiency within the feeding sector in terms of nutritional management, sorting, and marketing. While the identification of cattle that do not fit a certain market prior to exposure of discounts is desirable, a greater advantage would be earlier identification of those cattle, maximizing the opportunity to implement management strategies that favored increased efficiency through targeted feeding programs.

The research objective that defined Experiment 2 was to establish the period in a calf's life from weaning to harvest when accumulation of fat, specifically intramuscular fat, is most correlated to the end carcass quality grade that could be of future use for sorting cattle.

LITERATURE REVIEW

Experiment 1

Body Composition Influences in Breeding Females

Strong evidence exists that body composition plays a vital role in the regulation of estrous in beef cattle. This portion of the literature review attempts to capture the significance of the relationship between body composition and post partum interval, explore research on the relationship between body composition measures and carcass traits, and investigate the potential relationships between carcass traits and maternal ability. Published literature from experiments where carcass ultrasound was used in heifers or cows is also presented here.

The Relationship between Body Condition Score and Postpartum Interval

Immediately following parturition, a critical period of 80 days exists in which a cow must breed back to maintain a 365 day calving interval. Therefore, if two opportunities are to be presented for breeding, cows must be cycling by day 60 postpartum (Dunn and Moss, 1992). Previous research has been conclusive in that post partum interval is a dynamic trait affected by a variety of factors including season, suckling, forage conditions, nutritional stress, and age (Wetteman et al., 1986; Short et al., 1990; Randel, 1990; Dunn and Moss, 1992; Hess et al., 2005), but is mostly highly influenced by body condition, which reflects the sum of all three factors.

Body energy reserves at calving are the most influential factor on length of post partum interval according to Wettemann et al. (1986). Dunn and Moss (1992) emphasized an animal's ability to repartition nutrients, and this phenomenon's effect on reproduction. Mammals cannot perform for any extended period of time in a deficient state of any required nutrient. When the net energy of an animal's diet is significantly less than the energy expenditure of the animal; the result is a negative energy balance. Cows are able to repartition nutrients for physiological functions only if they have sufficient nutrients to meet their fundamental necessities which are prioritized in an inherent order essential to life; 1) basal metabolism, 2) activity, 3) growth, 4) basic energy reserves, 5) pregnancy, 6) lactation, 7) additional energy reserves, 8) estrous cycles and initiation of pregnancy, and 9) excess reserves (Short et al., 1990). Since reproduction is not essential to the survival of the individual animal, it is usually subordinate to those processes essential to life (basal metabolic rate, activity or growth). Randel (1990) found that underfed lactating cows have extended periods of ovarian inactivity which supports this theory of repartitioning.

The effects of nutrition upon reproduction depend upon a web of variables including nutritional content of feed, body condition of the cow, and other physiological functions such as lactation or growth. For example, growth in first calf heifers is an existing priority that takes precedence over reproduction thus reflecting the root of the common dilemma in achieving rebreeding success in first calf heifers (Short et al., 1990).

Body condition score (BCS), a subjective, visually assessed trait, is defined by degree of fat cover on an individual. The most commonly used scale is 1 to 9, with 1 representing the state of emancipation and 9 representing obesity (Wagner et al., 1988). Body condition score has been used with a high degree of accuracy to identify heifers and cows that will breed back at a faster rate (Corah et al., 1975; Dunn and Moss, 1992; DeRouen et al., 1994; Spitzer et al., 1995; Ciccioli et al., 2003.)

Cows experience an increased nutritional demand during the last trimester of gestation and in early lactation. Consequently, it is vital for most cows to calve in a body condition score of 5 to 6 and maintain that condition to account for the nutritional demands experienced post parturition (Spitzer et al., 1995; Ciccioli et al., 2003; Lake et al., 2007). DeRouen et al. (1994) reported that pre-partum body weight and condition fluctuations had less influence on reproductive performance than body condition at calving given that management conditions remain consistent after calving. A study by Ciccioli et al. (2003) showed that cows must be managed to maintain or increase body condition during lactation if expected to breed back in 80 days postpartum. This study also confirmed that cows fed to maintain or lose body condition during lactation have prolonged intervals from calving to estrus, are less fertile, and wean lighter calves (Ciccioli et al., 2003).

In studies that investigated post-calving supplemental effects Dunn et al. (1969) found that the pregnancy rate 120 days postcalving was directly related to post calving energy level in Angus and Hereford primiparous heifers. In the study, cows were fed a low-low, low-moderate, high-low, and high-moderate or high-high supplemental plane of nutrition pre-calving and post-calving for 60 days and then challenged to rebreed in a 60 day breeding season. Post partum interval was longer for cattle on a low pre-calving plane of nutrition, and the study concluded that pre-calving nutrition effects the first 100 days of post-calving estrous regulation, and low levels of nutrition pre-calving cannot be overcome by compensation through excessive supplementation post-calving (Dunn et al., 1969).

In summary, body condition score immediately prior to and during the breeding is critical. Body condition score should be managed so that cows have sufficient reserves to calve, lactate, and maintain an adequate amount of condition during the breeding season. Body condition score at calving is a good indicator of body condition score at breeding if cattle are managed to account for the increased nutritional demands that parturition and lactation present. Although a body condition score of 5-6 has been recommended in previous literature, it should be noted that this "optimum" condition score is based on achieving the shortest post partum interval.

Carcass Characteristics and Body Condition Score

It has been demonstrated that body condition score is highly related to reproductive performance and calf weaning weight. Bullock et al. (1991) and Apple et al. (1999) attempted to define the relationship between carcass traits and BCS in commercial cows. A study completed by Apple et al. (1999) was conducted with 83 mature culled beef cows of British influence 6 to 8 years of age, which were assigned BCS prior to slaughter. Cattle were sorted into body condition scores that ranged from 1 to 8. At slaughter, the carcasses of cows assigned BCS scores of 8, prior to slaughter, exhibited the most marbling. The percentage of carcasses grading

U.S. utility or higher was 16.7%, 20.0%, 63.6%, 43.3%, 73.3%, and 100.0% for cows assigned a BCS of 2, 3, 4, 5, 6, 7, and 8, respectively (Apple et al., 1999).

Bullock et al. (1991) evaluated the relationship between body condition and carcass traits on 39 Angus x Hereford cows aged from 3 to 10 years, which were sorted into three body condition groups based on ultrasonic measurements. One cow from each group was slaughtered for an initial benchmark representation from each body condition group. The remaining females were sorted into two sub groups; one fed to gain and one fed to lose weight. Two cows from each group were slaughtered to evaluate effects of nutrition. The correlation between BCS and marbling was 0.86 indicating that BCS can be used to predict marbling in mature cows (Bullock et al., 1991). Lake et al. (2007) found that among three-year-old Angus x Gelbvieh heifers managed to calve with body condition score of 4 had lower ultrasonic 12th rib fat at day 3 of lactation when compared to cattle that were managed to calve in a BCS of 6. Additionally, BCS was correlated with 12th rib fat at a correlation of $r = 0.87$ and with body weight at a correlation of $r = 0.75$ on day three of lactation (Lake et al., 2007).

Serial Carcass Ultrasound in Breeding Females

Rouse et al. (2001) used ultrasound to determine the changes in carcass composition with regard to the stresses of calving, lactation, and rebreeding in first calf Angus heifers. Body condition score and pregnancy data were not collected. Angus heifers were scanned for carcass traits five times: (1) before breeding, (2) before first calving, (3) at weaning of first calf, (4) before second calving, and (5) at weaning of second calf. Ribeye area increased linearly throughout the five scans in the study by Rouse et al. (2001), but the linear trend was not observed in this study in either herds A and B. Weight increased until calving, whereupon heifers lost an average of 38 kilograms during the first 183 days of lactation, and then resumed weight gain (Rouse et al., 2001). It should be noted that the postpartum weight loss did include fetal and placental weight. The pattern for subcutaneous fat followed that of body weight changes with values of 0.08, 0.16, 0.14, 0.24, and 0.29 inches for scans 1 through 5, respectively (Rouse et al., 2001). The intramuscular fat percentage measurements took longer to recover than subcutaneous fat levels although both traits followed the same pattern. This same pattern was observed in herds A and B. Mean values of intramuscular fat percentages were 4.95, 5.13, 4.53, 4.11, and 5.11 for scans 1 through 5, respectively (Rouse et al., 2001). While subcutaneous fat levels began to recover after weaning of the first calf, intramuscular fat percentage did not begin to increase until weaning of the second calf (Rouse et al., 2001). Two groups of heifers (n = 72 and n = 41), within the sample studied, did not deviate from the general trend of sample means for intramuscular fat percentage changes, but the rate of change differed by more than two percentage points from the sample means, and less than one percentage point from the sample means, respectively (Rouse et al., 2001).

The majority of research on post partum interval in primiparous heifers has been done using BCS as a measurement tool because it is conveniently assessed, and is highly related to fertility. Body condition can be used to identify which cows should rebreed in a timely manner. However, some cows will rebreed at lower BCS than recommended, and some will require more condition to conceive. It would be valuable to determine which heifers have greater chances for maternal productivity as yearlings, so efficiency in management could be improved prior to breeding. If body condition in first calf heifers is correlated to ultrasound carcass data, the potential of prediction, by means of ultrasound, of yearling heifers that have the potential to excel in maternal productivity could be greatly increased. Due to research that indicates maternal physiological processes influence body fat composition including intramuscular and subcutaneous fat depots, the potential for using these depots to predict maternal performance in yearling heifers exists.

Puberty and Body Composition

The ability of heifers to breed early in the breeding season is indicative of their overall lifetime performance in terms of calves and pounds weaned (Lesmeister et al., 1973). In a study consisting of 481 cows and 2,036 subsequent calves, Lesmesier et al. (1973) found that not only did heifers that bred earlier in the season continue to breed back early in succeeding breeding seasons, but calves born to these females had an advantage in average daily gain from birth through finish compared to later born contemporaries.

The initiation of puberty is characterized by the regulation of the GnRH regulator (Ojeda et al., 2006). There are many factors that can limit puberty in heifers such as nutrition (Hall et al., 1995), breed (Baker et. al, 1988), and season (Schillo et al., 1992). Hopper et al. (1993) found that when comparing Angus to

Santa Gertrudis heifers, Angus heifers were fatter at puberty and physiologically older at the same chronological age. This is most likely due to the puberty differences for breed type as found by Baker et al. (1988) who found that *Bos indicus* cattle are heavier, taller, and older at puberty. However, it seems that earlier maturing breeds like Angus have greater amounts of fat in reserves for times of nutritional stress such as gestation and lactation thereby having a better chance to be in a suitable body condition to breed back at these times (Hopper et al., 1993).

Wiltbank et al. (1985) found that heifers that were managed to achieve 318 kg at the initial breeding season conceived 20 days earlier in the breeding season than heifers managed to weigh 272 kg. Cattle were ½ to ¼ Brahman and the same trend was evident in the subsequent year's breeding season (Wiltbank et al., 1985).

Carcass Ultrasound as a Selection Tool

Little research has been done in terms of predicting maternal productivity in heifers using carcass ultrasound. With the low heritability of reproductive traits (heritability of pregnancy and first conception was found to be 0.13 ± 0.07 and 0.03 ± -0.03, respectively, by Minick et al. (2001) with data from six herds in 5 states with a population of 3,144 head of cattle), ultrasound offers potential as a tool for selection. More research is needed to determine if carcass ultrasound data can indeed be used to predict maternal performance of yearling heifers.

In a study conducted on Angus cattle, Minick et al. (2001) found that heavier yearling heifers were more likely to possess mature reproductive tracts at breeding than their lighter weight contemporaries. Additionally, heavier heifers exhibited larger ribeyes, more rump fat at one year of age, and were more likely to be cycling at one year of age. Heifers were scanned at 268, 303, 370 and 405 days of age (Minick et al., 2001). Patterson et al. (1992) showed similar findings in that heifers that weighed more at weaning were more likely to reach puberty earlier than their contemporaries in a study comparing Brahman x Herefords (n = 148) to Angus x Hereford (n = 148) heifers. The earlier maturing Angus x Hereford heifers produced heavier calves, but had a longer post partum interval (Patterson et al, 1992). However, this relationship was not exhibited in the Brahman x Hereford heifers (Patterson et al, 1992). It should also be noted that earlier maturing heifers in the study weaned heavier calves and consequently had decreased body condition scores at breeding which may be partly responsible for the longer post partum intervals (Patterson et al, 1992).

Until one year of age, heifers are typically managed as a single group, and so carcass data prior to one year of age is beneficial. Once exposed to bulls for the first time, variables such as pregnancy and cycling status emerge which heighten the opportunity for division of herd into management groups for efficiency purposes. After breeding, it becomes more economical to manage heifers based on their physiological needs. If a relationship between scanned carcass data taken at one year of age and maternal productivity exists, the potential to identify and sort heifers based on physiological potential, management needs, and predicted performance would also exist.

Wilson et al. (2001) found that in Angus, the heritability estimates from developing heifer carcass data were higher than those estimated from yearling bull data and thus more accurate in predicting carcass merit of steer-mate half-sibs. Perhaps this is due to the fact that carcass composition is more similar between yearling heifers and yearling steers than that of yearling bulls and yearling steers, or the fact that there is less variation among bulls than heifers when scanning took place. This finding shows a promising future for the continued research on carcass data of commercial females and their subsequent maternal performance and carcass merit of their offspring.

If scanned carcass data taken at one year of age could predict performance with regard to post partum interval and the carcass merit potential of her offspring, time and money could be saved. Additionally, heifers could be matched with bulls that complement the carcass merit profile of the female to produce more predictability in carcasses of offspring.

Experiment 2

<u>Body Composition Influences in Growing Feedlot Cattle</u>

The development of body composition measurements, especially intramuscular fat, has been studied with both serial slaughter and serial ultrasound in the past. Previous research indicates that body compositional changes in growing cattle are influenced by a variety of factors of both genetic and environmental origins. This portion of the literature review will present research that pertains to the relationship between carcass traits in growing beef cattle.

The Use of Parental Information to Predict Carcass Merit of Progeny

Relative variances in carcass traits measured via ultrasound have been proven to be passed to progeny through the additive genetic component. Heritability (the fraction of total phenotypic variation due to variation in breeding value differences) of carcass traits are moderately heritable with values reported by Kemp et al., (2002) as 0.36, 0.39, 040, 0.17, 0.38, and 0.49 for carcass ribeye area, carcass fat thickness, carcass marbling score, ultrasonic ribeye area, ultrasonic fat thickness, and ultrasonic percentage intramuscular fat, respectively, in a trial on 2,855 Angus steers. Similar results were published by Devitt and Wilton (2001) with values of 0.48, 0.23, and 0.52 for ribeye area, intramuscular fat, and backfat, respectively, from ultrasound data on purebred bull data consisting of eleven breeds.

Vieselmeyer et al. (1996) showed relative differences in EPDs based on ultrasound information gathered on yearling bulls were passed onto and exhibited in the carcasses of commercial progeny. Six bulls with low marbling EPDs (< 0.16 marbling score) and six bulls with high marbling EPDs (> 0.4 marbling score) were bred to commercial females at the MARC experiment station, and resulting progeny were finished and slaughtered. More carcasses of the high marbling EPD sired progeny finished choice than did carcasses sired by the low marbling EPD bulls. To support this, a study completed by Sapp et al. (2002) found that marbling scores can be increased in progeny by sire selection of high yearling IMF ultrasound readings and high IMF EPDs in Angus. Twenty bulls ranging from average, below average, and higher than average yearling IMF scores and marbling EPDs, when bred to commercial females passed on the relative differences in regard to average IMF in their steer progeny.

Deposition of Marbling

Bruns et al. (2004) published a study using 8 month old Angus steers fed to varying hot carcass weight goals of 204, 250, 295, 340, and 386 kg. Carcass data indicated that marbling was not a late maturing tissue, but a rather consistent developing tissue when nutrition was not compromised. Additionally, fractional growth for IMF, fat, and protein decreased with increasing hot carcass weight. When expressed in relation to hot carcass weight, marbling was deposited in a linear fashion while subcutaneous fat was deposited in a quadratic fashion (Bruns et al., 2004). Work by Rhodes et al. (2009) supports marbling deposition as linear in relation to hot carcass weight, but also reported subcutaneous fat as linear in relation to hot carcass weight as well. Authors reported that accretion rates for IMF and fat thickness were independent of diet (corn versus hay) if these depots were expressed as a function of hot carcass weight changes in Angus cattle (Rhodes et al., 2009).

Zinn et al. (1970) showed that marbling was a fat depot that was deposited in a stepwise fashion over time with the lean to fat ratio favoring fat as age (time) increased. Using 8-month-old Hereford steers and heifers (n = 200), cattle were finished in a conventional feeding system, and slaughtered at 270 days on feed. Every 30 days, representative cattle were slaughtered from the steer and heifer groups. Results showed that marbling score increased significantly from day 0 to 30, 90 to 120, 180 to 210, and 210 to 240. The conclusion of this study was that marbling deposition occurred in a step wise fashion for both steers and heifers increasing at 60 to 90 day intervals, followed by periods of dormancy (Zinn et al., 1970).

The similarities and differences in adipocyte change at different depots were explored by Cianzio et al. (1985) in which the development of adipocytes at 6 different fat depots (kidney, mesenteric, brisket, subcutaneous, intermuscular, and intramuscular) was tracked across 40 crossbred steers (sires were Limousin, Maine-Anjou, Angus, or Simmental and dams were British and dairy crossbred cows). Calves were serially slaughtered and evaluated at two month intervals from 11 to 19 months of age. Significant findings in this study included that average diameter of adipocytes in intramuscular fat increased (hypertrophy) from 11 to 17 months of age, and leveled off from 17 to 19 months. However, the number of adipocytes (hyperplasia) increased from 4.8 to 8 billion adipocytes per gram during months 11 through 19, with the most significant increase from month 13 to 15 (Cianzio et al., 1985). Additionally, in a regression model, the number of adipocytes in the intramuscular fat depots was a slightly better predictor of end quality grade, accounting for 57% of the variation of differences in quality grade, than was the diameter of adipocytes in intramuscular fat depots (Cianzio et al., 1985). Using a combination of cell number and cell size, the model variation was improved to account for 63% of the variation in quality grade reported using the marbling score system.

Robelin (1981) further supported the distinct asynchronous developmental patterns of adipocyte hypertrophy and hyperplasia. In a serial slaughter study, percentages of mature body weight were examined in relation to changes in the cellularity of adipose tissue (Robelin, 1989). Six Charolais and six Friesian bulls were slaughtered at 15, 25, 35, 45, and 65% of their mature weights (estimated at 900 kg for Charolais and 1,100 kg for Friesian) to examine the cellularity development of adipose. Between 15 and 65% of their mature size, adipose cell size (hypertrophy) increased 15-fold, but actual number of adipose cells (hyperplasia) increased 1.8-fold (Robelin, 1989). Similar to the work of Zinn et al., (1970) and Cianzio et al., (1985), hypertrophy was significant in that cell size increased from 15 to 45%, then stabilized, and hyperplasia characterized adipose tissue growth from 45 to 55% of mature weight (Robelin, 1989). The most significant changes within adipose development occurred between 45-55% of mature weight. Robelin (1989) suggested that hypertrophy is stabilized by a cell size threshold (50×10^4 μm^3), and then hyperplasia is induced either as actual multiplication of adipose cells or undifferentiated cells are recruited for adipocytes (Robelin, 1989). This theory would support the stepwise fashion of adipose deposition reported by Zinn et al. (1970) and Cianzio et al. (1985).

Later papers used computerized image analysis to examine the differences in development of intramuscular adipocyte deposition across breed types (Albrecht et al., 2006). In a study including German Angus, Galloway, Holestein Friesian, and Belgian Blue cattle (n = 190), similar trends of deposition were found across breeds, but developmental characteristics such as quantity, structure, and distribution were different. Cattle were serially slaughtered at 2, 4, 6, 12, and 24 months of age. From 2 to 24 months, changes in intramuscular fat as measured in the *longissimus dorsi* included a 40-fold increase in number of marbling flecks, and a 4-fold increase in the size of marbling flecks. Additionally, two developmental trends were recognized which concurred with work of Cianzio et al. (1985) and Zinn et al. (1970). The first trend was characterized by marbling flecks becoming larger (hypertrophy) which in turn coarsened the structure of flecks by elongating marbling flecks and increased the maximum skeleton line (Albrecht et al., 2006). This trend was followed by hyperplasia, or the appearance of new flecks which evened distribution of flecks. In this study quantity, structure, and distribution were measured through calculated ratios and counts of flecks within the *longissimus dorsi* muscle (Albrecht et al., 2006). Intramuscular fat content increased significantly, for Galloway cattle at 6 months, for German Angus and Holstein-Friesian at 12 months, but not until 24 months for Belgian Blues (Albrecht et al., 2006). Age, breed, and the interaction collectively accounted for 80, 60 and 70% of the variances for the traits of quantity, structure and distribution of intramuscular fat, respectively (Albrecht et al., 2006). Another finding from this study was the fact that intramuscular fat is deposited from ventral to dorsal fashion within the *longissimus dorsi* (Albrecht et al., 2006).

A slightly different study was conducted on fed Angus steers (n = 85) targeted for finish at hot carcass weights of 204, 250, 295, 340, and 386 kg (Bruns et al., 2004). Linear advances in marbling were reported, and with the greatest advances occurring in marbling relative to carcass weight occurred at less than 300 kg during this study (Bruns et al., 2004). This significant increase in marbling during early development suggests that this point in time may provide insight into the carcass performance potential of an individual.

Due to the complexity of marbling across breed and management variables, ultrasound offers a significant advantage in determining a specified marbling endpoint, or predicting days on feed to reach a marbling target. In a study consisting of 137 Limousin and Simmental crossbred steers (group 1) and 292 Angus and Angus x Hereford steers (group 2), Brethour (2000) found through serial ultrasound, marbling increased slowly upon entry into the feedlot at an average rate of one marbling score every 100 days for yearling fed cattle. Cattle were serially scanned for a total of four scans beginning at entry into the feedlot at 14 months of age for group one and 12 months of age for group two. Scanning took place on day 0, 37, 76, and 123, and cattle averaged 166 days on feed prior to harvest (Brethour, 2000). He observed that once an animal reached low Choice, the rate of deposition for the intramuscular fat depot increased at a significantly faster rate (Brethour, 2000). The rate of marbling deposition was described by Brethour (2000) as best fitting a modified power function versus an exponential model. Brethour (2000) also reported that beef cattle with only enough percent intramuscular fat to grade Standard-0, upon entry into the feedlot, were consistently unable to grade Low Choice, in both breed types, within 200 days. Using ultrasound measurements of percent intramuscular fat to predict marbling in the carcass in group 1 was demonstrated by R–square values of 0.18, 0.54, 0.24, and 0.51 at day 0, 37, 76, and 123, respectively (Brethour, 2000). For group 2, R–square values were 0.217 and 0.337 for arrival and day 90, respectively (Brethour, 2000). The R–square values that explain the relationship between carcass backfat thickness and carcass marbling score were 0.17 for group 1 and 0.07 for group 2 (Brethour, 2000). At 3 mm of backfat thickness, ultrasound was 75% accurate in predicting marbling scores when an animal reached at a backfat thickness of 10 mm (Brethour, 2000). This study illustrated the ability of ultrasound to identify cattle that will not grade Choice at a desirable back fat measurement, and to sort cattle into "clusters" for market and feeding efficiency purposes upon entry into the feedlot.

Several serial ultrasound studies have reported that ultrasound measurements are more predictive of carcass composition when taken closer to harvest date (May et al., 2000; Rouse et al., 2000; Greiner et al., 2003.; Wall et al., 2004). However, to improve production efficiency producers need to access predictive ultrasound measures earlier in the production process.

Using Carcass Ultrasound to Predict Carcass Composition

Published correlations values suggest that ultrasound measurements are more accurate in predicting carcass composition when taken closer to harvest date. At one day prior to harvest, May et al. (2000) found a correlation of r = 0.65 and r = 0.37 between ultrasound and carcass traits of fat thickness and ribeye area, respectively. At 5 days prior to slaughter, Greiner et al. (2003) reported a correlation of r = 0.66 for ultrasound and carcass fat thickness. At 6 days prior to slaughter, Rouse et al.

(2000) published a correlations ranging from r = 0.57 and r = 0.43 for ultrasound and carcass fat thickness and ultrasound and IMF, respectively. In the same publication correlations between ultrasound and fat thickness were reported as r = 0.4 and r = 0.28 for 46 and 90 days prior to harvest, respectively. Likewise, in the same publication, correlations between ultrasound and carcass IMF were reported as r = 0.31 and r = 0.31 for 46 and 90 days prior to harvest, respectively. Wall et al. (2004) reported correlations of r = 0.37 and r = 0.39 between ultrasound IMF and carcass IMF for 7 and 90 days prior to harvest, respectively. Wall et al. (2004) reported correlations of r = 0.54 and r = 0.33 between ultrasound fat thickness and carcass fat thickness for 7 and 90 days prior to harvest, respectively. The study by Wall et al. (2004) used serial ultrasound to develop prediction equations for carcass composition in live animals. To predict marbling at 96 to105 and 61 to 69 days pre-harvest, stepwise regression was used. The results showed the ultrasound measurements of percent intramuscular fat (UIMF, r-square = 0.393), the natural log of fat thickness (UFAT, r-square = 0.443), and ADG (r-square = 0.461) were most important in predicting marbling 96-105 days pre-harvest. When predicting marbling at 61-69 days pre-harvest, the stepwise regression only listed UIMF (r-square = 0.427) and the natural log of UFAT (r-square = 0.466) as relevant independent variables in the equations. A similar study performed by Rouse et al. (2000) used four groups of steers from differing backgrounds to perform serial scans, collect carcass data, and develop prediction equations for intramuscular fat percentage yielding r-square values ranging from 0.35 to 0.51 at 90 days prior and just before slaughter, respectively. Cattle were of Simmental and Angus breed origin in both studies. Using real time ultrasound IMF values collected 2-5 days prior to slaughter to predict intramuscular fat in carcasses has been used to develop prediction models with r-square values ranging from 0.69–0.72 (Hassen et al., 2001).

Combining Ultrasound Data and Background Information

The ability of ultrasound to predict carcass composition for cattle can be strengthened with additional information regarding the calf's background information. Beefmaster steers (n = 160), scanned at 56-day intervals, showed increased accuracy in prediction models where additional information was known such as sire, ultrasound information, and ranch of origin (Dean et al., 2006). All cattle had information pertaining to weight, muscle and frame score, and ultrasound measures. However, only a portion of the cattle had known sires. The results indicated that percentage of variation accounted for was greater in cattle with additional pieces of information such as known sire. Ultrasound information was used to a greater potential when used in combination with other pieces of information that accounted for variation in carcass traits such as sire and ranch of origin. This study indicated the potential value of additional calf background information in combination with ultrasound measurements for increased predictability of profit on a per animal basis.

Summary of Literature Review

As extensive research supports, body condition score has been a reliable indicator of reproductive performance in beef cattle and regulation of the estrous cycle. Limited research has been published on the relationship between either body condition score or reproductive performance and carcass ultrasound traits. The purpose of this study was to explore ultrasound measures of body composition as a means to evaluate potential maternal productivity in yearling heifers. The research objectives that defined Experiment 1 were to 1) study relationships between maternal productivity and ultrasound body composition measures in commercial females, and 2) establish ultrasound carcass data thresholds which accurately predict maternal performance in yearling heifers.

Research pertaining to changes in body composition as expressed through serial slaughter and serial ultrasound in growing beef calves have been summarized in this paper. Marbling deposition occurs consistently throughout a calf's life and has been shown to be linear when expressed as a function of hot carcass weight. The research objective that defined Experiment 2 was to establish the period in a calf's life from weaning to harvest when accumulation of fat, specifically intramuscular fat, is most correlated to the end carcass quality grade that could be of future use for sorting cattle.

MATERIALS AND METHODS

This project was organized as two distinct, but related experiments. Originally, the calves from Experiment 1 were to be used in Experiment 2. However, due to unforeseen management issues, only 25% of the calves were retained for the project, and the other 75% of the calves in Experiment 2 came from outside sources. Body composition measures in breeding females were evaluated via ultrasound, body condition score evaluation, and weight before and after the breeding season in both first calf heifers and primiparous heifers. This component is referred to as *Experiment 1*. Ultrasound measures of body composition as well as weight were also investigated in growing steers to every 56 days from preconditioning to slaughter. This component is referred to as *Experiment 2*. Both experiments were designed to investigate the efficacy of using carcass ultrasound to sort cattle based on a desired endpoint. The desired endpoints were pregnancy and quality grade in experiments 1 and 2, respectively.

Experiment 1

<u>Cattle</u>

There were four experimental groups of cattle upon which data were collected, all of which were privately owned cattle in cooperator herds. The groups differed in breed composition, calving dates, calving locations, or age, as illustrated in Tables 1 and 2. Herds A and B were F_1 Brahman x Hereford heifers (n = 412) ranging in age from 9 to 15 months when acquired from Nixon and Poteet, Texas and transported to Parker County Texas. Cattle that did not breed during the initial

90 day breeding season were exposed to bulls for an additional 90 days before they were culled from the experiment. This would have been the first breeding season for these heifers. It is important to note, that although heifers arrived in a group with a spread of an estimated 6-month range in age, only heifers that calved as 2-yr-olds were utilized for this project. Cattle were divided into a spring (herd A) and fall (herd B) calving groups, and these were analyzed separately. The management and data collection schedules for these two herds are shown in Figure 1. Herd A was divided into four groups to account for seasonal variations in the weather and forage supply since the calving season spanned January to May. Group 1 through 4 in herd A had approximately 50 calves each and included heifers that calved within 45 days. Herd B was managed as a single group. The breeding performance trait accessed was the ability for the first calf heifer to rebreed in the postpartum breeding season of 45 or 90 days, respectively, for herds A and B. Additionally, two sets of yearling heifers, herds C and D, were evaluated for the same aforementioned traits prior to and after the initial breeding season, as shown in Figures 2 and 3, respectively. Breed composition of these heifers was Beefmaster (n = 100 and n = 72 for herds C and D, respectively). The performance trait accessed for herds C and D was pregnancy status as a result of the initial 45 day breeding season. Herds C and D were both managed on a single ranch in Shackelford County, Texas, during two management seasons (2006 - 2007 and 2008 - 2009). A summary of calving and weaning dates across these herds is provided in Table 1.

Cows in herd A were challenged to rebreed for the first postpartum breeding season in 45 days; cows in herd B were challenged to rebreed for the postpartum breeding season in 90 days. Cattle in herds C and D were challenged to breed at 14 months during an initial 45 day breeding season. Cattle that were determined as pregnant were designated to have a pregnancy status of 1, and cows that were determined not pregnant were designated as 0. For herds A and B this represented rebreeding status after their second breeding season, whereas for Herds C and D, this represented pregnancy status following their first breeding season.

Data Collection - Ultrasound

Data were collected at various time points in these four herds that corresponded to typical times when production might be evaluated. The time frame included the age range from approximately one year of age to two years of age in herds A and B and spanned the postpartum breeding seasons. The time frame in the other two herds included before and after the initial breeding season for yearling heifers. Four ultrasound measurements of ribeye area (REA), 12^{th} rib fat thickness (RibFat), percent intramuscular fat (IMF), and rump fat (UFAT) were collected by a single, certified ultrasound technician utilizing an ALOKA 500V ultrasound machine with a 17 cm 3.5 GHz probe and Biotronics Inc. (Ames, IA) software. Images were interpreted by the National CUP Lab in Ames, Iowa. In addition to ultrasound data, body condition scores (BCS) and weights were collected at the same times, with pregnancy status recorded as well on appropriate dates. A summary of the dates for data collection across all four herds is provided in Table 2.

Statistical Analyses

All data were analyzed with SAS 9.1 (SAS Institute, Cary, NC). For herds A, B, C and D, simple means and simple Pearson correlations were calculated for all traits, measured across time, each scan time, and among rebreeding/pregnancy status. These statistics were evaluated across the entire dataset, and compared among the heifers that were determined pregnant after the breeding season and those that were determined open for each herd. An ANOVA Mixed model analysis with repeated measures was performed for ultrasound traits, with pregnancy status (yes or no), cow id (group), and time as main class variables, with appropriate interactions investigated. Least squares means and associated significance levels from two-tailed t-tests were obtained for rebreeding/pregnancy status across time for each trait measured. Additionally, a Glimmix Procedure (logistic regression) analysis was evaluated for pregnancy status (as confirmed via reproductive ultrasound by a veterinarian) as the dependent variable to determine which traits significantly impacted breeding success/failure. Ultrasound traits at each collection time were evaluated along with the conventional tool of body condition score. Odds ratios were calculated for herds A, C, and D, but herd B due to missing data points. Weaning weights were available for calves in herd A and weaning weight (above or below the 312 pound average) and weaning status (whether the cow weaned her first calf or not) were investigated in both the repeated measures as class variables and in the glimmix procedure as an independent variable.

Experiment 2

Cattle

As shown in Table 2, steers (n = 104) of four origins, born in the spring of 2007 (January through May), were serially scanned beginning at approximately 265 kg of body weight through harvest in 56 day ± 6 intervals, as illustrated in Table 2. Cattle were entered into a feedlot in Mclean, Texas in June of 2008, fed a standard step-up diet, and harvested in three lots in November 2008, January 2009, and March 2009. Carcass data were collected upon harvest through the commercial beef plant by their personnel.

Data Collection - Ultrasound

Ultrasound measurements were collected by a single, certified technician and included ribeye area (REA), 12^{th} rib fat thickness (RibFat), percent intramuscular fat (IMF), and rump fat (UFAT). Images were taken with an ALOKA 500V ultrasound machine with a 17 cm 3.5 GHz probe and Biotronics Inc. software. Images were interpreted by the National CUP Lab in Ames, Iowa. Weights were also recorded each time ultrasound measurements were obtained. Carcass data included marbling score, ribeye area, back fat, yield grade, hot carcass weight, and KPH (kidney, pelvic, and heart fat) at slaughter.

Statistical Analyses

All data were analyzed with SAS 9.1 (SAS Institute, Cary, NC). Simple means, standard deviations and ranges were calculated for all traits, and simple Pearson correlations across time were evaluated. An ANOVA-Mixed model with repeated measures analysis (PROC MIXED) was performed for each ultrasound trait as the dependent variable with days in program, origin, and time as main class variables, with appropriate interactions investigated. Least squares means were obtained for each trait across time. An analysis of the Glimmix Procedure (a logistic regression approach) was also performed to determine what traits significantly impacted cattle obtaining a marbling score of 600 (Modest Ch) or greater at slaughter. Intramuscular fat percentage at each scan time was used as the independent variables.

Upon investigation of line plots with intramuscular fat plotted against time, it was determined that there was an exponential factor to the intramuscular fat deposition for this population. Intramuscular fat percentage, measured via real time ultrasound, was regressed across days for the entire data set and it was determined that days and days squared were both significant in predicting intramuscular fat in a linear regression procedure. Next, a regression was performed for every observation. Intramuscular fat percentage was regressed across days. Subsequent beta coefficients for each observation were obtained. The model used was $Y = Bo + B_1X + B_2^2$ where Y was the value of intramuscular fat percentage, and X was the number of days to reaching the specified value of Y. It was determined that Y would be set to 4.0, the value of intramuscular fat that is equivalent to the quality grade of choice. Using the quadratic equation, X (days to choice) was obtained for each observation. The intercept, B_1, and B_2 were tested in an ANOVA-Mixed procedure to determine the effect of end quality grade (Choice or above and Choice - and below) as a class variable. Multiple regressions using the stepwise method determined which ultrasound and weight variables were useful in determining marbling score, and days to choice, for each scan time, under the constraint of having a *P*–value of less than 0.15.

RESULTS AND DISCUSSION

Experiment 1

<u>General Statistical Summaries</u>

General descriptive statistics are presented in Tables 5, 6, 7, and 8 for Herds A, B, C, and D, respectively. Furthermore, Tables 9 through 16 show simple descriptive statistics of females that were classified as pregnant vs. not pregnant in Herds A through D, respectively. Simple means were compared to least squares means from formal analyses as a check measure. Measures of body composition as exhibited in ultrasound traits, body condition score, and weight appeared to be generally higher in cows with a pregnancy status of 1 across herds A and B (Tables 9 and 10, and Tables 11 and 12, respectively). In herds C and D, heifers with a pregnancy status of 1 appeared to differ little from the heifers that with a pregnancy status of 0 (Tables 14-16).

<u>Correlation Coefficients</u>

Evaluation of correlations among traits had two specific focus areas: (1) correlations of the same trait evaluated across times, and (2) correlations among traits that were evaluated at the same time. As expected, correlations among same traits were stronger with subsequent scans as shown in Tables 17, 18, 19, and 20 among herds A, B, C, and D. In Tables 21 through 31, correlation coefficients among herds within scan times are expressed. Ribfat and rump fat were correlated ($r = 0.82$, $P < 0.001$; $r = 0.83$ $P < 0.001$; $r = 0.79$ $P < 0.001$) for scans 2, 3, and 4, respectively in herd A. REA and BCS were correlated ($r = 0.75$, $P < 0.001$; $r = 0.74$

$P < 0.001$; r = 0.66 $P < 0.001$) for scans 2, 3, and 4, respectively in herd A. REA and BCS were correlated (r = 0.78, $P < 0.001$; r = 0.50 $P < 0.001$) for scans 2, and 3, respectively in herd B. Ribfat and rump fat were correlated (r = 0.78, $P < 0.0001$; r = 0.49 $P < 0.0001$) for scans 2, and 3, respectively, in herd B. Similarly, the correlation coefficients for ribfat and UFAT were r = 0.54 ($P < 0.001$), and r = 0.42 ($P = 0.0002$), for herd C in scans 1 and 2, respectively. Correlation coefficients for ribfat and UFAT were r = 0.61 ($P < 0.001$), and r = 0.70 ($P < 0.001$) in herd D for scans 1 and 2, respectively. Ribeye area and body condition score were correlated at r = 0.52 ($P < 0.001$) and r = 0.061 ($P = 0.550$) in herd C at times 1 and 2, respectively. Ribeye area and body condition score were correlated at r = 0.29 ($P = 0.013$) in herd D at time 1; body condition score was not collected at scan 2 in herd D.

Interestingly, some correlations across time were more variable than others. It should also be noted that the correlations for ribeye area with itself at scans 1 and 2 were extremely low (r = 0.09, $P = 0.241$ and r = -0.02, $P = 4728$) for both herds A and B, respectively. These neutral correlations could be due to the fact that different technicians were used for scans 1 and 2 (the only time technicians were different). At times 2 and 3, the correlations for REA were r = 0.78 ($P < 0.001$) and r = 0.46 ($P = 0.001$) for herds A and B, respectively. The duration from scans 2 to 3 was much shorter for herd A than herd B (approximately 6 months versus 1 year) which could partially explain the large difference in correlations among the two herds. The correlations between REA with itself at scans 1 and 2 were r = 0.36 ($P < 0.001$) and r = 0.80 ($P < 0.001$) for herds C and D, respectively.

Body condition score correlated with itself at times 2 and 3 were r = 0.63 and r = 0.003 for herds A and B, respectively. The correlations for BCS with itself evaluated at scans times 3 and at weaning of the first calf were r = 0.43 and r = 0.31 in herds A and B, respectively. These weak correlations suggest that cattle were changing in both BCS and REA during the course of data collection. Again the time lapse between scans 2 and 3 was approximately 6 months for herd A while it was 1 year for herd B. The correlations between body condition score with itself at scans 1 and 2 were r = 0.16 ($P < 0.001$) for herd C.

Correlations across time for herds A and B showed IMF correlations to decrease with subsequent scans. For IMF evaluated at scans 1 and 2, 2 and 3, and 3 and 4 the correlations of IMF with itself taken at those times were r = 0.74 ($P < 0.001$), r = 0.67 ($P < 0.001$), and r = 0.56 ($P < 0.001$), respectively for herd A. For IMF evaluated at scans 1 and 2, and 2 and 3 the correlations of IMF with IMF taken at those times were r = 0.69 ($P < 0.001$) and r = 0.50 ($P < 0.001$), respectively for herd B. The correlations between ribeye area with itself at scans 1 and 2 were r = 0.07 ($P = 0.4892$) and r = 0.57 ($P < 0.001$) for herds C and D, respectively.

Ribfat evaluated at times 1 and 2, 2 and 3, and 3 and 4 correlated with itself across time was r = 0.43 ($P < 0.001$), r = 0.57 ($P < 0.001$), and r = 0.59 ($P < 0.001$), respectively, in herd A. Interestingly, UFAT in herd A was correlated across evaluation times 2 and 3, and 3 and 4 at r = 0.64 ($P < 0.001$) and r = 0.61 ($P <$

0.001). While ribfat correlations grew stronger across time in herd A, rump fat remained constant. In herd B, ribfat correlated with itself across time for scans 1 and 2, and 2 and 3 was r = 0.66 ($P < 0.001$) and r = 0.35 ($P < 0.001$), respectively. The correlations between ribfat with itself at scans 1 and 2 were r = 0.12 ($P = 0.226$) and r = 0.27 ($P = 0.021$) for herds C and D, respectively.

When looking at the general summary statistics, cattle in herd A lost approximately one half of a body condition score from scan 2 through 30 days post partum and then lost an additional score from the beginning to the end of the post partum breeding season of 45 days. The ribeye area fluctuated by approximately 7 square centimeters between scans 2 through 4 eventually averaging out at 5.9 cm^2 less on the post partum scan than the average ribeye area of 47.2 cm^2 at yearling age, in herd A. Herd B was also characterized by dropping body condition score and ribeye size through the course of data collection. Body condition score in herd B was evaluated at 6.2 at scan 2, but dropped to 4.8 at scan 3. Likewise, ribeye area in herd B increased 10.8 cm^2 to an average of 53.5 but fell sharply when re-evaluated at scan 3 averaging only 40.4 cm^2. As cattle lost body condition immediately following parturition and through lactation, ribeye size decreased simultaneously.

<u>Repeated Measures Analyses</u>

Results from the mixed model, repeated measures analyses are discussed individually for each trait below. Least squares means for traits across time and pregnancy status are provided in Table 32 for Herd A, Table 33 for Herd B and Table 34 for Herds C and D pooled. Additionally, these least squares means are graphically presented by trait in Figures 4 through 8. Significance values for these effects as well as residual variances can be found in Appendix B. Class variables included pregnancy status, group (in herd A only), time, and the pregnancy status by time interaction. Weaning weights, below or above the 312 pound average, of calves from herd A were investigated as a class variable to determine the influence of weaning weight on ultrasound traits and body condition score. Weaning weight influenced body condition score ($P = 0.001$) but did not influence IMF ($P = 0.315$), REA ($P = 0.080$), or Ribfat ($P = 0.496$). There was a trend for weaning status (whether a cow weaned her first calf or not) to impact BCS ($P = 0.0822$).

Weight

Weight was not influenced by group ($P = 0.586$), but was influenced by pregnancy status ($P = 0.004$), time ($P < 0.001$), and time by pregnancy status interaction ($P = 0.009$) in herd A. Weight was not influenced pregnancy status ($P = 0.902$) herd B. Weight was influenced by year ($P = 0.001$), by pregnancy status ($P = 0.015$), time ($P < 0.001$), but not by time by pregnancy status interaction ($P = 0.450$) in herds C and D. Due to inconsistency with the scales and resulting missing data points, least square means for weight were only available at times 1 and 4 in herd A and time 1 in herd B. In herd A, cattle with a pregnancy status of 1 weighed more at scan time 4 than cattle with a pregnancy status of 0 ($P < 0.05$). In herds C and D, cattle with a pregnancy status of 1 weighed more at scan 1 ($P < 0.05$) but not at scan time 2.

Body condition score

Body condition score was influenced by group (*P* = 0.001), pregnancy status (*P* < 0.001), and time (*P* < 0.001), but not the pregnancy status by time interaction (*P* = 0.862) in herd A. Body condition score was influenced by time (*P* < 0.001), but not pregnancy status (*P* = 0.224), or the pregnancy status by time interaction (*P* = 0.227) in herd B. Due to body condition score not being measured at scan 1, and missing data points at scan 3, least squares means were only available for body condition score at times 2 and 4 for herd A, and times 2 and 3 for herd B. Body condition score was influenced by pregnancy status (*P* = 0.059), time (*P* < 0.001), year (*P* < 0.001), and the pregnancy by time interaction (*P* = 0.035) in herds C and D.

Body condition score was different across pregnancy status within time for scans 2 (*P* < 0.001) and 4 (*P* < 0.001) in for herd A. Body condition score was lower (*P* < 0.05) in females that failed to obtain pregnancy in Herd A at time 2 (6.2 vs. 6.7) and time 4 (4.6 vs. 5.2; Table 32); however, this was not the case in Herd B (Table 33), although the differences in BCS at time 2 were very similar values to those observed in Herd A (6.2 vs. 6.6). In herd B, body condition score differed within pregnancy status between times 2 and 3 (6.2 vs. 4.7 in heifers that failed to rebreed and 6.6 vs. 4.7 in heifers that bred back). In herds C and D, heifers that became pregnant had higher body condition score at time 1 (5.6 vs. 5.3), but not at time 2 (both 5.2). Body condition scores at scan 1 differed (*P* = 0.006) within pregnancy status across time in herds C and D.

Figure 4 shows the trend of decreased body condition score across scan times, but cattle with a pregnancy status of 1 tended to maintain a higher body condition score throughout the project. These findings concur with previous research that suggests a threshold body condition score of 5 to 6 at calving is essential for cows to rebreed following parturition (Spitzer et al., 1995; Ciccioli et al., 2003; Lake et al., 2007).

Intramuscular fat percentage

Intramuscular fat percentage was influenced by group ($P = 0.097$), pregnancy status ($P = 0.037$), time ($P < 0.001$), and the pregnancy by time interaction ($P = 0.029$) in herd A. Intramuscular fat percentage was influenced by time ($P < 0.0001$), but not pregnancy status ($P = 0.565$), or the pregnancy by time interaction ($P = 0.817$) in herd B. Intramuscular fat percentage was influenced by year ($P < 0.001$), but not pregnancy status ($P = 0.246$), time ($P = 0.435$), or pregnancy by time interaction ($P = 0.116$) in herds C and D.

Measures of IMF were different during scan 3 among pregnancy status within time ($P < 0.001$) in herd A, where heifers that bred back had 3.27% IMF, but heifers that failed to breed back only had 2.79% IMF. In herds B, C, and D, measures of IMF were not different across pregnancy status within time. Furthermore, across times within pregnancy status, IMF in herds C and D did not differ. In contrast, IMF did differ across times within pregnancy status for herds A and B, with the exception of times 3 and 4 ($P = 0.268$) for bred cattle, and times 2 and 3 ($P = 0.248$) for open cattle, for herds A and B, respectively. In herd A, IMF was different in females that rebred vs. those that did not at time 2 ($P = 0.054$) and time 3 ($P < 0.001$), but were not different at times 1 ($P = 0.160$) or 4 ($P = 0.198$). Intramuscular fat percentage with a pregnancy status of 1 in herd A remained higher across all four scan periods. Although IMF in herd B were lower at scan time 1, for cattle with a pregnancy status of 1, the ending IMF at scan 3 was higher for this group of cattle ($P = 0.036$). In herds C and D, IMF was similar at scan time one, but cattle with a pregnancy status of 1 had lower IMF at scan 2. The initial increase in IMF and then subsequent decreases concurs with literature published by Rouse et al. (2001) in Angus females scanned five times from yearling age to the weaning of their second calf. Rouse et al. (2001) reported that Angus first calf heifers gained IMF until first parturition and IMF reserves did not begin to replenish until after the second calf was born. Cattle in herds A and B were not scanned beyond weaning of the first calf, however, IMF levels in both herds were both higher at scan 3 than they were at scan 1. It should be noted that the cattle in the study by Rouse et al. (2001) were purebred Angus cattle.

Bullock et al. (1991) published a correlation of r = 0.86 between marbling and body condition score in cull beef cows at slaughter. Cows in their project differed from cattle in our work as they were mature, open, and not lactating. Furthermore, cows in their project were medium to large framed black white faced cows of varying body condition obtained through local salebarns. Minick et al. (2001) reported that IMF measurements took longer to recover after parturition in primiparous Angus heifers than did ribfat. It was reported that IMF levels decreased after parturition and did not begin to increase until after the second parturition.

Although cattle in this experiment were not scanned through the second calving, the IMF values did fluctuate in herds A and B. At scan one, or yearling age, IMF values were 2.5 and 2.4 for herds A and B, respectively. At scan two, IMF levels peaked in both herds to 3.4 and 3.2 for herds A & B respectively. After calving and approximately 30-60 days of lactating, cattle in herds A and B expressed IMF values of 3.1 and 2.7, respectively. Loss of IMF while experiencing the physiological burdens of pregnancy, parturition, and lactation concurred with those findings by Rouse et al. (2001).

Ribeye area

Ribeye area was influenced by group ($P = 0.006$), pregnancy status ($P = 0.006$), time ($P < 0.001$), and the pregnancy by time interaction ($P = 0.026$) in herd A. Ribeye area was influenced by time ($P < 0.001$), but not by pregnancy status ($P = 0.107$), or the pregnancy by time interaction ($P = 0.284$) in herd B. Ribeye area was influenced by time (P < 0.001), year ($P < 0.001$), pregnancy status ($P = 0.0007$), and the pregnancy by time interaction (P = 0.0002), and, in herds C and D.

Ribeye area across pregnancy status was different at scans 2 ($P = 0.001$), 3 ($P = 0.007$), and 4 ($P = 0.002$) in herd A Ribeye area decreased ($P < 0.05$) across time for herds A and B (Figure 6) within pregnancy status with one exception that held constant across both herds. Cattle with a pregnancy status of 1 did not differ in ribeye area at times 1 and 3 in either herds A or B ($P = 0.370$ and $P = 0.404$), suggesting cattle that rebred had not decreased in ribeye area compared to cattle that failed to rebreed. Cattle in herds C and D increased between scan times 1 and 2, and cattle with a pregnancy status of 1 had larger ribeye area with a more pronounced difference at time 1 (*P* < 0.001). Ribeye area in herds C and D differed (*P* < 0.05) across time within pregnancy status. This is in accordance with Minick et al. (2001) who concluded that Angus heifers with greater ribeye areas were more apt to be cycling at one year of age when scanned prior to the first breeding season. This study also reported REA as a linear growth curve over a five scan period of (1) before breeding, (2) before first parturition, (3) at weaning of first calf, (4) before second parturition, and (5) at weaning of their second calf. It should be noted that these cattle were purebred Angus cattle and rebreeding data or supplementation strategies were not reported.

Ribfat

Ribfat was influenced by group (*P* = 0.001), pregnancy status (*P* < 0.001), time (*P* < 0.001), and pregnancy by time interaction (*P* < 0.001) in herd A. Ribfat was similarly influenced by pregnancy status (*P* = 0.004), time (*P* < 0.001), and the pregnancy by time interaction (*P* = 0.051) in herd B. Ribfat was influenced by time (*P* < 0.001) and year (*P* = 0.019), but not by pregnancy status (*P* = 0.114) or the pregnancy by time interaction (*P* = 0.081) in herds C and D.

Ribfat differed between pregnancy status 1 and 0 at times 1 (*P* = 0.001), 2 (P = 0.007), and 3 (*P* = 0.002), in herd A, time 2 (*P* = 0.020), in herd B, and time 2 (*P* < 0.001), in herds C and D. In herds A and B, ribfat differed across all times within pregnancy status, with the exception of times 1 and 2 (*P* = 0.646) in herd A, and times 1 and 3 (*P* = 0.622) in herd B for cattle with a pregnancy status of 0. Across time and within pregnancy status, ribfat differed (*P* < 0.002) between scans 1 and 2 for herds C and D. Cattle with a pregnancy status of 1 appeared to express higher levels of ribfat at all scan periods for herds A, B, C, and D.

Across pregnancy status within time, cattle differed in ribfat at scan time 2 and 3 (*P* < 0.001) with ribfat being greater for cattle with a pregnancy status of 1, but ribfat did not differ at scans 1 and 4 (*P* = 0.066 and *P* = 0.549, respectively) in herd A. Across pregnancy status within time, cattle differed in ribfat at scan time 2 (*P* = 0.001) but not at scans 1 and 3 (*P* = 0.646 and *P* = 0.108, respectively) in herd B. Across pregnancy status within time, cattle differed in ribfat at scan time 2 (*P* = 0.019) expressed as cattle with a pregnancy status of 1 having a greater amount of ribfat, but ribfat did not differ at scan 1 (*P* = 0.935) in herds C and D.

Rouse et al. (2001) reported ribfat recovered in primiparous heifers after the weaning of the first calf. Ribfat levels fell to the lowest average at scan 4 for both herds A and B and did not recover. It should be noted that cattle in the study by Minick et al. (2001) were scanned longer than cattle in this paper.

Rump fat

Rump fat was influenced by group (*P* = 0.002), pregnancy status (*P* < 0.001), time (P < 0.001), and by the pregnancy by time interaction (*P* = 0.001) in herd A. Rump fat was influenced by pregnancy status (*P* = 0.010), time (*P* = 0.002), and not by the pregnancy by time interaction (*P* = 0.848) in herd B. Rump fat was influenced by pregnancy status (*P* = 0.033), time (*P* < 0.001), and year (*P* < 0.001), but not the by pregnancy by time interaction (*P* = 0.636) in herds C and D.

Measures of UFAT across pregnancy status differed in herd A at times 2 (*P* < 0.001) and 3 (*P* < 0.001), but only at time 3 (*P* = 0.027) in herd B; UFAT differed in herds C and D at time 2 (*P* = 0.049). Cattle with a pregnancy status of 1 displayed higher levels of rump fat at all times in all herds. Across time within pregnancy status, measures of UFAT differed at all times in herds A and B. It is important to note that UFAT was not measured at scan 1 on either herd A or B. Across time within pregnancy status, measures of UFAT differed from scan 1 to 2 (*P* < 0.013) in herds C and D.

Minick et al. (2001) reported that Angus heifers with higher amounts of rump fat when adjusted to 395 days had higher reproductive tract scores. This finding concurs with cattle in herds C and D with a pregnancy status of 1 having higher amounts of ribfat and rump fat at both scan times and *P* < 0.05 at scan 2. This suggests that cattle in herds C and D were more likely to be reproductively mature as expressed through higher levels of rump and rib fat.

<u>Glimmix – Logistic Regression of Pregnancy Status</u>

A logistic regression procedure (PROC GLIMMIX) was performed to determine which ultrasound traits at different evaluation times influenced pregnancy status. Weaning weight was tested as the independent variable to determine the impact on pregnancy status in herd A but was found to have a marginal effect (*P* = 0.053) on pregnancy. Weaning status (if a cow weaned her first calf) was also found to have no effect on pregnancy status (*P* = 0.145). Weaning status was also investigated as an independent variable along with ultrasound traits and with body condition scores across scan times. Weaning status only impacted pregnancy status at scan 3 (*P* = .0074) when tested with ultrasound traits, and at scan 4 (*P* = 0.035) when tested with body condition score. Weaning status was removed from the model during scan times when it was not significant.

Rump fat was not placed in the model because of the high correlations between rib fat and rump fat. Rib fat was chosen to be analyzed over rump fat because the measurement can be obtained from the ribeye image, and would be more practical since an additional image would not be needed as in the case of rump fat. The same procedure was performed using body condition score only at these scan times to determine how it impacted pregnancy status. The results were compared to determine if ultrasound could be any more successful than the conventional method of BCS to predict pregnancy likelihood.

Ultrasound traits

Parameter estimates, standard errors, and significance values for the effects of ultrasound traits on pregnancy status at different times for herd A are in Table 35. Among traits evaluated at scan time 1, the traits that impacted pregnancy status were IMF (*P* = 0.0253) and Ribfat (*P* = 0.0145). Among traits evaluated at scan 2, the only trait that impacted pregnancy status was ribfat (*P* = 0.0135). Among traits evaluated at scan times 3 and 4, none significantly impacted pregnancy. This suggests that cattle with a pregnancy status of 1 were fatter at scan 1; potentially older and further along in their growth curve with less growth requirements while lactating.

Parameter estimates, standard errors, and significance values for the effects of ultrasound traits on pregnancy status at different evaluation times for herd B can be found in Table 36. Among traits evaluated at scan time 1, the traits that impacted pregnancy status were IMF (*P* = 0.025) and Ribfat (*P* = 0.014). Among traits evaluated at scan time 2, the only trait that impacted pregnancy status was ribfat (*P* = 0.022). Among the traits evaluated at scan 3, only trait that impacted pregnancy was ribeye area (*P* = 0.013).

Parameter estimates, standard errors, and significance values for the effects of ultrasound traits on pregnancy status across time for herd C can be found in Table 37. Among traits evaluated at scan time 1, the only trait that impacted pregnancy status was REA (*P* = 0.023). Among traits evaluated at scan time 2, the only trait that that impacted pregnancy status was ribfat (*P* = 0.035). Heifers were challenged immediately following scan 1 to conceive in 45 days so it would be probable that larger heifers at time 1 would be more likely to be cycling at that time if these ribeye area differences reflected age differences.

Parameter estimates, standard errors, and significance values for the effects of ultrasound traits on pregnancy status across time for herd D can be found in Table 38. The only trait that impacted pregnancy status at scan time 1 was REA (*P* = 0.007). There were no traits that impacted pregnancy status at scan time 2, although IMF showed a trend (*P* = 0.07). The impact of REA at time 1 in both herds suggest that relative differences in size at this time were likely an indicator of maturity.

Body condition score

Parameter estimates, standard errors, and significance values for the effects of body condition scores on pregnancy status across time for herd A can be found in Table 39. Body condition scores were not taken at scan time 1 for herd A. Body condition scores impacted pregnancy at significance levels of $P < 0.05$, at scan times 2 ($P = 0.001$), 4 ($P < 0.001$), and 30 days post parturition (BCS PP) ($P = 0.001$). This agrees with work done by DeRouen et al. (1994) who found that pre-partum body weight and condition fluctuations of increasing or decreasing up to one condition score ranging from BCS of 4–7 had lesser influence on reproductive performance than body condition at calving. De Rouen et al. (1994) concluded that cows in a body condition score of 6-7 had the shortest post partum interval while cattle with a body condition score of >5 had a shorter post partum interval than cows in body condition of 4. Cattle in the study published by DeRouen et al. (1994) were primiparous crossbred cows.

Parameter estimates, standard errors, and significance values for the effects of body condition scores on pregnancy status across time for herd B are presented in Table 40. It should be noted that body condition scores were not taken at scan time 1 or 30 days after parturition on herd B. Body condition scores did not impact pregnancy at scan times 2 or 3, but did for scan time 4. Cows in this herd were managed to calve in the fall in West Texas. All cattle had low body condition scores without much variation so there simply may not have been enough variation within body condition scores to suggest a difference between pregnancy statuses.

Parameter estimates, standard errors, and significance values for the effects of body condition scores on pregnancy status across time for herd C can be found in Table 41. Body condition score impacted pregnancy status (*P* = 0.018) for scan time 1 only.

Parameter estimates, standard errors, and significance values for the effects of body condition scores on pregnancy status across time for herd D can be found in Table 42. It should be noted that body condition score was not taken at scan 1 on herd D, and it did not appear to impact pregnancy status at scan time 2 (*P* = 0.117).

<u>Odds Ratios – Ultrasound Traits</u>

Odds ratios were calculated for herds A, C, and D for those traits that impacted pregnancy status at a significance level of $P < 0.05$. The odds ratio represents a way to compare the likelihood of the event occurring among two groups. An odds ratio of 1 to 1 suggests that the event is equally likely to occur in both groups. An odds ratio of greater than 1 would suggest that the likelihood of the event occurring is greater in the control group when compared to the treatment group. The treatment group would represent a theoretical situation in which the average ultrasound traits or body condition scores were higher. The odds ratios that were generated from the Glimmix Procedure for herd A indicated that a 1% increase in the average IMF at scan 1 (2.5 % to 3.5 %) would increase the odds of a desirable pregnancy status by 1.931 to 1. Therefore increasing the average IMF at scan 1 in herd A to 3.5% would increase the odds of cattle successfully rebreeding by 93%. Odds ratios at scan 1 indicated that a 0.10 cm increase in the average ribfat at scan 1

(0.287 cm to 0.387 cm) would increase the odds of a desirable pregnancy status by 1.88 to 1 (88%) in herd A.

Odds ratios at scan 1 indicated that a 6.45 cm^2 increase in the average ribeye area at scan 1 (47.0 cm^2 to 53.53 cm^2) would increase the odds of a desirable pregnancy status by 1.73 to 1 (73%) in herd C. Odds ratios at scan 2 indicated that a 0.10 cm increase in the average ribfat at scan 2 (0.254 cm to 0.356 cm) would increase the odds of a desirable pregnancy status by 1.73 to 1 (73%) in herd C.

Odds ratios at scan 1 indicated that a 6.45 cm^2 increase in the average ribeye area at scan 1 (41.9cm^2 to 48.3 cm^2) would increase the odds of a desirable pregnancy status by 2.74 to 1 (274%) in herd D. Odds ratios at scan 2 indicated that a 1% increase in the average IMF at scan 2 (4.6 % to 5.6 %) would increase the odds of a desirable pregnancy status by 0.05 to 1 or just 5% for herd D.

<u>Odds Ratios – Body Condition Score</u>

Odds ratios were calculated for herds A, C, and D for body condition scores that impacted pregnancy status at a significance level of $P < 0.05$. The odds ratios that were generated from the Glimmix Procedure for herd A indicated that a body condition score increase of 1 score would increase the odds of a desirable pregnancy status when evaluated at scan time 2, scan time 3, or 30 days postpartum, and scan time 4 by 1.75, 2.95, 1.94, and 3.67 to 1, respectively. The population averages for body condition scores at these times were 6.4, 6.0, 5.5, and 4.9, and the odds ratios were calculated assuming these averages could be increased by one score. Although group was not significant in the analysis, the 30 day post partum body condition score was investigated among the 4 groups in herd A. It was discovered that the predicted odds ratios increased considerably when body condition score average was lower, indicating a stronger impact on a positive pregnancy status with the addition of body condition score when condition was lower or modest. Among groups in herd A, odds ratios indicated that an increase in body condition by one score at 30 days postpartum for the following averages of 6.1, 6.0, 6.2, and 5.8 increased the likelihood of a desirable pregnancy status by 1.536, 2.498, 2.551, and 4.775 to 1, respectively. Odds ratios at scan 2 indicated that an increase in body condition score from 5.5 to 6.5 would increase the odds of a desirable pregnancy status by 2.89 to 1 for herd C.

Experiment 2

General Statistical Summaries

General means, standard deviations and ranges of carcass ultrasound traits and weights are expressed in Table 43. When initially scanned, steers averaged 265.3 kg weight, 2.8% intramuscular fat (IMF), 41.5 cm^2 ribeye area (REA), 0.34 cm rump fat (UFAT), and 0.23 cm ribfat. Over the course of approximately 336 days, steers increased on average 280 kg, 1.8 % IMF, 39 cm^2 REA, 0.76 cm of UFAT, and 0.78 cm of ribfat. Descriptive statistics for carcass traits are provided in Table 44; steers averaged hot carcass weight of 361.6 kg, REA of 85.1, backfat of 1.76 cm, marbling score of 614 (small Choice), and a yield grade of 3.1. By setting the initial scan as day 0, steers averaged 237 days to reaching an IMF of 4 % or the equivalent of quality grade small choice. Descriptive statistics for carcass traits by quality grade are provided in Appendix B (Table B-1).

Correlation Coefficients

As expected, correlations among the same traits measured over time were stronger with subsequent scans. Marbling score (Table 45) was correlated fairly consistently to ultrasound IMF at times 1, 2, 3, 4, 5, and 6 at r = 0.32 (P = 0.005), r = 0.31 (P = 0.008), r = 0.34 (P = 0.003), r = 0.42 (P = 0.003), r = 0.40 (P = 0.006), r = 0.40 (P = 0.005), respectively. In previous studies, Wall et al. (2004) found a correlation of r = 0.63 between carcass marbling score and ultrasound IMF taken at 96 to 105 days prior to slaughter. At scans taken closer to slaughter correlations as high as r = 0.69 and r = 0.85 have been reported by Perkins et al. (1997) and Brethour (2000), respectively. Carcass ribeye area (Table 46) was correlated to ultrasound REA at times 1, 2, 3, 4, 5, and 6 at r = 0.34 (P = 0.003), r = 0.37 (P = 0.001), r = 0.37 (P = 0.001), r = 0.432 (P = 0.006), r = 0.42 (P = 0.002), r = 0.52 (P < 0.001), respectively. Correlations between ribeye aea and carcass ribeye area became stronger as scan times approached slaughter and fall within the range of values previously reported. Wall et al. (2004) reported a correlation of r = 0.52 between carcass ribeye area and ultrasound ribeye area taken 96 to 105 days prior to slaughter. At 5 days prior to slaughter, Greiner et al. (2003) reported r = 0.86 between carcass ribeye area and ultrasound ribeye area. Backfat (Table 47) became increasingly correlated to ultrasound ribfat as time progressed with correlations at times 1, 2, 3, 4, 5, and 6 of r = 0.38 (P = 0.008), r = 0.46 (P < 0.001), r = 0.43 (P =

0.002), r = -0.016 (*P* = 0.890), r = 0.29 (*P* = 0.014), r = 0.52 (*P* < 0.0001), respectively. These correlations are lower than the correlation of r = 0.58 reported by Wall et al. (2004) between carcass fat thickness and ultrasound ribfat taken 96 to 105 days prior to slaughter, and r = 0.89 at five days prior to slaughter reported by Greiner et al. (2003). The correlations between backfat and ribfat were comparable to results found by Rouse et al. (2000) where correlations reported were r = 0.53, r = 0.64, and r = 0.72 between carcass fat thickness and ultrasound fat thickness at 90, 46, and 6 days prior to slaughter, respectively. Weight (Table 48) was correlated to hot carcass weight 1, 2, 3, 4, 5, and 6 at r = 0.31 (*P* = 0.007), r = 0.26 (*P* = 0.027), r = 0.20 (*P* = 0.090), r = 0.22 (*P* = 0.061), r = 0.12 (*P* = 0.300), r = 0.29 (*P* = 0.011), respectively. It should be noted that although the correlation between weight measured at scan time 6 and hot carcass weight is weak, the hot carcass weight was not comparable to a live weight because it accounted for dressing percentage. It is not clear as to why the correlations between hot carcass weight and weight measured at times 1-6 are so low, but the highest correlation exists between weight collected at scan 6 and hot carcass weight which is to be expected (r = 0.29, *P* = 0.011). Average daily gains were 0.46, 0.45, 0.83, 1.87, 1.47, and 0.80 kg for the time periods between scan times beginning at scan 1 and ending at slaughter.

Tables 50 through 55 include correlation coefficients for traits measured within scan time. Ribfat was correlated to UFAT at scan times 1, 2, 3, 4, 5, and 6 at r = 0.67 (*P* < 0.001), r = 0.68 (*P* < 0.001), r = 0.72 (*P* < 0.001), r = 0.88 (*P* < 0.001), r = 0.78 (*P* < 0.001), r = 0.65 (*P* = < 0.001), respectively. Weight was fairly consistently stable in its correlation to REA at scan times 1, 2, 3, 4, 5, and 6 at r = 0.65 (*P* < 0.001), r = 0.56 (*P* < 0.001), r = 0.80 (*P* < 0.001), r = 0.83 (*P* < 0.001), r = 0.73 (*P* < 0.001), r = 0.55 (*P* = < 0.001), respectively. Weight was more strongly correlated to UFAT closer to slaughter with correlations of r = 0.37 (*P* < 0.001), r = 0.15 (*P* = 0.121), r = 0.72 (*P* < 0.001), r = 0.78 (*P* < 0.001), r = 0.67 (*P* < 0.001), r = 0.46 (*P* = < 0.001), respectively, for scans 1-6. The correlations between ribfat and IMF became increasingly stronger across scans at r = 0.08 (*P* = 0.365), r = 0.16 (*P* = 0.102), r = -0.09 (*P* = 0.330), r = -0.04 (*P* = 0.293), r = 0.27 (*P* = 0.003), and r = 0.30 (*P* = 0.004) for scans 1-6, respectively.

Correlations among carcass traits at slaughter are presented in Table 56. The correlation between backfat and marbling score was weak at r = 0.05 (*P* = 0.636). The correlation between ribeye area and backfat was negative at r = -0.28 (*P* = 0.017). Strengthening relationships were found between backfat and KPH, hot carcass weight, and yield grade with correlations of r = 0.10 (*P* = 0.365), r = 0.25 (*P* = 0.033), r = 0.54 (*P* < 0.001), respectively. The correlations between marbling score and yield grade (r = -0.23, *P* = 0.052), ribeye area (r = 0.02, *P* = 0.809), hot carcass weight (r = -0.08, *P* = 0.502), and KPH (r = 0.09, *P* = 0.442) were all low. Hot carcass weight was correlated to ribeye area at r = 0.29 (*P* = 0.011) and to yield grade at r = 0.213 (*P* = 0.028).

<u>Repeated Measures Analyses</u>

The class variables in the repeated measures analysis were days (number of days from initial scan to slaughter), origin (based on breed composition and age of dam), time, and the time by origin interaction. Significance values for these effects as well as residual variances can be found in Appendix B.

Weight

Weight was influenced by days (*P* < 0.001), time (*P* < 0.001), time by origin interaction (*P* = 0.004), but not by origin (*P* = 0.084). Weight increased in a linear fashion as shown in Figure 9 with the largest increase between scans 4 and 5 with an increase of 102.5 kg (*P* < 0.001).

Ribeye area

Ribeye area was influenced by days (*P* < 0.001), time (*P* < 0.001), time by origin interaction (*P* < 0.001), but not by origin (*P* = 0.564). Ribeye area did not change between scans 1 and 2 or 2 and 3 with signficiance values of *P* = 0.29 and *P* = 0.079, respectively. However, beginning at scan 3-6 ribeye area increased for the remainder of the study in a linear fashion (*P* < 0.001) (Figure 10).

Ribfat

Ribfat was affected by days (*P* = 0.012), time (*P* < 0.001), time by origin interaction (*P* < 0.001), but not by origin (*P* = 0.354). Ribfat actually remained stagnant and not changing from scans 1-2 (*P* = 0.123), scans 2-3 (*P* = 0.596) but increased beginning at scan 3-6 (*P* < 0.001) (Figure 11).

Intramuscular fat

Intramuscular fat (IMF) was affected by days (*P* = 0.678), time (*P* < 0.001), time by origin interaction (*P* = 0.028), and by origin (*P* < 0.001). Intramuscular fat (IMF) had an exponential element to the curve as shown in Figure 11. IMF decreased between scans 1 and 2 ($P < 0.001$) and then increased in a linear fashion (Figure 12.) Intramuscular fat was not different at scan times 1 and 3 ($P = 0.972$) due to a drop in IMF from scan 1 to scan 2 ($P < 0.001$) and an increase between scans 2 and 3 ($P < 0.001$).

Rump fat

Rump fat (UFAT) was affected by days ($P < 0.001$), time ($P < 0.001$), time by origin interaction ($P < 0.001$), and by origin ($P < 0.006$). Similarly, UFAT decreased from scans 1-3 ($P < 0.001$) and then increased during the remainder of the study ($P < 0.05$) (Figure 13).

It should be noted that steers were on pastures from scan times 1 through 3. Between scan times 3 and 4, cattle were placed in a feedlot where nutrition exceeded maintenance requirements which most likely explain the body compositional trends in the figures mentioned. The stair-step marbling deposition pattern as described by Zinn et al. (1970) was not observed in this experiment. Cattle in this experiment lost IMF initially between scans 1 and 2 ($P < 0.001$), and then gained it back between scans 2 and 3 ($P < 0.001$) so the periods of dormancy referred to by Zinn et al. (1970) in IMF deposition were not observed during the first or second half of this study. Cattle in this experiment also accumulated IMF at 0.15% and 0.16% between scans 4 and 5 and scans 5 and 6, respectively. The average IMF of choice equivalent was reached between scans 5 and 6. The substantial increase in IMF when cattle reached the threshold of choice as described by Brethour (2000) was not observed in this study.

Although cattle increased in weight (*P* < 0.05) across scans 1-6, ribeye area did not changed between scans 1-3 (*P* = 0.54) and ribfat also stabilized (P = 0.43). Likewise IMF did not differ between scans 1 and 3 (*P* = 0.097). This shows that although cattle continue to increase in frame and weight, if nutritional requirements are not being met, cattle may not be increasing in ribeye size or deposition of IMF, ribfat, or rump fat.

Intramuscular Fat by Quality Grade

Additionally, quality grade (prime, choice, small choice, and select) was investigated across time for the trait of IMF (Figure 14). The class variables in the repeated measures analysis were quality grade, time, and the time by quality grade interaction. The trait IMF was influenced by time (*P* < 0.001), quality grade (*P* = 0.001), but not by the time by quality grade interaction (*P* = 0.847).

Prediction Equations for Marbling Score

Using stepwise regression to determine the most useful equation to predict marbling score at each scan time automatically places the constraint that the independent variables must have a significance level of at least 0.15 to be placed in the model. At scan 1, two equations were derived using IMF and/or ribfat. The equation with the highest R^2 was 0.17 and utilized both IMF and ribfat at time 1 (Table 57.) At scan 2, three equations were derived using IMF, weight, and UFAT singularly or collectively (Table 58). The equation with the highest R^2 was 0.23 and utilized IMF, UFAT and weight at time 2. At scan 3, two equations were derived using IMF and weight (Table 59). The equation with the highest R^2 was 0.19 and utilized both IMF and weight at time 3. At scan 4, three equations were derived using IMF, ribeye area, and weight (Table 60). The equation with the highest R^2 was 0.30 and utilized IMF, ribeye area, and weight at time 4. At scan 5, two equations were derived using IMF and ribfat (Table 61). The equation with the highest R^2 was 0.16 and utilized IMF and ribfat at time 5. At scan 6, two equations were derived using IMF and UFAT (Table 62). The equation with the highest R^2 was 0.25 and utilized IMF and UFAT at time 6.

These prediction models explain variation in marbling score similar to equations found to predict carcass intramuscular fat percentage by Rouse et al. (2000). Using carcass ultrasound data, Rouse et al. (2000) found that 30% of the variation in marbling could be explained using carcass ultrasound traits 90 days prior to harvest, which would be analogous to scan time 4 in this project. Additionally, Wall et al. (2004) reported that ultrasound IMF at 61 to 69 days and 90 to 105 days prior to harvest explained 42% and 39%, respectively, of the marbling score variation in Angus cattle.

Prediction Equations for Days to Choice

Using stepwise regression to determine the most useful regression equation to predict marbling score at each scan time automatically places the constraint that the independent variables must have a significance level of at least 0.15 to be placed in the model. Days to choice was the dependent variable and calculated as days from the current scan time to point in time where the animal attained an IMF of 4.0% or small Choice quality grade equivalent. At scan 1, two equations were derived using

IMF and ribfat. The equation with the highest R^2 was 0.20 and utilized both IMF and ribfat at time 1 (Table 63.) At scan 2, two equations were derived using IMF and UFAT (Table 64). The equation with the highest R^2 was 0.235 and utilized IMF and UFAT at time 2. At scan 3, three equations were derived using IMF, UFAT, and REA (Table 65). The equation with the highest R^2 was 0.41 and utilized IMF, REA, and UFAT at time 3. At scan 4, two equations were derived using IMF and UFAT (Table 66). The equation with the highest R^2 was 0.48 and utilized IMF and UFAT at time 4. At scan 5, only one equation was derived using IMF (Table 67). The resulting R^2 was 0.59. Cattle averaged 4.6 % IMF at scan 6 which exceeds the threshold for choice. Table 68 shows the regression equations derived for predicting days to choice at scan time 6.

Zinn et al. (1970) reported that Hereford cattle deposited marbling in 60 to 90 day intervals followed by periods of dormancy. Zinn et al. (1970) conducted this study on steers and heifers in a feedlot setting beginning at 8 ½ months of age and cattle were fed a step up ration of sorghum silage base. The population of steers discussed in this paper showed a linear increase in marbling over scan times 3 to 6 when nutritional requirements were exceeded by available feed. It is also important to note that steers in this project were at least 50 % Angus.

<u>Logistic Regression for Premium Choice Status</u>

Cattle were classified as having a marbling score of 600 (Modest Ch) or greater or 600 (Modest Ch) or less. Although there were 105 steers in the study, marbling scores were only obtained on 70 animals. Of the 70 animals, 31 animals had marbling scores of greater than 600 while 39 had marbling scores of less than 600. As shown in Table 69, IMF at scan times 1, 3, 4, and 5 were all significant (*P* < 0.05) in explaining the impact of IMF on whether steers attained premium choice or not. Intramuscular fat evaluated at scan time 2 was only marginally significant (*P* = 0.058) These results indicate that animals that attained premium choice differed in IMF percentages at every scan time suggesting these cattle consistently displayed higher amounts of IMF throughout the course of the project. Odd ratios suggest that if the average IMF for this set of steers would have been 3.78 instead of 2.78 at day 0, the odds for attaining a marbling score of 600 or greater at slaughter would have increased by three fold (3.105 to 1). During scans 2 and 3, odds ratios suggest that if the IMF during these times would have averaged 3.58 and 3.82, the odds of attaining a marbling score of greater than 600 would have increased by 2.5 and 2.8 to 1, respectively.

<u>Days to Choice</u>

Upon inspection of line plots plotting IMF across time for each observation, an exponential element to the IMF curve was suspected and confirmed with a regression. The variable days is the number of days beginning at scan 1 and ending on the day of the last scan (scan time 6). Both the variables days and days squared were significant in predicting IMF in a regression procedure. Therefore it was determined that the IMF deposition followed an exponential curve from scan times 1 through 6, and scans 3 through 6 could be described as linear. The decision to use an exponential curve concurs with Brethour (2000) who suggested that an exponential or modified power curve fit the IMF curve better than a linear curve. Using components of the model that was used to determine days to choice; the intercept and beta coefficients were also tested against marbling score of 600 or greater in an ANOVA procedure. The intercept, "days" parameter coefficient, and days squared parameter coefficients had resulting *P*–values of 0.028, 0.823, and 0.712, respectively. This indicates that scanning once is sufficient to determine if cattle have the propensity to grade Modest Choice or higher.

CONCLUSION

Experiment 1

The results of this study suggest that measures of body composition with real time ultrasound are affected by physiological stages in beef cow production such as pregnancy, and lactation and are useful in explaining the differences in primiparous heifers that rebreed in the first postpartum breeding season and those that do not. Cattle that had a pregnancy status of 1 maintained a higher threshold of body composition traits as measured by ultrasound and BCS from one year of age throughout weaning of their first calf. Cattle that had a pregnancy status of 1 had relative differences that suggested they were larger and more mature at one year of age than cattle with a pregnancy status of 0. Summary tables for herds A, B, C, and D are available in Appendix B.

In herd A, IMF was a significant influence on pregnancy status at time 1 (P = 0.025) and REA was different as well (P = 0.014). Looking back at the first pregnancy determination, cattle that successfully rebred in the post partum breeding season, had more ribfat at scan 2 (P = 0.013) and more body condition (P = 0.001). Post parturition scans (3rd scan) taken 30-60 days after calving revealed that body condition score had a marginal impact or pregnancy performance at scan 3 (P = 0.054). Differences in pregnancy status during the fourth scan taken at pregnancy determination and after the post partum breeding season were reflected in body condition score only (P < 0.001). These results suggest that Ribeye area and intramuscular fat percentage evaluated on yearling cattle may be a useful indicator of cattle that will maintain higher body condition scores at calving and through the breeding season post parturition. Additionally, the findings during scan 2 suggest that ribfat evaluated via real time ultrasound on bred cattle may be helpful in predicting which cattle are more likely to rebreed in short post parturition breeding seasons. Of the carcass ultrasound traits measured, IMF and ribfat were the most useful carcass ultrasound traits in comparison to body condition score in predicting maternal ability.

In herd B, cattle that rebred in a 90 day breeding season post parturition had more ribfat at scan 2 ($P = 0.022$). It should be noted that cattle in herd B at scan 2 were open while cattle in herd A at scan 2 were bred. Cattle that would successfully rebreed during the post partum breeding season had larger ($P = 0.013$) ribeye area measurements during the post partum scan (3rd scan) taken 30-60 days post calving. Body condition score was not a significant predictor of pregnancy status for the post partum breeding season as cattle across pregnancy status didn't differ from the 4.7 BCS average ($P = 0.992$). These findings suggest that cattle with more ribfat between 1 and 2 years of age may be more apt to rebreed in the postpartum breeding season. Additionally, when body condition score decreases, measurements such as ribeye area may be useful in explaining the severity of compositional loss.

In herds C and D, cattle with a pregnancy status of 1 had larger ribeye area measurements at time 1 ($P = 0.023$ and $P = 0.007$). Although not true for herd D, cattle with a pregnancy status of 1 in herd C had more ribfat ($P = 0.035$) at scan 2. These findings suggest that ribeye size is useful in predicting the breeding success in yearling heifers as it may be an indicator of sexual maturity within a contemporary group.

Summarizing the findings for herds A, B, C, and D, ribeye area appeared to have the largest impact on pregnancy status for the initial breeding season in yearling heifers for this project. Body condition score was consistently useful in predicting which cattle would rebreed in the post partum breeding season. However, carcass ultrasound offers the potential to provide knowledge of relative differences in carcass traits in yearling heifers that may be reflected in future rebreeding performance, as well as ability to maintain body condition score through parturition and lactation. The knowledge provided by carcass ultrasound allows a producer to be aware of relative differences in body compositional traits among a brood cow herd and adjust management accordingly before those differences are reflected in poor body condition. In predicting pregnancy status for primiparous heifers in a short post partum breeding season, IMF evaluated at one year of age and ribfat evaluated at pregnancy determination were useful and were reflected in higher body condition scores later in the production cycle. Ribfat taken between 1 to 2 years of age in open cattle was also a useful predictor in determining which primiparous cattle would successfully rebreed in a moderate (90 day) post partum breeding season. It seems that ribfat was useful in both open and bred cattle when evaluated between 1 and 2 years of age in determining which cattle were more likely to rebreed in a post partum breeding season.

Experiment 2

The results of this project suggest that real time ultrasound does provide the opportunity to capture the propensity of IMF deposition in young cattle. The regression analysis suggests that when calves are not being fed a plane of nutrition that exceeds growth demands that body composition trends including IMF tend to be exponential (scans 1 through 3) but become linear when nutrition exceeds requirements (scans 3 through 6). Regardless of the trend, these results also suggest that the relative differences in IMF in young cattle have residual effects throughout the remainder of days on feed and are subsequently expressed in the end quality grade. This provides an opportunity for optimal sorting at any point in time.

The prediction models suggest that marbling score is most accurately predicted among this population of cattle at scan 4 utilizing ultrasound traits of IMF, REA, and weight. The prediction model explains 30 % of the variation in carcass marbling score at this time (224 days post preconditioning). Prediction models for days to choice calculated from this population suggest that scan 5 was the most accurate in predicting days to choice. Although traits obtained at scan 5 could be used in a prediction equation to explain 59 % of the variation in days to choice, the average IMF percentage at this time was 3.8 % and bordering the 4 % mark of choice. It seems that scans 3 and 4 may be more beneficial in collecting data to predict days to choice because average IMF % at these times were 3.3 % and 3.8 %, respectively. The prediction models at scans 3 and 4 explained 40 % and 48 % of the variation in days to choice for this population of cattle. The prediction model developed at scan 3 explained approximately twice as much variation as the prediction models developed at scans 1 and 2. Although ribfat and UFAT were used in the model to predict days to choice for scans 1 and 2, ribeye area became important at scan 3 when cattle entered the feedlot.

The original intent of this study was to determine differences in marbling deposition for cattle that graded select and cattle that graded choice, but the majority of the cattle in this project graded choice and above. Although cattle in this project were sorting into groups of base choice and above or small choice and below, differences in ultrasound IMF were seen across time. To further validate these findings, more cattle and variation among end quality grade would be beneficial.

Overall Conclusion

Real time carcass ultrasound provides an opportunity to capture an animal's ability to deposit or maintain fat in a given environment. Across brood cows/heifers and growing steers, cattle with higher amounts of fat in body compositional traits, that can be measured with real time ultrasound, maintain those relative differences across time. When looking at the averages across cattle, relative differences in compositional traits were consistent across physiological stages of pregnancy, parturition, and lactation in primiparous heifers. Additionally, the relative differences in compositional traits were consistent across growth and plane of nutrition for growing beef calves in experiment 2. Relative differences in body compositional traits measured via ultrasound may be reflected in a brood cow's ability to maintain body condition score in the future as a result of stressors such as lactation and parturition. Cattle with higher measures of fat composition measured via real time ultrasound are more likely to reach endpoints deemed desirable, in this study, which were to conceive in a short initial or post partum breeding season for experiment 1, or to grade at least modest choice in experiment 2.

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APPENDIX A

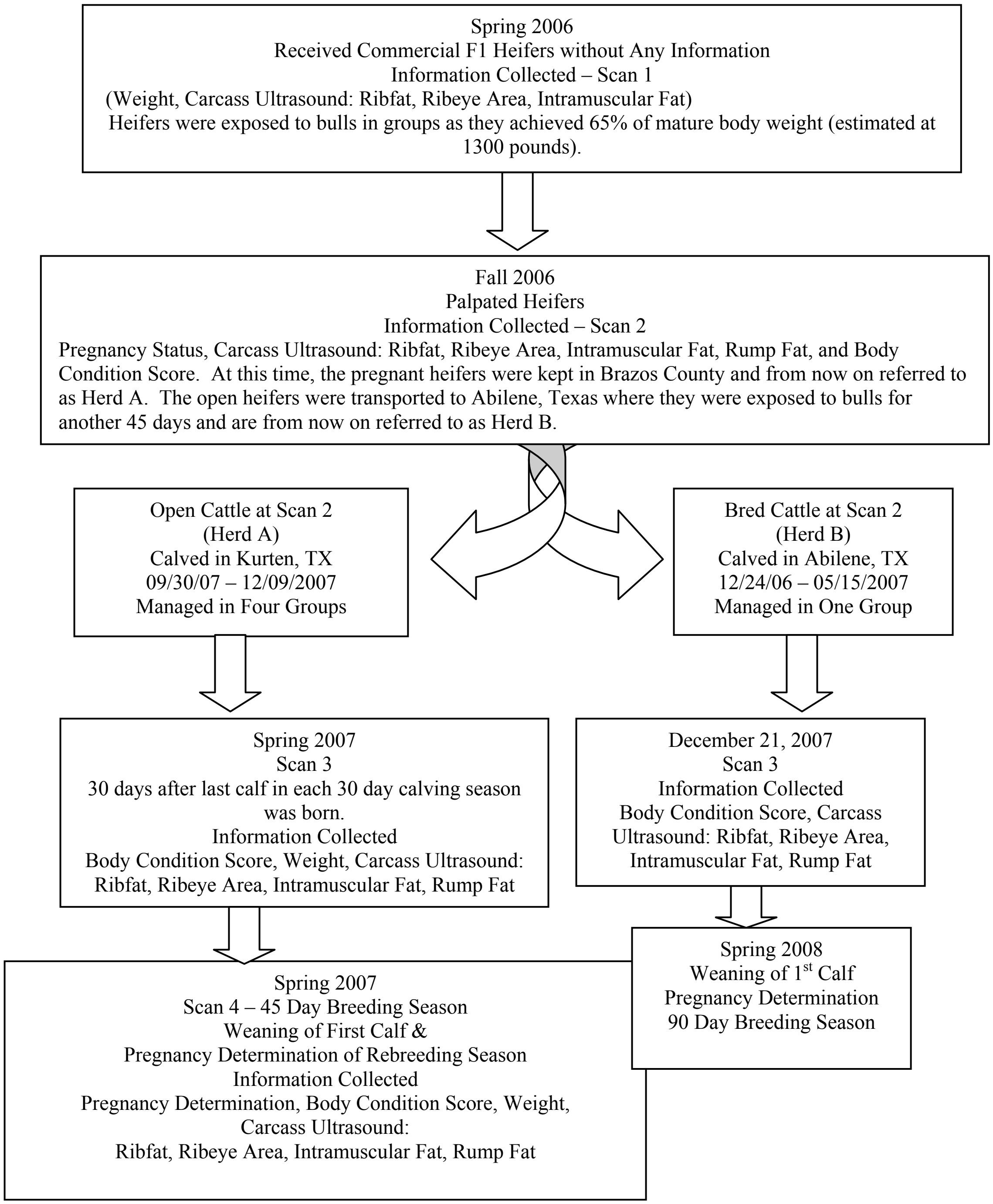


Figure 1. Flow chart describing the data collection for herds A and B.

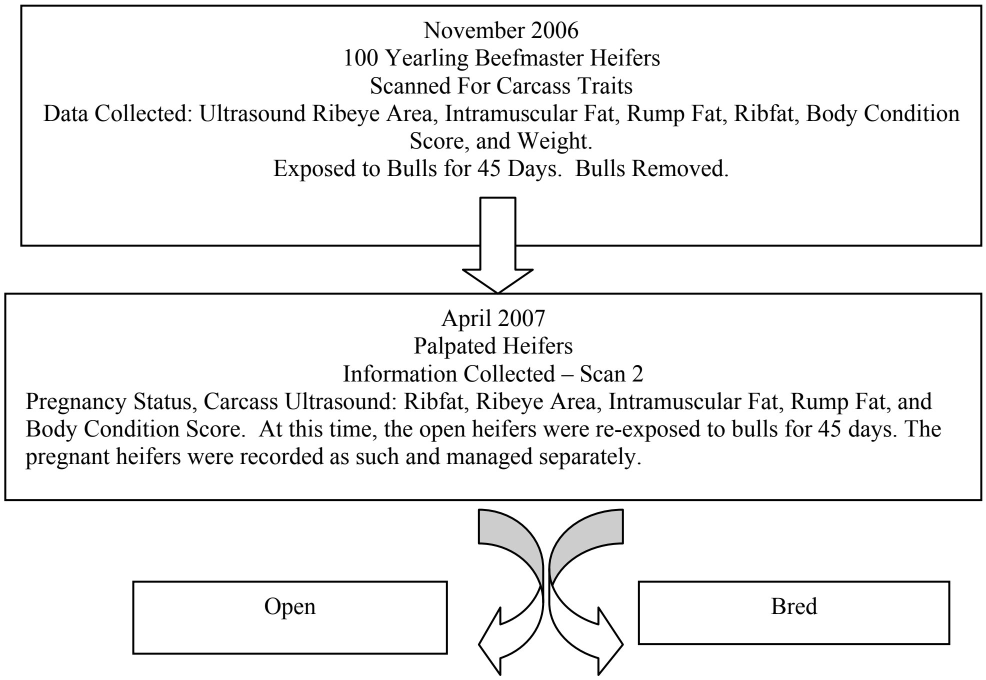


Figure 2. Flow chart describing the data collection for herds C.

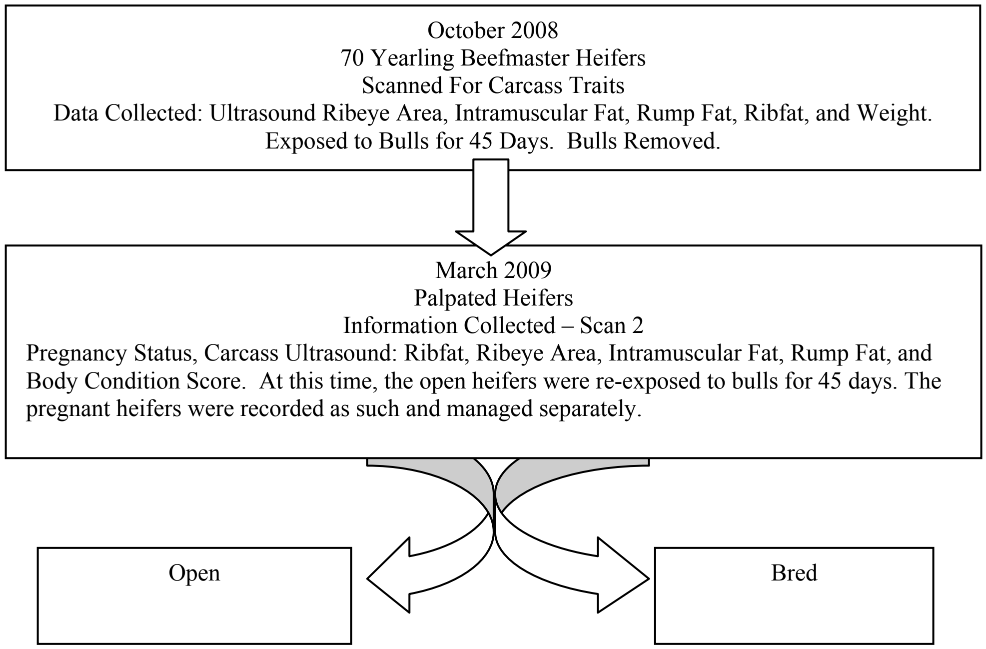


Figure 3. Flow chart describing the data collection for herd D.

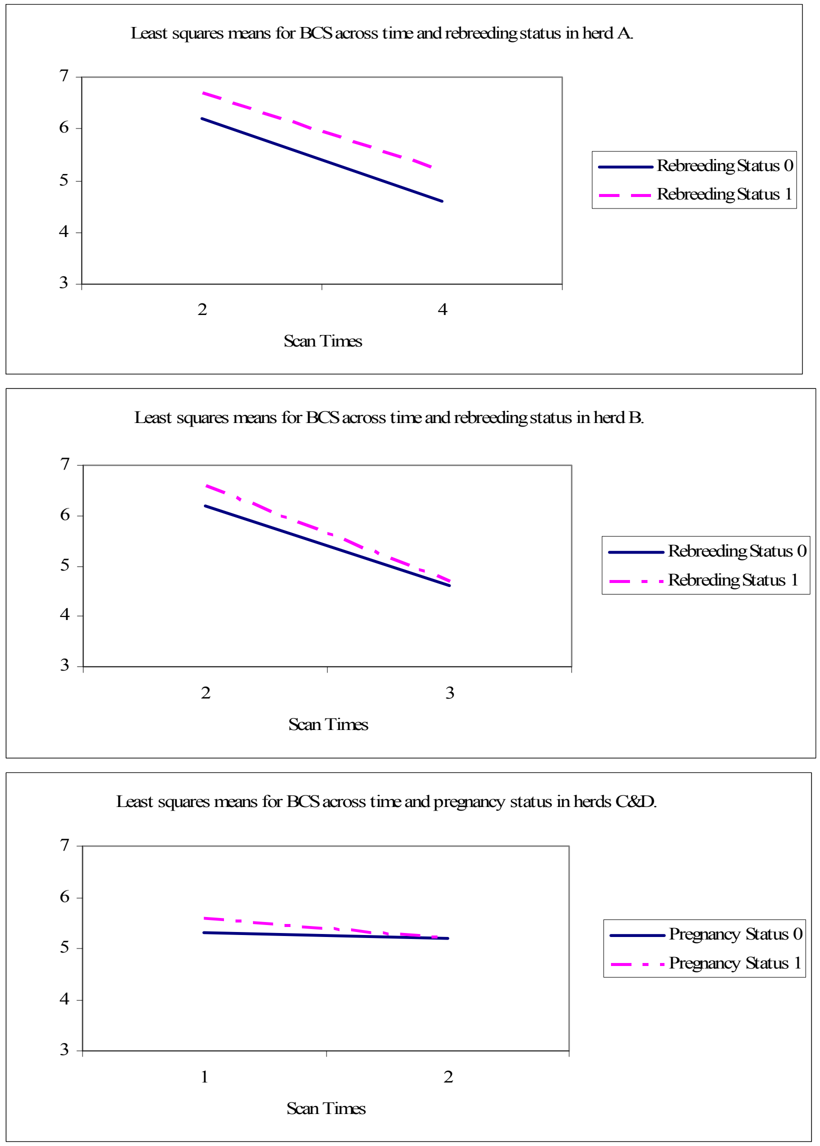


Figure 4. Representation of least squares means across time for body condition score in herds A, B, and C & D.

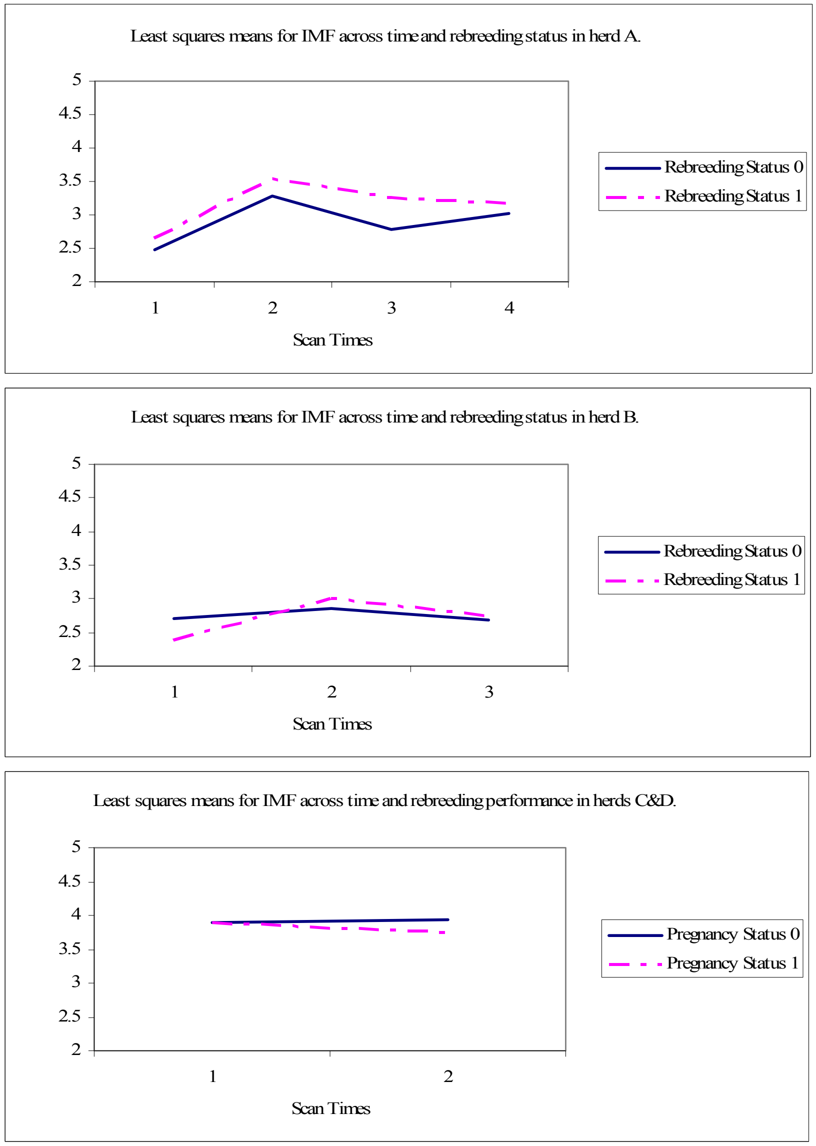


Figure 5. Representation of least squares means across time for intramuscular fat percentage in herds A, B, and C & D.

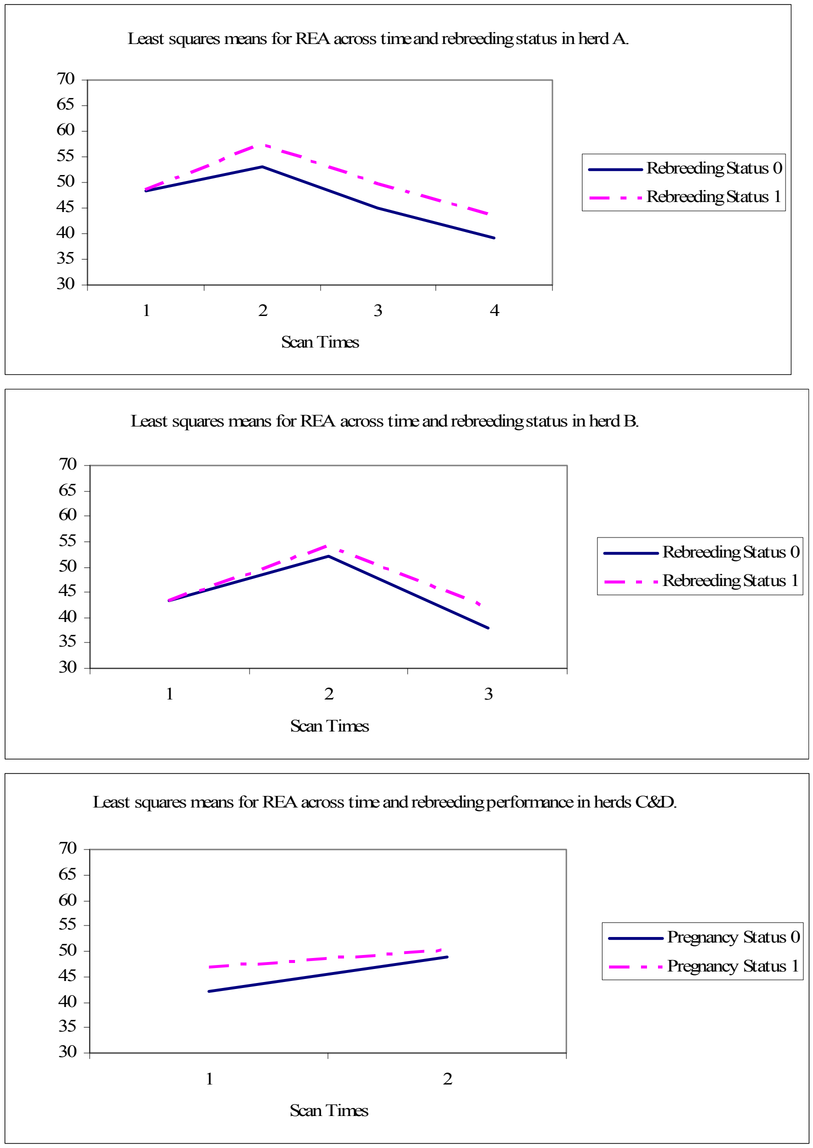
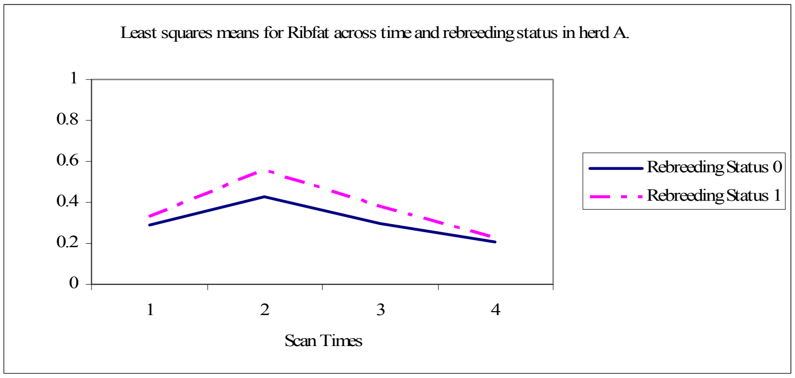
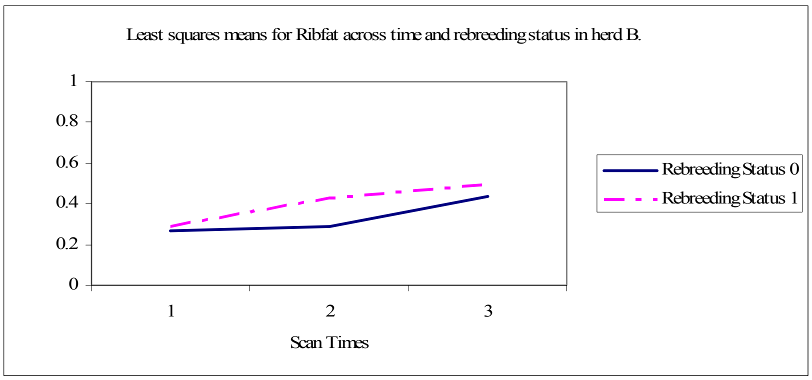


Figure 6. Representation of least squares means across time for ribeye area (cm^2) in herds A, B, and C & D.





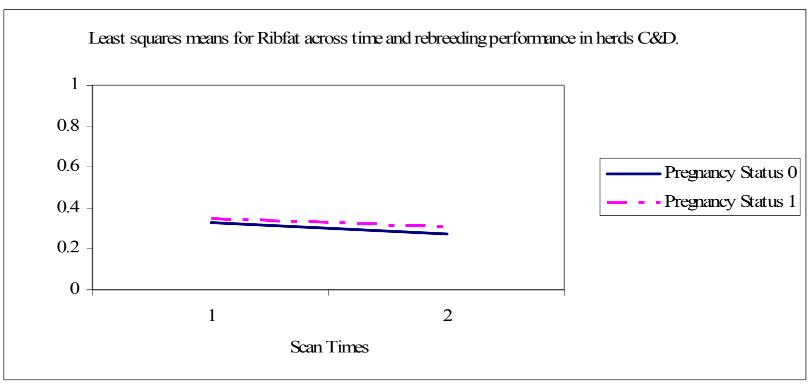


Figure 7. Representation of least squares means across time for 12th rib fat thickness (cm) in herds A, B, and C & D.

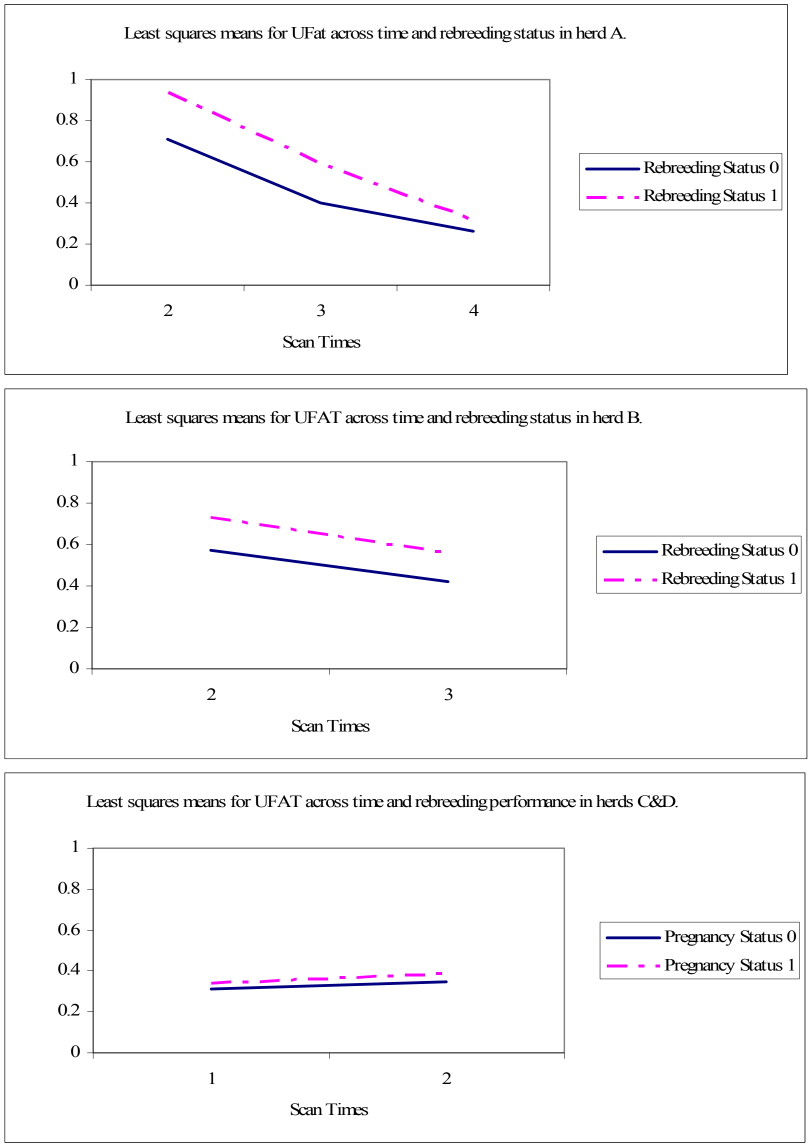


Figure 8. Representation of least squares means across time for fat depth between the gluteus medias and biceps femoris (cm) in herds A, B, and C & D.

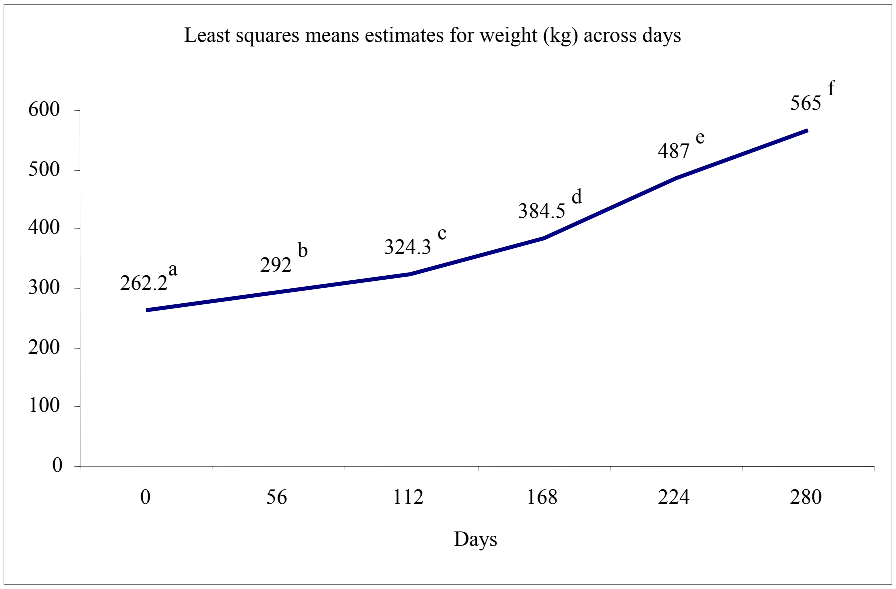


Figure 9. Least squares means estimates plotted across time for weight (kg.)
[a-f] Least square means across time with different superscripts differ by $P < 0.05$.

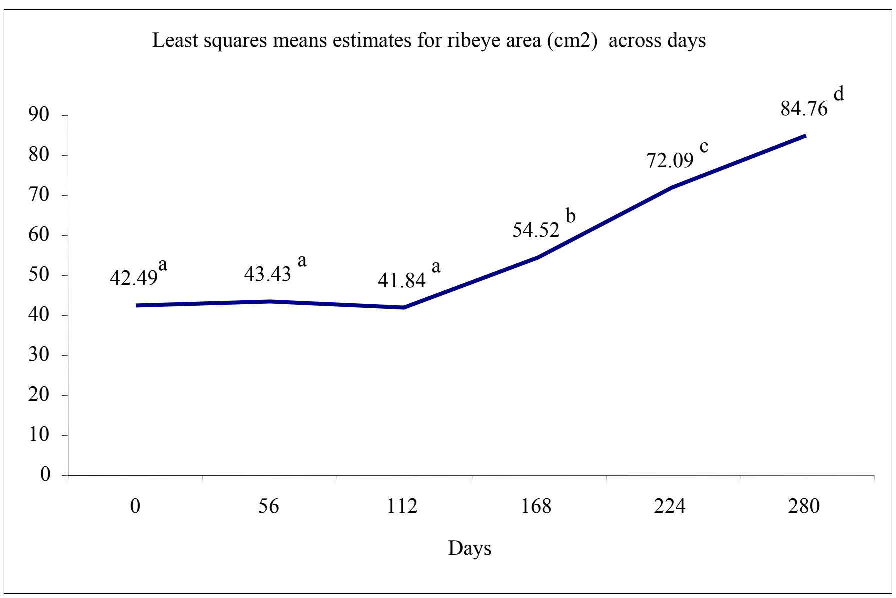


Figure 10. Least squares means estimates plotted across time for ribeye area (cm^2).
[a-d] Least square means across time with different superscripts differ by $P < 0.05$.

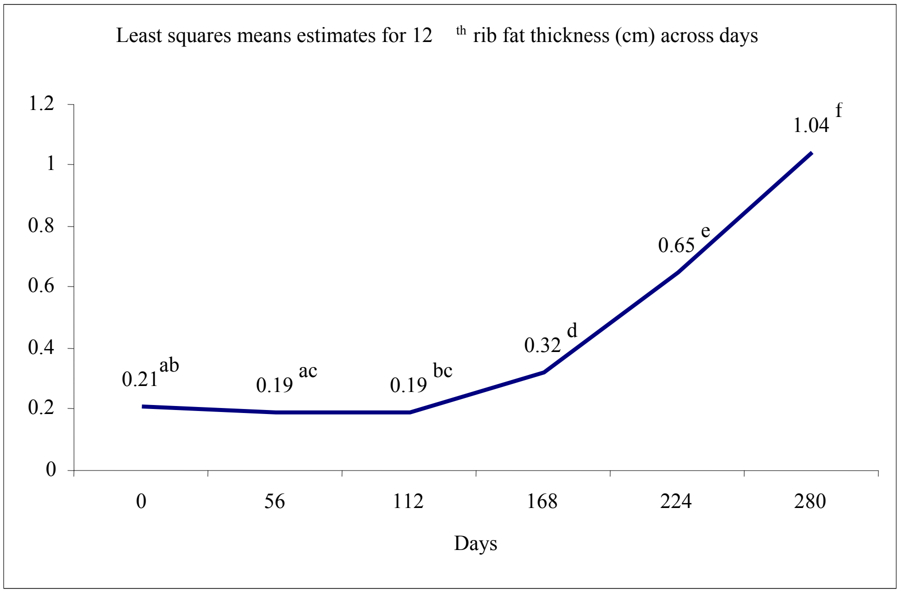


Figure 11. Least squares means estimates for rib fat across time (cm).
[a-f] Least square means across time with different superscripts differ by $P < 0.05$.

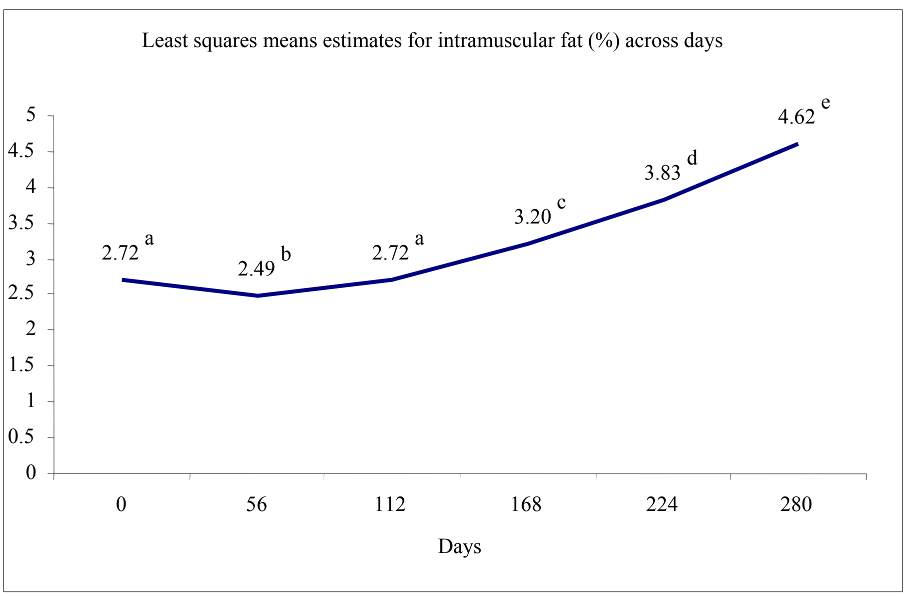


Figure 12. Least squares means estimates for IMF across time (%).
[a-e] Least square means across time with different superscripts differ by $P < 0.05$.

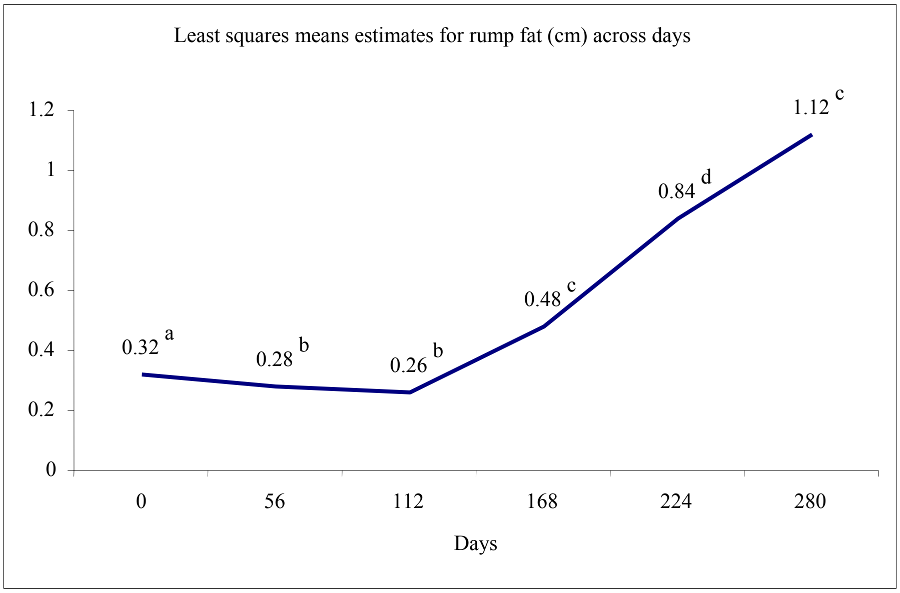


Figure 13. Least squares means for UFAT across time (cm).
[a-e] Least square means across time with different superscripts differ by $P < 0.05$.

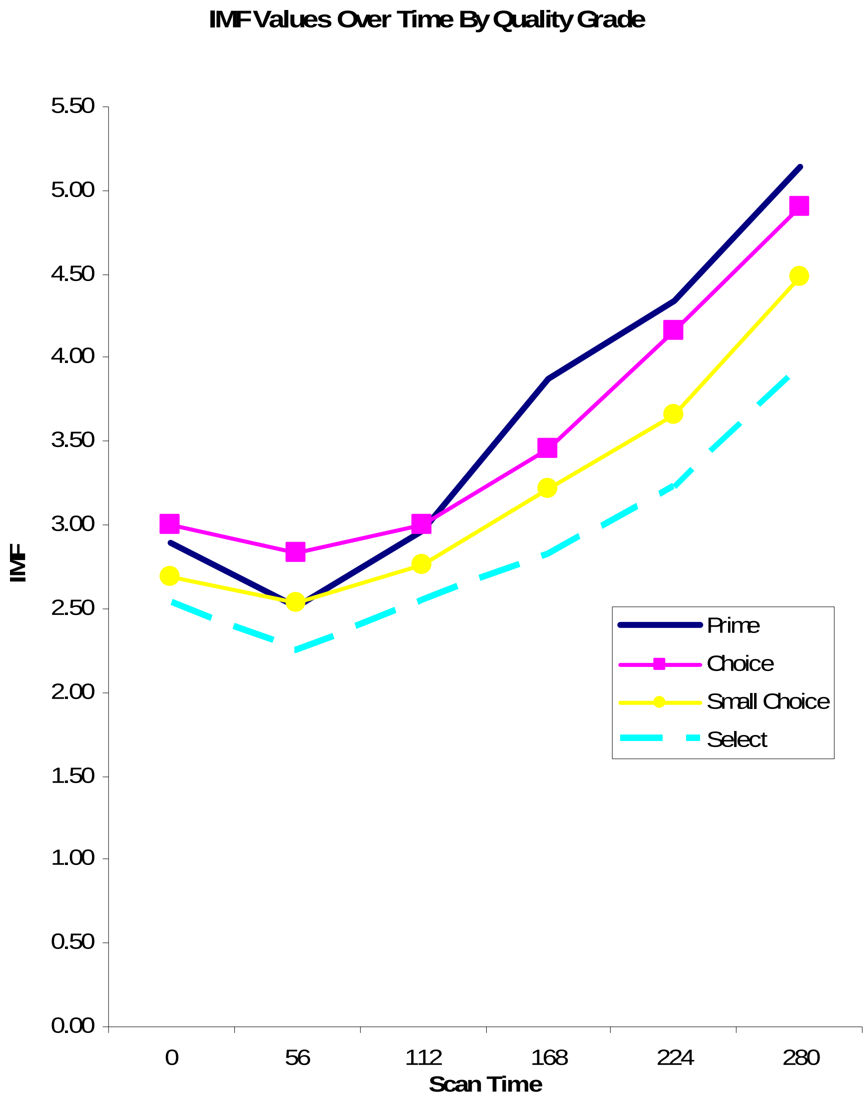


Figure 14. Least squares means for Intramuscular fat (%) across time by quality grade.

Table 1. Summary of relevant dates for Herds A,B,C, and D.

	Calving Season				Breeding Season			
Herd/Group	Start	End	Length (days)	Calves worked[1]	Start	End	Length (days)	Weaning[2]
A-1	12/24/2007	02/01/2007	38	03/01/2007	04/15/2007	06/01/2007	46	6/23/2007
A-2	02/03/2007	03/20/2007	45	04/11/2007	05/17/2007	07/01/2007	43	8/29/2007
A-3	03/21/2007	04/09/2007	19	04/13/2007	05/17/2007	07/12/2007	53	8/29/2007
A-4	04/09/2007	05/15/2007	36	06/12/2007	06/15/2007	08/1/2007	46	10/4/2007
B	09/30/2007	12/09/2007	70	12/21/2007	12//22/2007	3/22/2008	90	6/2/2008
C	--	--	--	--	11/03/2006	12/18/2007	45	--
D	--	--	--	--	10/31/2008	12/15/2008	45	--

[1]First calf heifers were scanned for the third time on this date.
[2]First calf heifers were scanned for the fourth time on this date.

Table 2. Scanning dates for herds A,B,C, and D.

Herd/Group	Scan 1	Scan 2	Scan 3	Scan 4
A/1	Spring 2006	10/15/2006	03/01/2007	6/23/2007
A/2	Spring 2006	10/15/2006	04/11/2007	8/29/2007
A/3	Spring 2006	10/15/2006	04/13/2007	8/29/2007
A/4	Spring 2006	10/15/2006	06/12/2007	10/04/2007
B	Spring 2006	10/15/2006	12/21/2007	06/02/2008
C	11/03/2006	05/02/2007	--	--
D	10/31/2008	03/05/2009	--	--

Table 3. Origin data for steers.

Source	n	Percentage of group	Dam breed	Sire breed	Age of dam[1]	Angus influence (%)
Brazos Co.	24	22	Brahman Hereford	Angus	2 years	50.0%
Taylor Co.	42	38	1/2 Angus	Angus	3 years	75.0%
Taylor Co.	17	16	3/4 Angus	Angus	2 years	87.5%
Parker Co.	26	24	1/2 Angus	Angus	unknown	75.0%

[1]Age of dam at calving.

Table 4. Serial scan dates and slaughter dates for experiment 2.

Lot	n	Scan 1	Scan 2	Scan 3	Scan 4	Scan 5	Scan 6	Scan 7	Slaughter date
8110	17	12/17/07	02/02/08	04/21/08	06/13/08	08/07/08	10/04/08	--	11/16/08
8110	20	02/02/08	04/21/08	06/13/08	08/07/08	10/04/08	10/04/08	--	11/16/08
8146	15	12/17/07	02/02/08	04/21/08	06/13/08	08/07/08	10/04/08	12/01/08	01/16/08
8146	25	02/02/08	04/21/08	06/13/08	08/07/08	10/04/08	12/01/08	--	01/16/08
8156	32	02/02/08	04/21/08	06/13/08	08/07/08	10/04/08	12/01/08	--	03/03/09

Table 5. Summary of traits collected at scan times 1,2,3 and 4 for herd A.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	182	6.4	1.1	4.0	8.0
BCS[a]PP	208	6.0	0.7	4.0	7.5
BCS[a]3	143	5.5	0.9	3.5	7.0
BCS[a]4	199	4.9	0.7	3.0	7.0
IMF[b]1 (%)	155	2.5	0.6	0.9	4.1
IMF[b]2 (%)	131	3.4	0.6	1.3	5.1
IMF[b]3 (%)	171	3.1	1.0	0.9	5.7
IMF[b]4 (%)	154	3.1	1.0	1.0	6.5
REA[c]1 (cm2)	155	47.2	7.5	31.0	67.1
REA[c]2 (cm2)	170	54.5	11.1	28.4	87.1
REA[c]3 (cm2)	161	48.1	9.6	27.7	75.5
REA[c]4 (cm2)	154	41.3	8.8	23.2	63.9
Ribfat[d]1 (cm)	155	0.29	0.08	0.10	0.53
Ribfat[d]2 (cm)	188	0.50	0.22	0.13	1.22
Ribfat[d]3 (cm)	174	0.35	0.18	0.13	1.40
Ribfat[d]4 (cm)	179	0.23	0.10	0.13	1.04
UFAT[e]2 (cm)	188	0.82	0.39	0.15	1.78
UFAT[e]3 (cm)	173	0.52	0.31	0.13	1.70
UFAT[e]4 (cm)	175	0.30	0.20	0.10	1.57
Weightf1 (kg)	145	279.7	39.3	180.9	389.1
Weightf2 (kg)	40	336.6	38.0	250.0	404.1
Weightf3 (kg)	142	418.3	54.4	285.0	545.5
Weightf4 (kg)	192	423.0	57.2	294.5	577.3

[a]BCS = body condition score taken at scans 2,3, and 4, respectively. BCSPP taken at 30 days post calving for each first calf heifer.
[b]IMF = intramuscular fat percentage taken at scans 1,2,3 and 4, respectively.
[c]REA = ribeye area taken at scans 1,2,3 and 4, respectively.
[d]Ribfat = 12^{th} rib fat thickness taken at scans 1,2,3 and 4, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2,3, and 4 respectively. UFAT was not collected at scan 1.

Table 6. Summary of traits collected at scan times 1,2 and 3 for herd B.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	46	6.5	1.2	4.5	8.0
BCS[a]3	91	4.8	0.6	3.5	6.5
BCS[a]4	82	5.3	0.6	4.0	7.0
IMF[b]1 (%)	79	2.4	0.7	0.9	4.2
IMF[b]2 (%)	42	3.2	0.6	1.3	4.0
IMF[b]3 (%)	96	2.7	1.0	0.4	6.0
REA[c]1 (cm2)	81	42.8	6.5	25.2	57.4
REA[c]2 (cm2)	45	53.5	11.1	34.2	77.4
REA[c]3 (cm2)	84	40.4	6.5	25.3	59.6
Ribfat[d]1 (cm)	81	0.29	0.08	0.10	0.51
Ribfat[d]2 (cm)	48	0.38	0.17	0.15	0.99
Ribfat[d]3 (cm)	88	0.47	0.17	0.20	1.24
UFAT[e]2 (cm)	47	0.65	0.28	0.23	1.35
UFAT[e]3 (cm)	76	0.51	0.26	0.20	1.57
Weight1[f] (kg)	80	237.7	29.4	161.4	314.5

[a]BCS = body condition score taken at scans 2,3, and at weaning, respectively.
[b]IMF = intramuscular fat percentage taken at scans 1,2, and 3, respectively.
[c]REA = ribeye area taken at scans 1,2, and 3, respectively.
[d]Ribfat = 12^{th} rib fat thickness taken at scans 1,2, and 3, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2 and 3, respectively. UFAT was not collected at scan 1.
[f]Weight = weight was only collected at scan time 1.

Table 7. Summary of traits collected at scan times 1 and 2 for herd C.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	99	5.5	0.5	4.0	6.5
BCS[a]2	95	5.0	0.5	4.0	6.5
IMF[b]1 (%)	93	3.8	0.5	2.9	5.0
IMF[b]2 (%)	96	3.0	0.6	1.4	4.6
REA[c]1 (cm^2)	98	46.8	7.9	27.1	65.1
REA[c]2 (cm^2)	97	51.4	6.5	34.2	71.0
Ribfat[d]1 (cm)	98	0.27	0.09	0.13	0.76
Ribfat[d]2 (cm)	99	0.35	0.10	0.18	0.71
UFAT[e]1 (cm)	99	0.43	0.15	0.18	1.09
UFAT[e]2 (cm)	97	0.37	0.14	0.18	0.99
Weight1 (kg)	99	307.5	39.6	202.3	429.5
Weight[f]2 (kg)	40	341.0	35.4	238.6	413.2

[a]BCS = body condition score taken at scans 1 and 2, respectively.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 1and 2, respectively.
[f]Weight was only collected for 40 head due to an error with the scale.

Table 8. Summary of traits collected at scan times 1 and 2 for herd D.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	71	5.5	0.4	4.5	6.0
IMF[b]1 (%)	70	3.9	0.7	2.0	5.5
IMF[b]2 (%)	71	4.6	0.9	1.8	7.3
REA[c]1 (cm^2)	70	41.9	6.1	29.0	58.7
REA[c]2 (cm^2)	71	47.3	6.2	34.2	64.5
Ribfat[d]1 (cm)	71	0.31	0.07	0.18	0.53
Ribfat[d]2 (cm)	71	0.36	0.12	0.15	0.71
UFAT[e]1 (cm)	71	0.22	0.08	0.10	0.46
UFAT[e]2 (cm)	71	0.38	0.10	0.23	0.69
Weight1 (kg)	71	289.0	24.7	227.0	344.0
Weight[f]2 (kg)	71	334.5	26.9	263.6	393.2

[a]BCS = body condition score taken at scan 1. BCS was not collected at scan 2.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2, respectively.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 1and 2, respectively.

Table 9. Summary of traits collected at scan times 1, 2, 3 and 4 for first calf heifers in herd A with a rebreeding status of 1.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	90	6.8	1.0	4.5	8.0
BCS[a]PP	99	6.2	0.6	4.0	7.5
BCS[a]3	71	5.7	0.8	4.0	7.0
BCS[a]4	99	5.2	0.6	4.0	6.5
IMF[b]1 (%)	69	2.7	0.6	1.4	4.1
IMF[b]2 (%)	60	3.5	0.6	1.7	5.1
IMF[b]3 (%)	90	3.3	0.9	1.0	5.7
IMF[b]4 (%)	91	3.2	1.0	1.0	6.5
REA[c]1 (cm^2)	69	47.2	7.2	33.5	67.1
REA[c]2 (cm^2)	85	56.9	10.4	31.6	84.5
REA[c]3 (cm^2)	87	49.8	8.6	32.9	75.5
REA[c]4 (cm^2)	86	43.2	8.0	27.7	63.2
Ribfat[d]1 (cm)	69	0.31	0.09	0.15	0.53
Ribfat[d]2 (cm)	93	0.57	0.21	0.15	0.97
Ribfat[d]3 (cm)	90	0.39	0.17	0.18	0.94
Ribfat[d]4 (cm)	96	0.23	0.09	0.13	0.58
UFAT[e]2 (cm)	94	0.82	0.39	0.15	1.78
UFAT[e]3 (cm)	92	0.61	0.33	0.18	1.70
UFAT[e]4 (cm)	90	0.33	0.16	0.13	0.89
Weightf1 (kg)	63	283.2	40.5	210.5	389.1
Weightf2 (kg)	9	332.8	47.0	281.8	400.9
Weightf3 (kg)	70	434.2	49.6	330.9	545.5
Weightf4 (kg)	96	440.3	45.9	332.7	559.1

[a]BCS = body condition score taken at scans 2,3, and 4, respectively. BCSPP = taken at 30 days post calving for each first calf heifer.
[b]IMF = intramuscular fat percentage taken at scans 1,2,3 and 4, respectively.
[c]REA = ribeye area taken at scans 1,2,3 and 4, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1,2,3 and 4, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2,3, and 4 respectively. UFAT was not collected at scan 1.

Table 10. Summary of traits collected at scan times 1, 2, 3 and 4 for first calf heifers in herd A with a rebreeding status of 0.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	92	6.1	1.2	4.0	8.0
BCS[a]PP	109	5.8	0.7	4.5	7.5
BCS[a]3	72	5.3	0.8	3.5	7.0
BCS[a]4	100	4.7	0.7	3.0	7.0
IMF[b]1 (%)	86	2.4	0.6	0.9	4.1
IMF[b]2 (%)	71	3.2	0.6	1.3	4.9
IMF[b]3 (%)	81	2.8	0.9	0.9	4.7
IMF[b]4 (%)	63	3.1	1.1	1.3	6.1
REA[c]1 (cm^2)	86	47.1	7.7	31.0	64.5
REA[c]2 (cm^2)	85	52.1	11.3	28.4	87.1
REA[c]3 (cm^2)	74	46.1	10.3	27.7	71.6
REA[c]4 (cm^2)	68	38.8	9.1	23.2	63.9
Ribfat[d]1 (cm)	86	0.27	0.07	0.10	0.51
Ribfat[d]2 (cm)	95	0.42	0.21	0.13	1.22
Ribfat[d]3 (cm)	84	0.31	0.19	0.13	1.40
Ribfat[d]4 (cm)	83	0.22	0.12	0.13	1.04
UFAT[e]2 (cm)	94	0.69	0.36	0.18	1.60
UFAT[e]3 (cm)	81	0.41	0.25	0.13	1.40
UFAT[e]4 (cm)	85	0.27	0.24	0.10	1.57
Weightf1 (kg)	82	277.1	38.4	180.9	376.4
Weightf2 (kg)	31	337.7	35.9	250.0	404.1
Weightf3 (kg)	72	402.8	54.7	285.0	504.5
Weightf4 (kg)	96	405.6	62.3	294.5	577.3

[a]BCS = body condition score taken at scans 2,3, and 4, respectively. BCSPP = taken at 30 days post calving for each first calf heifer.
[b]IMF = intramuscular fat percentage taken at scans 1,2,3 and 4, respectively.
[c]REA = ribeye area taken at scans 1,2,3 and 4, respectively.
[d]Ribfat = 12^{th} rib fat thickness taken at scans 1,2,3 and 4, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2,3, and 4 respectively. UFAT was not collected at scan 1.

Table 11. Summary of traits collected at scan times 1, 2, and 3 for first calf heifers in herd B with a rebreeding status of 1.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	24	6.6	1.1	4.5	8.0
BCS[a]3	45	4.7	0.6	3.5	6.5
BCS[a]4	44	5.5	0.7	4.5	7.0
IMF[b]1 (%)	40	2.3	0.6	1.4	3.6
IMF[b]2 (%)	23	3.2	0.6	1.3	4.0
IMF[b]3 (%)	48	2.8	0.8	0.5	3.9
REA[c]1 (cm2)	40	43.1	6.4	31.0	57.4
REA[c]2 (cm2)	24	54.3	10.1	38.1	77.4
REA[c]3 (cm2)	44	41.8	6.7	27.0	57.0
Ribfat[d]1 (cm)	40	0.30	0.09	0.10	0.51
Ribfat[d]2 (cm)	25	0.43	0.20	0.15	0.99
Ribfat[d]3 (cm)	46	0.49	0.19	0.20	1.24
UFAT[e]2 (cm)	24	0.68	0.27	0.23	1.17
UFAT[e]3 (cm)	41	0.58	0.29	0.20	1.57
Weight1[f] (kg)	39	238.9	30.0	179.5	314.5

[a]BCS = body condition score taken at scans 2,3, and at weaning.
[b]IMF = intramuscular fat percentage taken at scans 1,2, and 3, respectively.
[c]REA = ribeye area taken at scans 1,2, and 3, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1,2, and 3, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2 and 3, respectively. Not collected at scan 1.
[f]Weight = weight was only collected at scan time 1.

Table 12. Summary of traits collected at scan times 1, 2, and 3 for first calf heifers in herd B with a rebreeding status of 0.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]2	17	6.2	1.3	4.5	8.0
BCS[a]3	37	4.7	0.5	4.0	5.5
BCS[a]4	36	5.1	0.6	4.0	7.0
IMF[b]1 (%)	31	2.4	0.7	1.3	4.2
IMF[b]2 (%)	16	2.9	0.5	2.0	3.5
IMF[b]3 (%)	39	2.4	1.0	0.4	4.5
REA[c]1 (cm2)	31	43.2	6.3	31.0	54.8
REA[c]2 (cm2)	17	51.6	13.1	34.2	68.4
REA[c]3 (cm2)	33	37.7	4.4	25.3	44.6
Ribfat[d]1 (cm)	31	0.28	0.07	0.10	0.51
Ribfat[d]2 (cm)	18	0.29	0.09	0.15	0.48
Ribfat[d]3 (cm)	35	0.44	0.13	0.23	0.64
UFAT[e]2 (cm)	18	0.58	0.29	0.23	1.35
UFAT[e]3 (cm)	30	0.42	0.19	0.20	0.89
Weight1[f] (kg)	31	238.1	26.1	191.8	278.2

[a]BCS = body condition score taken at scans 2,3, and at weaning.
[b]IMF = intramuscular fat percentage taken at scans 1,2, and 3.
[c]REA = ribeye area taken at scans 1,2, and 3, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1,2, and 3, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 2 and 3, respectively. Not collected at scan 1.
[f]Weight = weight was only collected at scan time 1.

Table 13. Summary of traits collected at scan times 1 and 2 for heifers in herd C with a pregnancy status of 1.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	44	5.6	0.4	4.5	6.5
BCS[a]2	42	4.9	0.5	4.0	6.5
IMF[b]1 (%)	42	3.9	0.4	3.1	4.9
IMF[b]2 (%)	45	3.0	0.7	1.4	4.6
REA[c]1 (cm^2)	44	49.74	7.23	37.41	65.15
REA[c]2 (cm^2)	45	52.14	6.58	39.99	70.95
Ribfat[d]1 (cm)	45	0.3	0.1	0.2	0.8
Ribfat[d]2 (cm)	44	0.4	0.1	0.2	0.7
UFAT[e]1 (cm)	44	0.47	0.15	0.28	1.09
UFAT[e]2 (cm)	44	0.42	0.15	0.18	0.99
Weight1 (kg)	44	318.9	35.8	246.4	429.5
Weight[f]2 (kg)	17	349.7	32.3	304.5	404.5

[a]BCS = body condition score taken at scans 1 and 2, respectively.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2, respectively.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 1and 2, respectively.
[f]Weight was only collected for 40 head due to an error with the scale on that day.

Table 14. Summary of traits collected at scan times 1 and 2 for heifers in herd C with a pregnancy status of 0.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	55	5.4	0.6	4.0	6.5
BCS[a]2	53	5.0	0.5	4.0	6.5
IMF[b]1 (%)	51	3.8	0.5	2.9	5.0
IMF[b]2 (%)	51	3.1	0.6	1.7	4.5
REA[c]1 (cm^2)	54	44.36	7.66	27.09	61.92
REA[c]2 (cm^2)	52	50.79	6.42	34.19	62.57
Ribfat[d]1 (cm)	53	0.2	0.1	0.1	0.4
Ribfat[d]2 (cm)	55	0.3	0.1	0.2	0.5
UFAT[e]1 (cm)	55	0.41	0.14	0.18	0.69
UFAT[e]2 (cm)	53	0.34	0.12	0.18	0.69
Weight1 (kg)	55	298.4	40.4	202.3	382.7
Weight[f]2 (kg)	23	334.6	37.0	238.6	413.2

[a]BCS = body condition score taken at scans 1 and 2, respectively.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2, respectively.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 1and 2, respectively.
[f]Weight was only collected for 40 head due to scale error.

Table 15. Summary of traits collected at scan times 1 and 2 for heifers in herd D with a pregnancy status of 1.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	44	5.6	0.4	4.5	6.0
BCS[a]2	--	--	--	--	--
IMF[b]1 (%)	43	3.9	0.7	2.0	5.5
IMF[b]2 (%)	44	4.5	0.7	3.1	6.2
REA[c]1 (cm^2)	43	43.52	6.23	32.25	58.70
REA[c]2 (cm^2)	44	47.94	6.59	36.10	64.50
Ribfat[d]1 (cm)	44	0.3	0.1	0.2	0.5
Ribfat[d]2 (cm)	44	0.4	0.1	0.2	0.7
UFAT[e]1 (cm)	44	0.22	0.08	0.10	0.46
UFAT[e]2 (cm)	44	0.38	0.10	0.23	0.69
Weight1 (kg)	44	292.1	24.2	227.0	344.0
Weight2 (kg)	44	339.4	25.3	273.6	393.2

[a]BCS = body condition score taken at scan 1. BCS was not collected at scan 2.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2, respectively.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12^{th} rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat).

Table 16. Summary of traits collected at scan times 1 and 2 for heifers in herd D with a pregnancy status of 0.

Trait	n	Mean	SD	Minimum	Maximum
BCS[a]1	27	5.5	0.4	4.5	6.0
BCS[a]2	--	--	--	--	--
IMF[b]1 (%)	27	3.9	0.7	2.0	5.5
IMF[b]2 (%)	27	4.6	0.9	1.8	7.3
REA[c]1 (cm^2)	27	41.9	6.1	29.0	58.7
REA[c]2 (cm^2)	27	47.3	6.2	34.2	64.5
Ribfat[d]1 (cm)	27	0.31	0.07	0.18	0.53
Ribfat[d]2 (cm)	27	0.36	0.12	0.15	0.71
UFAT[e]1 (cm)	27	0.22	0.08	0.10	0.46
UFAT[e]2 (cm)	27	0.38	0.10	0.23	0.69
Weight1 (kg)	27	289.0	24.7	227.0	344.0
Weight2 (kg)	27	334.5	26.9	263.6	393.2

[a]BCS = body condition score taken at scan 1. BCS was not collected at scan 2.
[b]IMF = intramuscular fat percentage taken at scans 1 and 2, respectively.
[c]REA = ribeye area taken at scans 1 and 2, respectively.
[d]Ribfat = 12th rib fat thickness taken at scans 1 and 2, respectively.
[e]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat).

Table 17. Correlation coefficients, *P*-values, and number of measurements involving body composition measurements at scans 1-4 in herd A.

	Weight2	Weight3	Weight4
Weight1	0.72691	0.36106	0.30721
	<.0001	<.0001	0.0003
	40	114	134
Weight2		0.24759	0.44055
		0.1648	0.0091
		33	34
Weight3			0.6451
			<.0001
			129

[a]Weight measured at scan time 1,2,3,4, respectively.

	RibFat2	RibFat3	RibFat4
RibFat1	0.43794	0.23733	0.24742
	<.0001	0.0075	0.0045
	151	126	130
RibFat2		0.57435	0.38929
		<.0001	<.0001
		155	160
RibFat3			0.5935
			<.0001
			152

[a]Ribfat = 12th rib fat thickness measured via ultrasound at scan times 1,2,3,4, respectively.

	UFat3	UFat4
UFat2	0.64421	0.42956
	<.0001	<.0001
	153	154
UFat3		0.61363
		<.0001
		149

[a]Depth of fat between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan times 1,2,3,4, respectively.

	REA2	REA3	REA4
REA1	0.0985	0.28241	0.36059
	0.2418	0.0021	<.0001
	143	116	114
REA2	1	0.78693	0.59786
		<.0001	<.0001
		131	125
REA3			0.777
			<.0001
			125

[a]REA = ribeye area measured at scans 1,2,3,4, respectively.

	IMF2	IMF3	IMF4
IMF1	0.74554	0.59073	0.47448
	<.0001	<.0001	<.0001
	111	123	108
IMF		0.67252	0.577
		<.0001	<.0001
		112	92
IMF3			0.56457
			<.0001
			136

[a]IMF = Intramuscular fat percentage measured via ultrasound at scan times 1,2,3,4, respectively.

	BCS3	BCS4
BCS2	0.63368	0.46155
	<.0001	<.0001
	140	172
BCS3		0.43333
		<.0001
		136

[a]BCS = Body condition score evaluated at scan times 2,3,4, respectively.

Table 18. Correlation coefficients, P-values, and number of measurements involving body composition measurements at scans 1-3 in herd B.

	REA2	REA3
REA1	-0.0214	0.00689
	0.9108	0.9545
	30	71
REA2		0.46478
		0.0033
		38

[a]REA = ribeye area measured at scans 1,2,3, respectively.

	RibFat2	Ribfat3
RibFat1	0.66614	0.16053
	<.0001	0.1689
	32	75
RibFat2		0.35769
		0.0217
		41

[a]Ribfat = 12th rib fat thickness measured via ultrasound at scan times 1,2,3, respectively.

	BCS3	BCS4
BCS2	0.00349	0.03368
	0.9827	0.8387
	41	39
BCS3		0.31323
		0.0049
		79

[a]BCS = Body condition score evaluated at scan times 2 and 3 respectively, and at weaning of calves (4).

	IMF2	IMF3
IMF1	0.69119	0.36151
	<.0001	0.0011
	26	78
IMF2		0.509
		0.0007
		41

[a]IMF = Intramuscular fat percentage measured via ultrasound at scan times 1,2,3, respectively.

Table 19. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scans 1 and 2 for heifers in herd C.

Scan 1	Scan 2[a]	Scan 2[b]	Scan 2[c]
	Weight2	Weight2	Weight2
Weight1	0.4803	0.57558	0.30777
	0.0011	0.0021	0.2295
	43	26	17
	Ufat[d]2	Ufat[d]2	Ufat[d]2
Ufat[d]1	0.20011	0.3147	0.02336
	0.0459	0.0171	0.8818
	100	57	43
Ribfat[e]1	Ribfat[e]2	Ribfat[e]2	Ribfat[e]2
	0.12151	0.34637	-0.0553
	0.2261	0.0083	0.7216
	101	57	44
REA[f]1	REA[f]2	REA[f]2	REA[f]2
	0.3655	0.34799	0.37065
	0.0002	0.0092	0.0133
	99	55	44
IMF[g]1	IMF[g]2	IMF[g]2	IMF[g]2
	0.0722	0.13724	0.00537
	0.4892	0.3319	0.9731
	94	52	42
BCS[h]1	BCS[h]2	BCS[h]2	BCS[h]2
	0.16169	0.25387	0.10547
	0.1117	0.0567	0.5116
	98	57	41

[a]All heifers in herd C.
[b]Heifers with a pregnancy status of 0.
[c]Heifers with a pregnancy status of 1.
[d] UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[e]Ribfat = 12^{th} rib fat thickness.
[f]REA = Ribeye area.
[g]IMF = Intramuscular fat percentage.
[h]BCS = Body condition score.

Table 20. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan times 1 and 2 for heifers in herd D.

Scan 1	Scan 2[a]	Scan 2[b]	Scan 2[c]
	Weight2	Weight2	Weight2
Weight1	0.88047	0.89528	0.86675
	<.0001	<.0001	<.0001
	71	27	44
	Ufat[d]2	Ufat[d]2	Ufat[d]2
Ufat[d]1	0.49491	0.61081	0.43470
	<.0001	0.0007	0.0032
	71	27	44
Ribfat[e]1	Ribfat[e]2	Ribfat[e]2	Ribfat[e]2
	0.27295	0.32392	0.29356
	0.0213	0.0993	0.0531
	71	27	44
REA[f]1	REA[f]2	REA[f]2	REA[f]2
	0.80846	0.68632	0.86702
	<.0001	<.0001	<.0001
	70	26	44
IMF[g]1	IMF[g]2	IMF[g]2	IMF[g]2
	0.57322	0.64036	0.50111
	<.0001	0.0003	0.0006
	70	27	43

[a]All heifers in herd D.
[b]Heifers with a pregnancy status of 0.
[c]Heifers with a pregnancy status of 1.
[d]UFat = Depth between gluteus medius and biceps femoris
[e]Ribfat = 12th rib fat thickness.
[f]REA = Ribeye area.
[g]IMF = Intramuscular fat percentage.
[h]BCS = Body condition not evaluated at scan 2 on herd D.

Table 21. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 1 in herd A.

	RibFat1[a]	REA1[b]	IMF1[c]
Weight1	0.19771	0.67937	0.1405
	0.0175	<.0001	0.093
	144	144	144
RibFat1[a]		0.0426	0.30033
		0.5987	0.0001
		155	155
REA1[b]			0.02857
			0.7242
			155

[a]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 1.
[c]REA=Ribeye area measured via ultrasound at scan time 1.
[d]IMF=Intramuscular fat percentage measured via ultrasound at scan time1.

Table 22. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 1 in herd B.

	RibFat1[a]	REA1[b]	IMF1[c]
Weight1	0.27778	0.72746	0.23406
	0.0151	<.0001	0.0447
	76	76	74
RibFat1[a]		0.39751	0.48341
		0.0002	<.0001
		81	79
REA1[b]			0.21427
			0.0579
			79

[a]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 1.
[c]REA=Ribeye area measured via ultrasound at scan time 1.
[d]IMF=Intramuscular fat percentage measured via ultrasound at scan time1.

Table 23.Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 1 in herd C.

	RibFat1[b]	REA1[c]	IMF1[d]	BCS1[e]	Weight1
Ufat1[a]	0.6156	0.54056	0.23667	0.3411	0.49918
	<.0001	<.0001	0.0196	0.0004	<.0001
	103	102	97	103	103
Ribfat1[b]		0.47512	0.26488	0.3626	0.53376
		<.0001	0.0087	0.0002	<.0001
		102	97	103	103
REA1[c]			0.38447	0.5207	0.68863
			0.0001	<.0001	<.0001
			97	102	102
IMF1[d]				0.26961	0.20684
				0.0076	0.0421
				97	97
BCS1[e]					0.54399
					<.0001
					99

[a]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 1.
[b]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 1.
[c]REA =Ribeye area measured via ultrasound at scan time 1.
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 1.
[e]BCS = Body condition evaluated scan time 1.

Table 24. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 1 in herd D.

	RibFat1[b]	REA1[c]	IMF1[d]	BCS1[e]	Weight1
Ufat1[a]	0.54057	0.24461	0.07434	0.13092	0.20528
	<.0001	0.0413	0.5408	0.2765	0.0859
	71	70	70	71	71
Ribfat1[b]		0.18872	0.01152	0.25097	0.25267
		0.1177	0.9246	0.0348	0.0335
		70	70	71	71
REA1[c]			-0.20236	0.29266	0.47786
			0.093	0.0139	<.0001
			70	70	70
IMF1[d]				-0.00971	-0.21112
				0.9364	0.0794
				70	70
BCS1[e]					0.50688
					<.0001
					71

[a]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 1.
[b]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 1.
[c]REA =Ribeye area measured via ultrasound at scan time 1.
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 1.
[e]BCS = Body condition evaluated scan time 1.

Table 25. Correlation coefficients, *P*-values, and number of measurements for carcass ultrasound traits measured at scan 2 in herd A.

	REA2[b]	IMF2[c]	UFat2[d]	BCS2[e]	Weight2
RibFat2[a]	0.66325	0.4149	0.82681	0.73948	-0.30717
	<.0001	<.0001	<.0001	<.0001	0.0572
	170	130	187	180	39
REA2[b]		0.31709	0.66561	0.75428	0.50638
		0.0004	<.0001	<.0001	0.0019
		119	169	162	35
IMF2[c]			0.37809	0.33719	0.18631
			<.0001	0.0001	0.2992
			131	124	33
UFat2[d]				0.74759	-0.02223
				<.0001	0.8931
				180	39
BCS2[e]					0.54674
					0.0004
					38

[a]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 2.
[b]REA = Ribeye area measured via ultrasound at scan time 2.
[c]IMF = Intramuscular fat percentage measured via ultrasound at scan time 2.
[d]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 2.
[e]BCS = Body condition evaluated scan time 2.

Table 26. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 2 in herd B.

	RibFat2[b]	REA2[c]	IMF2[d]	UFat2[e]
BCS2[a]	0.64342	0.78962	0.31959	0.72002
	<.0001	<.0001	0.0444	<.0001
	45	42	40	45
RibFat2[b]		0.51588	0.42572	0.78835
		0.0003	0.0049	<.0001
		45	42	48
REA2[c]			0.33726	0.51368
			0.0358	0.0003
			39	45
IMF2[d]				0.41139
				0.0068
				42

[a]BCS = Body condition evaluated scan time 2.
[b]Ribfat = 12[th] rib fat thickness measured via ultrasound at scan time 2.
[c]REA = Ribeye area measured via ultrasound at scan time 2
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 2
[e]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 2.

Table 27. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 2 in herd C for heifers that failed to conceive.

	RibFat2[b]	REA2[c]	IMF2[d]	BCS2[e]	Weight2
Ufat2[a]	0.57538	0.45177	0.31056	-0.03624	0.54661
	<.0001	0.0004	0.0187	0.7928	0.0032
	59	58	57	55	27
Ribfat2[b]		0.39649	0.16034	0.22214	0.60893
		0.0021	0.2335	0.1031	0.0007
		58	57	55	27
REA2[c]			0.22952	0.04696	0.71863
			0.0888	0.736	<.0001
			56	54	27
IMF2[d]				0.10903	-0.06734
				0.4371	0.7491
				53	25
BCS2[e]					0.36491
					0.0668
					26

[a]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 2.
[b]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 2.
[c]REA =Ribeye area measured via ultrasound at scan time 2.
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 2.
[e]BCS = Body condition evaluated scan time 2.

Table 28. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 2 in herd D, (n=71)

	RibFat2[b]	REA2[c]	IMF2[d]	Weight2
Ufat2[a]	0.42754	0.35685	0.17658	0.34945
	0.0002	0.0023	0.1407	0.0028
Ribfat2[b]		0.47526	0.20223	0.33542
		<.0001	0.0908	0.0042
REA2[c]			0.1308	0.40327
			0.2769	0.0005
IMF2[d]				-0.01835
				0.8793

[a]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 2.
[b]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 2.
[c]REA =Ribeye area measured via ultrasound at scan time 2.
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 2.
[e]BCS = Body condition evaluated scan time 2.

Table 29. Correlation coefficients, *P*-values, and number of measurements for carcass ultrasound traits measured at scan 3 in herd A.

	RibFat3[b]	REA3[c]	IMF3[d]	BCS3[e]	Weight3	BCS3.5[f]
UFat3[a]	0.83835	0.54769	0.39973	0.57365	0.46059	0.5754
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
	153	146	155	118	117	171
RibFat3[b]		0.46629	0.3533	0.42662	0.28374	0.44493
		<.0001	<.0001	<.0001	0.0022	<.0001
		161	155	114	114	172
REA3[c]			0.24621	0.74035	0.65619	0.65194
			0.0027	<.0001	<.0001	<.0001
			146	107	107	159
IMF3[d]				0.33019	0.25061	0.2841
				0.0003	0.0064	0.0002
				118	117	169
BCS3[e]					0.73295	0.86136
					<.0001	<.0001
					141	143
Weight3						0.75125
						<.0001
						142

[a]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 3.
[b]Ribfat = 12th rib fat thickness measured via ultrasound at scan time 3.
[c]REA =Ribeye area measured via ultrasound at scan time 3.
[d]IMF = Intramuscular fat percentage measured via ultrasound at scan time 3.
[e]BCS = Body condition evaluated scan time 3.
[f]BCS3.5 = Body condition score evaluated 30 days post calving on each individual first calf heifer.

Table 30. Correlation coefficients, *P*-values, and number of measurements involving carcass ultrasound traits measured at scan 3 in herd B.

	UFat3[b]	Ribfat3[c]	REA3[d]	IMF3[e]
BCS3[a]	0.53169	0.18328	0.50241	0.14637
	<.0001	0.0972	<.0001	0.1662
	71	83	79	91
UFat3[b]		0.49404	0.44333	0.21399
		<.0001	<.0001	0.0634
		76	74	76
Ribfat3[c]			0.282	0.17586
			0.0094	0.1012
			84	88
REA3[d]				0.18615
				0.09
				84

[a]BCS = Body condition evaluated scan time 3.
[b]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 3.
[c]Ribfat = 12[th] rib fat thickness measured via ultrasound at scan time 3.
[d]REA = Ribeye area measured via ultrasound at scan time 3.
[e]IMF = Intramuscular fat percentage measured via ultrasound at scan time 3.

Table 31. Correlation coefficients, *P*-values, and number of measurements for carcass ultrasound traits measured at scan 4 in herd A.

	BCS4[a]	UFat4[b]	RibFat4[c]	REA4[d]	IMF4[e]
Weight4	0.62491	0.3955	0.32798	0.7	0.1436
	<.0001	<.0001	<.0001	<.0001	0.0871
	191	164	169	145	143
BCS4[a]		0.56616	0.41535	0.66702	0.14446
		<.0001	<.0001	<.0001	0.0768
		172	177	152	151
UFat4[b]			0.79224	0.48788	0.22444
			<.0001	<.0001	0.0066
			163	144	145
RibFat4[c]				0.43388	0.21428
				<.0001	0.0099
				153	144
REA4[d]					0.08666
					0.3288
					129

[a]BCS = Body condition evaluated scan time 4.
[b]UFAT = Depth between gluteus medius and biceps femoris muscles (rump fat) measured via ultrasound at scan time 3.
[c]Ribfat = 12[th] rib fat thickness measured via ultrasound at scan time 4.
[d]REA = Ribeye area measured via ultrasound at scan time 4.
[e]IMF = Intramuscular fat percentage measured via ultrasound at scan time 4.

Table 32. Least squares means for body composition traits[1] across time[2] and rebreeding status in herd A.

Failed to rebreed in a 45 day breeding season.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	--	2.48 ± 0.0858^{w}	48.31 ± 0.978^{w}	281.3 ± 5.327^{w}	0.29 ± 0.0161^{w}	--
2	6.2 ± 0.088^{aw}	3.29 ± 0.0892^{x}	52.94 ± 0.963^{ax}	--	0.43 ± 0.001^{ax}	0.71 ± 0.0303^{aw}
3	--	2.79 ± 0.086^{ay}	45.02 ± 1.00^{ay}	--	0.30 ± 0.016^{aw}	0.40 ± 0.0311^{ax}
4	4.6 ± 0.084^{ax}	3.02 ± 0.096^{z}	39.24 ± 1.085^{az}	406.7 ± 4.856^{ax}	0.21 ± 0.016^{y}	0.26 ± 0.0317^{y}

Successfully rebred in a 45 day breeding season.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	--	2.66 ± 0.095^{w}	48.66 ± 1.082^{w}	287.4 ± 6.211^{w}	0.33 ± 0.018^{w}	--
2	6.7 ± 0.089^{bw}	3.54 ± 0.094^{x}	57.43 ± 0.969^{bx}	--	0.56 ± 0.015^{bx}	0.94 ± 0.030^{bw}
3	--	3.27 ± 0.082^{by}	49.75 ± 0.946^{bw}	--	0.38 ± 0.015^{by}	0.59 ± 0.030^{bx}
4	5.2 ± 0.084^{bx}	3.18 ± 0.083^{y}	43.63 ± 975^{by}	438.8 ± 4.913^{bx}	0.23 ± 0.015^{z}	0.32 ± 0.031^{y}

[1]BCS = body condition score, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

[2]Time 1 = time at which animal was scanned for the first time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination), Time 3 = time at which animal was scanned for the third time (approximately 30 days after calving) and prior to breeding season, Time 4 = time at which animal was scanned for the fourth time (weaning of first calf and pregnancy determination for rebreeding performance).

[a-b]Least squares means across rebreeding status within time within an effect with different superscripts differ ($P < 0.05$).

[w-z]Least squares means across time within rebreeding status within an effect with different superscripts differ ($P < 0.05$).

Table 33. Least squares means for body composition traits[1] across time[2] and rebreeding status in herd B.

Failed to rebreed in a 90 day breeding season.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	--	2.37 ± 0.133^{x}	43.27 ± 1.364^{x}	238.06 ± 5.097	0.27 ± 0.0251^{x}	--
2	6.2 ± 0.203^{x}	2.85 ± 0.160^{y}	51.99 ± 1.836^{y}	--	0.29 ± 0.0323^{ax}	0.57 ± 0.067
3	4.7 ± 0.136^{y}	2.68 ± 0.123^{y}	38.05 ± 1.217^{az}	--	0.44 ± 0.0251^{ay}	0.42 ± 0.048^{a}

Successfully rebred in a 90 day breeding season.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	--	2.39 ± 0.118^{x}	43.22 ± 1.201^{x}	238.9 ± 4.544	0.29 ± 0.022^{x}	--
2	6.6 ± 0.170^{x}	3.00 ± 0.135^{y}	54.12 ± 1.546^{y}	--	0.43 ± 0.0274^{by}	0.73 ± 0.057^{x}
3	4.7 ± 0.123^{y}	2.75 ± 0.111^{z}	41.87 ± 1.097^{bx}	--	0.49 ± 0.021^{by}	0.56 ± 0.042^{by}

[1]BCS = body condition score, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm) and was not measured at time 1.

[2]Time 1 = time at which animal was scanned for the first time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination), Time 3 = time at which animal was scanned for the third time (approximately 30 days after calving) and prior to breeding season.

$^{a-b}$Least squares means across rebreeding status within time within an effect with different superscripts differ ($P < 0.05$).

$^{x-z}$Least squares means across time within rebreeding status within an effect with different superscripts differ ($P < 0.05$).

Table 34. Least squares means for body composition traits[1] across time[2] and rebreeding status in herds C & D.

Failed to conceive during the initial 45 day breeding season at 14 months of age.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	5.3 ± 0.055[ay]	3.90 ± 0.077	42.14 ± 0.774[ay]	291.5 ± 3.780[ay]	0.33 ± 0.113[y]	0.31 ± 0.014[y]
2	5.2 ± 0.05[z]	3.94 ± 0.077	48.90 ± 0.778[z]	336.5 ± 4.25[z]	0.27 ± 0.0113[az]	0.35 ± 0.014[az]

Successfully conceived during initial 45 day breeding season at 14 months of age.

Scan	BCS	IMF	REA	Weight	RibFat	Ufat
1	5.6 ± 0.049[by]	3.89 ± 0.069	46.81 ± 0.694[by]	305.4 ± 3.390[by]	0.35 ± 0.010[y]	0.34 ± 0.012[y]
2	5.2 ± 0.05[z]	3.75 ± 0.068	50.42 ± 0.688[z]	346.3 ± 4.06[z]	0.31 ± 0.010b[z]	0.39 ± 0.012[bz]

[1]BCS = body condition score was taken once and therefore not a repeated measure, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

[2]Time 1 = time at which animal was scanned for the first time (yearling) and prior to initial 45 day breeding season, Time 2 = time at which animal was scanned for the second time (pregnancy determination) approximately six months later.

[a-b]Least squares means across rebreeding status within time within an effect with different superscripts differ ($P < 0.05$).

[y-z]Least squares means across time within rebreeding status within an effect with different superscripts differ ($P < 0.05$).

Table 35. Effects of ultrasound traits[1] on rebreeding status across evaluation times[2] in herd A.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	-3.53 ± 1.41	0.0132
IMF1	0.65 ± 0.29	0.0253
Ribfat1	5.95 ± 2.40	0.0145
REA1	-0.0019 ± 0.02	0.9322
Scan 2		
Intercept	-2.62 ± 1.39	0.0632
IMF2	0.45 ± 0.35	0.2045
Ribfat2	3.67 ± 1.46	0.0135
REA2	-0.01 ± 0.02	0.5828
Scan 3		
Intercept	-2.67 ± 1.13	0.0200
IMF3	0.33 ± 0.21	0.1156
Ribfat3	1.33 ± 2.91	0.6477
REA3	0.11 ± 0.14	0.4003
Weaning[3]	1.116 ± 0.41	0.0074
Scan 4		
Intercept	-0.38 ± 1.10	0.7305
IMF4	0.052 ± 0.19	0.7837
Ribfat4	-0.25 ± 1.84	0.8891
REA4	0.018 ± 0.02	0.3862

[1]IMF = Intramuscular fat percentage, REA = Ribeye area (cm^2), Ribfat = 12^{th} rib fat thickness measured (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) (cm).
[2]Time 1 = first scan time (yearling), Time 2 = second scan time (pregnancy determination), Time 3 = third scan time (approximately 30 days after calving) - prior to breeding season, Time 4 = fourth scan time (weaning of first calf and pregnancy determination for rebreeding performance).
[3]Weaning = if cow weaned first calf.

Table 36. Effects of ultrasound traits[1] on rebreeding status across evaluation times[2] in herd B.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	0.33 ± 1.74	0.8464
IMF1	-0.21 ± 0.43	0.6243
Ribfat1	4.10 ± 3.77	0.2796
REA1	-0.017 ± 0.04	0.6735
Scan 2		
Intercept	-3.34 ± 2.73	0.2309
IMF2	1.02 ± 0.76	0.1885
Ribfat2	12.10 ± 5.03	0.0220
REA2	-0.065 ± 0.05	0.2025
Scan 3		
Intercept	-5.32 ± 1.98	0.0090
IMF3	0.12 ± 0.27	0.6485
Ribfat3	1.15 ± 1.86	0.5378
REA3	0.11 ± 0.04	0.0132

[1]IMF = Intramuscular fat percentage, REA = Ribeye area (cm^2), Ribfat = 12th rib fat thickness measured (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) (cm).

[2]Time 1 = first scan time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination), Time 3 = time at which animal was scanned for the third time (approximately 30 days after calving) - prior to breeding season.

Table 37. Effects of ultrasound traits[1] on pregnancy status across evaluation times[2] in herd C.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	-5.52 ± 2.15	0.0122
IMF1	0.36 ± 0.53	0.4966
Ribfat1	-0.74 ± 6.26	0.9053
REA1	0.54 ± 0.23	0.0234
Scan 2		
Intercept	-0.88 ± 2.01	0.6614
IMF2	-0.27 ± 0.34	0.4165
Ribfat2	16.97 ± 7.94	0.0354
REA2	-0.021 ± 0.23	0.9303

[1]IMF = Intramuscular fat percentage, REA = Ribeye area (cm^2), Ribfat = 12th rib fat thickness measured (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) (cm).

[2]Time 1 = time at which animal was scanned for the first time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination).

Table 38.Effects of ultrasound traits[1] on pregnancy status across evaluation times[2] in herd D.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	-4.23 ± 2.83	0.1392
IMF1	-0.12 ± 0.39	0.7523
Ribfat1	-3.43 ± 2.36	0.1511
REA1	0.15 ± 0.05	0.0070
Scan 2		
Intercept	0.10 ± 2.32	0.9639
IMF2	-0.57 ± 0.31	0.0734
Ribfat2	6.53 ± 4.28	0.1320
REA2	0.022 ± 0.04	0.6447

[1]IMF = Intramuscular fat percentage, REA = Ribeye area (cm^2), Ribfat = 12th rib fat thickness measured (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) (cm).
[2]Time 1 = time at which animal was scanned for the first time (yearling), Time 2 = time at which animal was scanned for the second time (pregnancy determination).

Table 39. Effects of body condition[1] rebreeding status across evaluation times[2] in herd A.

Effect	Estimate ± SE	*P*-value
Scan 2		
Intercept	-3.65 ± 1.14	0.0017
BCS2	0.66 ± 0.20	0.0016
Scan 3		
Intercept	-1.79 ± 1.03	0.0849
BCS3	0.39 ± 0.20	0.0544
Scan 4		
Intercept	-6.39 ± 1.27	<0.0001
BCS4	1.30 ± 0.25	<0.0001
Weaning[3]	0.866 ± 0.40	0.0357
Intercept	-5.62±1.43	0.0001
BCSPP	0.91±0.23	0.0001

[1]BCS = body condition score. BCSPP = body condition score 30 days post calving.
[2]Time 2 = second scan time (pregnancy determination), Time 3 = third scan time (approximately 30 days after calving) - prior to breeding season, Time 4 = fourth scan time (weaning of first calf and pregnancy determination for rebreeding performance).
[3]Weaning = if cow weaned first calf.

Table 40. Effects of body condition[1] on rebreeding status across evaluation times[2] in herd B.

Effect	Estimate ± SE	*P*-value
Scan 2		
Intercept	-1.45 ± 1.76	0.4153
BCS2	0.27 ± 0.27	0.3082
Scan 3		
Intercept	0.17 ± 1.87	0.9248
BCS3	0.003 ± 0.39	0.9924
Scan 4		
Intercept	-4.61 ± 2.13	0.0333
BCS	0.911 ± 0.40	0.0266

[1]BCS = body condition score. BCS30 = body condition score 30 days post calving.
[2]Time 2 = time at which animal was scanned for the second time (pregnancy determination), Time 3 = time at which animal was scanned for the third time (approximately 30 days after calving) - prior to breeding season.

Table 41. Effects of body condition score[1] on pregnancy status across evaluation times[2] in herd C.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	-6.08 ± 2.45	0.0149
BCS2	1.06 ± 0.44	0.0180
Scan 2		
Intercept	1.59 ± 2.00	0.4292
BCS2	-0.36 ± 0.40	0.3633

[1]BCS = body condition score.
[2]Time 1= time at which animal was scanned as a yearling. Time 2 = time at which animal was scanned for the second time (pregnancy determination).

Table 42. Effects of body condition score[1] on pregnancy status across evaluation times[2] in herd D.

Effect	Estimate ± SE	*P*-value
Scan 2		
Intercept	-4.90 ± 3.39	0.1531
BCS2	0.98 ± 0.61	0.1168

[1]BCS = body condition score.
[2]Time 2 = time at which animal was scanned for the second time (pregnancy determination).

Table 43. Summary of real time ultrasound traits and weights taken at scan times 1-6.

Trait	n	Mean	SD	Minimum	Maximum
IMF[a]1 (%)	105	2.8	0.6	1.5	4.4
IMF[a]2 (%)	104	2.6	0.7	1.4	5.1
IMF[a]3 (%)	107	2.8	0.6	1.7	4.6
IMF[a]4 (%)	104	3.3	0.7	1.9	5.8
IMF[a]5 (%)	108	3.8	0.9	1.7	6.4
IMF[a]6 (%)	89	4.6	0.9	2.8	6.6
REA[b]1 (cm2)	103	41.5	7.7	27.5	61.5
REA[b]2 (cm2)	104	42.8	8.2	24.9	67.4
REA[b]3 (cm2)	102	41.8	10.5	26.8	68.7
REA[b]4 (cm2)	103	53.4	16.6	30.7	90.3
REA[b]5 (cm2)	106	70.6	13.0	40.5	107.9
REA[b]6 (cm2)	82	80.5	9.8	59.5	108.6
Ribfat[c]1 (cm)	104	0.23	0.08	0.10	0.46
Ribfat[c]2 (cm)	104	0.21	0.07	0.10	0.58
Ribfat[c]3 (cm)	105	0.22	0.08	0.10	0.51
Ribfat[c]4 (cm)	104	0.34	0.18	0.10	0.86
Ribfat[c]5 (cm)	108	0.67	0.26	0.23	1.30
Ribfat[c]6 (cm)	87	1.01	0.32	0.36	1.88
UFAT[d]1 (cm)	105	0.34	0.11	0.13	0.71
UFAT[d]2 (cm)	105	0.29	0.11	0.10	0.58
UFAT[d]3 (cm)	107	0.28	0.11	0.13	0.71
UFAT[d]4 (cm)	104	0.50	0.24	0.18	1.30
UFAT[d]5 (cm)	108	0.86	0.29	0.30	1.88
UFAT[d]6 (cm)	85	1.10	0.32	0.64	2.16
Weight1 (kg)	105	265.3	38.0	190.9	404.5
Weight2 (kg)	107	295.2	39.5	219.5	437.3
Weight3 (kg)	109	329.9	52.5	247.7	518.2
Weight4 (kg)	106	389.5	81.9	269.1	620.5
Weight5 (kg)	108	491.9	77.2	345.5	702.3
Weight6 (kg)	89	545.8	47.1	459.1	709.1

[a]IMF = intramuscular fat percentage taken at scans 1-6, respectively.
[b]REA = ribeye area taken at scans 1-6, respectively.
[c]Ribfat = 12th rib fat thickness taken at scans 1-6, respectively.
[d]UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) taken at scans 1-6, respectively.

Table 44. Summary of carcass traits.

Trait	n	Mean	SD	Minimum	Maximum
Yield grade	105	3.1	0.6	2.0	5.0
Hot carcass weight (kg)	108	361.6	22.2	306.8	418.6
Marbling score (degrees)	71	614	118	430	880
Back fat (cm)	72	1.76	0.56	0.81	4.27
Ribeye area (cm2)	71	85.1	6.7	70.3	107.9
KPH (%)	71	2.3	0.4	2.0	3.5
Days in research program[a]	106	334	50	241	394
Days to choice[b]	101	237	82	11	441
Avg. daily IMF increase[c]	105	0.0064	0.0032	-0.0007	0.0165

[a]Calculated as the days from scan 1 to slaughter.
[b]Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 or the equivalent of choice to determine x or days to choice.
[c]Calculated as Intramuscular fat percentage accumulated between scan time 1 and scan time 6 divided by days in program.

Table 45. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound measures of IMF[a] at scan times 1-6 and carcass marbling score.

	IMF2	IMF3	IMF4	IMF5	IMF6	Marbling score
IMF1	0.46882	0.41119	0.35541	0.37215	0.39433	0.32402
	<.0001	<.0001	0.0003	0.0001	0.0001	0.0058
	102	104	100	104	88	71
IMF2		0.33257	0.36399	0.31987	0.36736	0.31723
		0.0006	0.0002	0.001	0.0005	0.0084
		103	99	103	86	68
IMF3			0.54443	0.50695	0.31271	0.34708
			<.0001	<.0001	0.0028	0.003
			102	106	89	71
IMF4				0.53372	0.34931	0.42969
				<.0001	0.0011	0.0003
				104	84	68
IMF5					0.71817	0.4015
					<.0001	0.0006
					88	70
IMF6						0.40537
						0.0005
						71

[a]IMF = Intramuscular fat percentage measured at scan times 1-6, respectively.

Table 46. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound measures of REA[a] at scan times 1-6 and carcass ribeye area.

	REA2	REA3	REA4	REA5	REA6	Carcass ribeye area
REA1	0.79732	0.77474	0.48816	0.40892	0.49935	0.34052
	<.0001	<.0001	<.0001	<.0001	<.0001	0.0039
	100	97	97	100	80	70
REA2		0.77732	0.49358	0.40126	0.49672	0.37093
		<.0001	<.0001	<.0001	<.0001	0.0018
		99	98	101	79	68
REA3			0.67918	0.62545	0.52764	0.37307
			<.0001	<.0001	<.0001	0.0019
			96	99	78	67
REA4				0.779	0.56843	0.32827
				<.0001	<.0001	0.0063
				102	78	68
REA5					0.68984	0.42836
					<.0001	0.0002
					81	69
REA6						0.52383
						<.0001
						66

[a]REA = Actual ribeye area measured at scan times 1-6, respectively.

Table 47. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound measures of Ribfat[a] at scan times 1-6 and carcass back fat.

	Ribfat2	Ribfat3	Ribfat4	Ribfat5	Ribfat6	Back fat
Ribfat1	0.60595	0.48355	0.14061	0.10892	0.22051	0.38737
	<.0001	<.0001	0.1651	0.2734	0.0426	0.0008
	101	101	99	103	85	71
Ribfat2		0.44867	0.18036	0.12133	0.15027	0.46172
		<.0001	0.074	0.2221	0.1724	<.0001
		102	99	103	84	69
Ribfat3			0.51503	0.34571	0.22195	0.43075
			<.0001	0.0003	0.0412	0.0002
			100	104	85	70
Ribfat4				0.77563	0.4964	-0.01687
				<.0001	<.0001	0.8906
				104	82	69
Ribfat5					0.80019	0.29002
					<.0001	0.0142
					86	71
Ribfat6						0.52771
						<.0001
						70

[a]Ribfat = 12th rib fat thickness measured at scan times 1-6, respectively.

Table 48. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound measures of weight[a] at scan times 1-6 and hot carcass weight.

	Weight2	Weight3	Weight4	Weight5	Weight6	Hot carcass weight
Weight1	0.8336	0.7680	0.5818	0.3724	0.5182	0.3141
	<.0001	<.0001	<.0001	.0013	<.0001	0.007
	72	72	72	72	72	72
Weight2		0.8972	0.7937	0.6119	0.6722	0.2620
		<.0001	<.0001	<.0001	<.0001	0.0273
		72	71	72	72	72
Weight3			0.8055	0.6186	0.6388	0.2023
			<.0001	<.0001	<.0001	0.0906
			71	72	71	72
Weight4				0.8277	0.8139	0.2248
				<.0001	<.0001	0.0613
				71	71	70
Weight5					0.8546	0.1245
					<.0001	0.300
					72	71
Weight6						0.2970
						0.0119
						71

[a]Weight measured at scan times 1-6, respectively.

Table 49. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound measures of UFAT[a] at scan times 1-6.

	UFAT2	UFAT3	UFAT4	UFAT5	UFAT6
UFAT1	0.68737	0.42942	0.26456	0.40015	0.5219
	<.0001	<.0001	0.0078	<.0001	<.0001
	103	104	100	104	84
UFAT2		0.40151	0.19106	0.28583	0.37047
		<.0001	0.0569	0.0033	0.0006
		104	100	104	83
UFAT3			0.64849	0.57786	0.36077
			<.0001	<.0001	0.0007
			102	106	85
UFAT4				0.84466	0.57441
				<.0001	<.0001
				104	80
UFAT5					0.79263
					<.0001
					84

[a]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).

Table 50. Correlation coefficients, *P* - values, and number of measurements involving real time ultrasound traits at scan time 1.

	Ribfat[b]1	UFAT[c]1	REA[d]1	Weight1
IMF[a]1	0.0897	0.08511	-0.0304	-0.163
	0.3652	0.388	0.7603	0.0967
	104	105	103	105
Ribfat[b]1		0.67319	0.51379	0.38986
		<.0001	<.0001	<.0001
		104	103	104
UFAT[c]1			0.45836	0.37745
			<.0001	<.0001
			103	105
REA[d]1				0.65831
				<.0001
				103

[a] IMF = Intramuscular fat percentage
[b] Ribfat = 12^{th} rib fat thickness.
[c] UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 51. Correlation coefficients, *P*-values, and number of measurements involving real time ultrasound traits at scan time 2.

	Ribfat[b]2	UFAT[c]2	REA[d]2	Weight2
IMF[a]2	0.16204	0.18967	0.02616	-0.0573
	0.102	0.0538	0.7931	0.5673
	103	104	103	102
Ribfat[b]2		0.68323	0.5283	0.26048
		<.0001	<.0001	0.0082
		104	104	102
UFAT[c]2			0.51731	0.15371
			<.0001	0.1211
			104	103
REA[d]2				0.56766
				<.0001
				102

[a]IMF = Intramuscular fat percentage
[b]Ribfat = 12th rib fat thickness.
[c]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 52. Correlation coefficients, *P*-values, and number of measurements involving ultrasound traits measured at scan 3.

	Ribfat[b]3	UFAT[c]3	REA[d]3	Weight3
IMF[a]3	-0.0959	-0.014	-0.1088	-0.0949
	0.3304	0.8864	0.2764	0.3307
	105	107	102	107
Ribfat[b]3		0.72156	0.69728	0.58316
		<.0001	<.0001	<.0001
		105	102	105
UFAT[c]3			0.6907	0.72219
			<.0001	<.0001
			102	107
REA[d]3				0.80002
				<.0001
				102

[a]IMF = Intramuscular fat percentage
[b]Ribfat = 12th rib fat thickness.
[c]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 53. Correlation coefficients, *P*-values, and number of measurements involving ultrasound traits measured at scan 4.

	Ribfat[b]4	UFAT[c]4	REA[d]4	Weight4
IMF[a]4	-0.104	-0.0931	-0.1962	-0.0537
	0.2936	0.3474	0.0471	0.5917
	104	104	103	102
Ribfat[b]4		0.88746	0.83264	0.8516
		<.0001	<.0001	<.0001
		104	103	102
UFAT[c]4			0.7967	0.7895
			<.0001	<.0001
			103	102
REA[d]4				0.83028
				<.0001
				101

[a]IMF = Intramuscular fat percentage
[b]Ribfat = 12th rib fat thickness.
[c]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 54. Correlation coefficients, *P*-values, and number of measurements involving ultrasound traits measured at scan 5.

	Ribfat[b]5	UFAT[c]5	REA[d]5	Weight5
IMF[a]5	0.27969	0.21597	0.11328	0.22998
	0.0034	0.0248	0.2476	0.0172
	108	108	106	107
Ribfat[b]5		0.787	0.57788	0.71665
		<.0001	<.0001	<.0001
		108	106	107
UFAT[c]5			0.56484	0.67816
			<.0001	<.0001
			106	107
REA[d]5				0.73353
				<.0001
				105

[a]IMF = Intramuscular fat percentage
[b]Ribfat = 12th rib fat thickness.
[c]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 55. Correlation coefficients, *P*-values, and number of measurements involving ultrasound traits measured at scan 6.

	Ribfat[b]6	UFAT[c]6	REA[d]6	Weight6
IMF[a]6	0.30368	0.13441	0.05543	0.16897
	0.0042	0.2201	0.6209	0.1134
	87	85	82	89
Ribfat[b]6		0.65509	0.23646	0.48426
		<.0001	0.0325	<.0001
		84	82	87
UFAT[c]6			0.17458	0.46411
			0.1238	<.0001
			79	85
REA[d]6				0.55851
				<.0001
				82

[a]IMF = Intramuscular fat percentage
[b]Ribfat = 12th rib fat thickness.
[c]UFat = Depth between gluteus medius and biceps femoris muscles (rump fat).
[d]REA = Ribeye area.

Table 56: Correlation coefficients, *P*-values, and number of measurements involving carcass data.

	Marbling score	Yield grade	Ribeye area	Hot carcass weight	KPH[a]
Back fat	0.05703	0.5433	-0.2822	0.25245	0.10898
	0.6366	<.0001	0.0172	0.0337	0.3656
	71	68	71	71	71
Marbling score		-0.23631	0.02918	-0.08097	0.09254
		0.0524	0.8091	0.5021	0.4427
		68	71	71	71
Yield grade			-0.33358	0.1520	-0.0500
			0.0054	0.1674	0.6855
			68	84	68
Ribeye area				0.29926	-0.0297
				0.0112	0.8058
				71	71
Hot carcass weight					-0.08435
					0.4843
					71

[a]KPH = Kidney, pelvic, and heart fat.

Table 57. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 1.

Scan 1			
Models	Variables	R-Square	CP
1	IMF1	0.0955	6.6125
2	IMF1, Ribfat 1	0.1774	2.0382
Equation 1	Marbling Score = 443.54752 + (61.69733 * IMF1)		
Equation 2	Marbling Score = 522.06126 + (65.721461 * IMF1) + (-421.64099 * Ribfat1)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, Ribfat = 12^{th} rib fat thickness measured via real time ultrasound (cm).

Table 58. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 2.

Scan 2			
Models	Variables	R-Square	CP
1	IMF2	0.1299	6.5852
2	IMF2, Wt2	0.1985	3.0949
3	IMF2 Wt2 UFAT2	0.2338	2.2706
Equation 1	Marbling Score = 462.04728 + (56.96121 * IMF12)		
Equation 2	Marbling Score = 786.18750 + (62.26685 * IMF2) + (-1.23013 * Wt2)		
Equation 3	Marbling Score = 802.29803 + (64.97933 * IMF2) + (-1.89461 * Wt2) + (-217.71687 * UFAT2)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm), Wt2 = weight at scan time 2.

Table 59. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 3.

Scan 3			
Models	Variables	R-Square	CP
1	IMF3	0.1643	1.336
2	IMF3, Wt3	0.1937	1.0737
Equation 1	Marbling Score = 395.82838 + (73.924291 * IMF3)		
Equation 2	Marbling Score = 693.83312 + (64.718991 * IMF3) + (-0.90408 * Wt3)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, Wt3 = weight at scan time 3.

Table 60. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 4.

Scan 4			
Models	Variables	R-Square	CP
1	IMF4	0.1846	9.6629
2	IMF4 REA4	0.2315	7.427
3	IMF4 REA4 Wt4	0.308	2.5181
Equation 1	Marbling Score = 403.04077 + (65.21724 * IMF4)		
Equation 2	Marbling Score = 266.72928 + (75.03289 * IMF4) + (2.29953 * REA4)		
Equation 3	Marbling Score = 514.39168 + (73.529151 * IMF4) + (4.47299 * REA4) + (-0.9896 * Wt4)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Wt4 = weight measured at scan time 4.

Table 61. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 5.

Scan 5			
Models	Variables	R-Square	CP
1	IMF5	0.1605	2.3256
2	IMF5, RibFat5	0.0467	0.5783
Equation 1	Marbling Score = 428.89953 + (49.339021 * IMF5)		
Equation 2	Marbling Score = 461.65043 + (57.654971 * IMF5) + (-110.65206 * RibFat5)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, Ribfat = 12th rib fat thickness measured via real time ultrasound (cm).

Table 62. Investigation of multiple regression models to predict marbling score using stepwise analysis of real time ultrasound measures[1] and weight at scan 6.

Scan 6			
Models	Variables	R-Square	CP
1	IMF6	0.1878	7.5854
2	IMF6 UFAT6	0.2859	1.5485
Equation 1	Marbling Score = 360.75838 + (56.37498 * IMF6)		
Equation 2	Marbling Score = 447.11473 + (65.37219 * IMF6) + (-119.93067 * UFAT6)		

[1]IMF = Intramuscular fat percentage measured via real time ultrasound, UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table 63. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 1.

Scan 1			
Models	Variables	R-Square	CP
1	IMF 1	0.1850	4.59
2	IMF 1, Ribfat1	0.2090	3.63

Equation 1 Days to Choice = 369.49 + (-47.60 * IMF1)

Equation 2 Days to Choice = 344.53 + (-49.29 * IMF1) + (131.27 * Ribfat1)

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.
[2]IMF = Intramuscular fat percentage measured via real time ultrasound, Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), Wt1 = weight measured at scan time1.

Table 64. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 2.

Scan 2			
Models	Variables	R-Square	CP
1	IMF 2	0.2080	4.17
2	IMF2, UFAT 2	0.2550	0.59

Equation 1 Days to Choice = 361.86 + (-48.75 * IMF 2)

Equation 2 Days to Choice = 334.49 + (142.87 * UFAT 2) + (-54.78 * IMF2)

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.[2]IMF = Intramuscular fat percentage measured via real time ultrasound, UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm), Wt2 = weight measured at scan time2.

Table 65. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 3.

Scan 3			
Models	Variables	R-Square	CP
1	IMF 3	0.3633	7.12
2	IMF 3, UFAT 3	0.3944	4.33
3	IMF 3, UFAT 3, REA 3	0.4156	3.06

Equation 1 Days to Choice = 414.62 + (-64.14 * IMF 3)

Equation 2 Days to Choice = 446.77 + (-113.22 * UFAT3) + (-63.97 * IMF3)

Equation 3 Days to Choice = 411.46 + (-200.57 * UFAT3) + (-61.66 * IMF3) + (1.28 * REA 3)

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.
[2]IMF = Intramuscular fat percentage measured via real time ultrasound, UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table 66. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 4.

Scan 4			
Models	Variables	R-Square	CP
1	IMF 4	0.4531	2.99
2	IMF 4, UFAT 4	0.4804	0.41

Equation 1 Days to Choice = 433.76 + (-60.12 * IMF4)

Equation 2 Days to Choice = 463.09 + (-61.75 * IMF4) + (-49.04 * UFAT 4)

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.
[2]IMF = Intramuscular fat percentage, Ribfat = 12th rib fat thickness measured via real time ultrasound (cm).

Table 67. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 5.

Scan 5			
Models	Variables	R-Square	CP
1	IMF 5	0.5982	-0.23
Equation 1	Days to Choice = 452.03 + (-55.57 * IMF5)		

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.
[2]IMF = Intramuscular fat percentage measured via real time ultrasound, Wt5 = weight at scan time 5.

Table 68. Investigation of multiple regression models to predict days to choice[1] using stepwise analysis of real time ultrasound measures[2] and weight at scan 6.

	Scan 6		
Models	Variables	R-Square	CP
1	IMF 6	0.4687	2.01
2	IMF 6, Weight 6	0.4903	1.12
Equation 1	Days to Choice = 502.13 + (-55.97 * IMF6)		
Equation 2	Days to Choice = 377.39 + (-56.37 * IMF6) + (0.23 * Weight 6)		

[1]Days to choice = Calculated by regressing IMF on days for each animal and using the resulting beta coefficients in a quadratic equation which set Y=4.0 (the equivalent of choice) to determine x as days to choice.
[2]IMF = Intramuscular fat percentage measured via real time ultrasound.

Table 69. Effects of ultrasound and animal body composition traits[1] on attaining marbling score 600 or greater across time.

Effect	Estimate ± SE	*P*-value
Scan 1		
Intercept	-3.49 ± 1.35	0.0147
IMF1	1.13 ± 0.47	0.0198
Scan 2		
Intercept	-2.19 ± 1.06	0.0422
IMF2	0.77 ± 0.40	0.0589
Scan 3		
Intercept	-2.70 ± 1.24	0.0326
IMF3	0.87 ± 0.42	0.0449
Scan 4		
Intercept	-3.03 ± 1.25	0.0184
IMF4	0.88 ± 0.37	0.0228
Scan 5		
Intercept	-3.54 ± 1.21	0.0048
IMF5	0.87 ± 0.30	0.0063

[1]IMF = Intramuscular fat percentage measured via real time ultrasound.
(Marbling score of 600 or greater (n=31), 600 or less (n=39)).

APPENDIX B

Table B-1. Carcass traits by quality grade

	Yield Grade	Hot Weight (kg)	Days to Choice (days)	Marbling Score	Back fat (cm)	Ribeye Area (cm^2)	KPH
Prime	3.2	350	196	848	1.79	82.81	2.7
Choice	3.12	367	253	704	1.73	85.93	2.28
Small Choice	3.25	369	293	557	1.86	84.73	2.34
Select	3.42	358	--	469	1.57	84.85	2.28

Table B-2. Levels of significance and variance estimates from repeated measures[1] in herd A.

	BCS	IMF	REA	Weight	RibFat	Ufat
Group	0.0001	0.097	0.006	0.586	0.0016	0.0026
Rebreed	<0.0001	0.0037	0.0006	0.0041	<0.0001	<0.0001
Time	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Group x Rebreed	0.5303	0.0004	0.7224	0.4309	0.5817	0.9143
Group x Time	<0.0001	0.0015	0.0013	<0.0001	<0.0001	0.0004
Rebreed x Time	0.8622	0.0296	0.026	0.0009	<0.0001	0.0018
Cow Variance	0.5523	0.5916	0.5529	0.6813	0.4320	0.6008
Residual Variance	0.7038	0.6298	81.7989	2303.96	0.02198	0.08727

[1] BCS = body condition score was taken once and therefore not a repeated measure, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table B-3. Levels of significance and variance estimates from repeated measures[1] in herd B.

	BCS	IMF	REA	Weight	RibFat	Ufat
Rebreed	0.2248	0.5657	0.1076	0.9025	0.0041	0.0109
Time	<0.0001	<0.0001	<0.0001	--	<0.0001	0.0022
Rebreed x Time	0.2277	0.8173	0.2841	--	0.0516	0.848
Cow Variance	-0.01628	0.6386	0.1514	0	0.2682	0.2777
Residual Variance	0.6874	0.5918	57.7841	805.60	0.01973	0.08320

[1] BCS = body condition score was taken once and therefore not a repeated measure, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table B-4. Levels of significance and variance estimates from repeated measures[1] in herd C&D.

	BCS	IMF	REA	Weight	RibFat	Ufat
Pregnancy	0.0599	0.2464	0.0007	0.0153	0.1143	0.0332
Time	<.0001	0.4353	<.0001	<.0001	<.0001	<.0001
Pregnancy x Time	0.0357	0.1161	0.0029	0.4506	0.0815	0.6361
Year	0.0001	<.0001	<.0001	0.0001	0.0195	<.0001
Year*Pregnancy*Time	<.0001	<.0001	0.5631	0.3087	0.1931	<.0001
Cow Variance	0.4336	0.3649	0.5068	0.6315	0.1681	0.2352
Residual Variance	0.2240	0.4266	43.5079	1044.72	0.009330	0.01445

[1] BCS = body condition score was taken once and therefore not a repeated measure, IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table B-5. Levels of significance and variance estimates for repeated measures[1] for Experiment 2.

Effect	IMF	REA	Ribfat	UFAT	Weight
days	0.6788	<.0001	0.0122	<.0001	<.0001
origin	0.0082	0.5648	0.3545	0.0069	0.0842
time	<.0001	<.0001	<.0001	<.0001	<.0001
time x origin	0.0287	<.0001	<.0001	<.0001	0.0042
steer variance	0.5130	0.4460	0.7059	0.6527	0.6453
residual	0.5166	65.8973	0.03458	0.03460	1029.17

[1] IMF = Intramuscular fat percentage measured via real time ultrasound, REA = Ribeye area measured via real time ultrasound (cm^2), Ribfat = 12th rib fat thickness measured via real time ultrasound (cm), UFAT = depth between gluteus medius and biceps femoris muscles (rump fat) measured via real time ultrasound (cm).

Table B-6. Summary table for herd A and traits that impacted pregnancy status across scan times 1–4.

SCAN 1			SCAN 2			SCAN 3			SCAN 4		
YEARLING			PREGNANCY DETERMINATION			30–60 DAYS POST CALVING			WEANING OF FIRST CALF		
SPRING 2006			OCTOBER 2006			JAN – MAY 2007			MAY – OCTOBER 2007		
IMF RIBFAT			**RIBFAT BCS**			**IMF* BCS**			**BCS**		
Status	Trait	Mean	Status	Trait	Mean	Status	Trait	Mean	Status	Trait	Mean
0	Weight	277	0	Weight	337	0	Weight	402	0	Weight	405
	RibFat	**0.26**		Ufat	0.69		Ufat	0.41		Ufat	0.26
	REA	47		**RibFat**	**0.42**		RibFat	0.30		RibFat	0.21
	IMF	**2.3**		REA	52		REA	46		REA	39
				IMF	3.2		**IMF**	**2.8**		IMF	3.0
				BCS	**6.1**		**BCS**	**5.2**		**BCS**	**4.6**
1	Weight	283	1	Weight	332	1	Weight	434	1	Weight	440
	RibFat	**0.31**		Ufat	0.95		Ufat	0.61		Ufat	0.33
	REA	47		**RibFat**	**0.57**		RibFat	0.39		RibFat	0.23
	IMF	**2.7**		REA	57		REA	49		REA	43
				IMF	3.5		**IMF**	**3.3**		IMF	3.2
				BCS	**6.7**		**BCS**	**5.7**		**BCS**	**5.1**

Traits in bold were significant in impacting pregnancy status at levels of $P < 0.05$.
IMF* was only marginally significant with a *P*-value of 0.0544.

Table B-7. Summary table for herd B and traits that impacted pregnancy status across scan times 1–3.

SCAN 1			SCAN 2			SCAN 3		
YEARLING			PREGNANCY DETERMINATION			30–60 DAYS POST CALVING		
SPRING 2006			OCTOBER 2006			DECEMBER 2007		
			RIBFAT			**REA**		
Status	Trait	Mean	Status	Trait	Mean	Status	Trait	Mean
0	IMF	2.3	0	IMF	2.9	0	IMF	2.6
	REA	43		REA	51		**REA**	**38**
	RibFat	0.28		**RibFat**	**0.28**		RibFat	0.43
	Weight	238		Ufat	0.58		Ufat	0.41
1	IMF	2.3		BCS	6.2		BCS	4.7
	REA	43	1	IMF	3.2	1	IMF	2.7
	RibFat	0.29		REA	54		**REA**	**41**
	Weight	238		**RibFat**	**0.43**		RibFat	0.49
				Ufat	0.74		Ufat	0.56
				BCS	6.6		BCS	4.7

Traits in bold were significant in impacting pregnancy status at levels of $P < 0.05$.

Table B-8. Summary table for herd C and traits that impacted pregnancy status across scan times 1-2.

SCAN 1			SCAN 2		
YEARLING			PREGNANCY DETERMINATION		
FALL 2006 **BCS** **RIBFAT** **REA**			SPRING 2007 **RIBFAT**		
Status	Trait	Mean	Status	Trait	Mean
0	**BCS**	**5.3**	0	BCS	5.0
	IMF	3.7		IMF	3.0
	REA	**44**		REA	50
	RibFat	**0.33**		**RibFat**	**0.25**
	UFAT	0.40		UFAT	0.34
	Weight	299		Weight	337
1	**BCS**	**5.6**	1	BCS	4.9
	IMF	3.9		IMF	2.9
	REA	**49**		REA	52
	RibFat	**0.36**		**RibFat**	**0.29**
	UFAT	0.46		UFAT	0.41
	Weight	318		Weight	352

Traits in bold were significant in impacting pregnancy status at levels of $P < 0.05$.

Table B-9. Summary table for herd D and traits that impacted pregnancy status across scan times 1-2.

SCAN 1			SCAN 2		
YEARLING			PREGNANCY DETERMINATION		
FALL 2008			SPRING 2009		
REA					
Status	Trait	Mean	Status	Trait	Mean
0	BCS	5.4	0		
	IMF	4.0		IMF	4.8
	REA	**39**		REA	46
	Weight	283		Weight	326
	Ribfat	0.38		Ribfat	0.29
	UFAT	0.22		UFAT	0.37
1	BCS	5.5	1		
	IMF	3.8		IMF	4.5
	REA	**44**		REA	48
	Weight	292		Weight	339
	Ribfat	0.35		Ribfat	0.32
	UFAT	0.21		UFAT	0.37

Traits in bold were significant in impacting pregnancy status at levels of $P < 0.05$.

Table B-10. Traits that differed across status in herds A & B ($P < 0.05$)

	BCS	IMF	REA	Weight	Rib Fat	UFAT
1						
2	A		A		A	A
3		A	A,B		A,B	A,B
4	A		A	A		

Traits that differed across status in herds C & D ($P < 0.05$)

	BCS	IMF	REA	Weight	Rib Fat	UFAT
1	C&D		C&D	C&D	C&D	
2						C&D

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