Ultrasound adjustment factors for purebred yearling Limousin bulls and heifers

by

Michael Clifford Anderson

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Gene H. Rouse, Major Professor
Doyle E. Wilson
John D. Lawrence

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Graduate College
Iowa State University

This is to certify that the master's thesis of

Michael Clifford Anderson

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

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GENERAL INTRODUCTION

Cattle producers are searching for ways to better improve the end beef product in a consumer driven market. In today's rapidly changing industry, consumers are willing to pay more for quality and producers are trying to find ways to more effectively generate that product. Buyers of beef in the market place want a lean, tender product with adequate juiciness and flavor and consumers want a satisfactory eating experience every time they buy beef. However, there has been considerable discussion in recent years on how to achieve this goal and how to best utilize the genetic variation in the different breeds of cattle to produce the most desirable product.

Packers realize they must reduce the amount of waste subcutaneous fat on the carcass either by trimming the excess fat or buy leaner cattle. Cattle feeders are looking for cattle that fit the bill in terms of marbling, limited external fat, and still have enough muscle to have a high yield of retail product. Consequently, seedstock and cow-calf producers are at the most important level in this chain. They must find the genetics that will consistently create the product the industry demands (Duello, 1993).

Although there is genetic variation in carcass traits between breeds of cattle, there may be just as much variation within a certain breed of cattle. In the past, producers continually tried to find ways to better understand the genetics within their herd, but it became clear that carcass testing was not for everyone. Not only was it costly, but time-consuming, as the generation interval of cattle was too long in order to make effective changes in a short-term period. As an alternative, real-time ultrasound has been researched and proven to be an effective way to measure body composition traits (Duello, 1993).

LITERATURE REVIEW

Accuracy of Ultrasound

Producers are continually trying to find ways to improve the end product. One method is through genetic selection. In the past, various breed associations have developed genetic improvement programs for beef cattle primarily based on growth, maternal, and reproductive traits. However, these programs have not focused on the end product until recently, mainly due to limited carcass data collection and the lack of premiums for superior carcasses. Two steps need to be taken in order for genetic improvement programs to be applied to carcass merit in cattle. First, seedstock producers must have an economic incentive from packers, retailers, or consumers to be interested in selection for carcass improvement. Second, the methods by which body composition measurements are taken need to be cost-effective, accurate, and reasonably quick. The use of ultrasound has provided results that can satisfy all of these needs (Wilson, 1992).

Reporting Accuracies

In the past, there have been many studies trying to validate the use of ultrasound as a means to measure body composition. Correlation coefficients have been the statistic used to report accuracy. Even though this is a useful tool, there are limitations when reporting correlations. These include 1) the idea that population variation affects correlation coefficients (i.e., a small variation in a population will decrease the coefficient, and a large variation will increase correlations); 2) correlation coefficients don't take bias into account (i.e., if a technician uses a scanning technique that over or underestimates the measurement, or if an interpretation technician over or underestimates the measurement while tracing the image); and 3) most producer groups don't understand correlation coefficients (Houghton and Turlington, 1992). An alternative method of reporting accuracies is by using the standard error of prediction (SEP) shown below.

$$SEP = \sqrt{\frac{\sum\sum (\text{Carcass} - \text{Ultrasound} - \text{Bias})^2}{n - 1}}$$

[where, Bias = mean difference in subclass of interest]

The standard error of prediction measures the ability to correctly rank animals. This has an advantage in that squaring the difference between two measurements gives more consideration to large errors compared to smaller differences (Robinson et al., 1992).

Carcass Traits vs. Ultrasound Traits

An even more interesting debate may not be over the accuracy of ultrasound compared to carcass traits of fat and longissimus muscle area, but how these traits relate to total carcass muscle and leanness. The reason that these carcass measurements have been taken is because they are indicator traits of total carcass muscle and leanness and are easily measured. Total dissection of the carcass is tedious and costly. This may mean that we should be correlating ultrasound measurements to these overall measures instead of the actual carcass measurement (Dolezal et al., 1989). In a study done by Koch et al., (1982), he reported that carcass fat is highly correlated to carcass percent fat trim and carcass percent retail product ($r = .77$ and $r = -.74$). Wallace et al. (1977) concluded that the correlation between carcass percent retail product and ultrasound fat thickness (-.72) to be nearly identical to percent retail product and carcass fat thickness (-.73). He also reported that the correlation of LMA to percent retail product to be similar and close to zero for ultrasound and carcass LMA. Genetic correlations between LMA and fat thickness were either negative

(Koch et al., 1982; Arnold et al., 1991; Shimada et al., 1992) or close to zero (Wilson et al., 1993). This indicates fat thickness could be reduced while increasing total lean muscle.

In a study done by Greiner (1997), research was conducted on 534 steers to relate ultrasound as a predictor of retail product. The R^2 value for weight of retail product in ultrasound using final weight, rib fat, ribeye area, and rump fat was .84. The R^2 value for percent retail product using final weight, rib fat, ribeye area, rump fat, and body wall thickness was .61. These correlate very well to the yield grade equations which had R^2 values .86 for weight of retail product and .65 for percent retail product. Ultrasound rib fat itself had a correlation of .74 to percent retail product compared to .68 for unadjusted carcass fat and .73 for adjusted carcass fat. Even though carcass ribeye area accounted for 6.5% more variation in percent retail product than ultrasound both measurements had the same correlation coefficients of .92 and .94 for actual and predicted yield on weight of retail product. This indicates that ultrasound measurements are capable of predicting overall carcass composition just as good as actual carcass measurements.

Fat Thickness

There have been many studies looking at the accuracy of ultrasound to carcass measurements of fat thickness and LMA. Robinson et al. (1992) conducted a study to evaluate these ultrasound measurements. The average correlations for rump fat and rib fat with carcass measurements were .92 and .90 with an average residual SEP of 1 mm. Duello et al. (1992) reported a correlation in rib fat of .86 in relation to carcass measurement and Greiner (1997) reported .89 for rib fat. In the past, correlations of rib fat between ultrasound and carcass measurements ranged from .75 to .96 with an average of .86 (Houghton and Turlington, 1992). Still, it has been shown that, in general, ultrasound fat measurements underestimate actual carcass measurements (Lewin and Busk, 1982). Greiner (1997) reported that ultrasound underestimated carcass fat .06 cm and had a mean fat deviation absolute difference of .16 cm in a study done on 534 steers. He also reported that the mean rump fat measurement on cattle with <1.02 cm of carcass fat was higher. This indicated that rump fat measurements could be better for leaner cattle so differences can be measured easier (Greiner, 1997).

Sound velocity varies between fat and muscle. Muscle has a velocity between 1,540 m/s and 1,630 m/s, whereas fat is between 1,460 m/s and 1,470 m/s (Wells, 1977). In cattle, these values are around 1,600 m/s and 1,470 m/s for muscle and fat, respectively. Most real time ultrasound machines are calibrated at 1,530 m/s. Thus, velocity through fat is slower than the calibration of the machine and reflected sound does not travel quite as far, so fat depths should be about 96% of the machine readings (Robinson et al., 1992).

Looking at rib fat, scan measurements tend to overestimate leaner cattle and underestimate fatter cattle (Robinson et al., 1992; Brethour, 1992; Greiner, 1997). However, as cattle increase in fat, measuring the thickness becomes increasingly difficult (Greiner 1997). Unlike the rump fat position, the rib fat measurement is taken in a concave area of the hanging carcass which may cause bunching of the fat layers and thus, a higher carcass fat depth (Robinson et al., 1992). As for the overestimation of the leaner cattle, this could be due to fat stripping or, as reported by Brethour (1992), tracing to the bottom of the band between fat and muscle could cause an increase in the ultrasound measurement. The deeper band is more distinguishable in fatter cattle and thus correlates better with carcass backfat thickness.

Ribeye Area

LMA usually has the lowest correlation to the carcass measurement of the three measurements (rump fat, rib fat, LMA). Robinson et al., (1992) observed the correlation of LMA with the carcass measurement to be .87 with an average residual SEP of 5 cm^2. Duello (1993) reported .78 for correlation and Greiner (1997) reported .86 on more recent data. This sounds very encouraging considering the fact that earlier studies conducted were not so favorable. Ranges for LMA correlation have been calculated from .20 to .90 (Houghton and Turlington, 1992). Many reasons may be expressed for this broad range in numbers. Stouffer (1988) concluded that many LMA differences occurred because of 1) dirt, hide thickness, and hair; 2) fat thickness differences at the 12^{th}-13^{th} rib; 3) split-screen interpretation; and 4) poor definition of medial and lateral ends. Improper placement of the transducer, poor image quality (Cross, 1989), or inaccurate interpretation of the image can explain some of the low correlations in LMA (Miles et al., 1972). A study done by Waldner et al. (1992) found LMA of bulls less than 70 cm^2 to be underestimated compared to actual carcass measurements, and those over approximately 85 cm^2 were overestimated. Similar findings were reported by Henderson-Perry et al. (1989) and Kreider et al. (1986) where they found LMA to be overestimated and McMillin et al. (1987) concluded ultrasound underestimated LMA. However, Smith et al. (1990) saw that cattle with LMA > 104 cm^2 were underpredicted, and those with LMA < 84.5 cm^2 were overpredicted. Waldner et al. (1992) also concluded that taking these LMA measurements provided the best correlations at twelve months of age. In a study on 534 steers, Greiner (1997) reported that ultrasound overestimated ribeye area by about 71 cm^2 with a mean absolute difference of 3.31 cm^2 compared to carcass data, but ultrasound tended to overestimate light-muscled steers and underestimate heavy-muscled steers. Even more interesting were his findings on carcass fat categories relative to the ability of ultrasound to predict ribeye area. Ultrasound underestimated carcass ribeye area in leaner cattle with the opposite effect occurring in fatter cattle. Also, the standard deviation and standard error of prediction for ribeye area increased as carcass fat increased, thus concluding that as fat increases, the ability and accuracy of ultrasound for ribeye area decreases (Greiner, 1997). Despite these variations in results, they show that ultrasound can predict fat thickness very accurately and, although LMA is lower, it still evaluates it fairly well.

Percent Intramuscular Fat

It has been shown that ultrasound percent intramuscular fat is highly correlated to actual percent fat in the muscle and marbling score. However, there is a broad range from almost 2% to 10% actual percent intramuscular fat when compared to a marbling score of $Small^0$ to $Small^{90}$. This further validates the subjective measure of the USDA graders in determining fat within the muscle and that their measurements are not perfect (Hassen et al., 1997). Ultrasound measurement of percent intramuscular fat offers an objective method for prediction compared to the subjective method of marbling scores and assigning quality grades by USDA graders. Therefore, the models being developed by Iowa State University have based the accuracy and validation on the chemically extracted percent fat in the longissimus muscle. Studies conducted up to 1994 concluded that a prediction model using the Fourier transformation and texture parameters could accurately predict percent intramuscular fat. In a group of 119 beef carcasses scanned, almost 80% of the images were predicted to within 1.5%, and more than 60% were predicted within 1% compared to actual chemical extraction (Amin et al., 1994). Still, there were other studies that didn't show as favorable signs (Hassen et al., 1995). Therefore, more research had to be conducted to validate a model to predict intramuscular fat. Another study conducted by Wilson et al. (1998) compared correlations among actual percent intramuscular fat, USDA marbling score, and ultrasound percent fat. Correlations for actual percent fat and marbling score for data generated in 1996 and 1997 were .95 for 1996, .82 for 1997, and .89 for combined years. Correlations between actual percent fat and ultrasound percent fat using the ISU developed software were .80 and .85 for 1996 and 1997 (Amin et al., 1997). It can be assumed that ultrasound does a good job of correlating percent fat to the subjective grading of the USDA. Ultrasound tends to overestimate percent fat in lower marbling cattle and underestimate those in the higher marbling categories. Additionally, biases between technicians, the limiting predictability of the regression formula, and machine variation can play a role in accuracy. Temperature fluctuations can cause differences in gain settings. Therefore, technicians must calibrate their machines, even on the same day, to make sure the percent intramuscular fat is being interpreted correctly. Still, genetic progress for percent intramuscular fat is possible using ultrasound. If good technician/interpretation systems are used, SEP should be less than 1%, rank correlations should be greater than .7, and biases should be less than .5% (Wilson et al., 1998). Another way to increase accuracy is taking multiple images per animal. Instead of taking multiple measurements within an image, taking multiple images and placing the box at the appropriate location reduces SEP. Taking four images per animal can reduce standard error to approximately 0.37%, but taking more than four images has little effect on improving accuracy (Hassen et al., 1997).

Koots et al. (1994) found ultrasound percent intramuscular fat genotypic correlations of .26, .33, .20, and .98, and phenotypic correlations of .13, .27, -.11 and .63 with carcass weight, fat thickness, loin muscle area, and marbling. He concluded that although the phenotypic correlation is lower, the genotypic correlation indicates that fat thickness and percent intramuscular fat are traits that could be controlled by the same genes and environment may play more of a role than previously thought (Koots et al., 1994). Even though it has been stated that reducing fat thickness will also reduce marbling (Koch et al., 1982; Lamb et al., 1990), Wilson et al., (1993) revealed that there was a genetic correlation of -.13 between the two, and Shimada et al., (1992) reported -.41 for fat and marbling genetic correlation. Since the genetic correlation between subcutaneous fat and percent intramuscular fat is low, producers could select for leaner cattle and still not affect marbling, or, may even increase this trait.

Carcass Traits vs. Growth Traits

Overall, the genetic correlations between carcass traits and growth traits such as weaning and post-weaning traits are moderately high (Koch et al., 1982; Lamb et al., 1990). Marbling was said by many to be positively correlated with pre- and post-weaning traits (Koch et al., 1982; Lamb et al., 1990; Arnold et al., 1991). There have been discrepancies for fat thickness and these same traits as results have indicated positive, null and negative genetic correlations (Koch et al., 1982; Lamb et al., 1990; MacNeil et al., 1991). Most of the correlations reported by various sources have been inconsistent. Many reasons could explain this such as the small data sets that were used, the manner in which the data was collected, and differences in ages and genotypes. Minick et al. (2000b) reported that both Angus bulls and heifers have positive genetic and phenotypic correlations between growth and carcass traits. In both data sets, as weight increased, ribeye area and fat thickness increased as well. Additionally, as fat thickness increased, ribeye area was larger as well.

Differences in Handling and Chilling Procedures

Another important factor that may affect accuracy is the possible differences in carcass handling and chilling procedures (Mersmann, 1982). Lauprecht et al. (1957) found few differences when looking at changes occurring during the chilling process. However, Turlington (1990) looked at a study of 25 barrows scanned 1 day pre-slaughter. After each hog was killed, one half of the carcass was hung and the other half was placed in a standing position using a special rack. The data indicates no significant difference ($p > .05$) in backfat between the live animal and standing carcass, but there were significant differences between the live animal and hanging carcass. In each case, the hanging carcass always had the higher backfat measurement. LMA was significant in all 3 positions as well, with the live animal measurement being in between the standing and hanging carcass. Even though there is not similar data in sheep and cattle, one can assume that carcass position does influence carcass measurement (Turlington, 1990). In the experiment mentioned before by Robinson et al. (1992), carcass measurements were taken on both left and right sides and correlations were compared from the mean of left and right sides of the carcass, the same side of the carcass as the scan side, and the opposite side of the scan side. Correlations were the highest between the scan data and the average of the left and right sides of the carcass rather than the particular side scanned. Again, this suggests there are differences due to ribbing and chilling procedures rather than biological differences in some cases.

Technician Bias and Repeatability

Possibly the most important factor in all of these correlations is technician bias. Correlation coefficients do not take this into account (Houghton and Turlington, (1992). Robinson et al. (1992) studied the accuracy and repeatability of scanning technicians. There were 30 cattle, 8 people, and 3 different stations used in the experiment. The SE of difference between repeat measurements was set at < 1.5 mm for rump fat, < 1.0 mm for rib fat, and < 6.0 cm^2 for LMA. The SE between repeat measurements was about .6 mm for both fat traits, and about 4.0 cm^2 for LMA. While the SEP was higher between scan measurements and carcass measurements, there are several reasons why this may have occurred. Even if the repeatability in capturing the image is high, interpretation bias can play a role. Identifying the lateral and medial boundaries and the problem of split-screen tracing can cause differences in measurements. This especially can occur in fatter cattle where the boundaries and image clarity are harder to distinguish (Greiner, 1997). Since 1991, 17-cm transducers have been used which reduced variation 25%, and the use of a computer package to trace the images increased accuracy by another 10% (Robinson et al., 1992). Brethour (1992) conducted another repeatability study for fat thickness on 217 cattle and a correlation study of 580 animals between ultrasound and carcass measurement. The correlation for repeatability was .975. The average difference between measurements was .72 mm and this was directly related to differences in backfat. Ultrasound averaged about 8% less than actual carcass measurements. Cattle with backfat measuring < 10 mm averaged 1.43 mm absolute difference, and those with > 10 mm averaged 1.89 mm. Turner et al. (1990) reported correlations of >.7 for both fat and LMA for approved technicians and their repeatability was > .95.

Even though accuracy and repeatability need to be observed comparing ultrasound and carcass measurements, one must remember that carcass measurements are not without error. Rouse et al. (1992) compared two experienced carcass evaluators and obtained correlations of .97 and .94 between the two for fat and LMA, respectively. Another study was done in Australia where two people measured each side of a carcass twice. The difference between carcass evaluators on LMA was 1.3 cm^2 ($\pm$ .20) (Robinson et al., 1992).

Correlations Among Ultrasound Traits

Correlations among ultrasound measurements themselves must also be observed. Rump fat seems to correlate well with rib fat thickness. In ultrasound measurements done on the Iowa Cattlemen's Association bull test, rump fat measurements were added in addition to rib fat, ribeye, and percent intramuscular fat images. The rump fat had an average correlation of about .60 to rib fat with just a limited number of data points (Wilson et al., 1997). In 1999, over 4,000 yearling Angus bulls were studied and the phenotypic correlation between percent intramuscular fat and rib fat was .12. The phenotypic correlation between percent intramuscular fat and rump fat was .17. This is in contrast to the .00 correlation reported in the 1998 Angus Sire Evaluation Report. Wilson et al. (1999b) concluded that this difference can be accounted for in that the age range of the carcass steer data is much broader, and the yearling bull data age range is much narrower. Genetic correlations were also reported for other traits of interest. Percent intramuscular fat had correlations of -.12, .17, and .12 with ribeye area, rib fat, and rump fat. Ribeye area had a correlation of .23 with rib fat, a correlation of .25 with rump fat, and rib fat had a genetic correlation of .82 with rump fat (Wilson et al., 1999b). In 2000, over 89,000 Angus bulls and heifers were evaluated. Genetic correlations were similar compared to earlier evaluations. Percent intramuscular fat had correlations of -.05, .20, and .17 with REA, rib fat, and rump fat, respectively. Ribeye area had correlations of .26 and .20 with rib fat and rump fat, and rib fat had a .65 genetic correlation with rump fat. Phenotypic correlations were similar for these traits as well (Crouch et al. 2000).

Centralized Ultrasound Processing

Even though ultrasound has been proven to correlate with carcass measurements, efforts were under way in 1998 between the American Angus Association and Iowa State University to further improve its accuracy and credibility. Since the American Angus Association has the largest database for carcass traits, the logical step was to join with Iowa State University for a two-year research project. The concept of Centralized Ultrasound Processing (CUP) was a key step in breed associations accepting ultrasound data on an industry-wide basis. The purpose of CUP was to provide an unbiased third party to evaluate both the technicians scanning the cattle and the interpreter looking at the images. By sending all images to CUP, this would help eliminate the variation of having many interpretation technicians throughout the country. Not only did the lab train a small group of interpretation technicians, but also looked at image quality to make sure the best and most consistent data was being used for genetic evaluations (Hays et al., 1999).

After the second training and certification, a new hardware technology was being accepted. Both the Aloka 500 and Classic 200 scanners were being used through CUP from 30 technicians around the country. In 1999, the American Simmental Association and North American Limousin Foundation started accepting data processed through CUP (Hays et al., 1999). In 2001, the CUP lab transferred to a privately-owned entity and processed over 100,000 cattle from 14 breed associations and over 80 technicians (Iowa State Univ., 2002).

Genetic Parameters

In order for a breed association to put together a genetic evaluation, one must estimate the heritabilities on both carcass traits and ultrasound traits. Many sources of literature have reported on the heritabilities of carcass traits such as carcass weight, fat thickness, longissimus muscle area, and marbling as the main ones of relevancy. The average heritabilities for these traits were .48, .43, .40, and .41 (Koch et al., 1982; Benyshek et al., 1988). Wilson et al. (1993) generated heritability estimates of .31, .26, .32, and .26 from Angus field data for hot carcass weight, marbling score, carcass LMA, and carcass fat. Woodward et al. (1992) reported a .23 heritability estimate for marbling on Simmental cattle, while Koots et al. (1994) reported .47, .44, .38, and .49 for carcass weight, fat thickness, marbling, and longissimus muscle area.

Ultrasound traits appear to have moderate heritability estimates. Sources reported .26, .40, .21, .11, .27, and .25, .14, .30, .36, .27 for LMA and rib fat thickness (Arnold et al., 1991; Johnson et al., 1993; Robinson et al., 1993; Shepard et al., 1995; Kriese and Schalles, 1994). Although Turner (1990) reported a lower heritability for LMA, and Johnson (1992) for rib fat thickness of .14, Kriese and McElhenney (1995) reported estimates of .29 and .15 for ultrasound and carcass rib fat, and .37 and .15 for LMA between ultrasound and carcass measurements. Johnson (1992) suggested that his low estimate of fat thickness might have been due to the difficult ability of Brangus bulls to deposit fat on a low nutrition level. Duello et al. (1993b) computed heritabilities of .87 and .21 for LMA and rib fat in the Simmental data. The Angus data estimate for LMA was .64, but the rib fat could not be computed because the sire variance was 0, so there was not a genetic effect but an environmental one (Duello et al., 1993b). Although limited data reports have been given for percent intramuscular fat, Wilson et al. (1993b) reported a heritability of .38 and Koots et al. (1994) reported .49. Nearly 4,500 Angus bulls were researched under the AAACUP project in 1999. Heritabilities for percent intramuscular fat, ribeye area, rib fat, and rump fat were .42, .39, .44, and .52. Even though the mean values and variations were nearly the same for rib fat and rump fat, the higher heritability for rump fat indicates it is a more repeatable trait and would continue to be taken in the future in hopes of better predicting the retail product equation estimate in live cattle (Wilson et al., 1999b). In 2001, over 8,000 Angus heifer scans were observed, and the heritability for percent intramuscular fat was .42 and .56 for rump fat (Wilson et al., 2001). Over 98,000 Angus records were observed in 2000, and heritabilities for REA, percent intramuscular fat, rib fat, and rump fat were .36, .37, .37, and .41 (Crouch et al. 2000). In 2001, the North American Limousin Foundation looked at 4,875 records to determine heritability estimates for both carcass data and ultrasound data. They reported .35, .51, and .38 for LMA, percent intramuscular fat, and fat thickness for carcass data and .42, .28, and .56 for ultrasound data (Andersen et al. 2001).

Adjusting Carcass Data

In order to fairly compare sires for genetic merit of carcass traits, the data must be adjusted to a common endpoint. In most steer data, the age at slaughter can vary to less than 365 days to more than 700 days (Wilson et al., 1993). There are three common ways to adjust carcass data: 1) age-constant; 2) weight-constant; and 3) compositional-constant endpoints (Duello, 1993).

Cundiff et al. (1969) looked at these adjustment procedures for Angus, Hereford, and Shorthorn cattle. The traits they evaluated were retail product, fat trim, and bone. The heritability estimates for retail product were .64, .42, and .43 for age-constant, weight-constant, and age and weight-constant combined. He also reported that the standard deviation was 2.4 times greater for age-constant adjustments than weight-constant or age and weight-constant. He concluded that single trait selection would be more effective for an age-constant adjustment than a weight-constant one. Swinger et al. (1965) reported .65 for the age-constant heritability and .24 for the weight-constant adjustment.

The fat trim heritabilities for constant age, constant weight, and both age and weight-constant adjustments were .46, .37, and .42 (Cundiff et al., 1969). He suggested that even though the phenotypic variation was less for fat trim at a constant weight than a constant age, the variance from additive gene effects were about the same. The variances for fat trim and retail product were nearly the same with weight being held constant (Cundiff et al., 1969). Cundiff et al. (1969) concluded that adjusting carcass data to an age-constant endpoint would further improve genetic production and carcass traits.

Johnson et al. (1993) reported that the genetic and phenotypic variances were smaller for weight-constant adjustments than age-constant ones. However, Arnold et al. (1991) found heritabilities to be about the same when adjusted to a constant age or weight endpoint. In most cases, the constant age-endpoint is used for better comparing growing animals. The best way to decide on whether to use age or weight constant adjustments is to look at how traits change as animals grow. Serial slaughter can accomplish this but it is very time consuming, and there are usually small sampling numbers, which can increase error (Koch et al., 1995; Wilson et al., 1993; Duello, 1993).

Adjusting Ultrasound Traits

Arnold et al. (1991) adjusted ultrasound measurements to a constant age endpoint. He found the genetic correlation between fat and rib eye area to be higher (.48) than in the weight-constant analysis (.39). Still, this indicates that backfat measurements were positively correlated with growth rate and size instead of maturity level. The age adjustment for the ultrasound traits may explain why the carcass correlation between fat and rib eye area was -

.37 compared to the positive relationship found in ultrasound. If breeding cattle are going to be evaluated based on ultrasound, selection should be based on ribeye area adjusted for age, weight and fat (Turner et al., 1990). Age was also used for the constant end-point, linear adjustment for the Iowa Cattlemen's Association bull testing station for ribeye area, fat thickness, and percent intramuscular fat. Serial scanning can also be done on ultrasound traits. This would be the ideal way to adjust the data but is usually not feasible for breeders. However, if cattle are scanned close to a year of age, fat, ribeye area, and percent intramuscular fat can be accurately adjusted (Duello et al., 1992). In 1999, over 1,200 Angus heifers were evaluated, and a linear adjustment was used. Linear and linear-quadratic effects were looked at, but only ribeye area had a significant quadratic effect and the R^2 value was unchanged when compared to the linear model. Both regressions on age and weight per day of age were developed (Wilson et al., 1999). Collectively, in 2000, over 27,000 Angus bulls and over 7,000 developing Angus heifers were observed. In this research, animal age, age of dam, animal scanning weight, and animal gain from weaning to scanning were used as independent covariates both by themselves and together. Interestingly, the age of dam effect was too significant to ignore, as was the gain from weaning to scanning. Dams that were two and three years old seemed to have a higher percent intramuscular fat value in their progeny, so this needed to be accounted for in order to fairly compare them to older dams. Additionally, scan weight was adjusted by age of dam due to the fact that the younger dams' calves wouldn't be as heavy as calves from cows that were in prime production. After looking at the R^2 values, weight regressions were used for ribeye area and both fat measurements (rib and rump), and age regressions were used for percent intramuscular fat (Wilson et al., 2000).

Breed and Sex Differences

It is well known that yearling bulls both grow at a faster rate and put on muscle at a faster rate than their steer and heifer equivalents. They also deposit subcutaneous fat at a slower rate, and have less intramuscular fat (Duello, 1993; Reiling et al., 1991; Minick et al., 2000b). Reiling et al. (1991) indicated that there were few variations in fat among slaughter bulls, but that ribeye area increased significantly as age progressed. In contrast, steers were found to significantly increase in fat thickness, but not change much in ribeye area. This can be due in part to different hormones between the two and the fact that at a year of age, bulls are at an earlier point in their growth curve than steers (Minick et al., 2000). Intramuscular fat was lower in bulls than steers, but the rate at which it was deposited was similar (Reiling et al., 1991). A possible problem in comparing bulls against steers is the different times at which the data is collected. Bulls are scanned around one year of age. Steers, on the other hand, may be marketed around 14-16 months of age, so it is difficult to compare absolute numbers in scan data between the two. However, the absolute differences should be similar. For example, if Bull A has a larger ribeye than Bull B, Bull A's steer progeny should have larger ribeyes than Bull B's (Minick et al., 2000). Interestingly, data compared from 1998-1999, Angus bulls and heifers seemed to have similar trends in scan data of scan weight, rib fat, and ribeye area. Both sexes indicated that the heavier animals had more external fat and larger ribeye areas (Minick et al., 2000).

Another potential problem in developing EPD's is the small variability in fat thickness and percent intramuscular fat especially in continental breeds such as Limousin, Charolais, and Simmental. In this case, it may be beneficial to measure fat thickness over the rump so that more variation can be found (Greiner, 1997). Duello et al. (1992) found more variation in fat cover among Angus bulls when compared to Simmental bulls. In a study of 208 Angus and Simmental bulls serially scanned four times throughout 1989 and 1990, it was found that both breeds showed a linear effect of regression on age for rib fat and ribeye area. The ribeye area for Simmental bulls increased from a difference of one inch at the first scan to nearly two inches by the fourth scan compared to the Angus bulls. Fat thickness increased linearly as well for both breeds, with Angus bulls increasing at a somewhat faster rate (Duello et al., 1992b).

However, after collecting more data from serial scans between 1989-1992, the equations had changed. The R^2 statistics for rib fat and ribeye area for Angus and Simmental bulls was significantly different when comparing a linear adjustment to a linear and quadratic adjustment. A difference of .23 for Angus and .28 for Simmental was seen for fat, and .18 for Angus and .10 for Simmental was reported for ribeye area. The curve in the ribeye area suggested that the Simmental bulls put on muscle at a faster rate of increase and continued to put on muscle whereas Angus seemed to level off later in the growth period. This indicates a later maturity pattern in Simmental bulls. Fat thickness increased only about one-tenth of an inch, but the Angus increased nearly three times that of the first scan, however, both leveled off toward the fourth scan which is quite different than the steer and heifer data. These differences may be explained in that the bulls are on a lower plane of nutrition and that the onset of puberty in bulls may inhibit them from depositing more fat (Duello et al., 1993).

Even though most breeders in the past usually scanned only yearling bulls, a report by Wilson et al. (2001) indicated that ultrasound measurements on heifers may be just as, or even more, beneficial when compared to the bull data. The heritability estimates were all above .40 for the ultrasound traits and were all higher than the bull ultrasound data. This may become a key discovery, because the heifer data could better indicate what their half-sib steer progeny will do based on ultrasound (Wilson et al., 2000).

Without question, the Angus ultrasound database is the largest of any breed. However, other breeds must also develop proper adjustment procedures as well. The majority of these breeds have based these adjustments off of data collected in the Iowa Cattlemen's Association bull test station. Ultrasound measurements were adjusted to an age-constant endpoint for REA and percent intramuscular fat (% IMF). A 0-day age intercept within breed was determined and this was combined with the individual's growth rate. For purposes of this research paper, only Limousin equations for REA and % IMF are reported as follows: (Currently, fat measurements are not adjusted)

Adjusted REA = 5.085 + [(actual REA – 5.085)/age] * 365

Adjusted IMF = -2.235 + [(actual IMF + 2.235)/age] * 365

However, these equations are based on 65 head of yearling bulls, and are also used for heifer adjustment factors (Wilson et al. 1995).

Therefore, a more thorough analysis needs to be done so that accurate adjustment procedures can be developed for both Limousin bulls and heifers based off of a larger data set.

ULTRASOUND ADJUSTMENT FACTORS FOR PUREBRED YEARLING LIMOUSIN BULLS AND HEIFERS

A paper to be submitted to the Journal of Animal Science

M. C. Anderson[1], G. H. Rouse[1], D. E. Wilson[1], and K. Andersen[2]

ABSTRACT

For this study, 1,267 yearling Limousin heifers and 2,745 yearling Limousin bulls were analyzed using PROC MEANS, GLM, and STEPWISE procedures of SAS to compute age-constant adjustment factor equations. In early analysis, embryo transfer calves exhibited a significant difference in weaning weight and scan weight and were therefore removed from the data set. Bulls were adjusted to a 365-day endpoint, whereas heifers were adjusted to 380 days as well as to a bull equivalent. Significant covariates for rump fat, 12^{th}-13^{th} rib fat thickness, and ribeye area were actual percent Limousin blood and scan weight. R^2 values for bulls and heifers on rump fat were .44 and .51, .52 and .55 for rib fat, and .57 and .58 for ribeye area. Percent intramuscular fat R^2 values were .42 for both bulls and heifers. Actual percent Limousin blood and scan age were the covariates used for percent intramuscular fat. Although age of dam at scanning was significant (p-value < .10), no distinct trends were found and the R^2 value was not improved enough to include age of dam at scanning in the

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[1]Department of Animal Science, Iowa State University, Ames, IA 50011.
[2]North American Limousin Foundation, Englewood, CO 80112

model. Yearling Limousin heifers appear to show more fat variation and more percent intramuscular fat variation than bulls. Additionally, the change in percent Limousin blood has more impact on ultrasound traits of heifers than bulls. These results indicate breeders should be encouraged to scan their replacement females as well as their yearling bulls.

INTRODUCTION

In today's rapidly changing market, consumers are demanding a high-quality and lean product that is consistent. In the past, producers did not have any incentive to produce superior quality beef. However, grid marketing systems such as Certified Angus Beef and Laura's Lean Beef are now paying premiums to producers who can deliver a product that meets a given set of specifications. Therefore, it's more important than ever that producers are aware of the genetic composition of their cattle.

Producers are continually faced with the challenge of genetic improvement of their herds. Realizing that feeding and management alone can not accomplish the change necessary to meet the specifications of certain marketing systems, producers had to find a way to make changes genetically. Until recently, the only way to do this was through traditional carcass progeny testing on slaughter steers and heifers. Not only was this extremely costly, but also time-consuming as sires would be at least three years old before carcass data would be available on their first calf crop. Additionally, there was no way to test breeding cattle through carcass testing to see how replacement heifers and commercial bulls would perform themselves. The only way to do this was to test their progeny.

With real-time ultrasound being implemented as a lower-cost and more time-efficient alternative, producers now have the power to make quicker and more dramatic genetic changes among beef cattle. With ultrasound, they can make breeding decisions earlier by scanning the yearling bulls and replacement heifers and utilize the full animal model. This is the first step in better improving the consistency and quality of beef. Producers must be able to quantify these differences much like they compare traditional growth and reproductive traits.

In order to implement ultrasound data into a genetic evaluation, certain procedures need to be taken. First, breed specific heritabilities must be estimated along with genetic and environmental relationships. Secondly, ultrasound measurements need to be adjusted to a common end point so that all records can be compared equally. Finally, a sufficient amount of data must be collected in order to obtain the most accurate adjustments possible. If these criteria are met, carcass trait expected progeny differences for ultrasound could be generated with confidence.

The American Angus Association has the largest carcass database ever assembled. Consequently, it is important for other breed associations to evaluate their genetics as well. Continental breeds such as Charolais, Gelbvieh, and Limousin are characterized by superior carcass leanness and retail yield, but are also associated with lower levels of marbling. Therefore, these types of cattle need to be evaluated and compared to British breeds as to how their ultrasound traits are adjusted. Currently, the North American Limousin Foundation has an ultrasound database that is one of the larger ones among Continental breeds.

The objectives of this study were to first increase the ultrasound database for yearling Limousin bulls and heifers. Secondly, to evaluate and calculate adjustment factors for ultrasound traits and see how these adjustments compare to the current adjustment procedures and how much they differ between bulls and heifers. Finally, to compute these adjustment factors in an effort to calculate expected progeny differences for ultrasound carcass traits.

MATERIALS AND METHODS

Description of Data

Ultrasound measurements were collected from certified technicians using either the Aloka 500-V unit (Corometrics Medical Systems, Wallingford, CT) equipped with a 3.5-MHz, 17.2-cm linear array transducer or the Classic 200 unit (Classic Medical, Tequesta, FL) with a 3.5-MHz, 18-cm linear array transducer. Images collected and interpreted were done by certified technicians validated through the Centralized Ultrasound Processing training and certification program and also by the training performed by the Annual Proficiency Testing and Certification program all held at Iowa State University. All of the images collected by technicians were stored on a ZIP™ disk and were then sent to the Centralized Ultrasound Processing (CUP) Laboratory located in Ames, IA. The technician was required to collect a rump fat image, a 12-13th rib cross-sectional image and four longitudinal images of the longissimus dorsi muscle for each animal scanned. The images were then interpreted by certified lab technicians to determine a rump fat thickness measurement, a 12-13th rib fat thickness measurement, a ribeye area measurement and a % intramuscular fat measurement. The technician also sent in birthdates and weights on each animal. Additional requirements included clipping all hair in the region of scanning to within one-half inch or less and weights must have been taken within ± seven days of the scanning date. After all interpretations were done, the CUP Laboratory adjusted the data for each animal that was within 300-450 days of age. The breeder received actual measurements, adjusted 365-day measurements and contemporary group ratios. Currently, the adjustment procedures used for yearling Limousin bulls and heifers are from the Beef Improvement Federation Guidelines.

Editing of Data

Information needed on each animal other than ultrasound measurements was provided by the North American Limousin Foundation's database. The data included in this project is from 1998-2001. Table 2 shows the distribution of data collected. Before data editing, 2,356 heifers and 4,622 bulls were available for analysis. After data editing there were 1,267 heifers and 2,745 bulls used for analysis. To insure the most accurate adjustment equations possible, restrictions were placed on the data set. For instance, animals were deleted if they did not have recorded measurements such as scan weight, weaning weight, weaning contemporary group, scan management code, actual percent Limousin blood, and sire identification. Additionally, animals with negative gain or gains greater than six lbs. per day from weaning to yearling were deleted as were cattle with less than two head in a contemporary group. In order to include the greatest number of animals, the age window was increased to 260-500 days of age compared to 300-450 days.

Contemporary Groups

Correctly grouping animals into contemporary groups is essential for accurate data analysis. A contemporary group number was assigned to each animal. Categories included were breeder code, calf birth year, weaning contemporary group, and scan management group. Animals that have these four categories in common were placed in the same contemporary group. The weaning contemporary group assigned by the breeder was used because weaning contemporary group numbers assigned by the breed association took into consideration percent Limousin blood which needed to be statistically analyzed separately for adjustment procedures.

Statistical Analysis

All statistical analyses were performed using PROC MEANS, GLM, and STEPWISE procedures of SAS (Delwiche et al., 1998). Contemporary group effects were absorbed in the GLM analysis. Independent covariates considered in the analyses individually and together included: animal age, animal scan weight, animal gain from weaning to scanning, age of dam (AOD), and actual percent Limousin blood. Since no serial ultrasound measures on individual animals were available, all regression analyses were within sex classes and used pooled records.

RESULTS AND DISCUSSION

In early 2001, Limousin breeders were personally contacted around the country and encouraged to scan yearling Limousin bulls as well as yearling Limousin heifers in order to increase the breed association's ultrasound database. Table 1 shows the past three years of ultrasound scans and how they have increased. Breeders tend to scan yearling Limousin bulls as opposed to yearling Limousin heifers. Many reasons may explain this but the main one is that the bulls are usually marketed for sale each year, so scanning them has more economic justification. However, it's been shown that scanning yearling heifers is just as important, if not more, as scanning bulls (Wilson et al., 1999). Fifty-six percent more heifers were scanned in 2000 than in 1999 and 46% more were scanned in 2001 than in 2000. From 1998-2001, the increase was nearly 2.5 times. Bulls also increased in the number of animals scanned. A 97% increase was shown in 1999 compared to 1998, while 2001 showed a 39% increase. Over all four years, almost three times as many bulls were scanned from 1998 to 2001. Hopefully this trend will continue as more breeders realize the impact that ultrasound can have on the beef industry.

When conducting genetic evaluations for expected progeny differences, most breeds eliminate embryo transfer calf performance records from the evaluation. The main reason for this is that embryo calves are usually higher performing since most are raised by a superior-milking recipient cow. In this data set, information was provided on each calf as to whether they were the result of embryo transfer, artificial insemination, or natural service. There were 788 embryo bulls and 682 embryo heifers in the original data set. Tables 3 and 4 show comparisons of actual weaning weight and scan weight for embryo transfer calves to non-embryo calves. The average increase in weaning weight was 80 lbs. for bulls and heifers, while being 77 lbs. for heifers and 100 lbs. for bulls in scan weight difference. When looking at the different ways these calves were managed as far as being fed supplemental creep feed, the results are somewhat similar. Even though non-embryo transfer calves fed creep feed had a lower weaning weight than non-creep calves, their scan weight was much heavier. It can be assumed that the creep-fed calves were already accustomed to eating feed and therefore gained faster from weaning to scanning. However, embryo transfer calves didn't show the same differences. The weaning weights of the non-creep group were still heavier, but the scan weight between creep fed and non-creep fed calves was very similar. A possible explanation for this is that the embryo calves were receiving the necessary energy needs from the superior milking recipient cow and supplemental creep feed had little effect on the calf's performance. The differences found between creep fed calves and non-creep fed calves were absorbed in the contemporary group effect so no adjustment would be needed. Still, the substantial difference in weaning weight and scan weight shown in Tables 3 and 4 between the overall groups of embryo and non-embryo calves is too great to ignore. Therefore, embryo transfer calves were not included in computing adjustment factor equations.

Differences among technicians and differences among the various diets fed to bulls and heifers from weaning age to scan age were also analyzed. The same technician scanned a given group of cattle within each scan contemporary group. Consequently, the differences that were present among technicians were absorbed in the contemporary group effect. Breeders report various diets that the cattle have been fed from weaning to scanning age. There are three different feed codes for breeders to submit information. A diet code of one is equal to no concentrate being fed to the cattle, diet code two means fifty percent or less of the diet consists of concentrate, and diet code three means over fifty percent of the diet consists of concentrate. Non-significant values (p-value > .10) for diet codes ranged from .21 to .96 when looking at the four ultrasound traits for bulls and heifers. Therefore, diet did not need to be included in the model nor did there have to be different adjustment equations developed for each diet.

Variables that were then considered for model development included age at scanning, scan gain, scan weight, actual percent Limousin blood, and age of dam at scanning. Scan gain was calculated by taking the actual scan weight minus the actual weaning weight and dividing by the days from weaning to scanning. For percent Limousin blood, each animal had two categories. One category was the actual percent Limousin blood in the animal, and the second was the breed percent blood. The North American Limousin Foundation categorically groups calves by percent blood. Heifers over 87% blood are considered a purebred, whereas bulls over 93% are considered a purebred. This explains the higher adjusted ribeye area for bulls compared to the actual ribeye area in Table 2. Although bulls were adjusted to 365 days, they were also adjusted to a common 93% Limousin blood, but since the average percentage was 86.4%, ribeye area was adjusted higher. Percentage values such as 42% actual blood are rounded to 50% breed blood, and values such as 63% actual blood are rounded to 75% breed blood. Since the American Angus Association is the only breed that has adjustment factor equations specific for their breed, no other breed has observed the significance of non-purebred cattle. With the onset of hybrid cattle and breed associations accepting these cattle into their genetic database, percentage cattle need to be analyzed for their effect. Therefore, it was necessary to use the actual percent blood of each calf in order to get the most accurate estimates possible as opposed to a general category of percent blood.

Wilson et al. (2000) discovered that the age of the dam had a significant effect on both scan weight of the calf and the amount of percent intramuscular fat (% IMF) in Angus cattle. Table 5 shows these results and the corresponding adjustment procedures. Calves born to first and second-calf females tended to have lighter weights at scanning and a higher % IMF. A dam of six years old was used as the base for adjusting the scan weight and % IMF. As can be seen in Table 5, significant differences do exist according to the age of dam category. However, in the Limousin data, trends were simply not as apparent or consistent as found in the Angus data. The main explanation for this inconsistency could be the low number of cattle scanned to get an accurate estimate. Or, if the current genetics found in young Limousin females are that much more superior to older age dams. The age of dam category was significant in bulls (p-value < .0001), but was not significant in heifers (p-value

= .84). However, both bulls and heifers had significant values when age of dam was used as a continuous variable in days. Still, it does not seem logical to adjust for each day of age for the dam, thus no adjustment will be used at this time.

Table 6 shows the various models with significant covariates (p-value < .10) using PROC GLM. For each ultrasound trait, model 1 includes significant covariates and how the R^2 value changes by taking out various covariates. PROC STEPWISE was used to evaluate what variables entered the adjustment equation first and then eliminate covariates while analyzing how R^2 values changed. Contemporary groups (CG) were absorbed in the model as fixed effects. No matter which model was used for rump fat thickness, rib fat thickness, or ribeye area, scan weight and actual percent Limousin blood were the first two covariates to enter the model each time. Excluding scan age, scan gain, and age of dam from the model did not lower the R^2 value enough to keep them in. However, actual percent blood did play a significant role. In bulls, percent blood increased the R^2 value by approximately 6% for both fat measurements and ribeye area. The heifer model R^2 value was increased by 10% for rump fat, and approximately 6-7% for rib fat and ribeye area when including actual percent Limousin blood. For % IMF, the same approach was used, but instead of scan weight being used with actual percent Limousin blood, scan age was the other covariate. The age of dam effect for the bulls did increase the R^2 value by about 1%, but as stated before, there was no real trend and no feasible way to adjust the data by using the age of the dam. Collectively, actual percent Limousin blood and scan weight were used as the final model covariates for rump fat, rib fat, and ribeye area, whereas, actual percent Limousin blood and scan age were used for % IMF. Tables 7 and 8 show the final models for each trait in bulls and heifers. In order to properly adjust the data for both bulls and heifers to a common age endpoint using scan weight as one of the covariates, scan weight itself must be adjusted. An adjusted scan weight was obtained by taking the actual scan weight and adding or subtracting the total weight gained over or under 365 days of age for bulls and 380 days of age for heifers. Table 2 shows the average age at scanning of heifers to be 382 days of age. Therefore, it was only logical to adjust heifers to an endpoint close to when they were scanned instead of adjusting back to 365 days of age.

Additionally, for genetic evaluation and the subsequent generation of expected progeny differences, heifers were adjusted to a bull equivalent. To account for distribution variation differences between the sexes, a multiplicative adjustment was used. Taking the mean standard deviation on bulls for each trait, and dividing it by the mean standard deviation for the heifers for each trait obtained the multiplicative factors located on the bottom of Table 7. It must be noted that these multiplicative factors will only be used for genetic evaluation predictions and the adjusted data that each breeder receives on a group of cattle will be without the multiplicative adjustment.

Figures 1-8 show comparisons of each ultrasound trait relative to its covariate used in the model and how the traits change. Combining this information with that from Table 2, heifers appear to show more variation in both fat cover and % IMF. Not only do they show more deviation in % IMF, but they also exhibit more of an effect from actual percent Limousin blood on % IMF when compared to bulls. Additionally, looking at Figure 4, heifers tend to increase more and at a faster rate in % IMF as they get older. As expected, bulls show more variation in ribeye area according to Table 2, but the effect of percent Limousin blood seems to have a very similar effect on them as it does on the heifers in Figure 7. These conclusions can be supported when looking at the adjustment equations in

Tables 7 and 8. The regression coefficients for heifers are slightly higher than bulls for both fat traits and % IMF. Bulls have higher coefficients for ribeye area, but the biggest observation is found in % IMF. The heifer regression coefficient for percent Limousin blood is over two times higher than bulls as is the scan age coefficient. Consequently, this may be a significant indication to breeders that yearling Limousin heifers show more variation in % IMF, and also the rate at which they change when they get older and the change according to percent Limousin blood is greater than bulls. Thus, breeders should get a better idea of where they are genetically in their herd from both a subcutaneous and intramuscular fat standpoint if they scan their yearling Limousin heifers in addition to their yearling Limousin bulls.

Table 9 shows the differences and variations in the adjustment factor equations obtained in this paper compared to the current BIF equations. Currently, fat measurements are not adjusted, so comparisons can only be made for % IMF and ribeye area. Although the standard deviation for % IMF is lower for the new equations, the BIF equations do not account for percent Limousin blood. For example, cattle that consist of 50% Limousin blood compared to those that are 90% were not adjusted to a common percentage. Thus, breeders were misled when looking at adjusted numbers. With the new equations, all cattle can be equally compared to both a common age and percent Limousin blood adjustment. Additionally, the BIF adjusted ribeye area equation does not use scan weight to adjust this trait, which in this analysis, turned out to be the most significant covariate.

Table 10 shows the adjusted correlations among the various ultrasound traits. These correlations compare positively to the larger Angus database. Fat correlations with percent intramuscular fat are moderately positive for rib and rump fat. The higher correlations for heifers are again due to more variation than bulls. Ribeye area is slightly negative with % IMF, and rib fat and rump fat have a .60 correlation for bulls and .66 for heifers. These lower values compared to the Angus data can be explained by the much smaller data set and less variation within the Limousin breed.

IMPLICATIONS

Results from this study indicate that breeders should not overlook scanning their replacement yearling Limousin heifers. Even more importantly, is the inclusion of a percent Limousin blood adjustment to fairly compare percentage cattle to purebred cattle. The small variation in subcutaneous fat and intramuscular fat in Limousin cattle combined with a limited data set may decrease the accuracy of these equations. Also, as the ultrasound database increases, the effects of the age of the dam need to be re-analyzed to see if they can be incorporated into these equations. The adjustment equations developed here are different than the current BIF equations used. Therefore, other breeds should be encouraged to develop breed-specific adjustment factor equations as well in order to better compensate for distinct breed differences.

Table 1: Number of Cattle Scanned by year

	1998	1999	2000	2001	
Yearling Heifers	402	403	630	921	2356
Yearling Bulls	573	1128	1221	1698	4622

Table 2: Distribution of data for ultrasound measurements

Yearling Limousin bull ultrasound measures (2,745 head)

Trait	Mean	Std. Dev.	Minimum	Maximum
Age, days	366	35	270	498
Actual % Limousin Blood, %	86.4	12.1	41.8	100
Gain, lbs/day	2.92	0.58	0.2	4.8
Adjusted Scan Weight, lbs	1080	124	647	1457
Actual % IMF, %	2.71	0.58	1.07	5.28
Adjusted % IMF, %	2.67	0.58	0.96	5.02
Actual ribeye area, sq. in.	14.24	1.85	8.20	20.80
Adjusted ribeye area, sq. in.	14.38	1.81	7.72	20.69
12-13th rib fat thickness, in.	0.16	0.08	0.04	0.54
Adjusted 12-13th rib fat thickness, in.	0.15	0.08	0.001	0.55
Rump fat thickness, in.	0.18	0.08	0.02	0.56
Adjusted rump fat thickness, in.	0.17	0.08	0.001	0.54

Yearling Limousin heifer ultrasound measures (1,267 head)

Trait	Mean	Std. Dev.	Minimum	Maximum
Age, days	382	29	298	494
Actual % Limousin Blood, %	85.6	13	42.6	100
Gain, lbs/day	1.94	0.49	0.2	4.8
Adjusted Scan Weight, lbs	896	97	534	1269
Actual % IMF, %	3.35	0.79	1.50	7.49
Adjusted % IMF, %	3.32	0.76	1.57	7.09
Actual ribeye area, sq. in.	12.00	1.67	6.70	19.60
Adjusted ribeye area, sq. in.	11.98	1.60	7.51	19.72
12-13th rib fat thickness, in.	0.20	0.09	0.03	0.62
Adjusted 12-13th rib fat thickness, in.	0.19	0.09	0.01	0.61
Rump fat thickness, in.	0.21	0.10	0.03	0.58
Adjusted rump fat thickness, in.	0.21	0.09	0.01	0.58

Table 3: Differences in Weaning and Scan Weight of Embryo Transfer Calves

Bulls				
Non-ET Calves (3,579)	WW	598	WeanAge	200
	SWT	1078	ScanAge	366
ET Calves (1,043)	WW	680	WeanAge	203
	SWT	1179	ScanAge	378
Non-ET Calves				
No Creep (2,217)	WW	603	WeanAge	205
	SWT	1040	ScanAge	365
Creep (1,362)	WW	589	WeanAge	192
	SWT	1143	ScanAge	366
ET Calves				
No Creep (898)	WW	689	WeanAge	203
	SWT	1180	ScanAge	379
Creep (145)	WW	637	WeanAge	201
	SWT	1178	ScanAge	371

Table 4: Differences in Weaning and Scan Weight of Embryo Transfer Calves

Heifers				
Non-ET Calves (1,509)	WW	550	WeanAge	201
	SWT	901	ScanAge	382
ET Calves (847)	WW	630	WeanAge	202
	SWT	978	ScanAge	390
Non-ET Calves				
No Creep (946)	WW	551	WeanAge	203
	SWT	880	ScanAge	381
Creep (563)	WW	548	WeanAge	197
	SWT	930	ScanAge	384
ET Calves				
No Creep (759)	WW	639	WeanAge	203
	SWT	978	ScanAge	390
Creep (88)	WW	568	WeanAge	198
	SWT	972	ScanAge	387

Table 5: Age of dam adjustments for scan weight and % IMF

Limousin AOD	Heifers Freq.	Scan Wt Adjustment	Bulls Freq.	Scan Wt Adjustment
2	351	7.048	660	8.249
3	196	6.443	411	-3.96
4	165	11.42	341	-12.288
5	122	0	317	0
6	99	9.637	261	-22.506
7	83	-13.368	216	-7.404
8	72	-18.642	170	-17.199
9	63	5.551	149	-10.259
10	56	-3.091	85	-13.855
11	20	8.03	69	-1.497
>12	41	32.615	76	-2.515

Angus AOD	Heifers Freq.	Scan Wt Adjustment	% IMF Adjustment	Bulls Freq.	Scan Wt Adjustment	% IMF Adjustment
2	1746	46.82	-0.13	5237	73.24	-0.094
3	1305	25.62	-0.12	4246	33.66	-0.034
4	1198	9.98	-0.02	3562	12.23	0
5	887	0.64	-0.03	3175	0.72	0.02
6	682	0	0	2544	0	0
7	570	2.28	0.03	2067	1.7	-0.02
8	418	8.1	-0.06	1599	5.86	0.03
9	328	13.85	0.02	1044	14.29	0.01
10	183	15.49	-0.11	671	18.4	0.08
11	143	28.52	0.10	534	22.8	0.07
>12	237	34.23	0.07	696	40.59	0.06

Table 6: R^2 Values for various models with significant covariates

Rump Fat Thickness: Heifers							R^2
1)	CG	% Lim	Scan Age	Scan Gain	Scan Wt		0.51
2)	CG	% Lim		Scan Gain	Scan Wt		0.51
3)	CG	% Lim			Scan Wt		0.51
Rump Fat Thickness: Bulls							R^2
1)	CG	% Lim			Scan Wt		0.44
Rib Fat Thickness: Heifers							R^2
1)	CG	% Lim		Scan Gain	Scan Wt		0.55
2)	CG	% Lim			Scan Wt		0.55
Rib Fat Thickness: Bulls							R^2
1)	CG	% Lim	Scan Age	Scan Gain	Scan Wt	Age of Dam	0.51
2)	CG	% Lim		Scan Gain	Scan Wt	Age of Dam	0.51
3)	CG	% Lim			Scan Wt	Age of Dam	0.51
4)	CG	% Lim			Scan Wt		0.52
Ribeye Area: Heifers							R^2
1)	CG	% Lim		Scan Gain	Scan Wt		0.58
2)	CG	% Lim			Scan Wt		0.58
Ribeye Area: Bulls							R^2
1)	CG	% Lim		Scan Gain	Scan Wt	Age of Dam	0.57
2)	CG	% Lim		Scan Gain	Scan Wt		0.57
3)	CG	% Lim			Scan Wt		0.57
Percent IMF: Heifers							R^2
1)	CG	% Lim	Scan Age	Scan Gain	Scan Wt	Age of Dam	0.43
2)	CG	% Lim	Scan Age		Scan Wt	Age of Dam	0.43
3)	CG	% Lim	Scan Age			Age of Dam	0.43
4)	CG	% Lim	Scan Age				0.42
Percent IMF: Bulls							R^2
1)	CG	% Lim	Scan Age	Scan Gain	Scan Wt	Age of Dam	0.43
2)	CG	% Lim	Scan Age		Scan Wt	Age of Dam	0.43
3)	CG	% Lim	Scan Age			Age of Dam	0.43
4)	CG	% Lim	Scan Age				0.42

Table 7: Final adjustment factor equations for yearling Limousin heifers

Rump Fat

$$\text{Adj. Rump Fat} = \text{Actual} + [((87 - \text{Actual \% Blood})^* -.001606522) + ((\text{Adjusted ScanWt} - \text{Actual ScanWt})^* .0002584428)]$$

Rib Fat

$$\text{Adj. Rib Fat} = \text{Actual} + [((87 - \text{Actual \% Blood})^* -.0013406982) + ((\text{Adjusted ScanWt} - \text{Actual ScanWt})^* .0002226396)]$$

REA

$$\text{Adj. REA} = \text{Actual} + [((87 - \text{Actual \% Blood})^* .012744896) + ((\text{Adjusted ScanWt} - \text{Actual ScanWt})^* .007453395)]$$

IMF

$$\text{Adj. IMF} = \text{Actual} + [((87 - \text{Actual \% Blood})^* -.012715012) + ((380 - \text{Scan Age})^* .003462767)]$$

$$\text{Adjusted Scan Weight} = \text{Actual Scan Wt.} + (380 - \text{Scan Age}) * \text{Gain}$$

$$\text{Gain} = \frac{\text{Actual Scan Weight} - \text{Actual Weaning Weight}}{\text{Scan Age} - \text{Weaning Age}}$$

Multiplicative Adjustment Factor to Adjust Heifers to a Bull Equivalent (these factors would be the last thing to multiply each equation by)

Rump Fat = .831
Rib Fat = .827
REA = 1.107
IMF = .743
ScanWt = 1.228

Table 8: Final adjustment factor equations for yearling Limousin bulls

Rump Fat

Adj. Rump Fat = Actual + [((93 – Actual % Blood)* -.0015415259) +
((Adjusted ScanWt – Actual ScanWt)* .000180316)]

Rib Fat

Adj. Rib Fat = Actual + [((93 – Actual % Blood)* -.0012693644) +
((Adjusted ScanWt – Actual ScanWt)* .0001788713)]

REA

Adj. REA = Actual + [((93 – Actual % Blood)* .017993746) +
((Adjusted ScanWt – Actual ScanWt)* .008668315)]

IMF

Adj. IMF = Actual +[((93 – Actual % Blood)* -.005991308) +
((365 – Scan Age)* .001574971)]

Adjusted Scan Weight = Actual Scan Wt. + (365 – Scan Age) * Gain

$$\text{Gain} = \frac{\text{Actual Scan Weight} - \text{Actual Weaning Weight}}{\text{Scan Age} - \text{Weaning Age}}$$

Table 9: Adjustment factor equation comparisons

Heifers						
		Actual	**Adjusted**	**Diff.**	**BIF Adj.**	**Diff.**
REA	Avg.	12.000	11.982	0.018	11.693	0.308
	St. Dev.	1.668	1.600	0.068	1.558	0.110
IMF	Avg.	3.347	3.322	0.025	3.122	0.225
	St. Dev.	0.785	0.759	0.026	0.842	-0.057
Bulls						
		Actual	**Adjusted**	**Diff.**	**BIF Adj.**	**Diff.**
REA	Avg.	14.240	14.379	-0.139	14.267	-0.028
	St. Dev.	1.846	1.807	0.040	1.857	-0.011
IMF	Avg.	2.707	2.664	0.043	2.739	-0.032
	St. Dev.	0.583	0.578	0.005	0.721	-0.138

BIF Adjustment Factor Equations

$$\text{Adj. REA} = 5.085 + \frac{(\text{Actual REA} - 5.085)}{\text{Scan Age} * 365}$$

$$\text{Adj. \% IMF} = -2.235 + \frac{(\text{Actual \% IMF} + 2.235)}{\text{Scan Age} * 365}$$

Table 10: Correlations Among Ultrasound Traits

Limousin Bull Phenotypic Correlations Among Adj. Ultrasound Traits

Trait	% IMF	Ribeye Area	Rib Fat	Rump Fat
% IMF	**1.00**			
Ribeye Area	-.07	**1.00**		
12-13th Rib Fat Thickness	.24	.29	**1.00**	
Rump Fat Thickness	.20	.21	.60	**1.00**

Limousin Heifer Phenotypic Correlations Among Adj. Ultrasound Traits

Trait	% IMF	Ribeye Area	Rib Fat	Rump Fat
% IMF	**1.00**			
Ribeye Area	-.08	**1.00**		
12-13th Rib Fat Thickness	.32	.25	**1.00**	
Rump Fat Thickness	.31	.16	.66	**1.00**

Figure 1: Rump Fat vs. Scan Weight

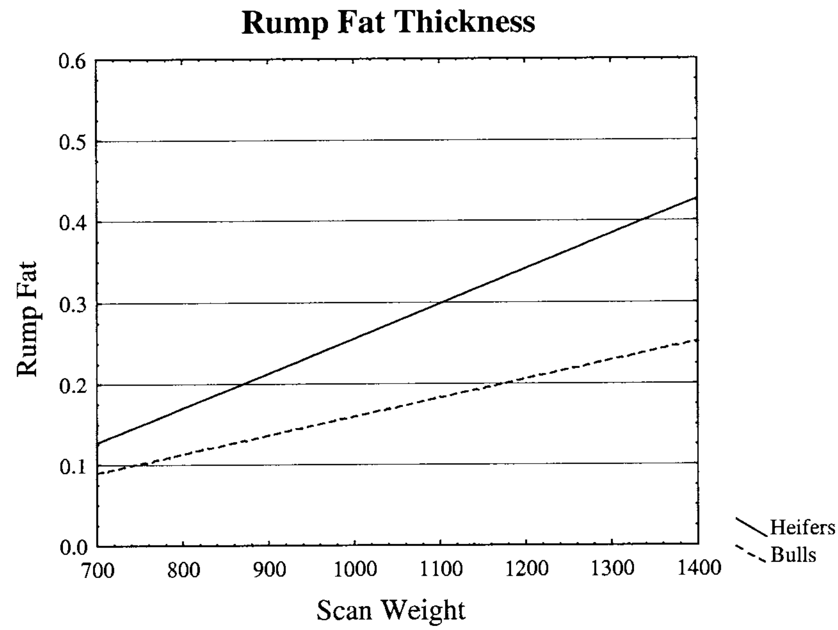


Figure 2: Rib Fat vs. Scan Weight

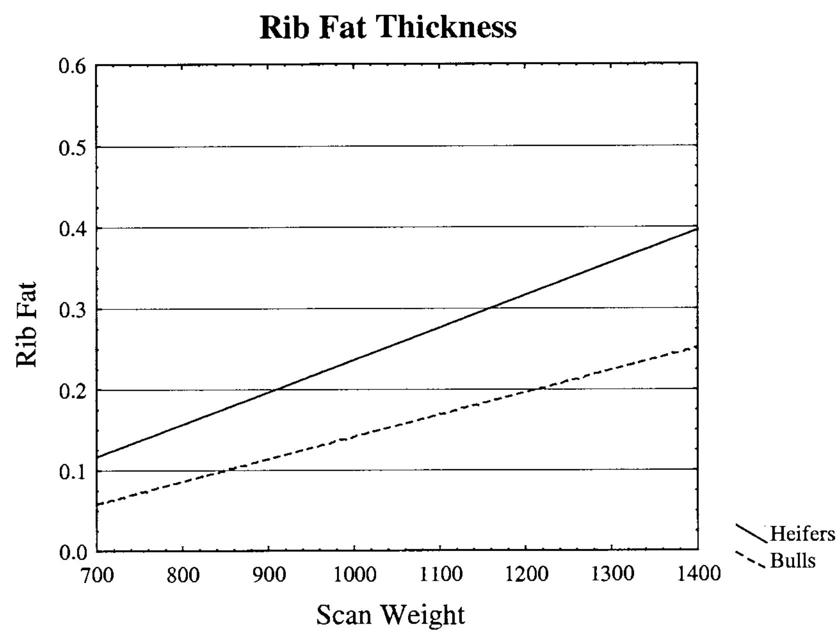


Figure 3: Ribeye Area vs. Scan Weight

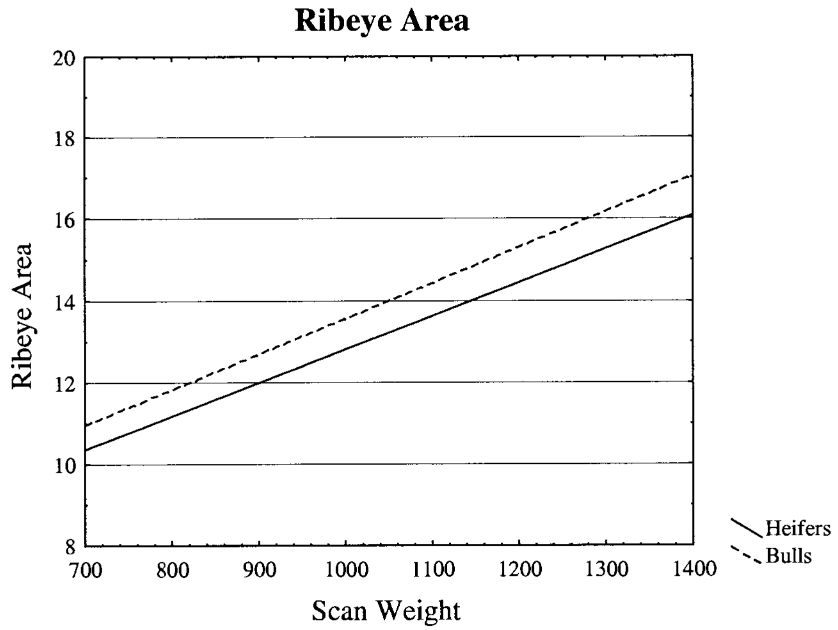


Figure 4: Percent IMF vs. Scan Age

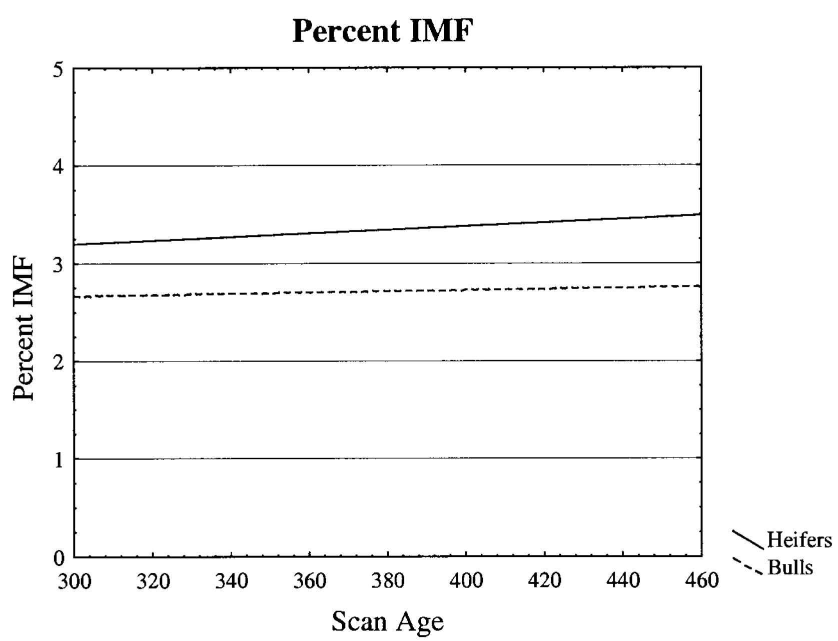


Figure 5: Rump Fat vs. Percent Limousin Blood

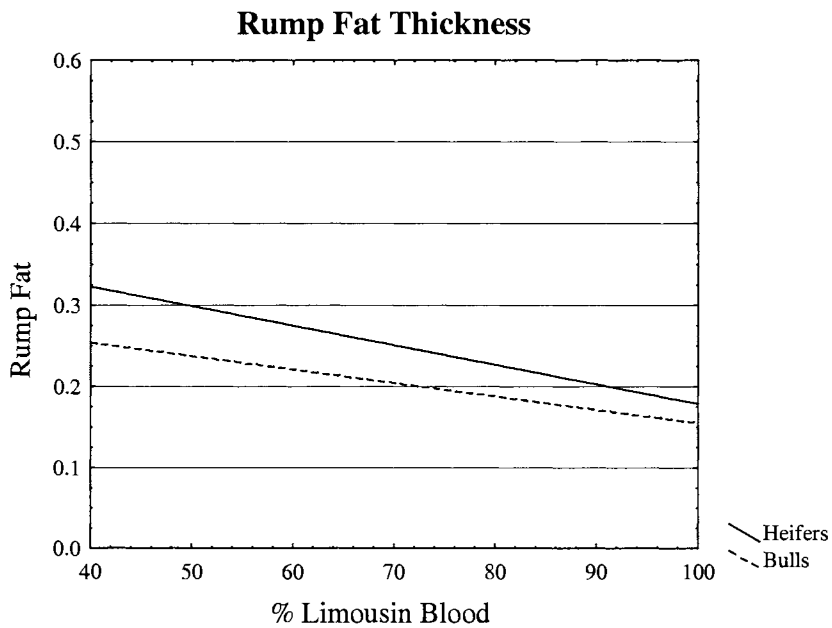


Figure 6: Rib Fat vs. Percent Limousin Blood

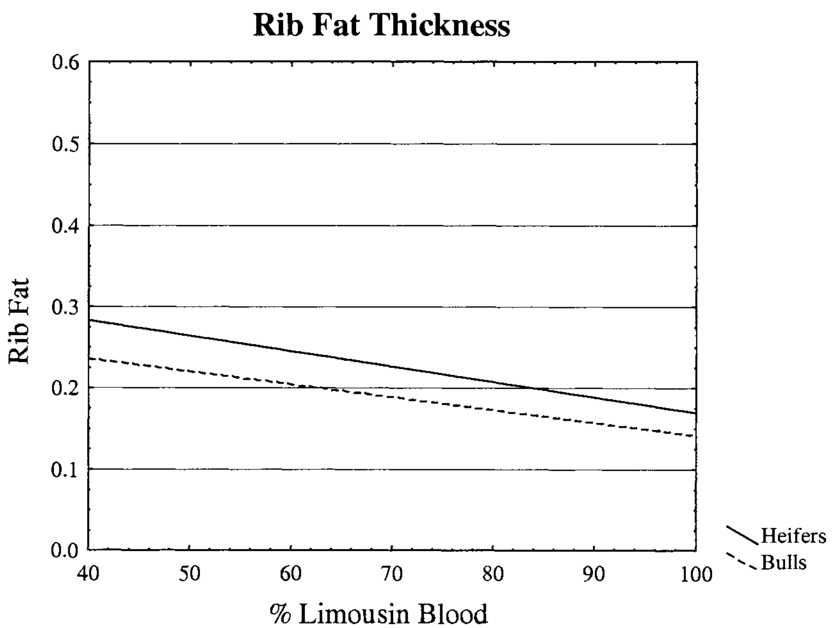


Figure 7: Ribeye Area vs. Percent Limousin Blood

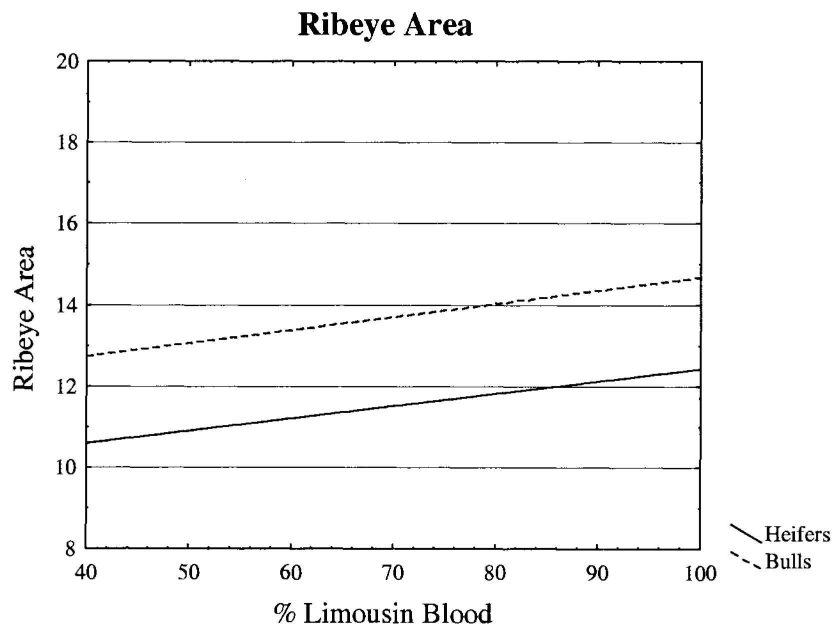
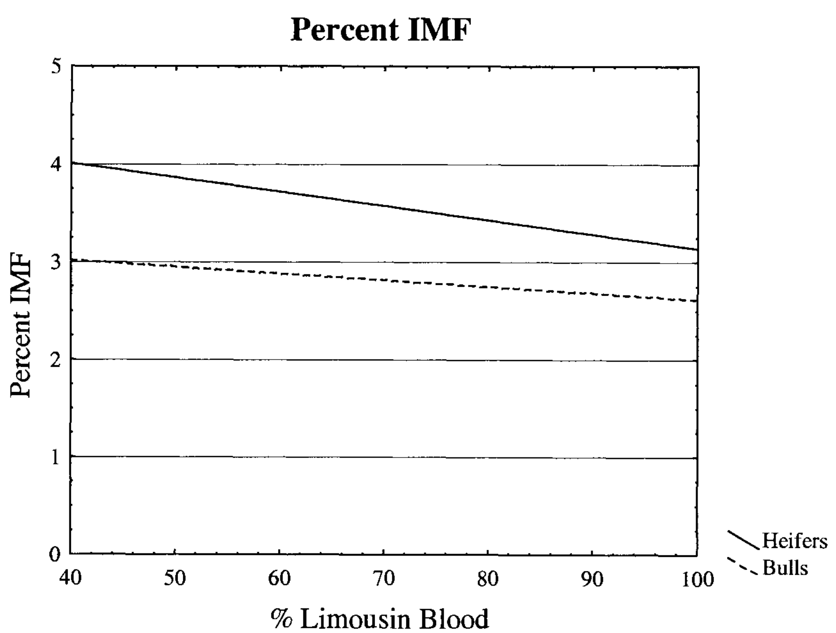


Figure 8: Percent IMF vs. Percent Limousin Blood



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