December 2001

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Proceedings, The Range Beef Cow Symposium XVII
December 11, 12 and 13, 2001, Casper, Wyoming

THE USE OF ULTRASOUND TECHNOLOGY IN GENETIC SELECTION DECISIONS

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INTRODUCTION

Today, real-time ultrasound (RTU) can be used to gather live cattle data that subsequently can be used for the genetic prediction of carcass cutability and meat quality traits. Initially, identification of sires that were superior for carcass merit could only be accomplished through progeny testing, an expensive, slow and logistically complicated process. Today, breed associations use RTU data solely or in combination with actual carcass data for computation of carcass EPD. While much research should be done to improve the accuracy and cost of the technology, RTU provides a valuable tool for genetic selection of carcass merit.

COMMONLY USED HARDWARE AND SOFTWARE

Two systems for external fat and ribeye area measurement are most commonly used: 1)Classic Scanner 200 (distributed by Classic Ultrasound Equipment, Tequesta, Fl.) and 2) Aloka 500V (Wallingford, CT). Both of these systems are equipped with linear transducers that can capture a ribeye image with a single scan.

Herring et al. (1998) referred to four RTU systems for intramuscular fat prediction. Two of these or their descendents are the most commonly used for intramuscular fat prediction: 1) CPEC (Oakley, KS), which uses an Aloka 210 system equipped with a 3.5-MHz, 12.5-cm transducer (distributed by Aloka USA, Inc., Wallingford, CT) along with a 2) system developed by Iowa State University which uses an Aloka 500V with a 3.5-MHz, 17-cm transducer (distributed by Aloka USA, Inc., Wallingford, CT). The former was developed by Dr. John Brethour, Kansas State University and the latter by Dr. Doyle Wilson and Dr. Gene Rouse, Iowa State University.

ULTRASOUND ACCURACY, PRECISION AND REPEATABILTY

Today, most researchers and producers agree that RTU data are credible when gathered under the right circumstances. However, a brief review is provided. Cochran and Cox (1957) define accuracy as the closeness with which a measurement approaches its true value. The term precision refers to the degree of dispersion of a group of observations. In other words, if RTU were to rank a set of steers correctly it would be "precise", but if it ranked them correctly at the exact values it would be "precise" and "accurate", respectively. For purposes of EPD calculations, it is necessary only that measurements be precise, since contemporary group effects are removed during the computations. Generally, we think of repeatability as the correlation between serial measures on the same animal. Correlations closer to 1 indicate a more desirable degree of precision or repeatability.

12-13th Fat Thickness and Ribeye Area

Herring et al. (1994) conducted a study to compare the accuracy and repeatability of two commonly used RTU systems, while at the same time comparing technician effects. Forty-four Hereford-sired steers were measured ultrasonically on two consecutive days, with slaughter following the second RTU measure by no more than 48 hours. While correlations are most often used to denote accuracy and repeatability, in this study statistics to aid in minimizing the impact of sample variation and bias were developed. The statistics were root mean squared error (RMSE) and error standard deviation (ESD). Correlations for accuracy of machine and technician when evaluating RTU measured longissimus muscle area were quite varied. The correlations for the least precise of the three technicians were .39 and .52, whereas the most precise technician had correlations of .71 and .72. The least accurate machine/technician combination resulted in a RMSE of 13.97, while the most accurate combination had a RMSE of 6.56. With respect to RTU measured fat depth at the 12-13th rib site, correlations were all similar, ranging from .57 to .66. The RMSE calculations were also similar ranging from .27 to .33. Herring et al. (1994) stated, "fatter steers were more difficult to measure and interpret." This is in agreement with other studies (Perkins et al. 1992a, Smith et al. 1992). Correlations for the repeatability of RTU measured longissimus muscle area ranged from a low of .37 and .36 for the least repeatable technician, to a high of .82 and .90 for the most repeatable technician. The range in RMSE calculations went from 11.32 for the least repeatable technician/machine combination to 3.89 for the most repeatable combination. Correlations for the repeatability of RTU measured fat depth ranged from .73 to .90. The RMSE calculations for these correlations were .20 and .14, respectively.

As reported by Perkins et al. (1992a), 494 steers and 151 heifers were ultrasonically measured in an attempt to evaluate the accuracy and precision of RTU. Correlations between actual carcass data and RTU measures were used to evaluate the precision of these measures. Correlations between RTU measures and carcass traits were .75 and .60, for fat depth and ribeye area, respectively. To evaluate accuracy, frequency distributions of differences between actual carcass data and RTU measured values were used. Estimates of carcass fat depth via RTU were within .1 in 70% of the time and within .2 in 95% of the time. Fifty-three percent of the time RTU estimates of longissimus muscle area were within 1 in^2 and within 2 in^2 84% of the time.

Perkins et al. (1992b) ultrasonically measured 36 feedlot steers of varying breed-types two days prior to slaughter. Carcass measurements were taken 48 hours post-mortem. The researchers reported repeatability correlations, for two different technicians, of .83 and .84 for RTU measured longissimus muscle area and .90 and .97 for RTU measured fat depth.

Intramuscular Fat

Many studies have demonstrated the importance that intramuscular fat has on profitability of feedlot cattle and the palatability of the subsequent retail product. However, few studies have evaluated the accuracy, precision, and repeatability of estimating intra-muscular fat via RTU techniques.

Herring et al. (1998) evaluated four of the most commonly used commercial RTU systems on 81 crossbred steers. The steers were measured 8 to 14 d prior to slaughter at the 12–13th rib site. Following slaughter, marbling scores were determined by a USDA grader. Three statistics were used to evaluate the RTU systems for accuracy. First, root mean squared error (RMSE; Herring et al, 1994), which was conservative on both ranking and degree of accuracy of a given system. Secondly, bias was calculated to provide an indication of average direction and magnitude of error. The third statistic was a standard error of prediction (SEP). While this was similar to RMSE, it included a correction factor for bias and thus was more useful for genetic prediction. The range for RMSE, when evaluating the proficiency of RTU determinations of intramuscular fat, was from .73 to 2.52, whereas the range for SEP was .73 to 2.19. The lower end of both of these ranges indicated that the use of some systems can result in a relatively high degree of accuracy. To determine accuracy of a given system, least squares (LS) means for a newly defined variable were calculated. The variable was defined as the RTU measure – bias – actual marbling score. The lower the LS mean the more accurate the system. LS means ranged from .61 ± .06 to 1.81 ± .06. To evaluate the effect of level of marbling on precision, a model was fit with marbling class and a nested random animal effect within marbling class. The LS means were then derived and ranged from 1.22 ± .15 to 1.86 ± .11 for the lower marbling class, which had an average marbling score of slight 30. For the higher marbling class, which had an average marbling score of modest 52, the range was from 1.49 ± .17 to 2.52 ± .17. These ranges indicated that RTU systems were more accurate at the lower marbling levels. As a result, the researchers suggested that RTU on breeding bulls could be performed without sacrificing accuracy. According to Herring et al. (1998), "If ultrasound could be used to gather data for genetic evaluations using breeding and feeding cattle, many more sires could be evaluated at a younger age with a higher degree of accuracy, foregoing the task of designed progeny testing based on collection of carcass data."

Hassen et al. (1999b) conducted a study using 144 bulls, heifers, and steers receiving repeated RTU measures to determine repeatability of intramuscular fat estimates derived from RTU. Repeatability was defined as the correlation between repeated measures on an individual animal. Each animal was scanned 5 to 6 times, with an average age of 433 d, by a certified RTU technician. Animals were divided into two groups: those with less than 4.79% intramuscular fat via RTU determination and those above. Repeatability measures were then determined for each group. Overall repeatability of RTU predicted intramuscular fat was .63 ± .03. The lower marbling group produced less repeatable measures than those from the higher marbling group. Bulls showed less variation (SD of .82%) than steers and heifers, .97 and 1.02% respectively. However, the steer measurements were more repeatable than for bulls and heifers. Standard error of the RTU predictions for intramuscular fat was reduced by 50% when the number of images per animal increased from three to four. Hassen et al. (1999b) suggests that for cattle with less than 4.79% intramuscular fat via RTU, it is currently necessary to include sibling RTU information and / or carcass information to properly calculate carcass EPD due to the low repeatability of RTU predicted intramuscular fat in this group.

Brethour (2000), using the CPEC technology referred to earlier, predicted carcass marbling score on 144 calves averaging 483 lb. Carcass marbling scores were measured on the same calves 252 d later (Figure 1). Initial marbling predictions were 78% accurate in classifying future quality grade and predicting whether an animal would grade USDA Choice. RTU predictions for marbling at weaning could be beneficial for genetic prediction as well as feedyard management.

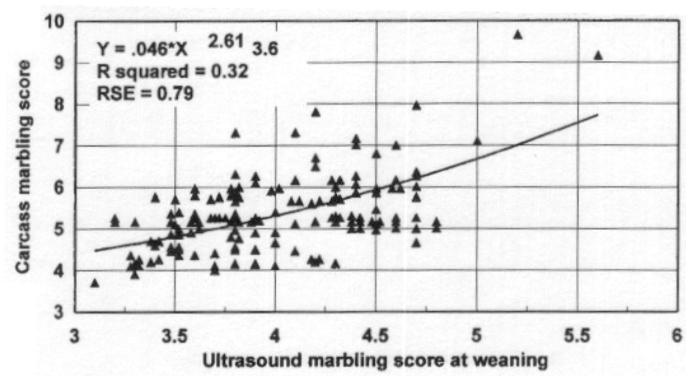

Figure 1. Ultrasound marbling estimate on calves (average age = 210 d) and carcass marbling scores 252 d later.

Today, it is generally accepted that when using credible technician-hardware combinations, credible RTU data for 12-13th fat thickness, ribeye area and intramuscular fat can be gathered.

GENETIC PARAMETERS OF ULTRASOUND TRAITS

Whether gathered from breeding or feedlot cattle, the heritabilities of and genetic correlations among traits used in EPD computations must be understood. Because many databases of RTU traits are still evolving, limited information exists on these genetic parameters when compared to other production traits. Many of these parameters from seedstock cattle were reported by Bertrand et al. (2001) in a review (Table 1).

Heritabilities, Genetic Correlations, and Correlated Responses

Hassen et al. (1999a) estimated heritabilities and genetic correlations for carcass traits from 509 and 448 bulls and steers, respectively. The breed makeup of the cattle used in the study consisted of a small group of composite cattle in the first year and a combination of Angus and Simmental sired progeny from 1992 to the end of the study in 1996. For bulls, heritabilities for carcass weight, percent retail product, weight of retail product, fat thickness, and longissimus muscle area were .43, .04, .46, .05, and .21, respectively. The corresponding values for steers were .32, .24, .40, .42, and .07, respectively. Genetic correlations for carcass longissimus muscle area with hot carcass weight, percent retail product, and weight of retail product in bulls were .67, .93, and .82, respectively. Genetic correlations for carcass fat thickness for the same corresponding traits were -.94, -.31, and -.88, respectively. There were substantial differences in genetic correlations when looking at the steer data. The genetic correlations for carcass longissimus muscle area with hot carcass weight, percent retail product, weight of retail product, and carcass fat depth in steers were .88, -.18 -.36, and -.25, respectively. Genetic correlations in steers for fat thickness with hot carcass weight, percent retail product, and weight retail product were .25, -.90, and -.09, respectively. The genetic correlations for the same traits in bulls were -.94, -.31, and -.88, respectively. In bulls, longissimus muscle area was highly positively correlated with percent retail product and weight of retail product. It was low to moderately negatively correlated with the same traits in steers. In addition, there was a distinct difference in the genetic correlations between fat depth and carcass weight across the gender groups. The steers exhibited a low to moderate correlation whereas the genetic correlation for the bull group was highly negative.

Wilson et al. (1999) conducted a study designed to compare sire EPD derived via RTU measurements versus EPD calculated from carcass data of steer progeny. Of the 497 sires represented, 193 had both progeny with RTU measures and progeny with actual carcass measurements. The results of the study indicated high rank correlations between RTU based EPD and carcass data based EPD when the accuracy of the former group reached levels of .8 or higher. The rank correlations of these high accuracy sires for marbling score/percent intramuscular fat, longissimus muscle area, and fat depth were .83, .91, and .84, respectively. Heritability estimates for fat depth , longissimus muscle area, and percent intramuscular fat were .44, .39, and .42, respectively. The genetic correlations between fat depth and longissimus muscle area, as well as fat depth and intramuscular fat were .23 and .17, respectively. The genetic correlation between longissimus muscle area and intramuscular fat was -.12.

Moser et al. (1998) reported heritabilities and genetic correlations for carcass and RTU traits in Brangus and Brangus-sired cattle. The study was designed to examine genetic relationships between carcass measurements in terminal progeny with RTU measures in yearling breeding stock. No animals in this study had both RTU and carcass measures. The records were merged from data already on file with the International Brangus Breeders Association. The final data set consisted of 2,028 animals with carcass measures (1,778 steers and 250 heifers) and 3,583 head of breeding stock with both yearling weights and RTU measures (2,364 bulls and 1,219 heifers). Heritabilities for carcass fat depth, carcass longissimus muscle area, carcass weight, RTU measured fat depth, RTU measured longissimus muscle area, and yearling weight were .27 ± .05, .39 ± .05, .59 ± .06, .11 ± .03, .29 ± .04, and .40 ± .04, respectively. These heritability levels indicate that selection based on these traits should result in favorable changes in the trait(s) of interest. Genetic correlations between carcass fat depth and RTU measured fat depth, carcass longissimus muscle area and RTU measured longissimus muscle area, and carcass weight and yearling weight were .69 ± .18, .66 ± .14, and .61 ± .11, respectively. The researchers commented that these relationships between RTU and carcass measures are favorable and moderately strong and should have the potential to lead to predictable changes in carcass traits in terminal progeny.

Izquierdo et al. (1997) reported on a study designed to compare fat composition determinations made via RTU to actual carcass data and chemical extraction of intramuscular fat. The results from 229 Angus bulls and 341 Angus steers are reported here. The heritabilities, on an age constant basis, in steers for carcass fat depth, RTU determined fat depth, chemical determinations of intramuscular fat, RTU predicted intramuscular fat, and USDA marbling score were .32, .50, .45, .81, and .79, respectively. On a weight constant basis in steers the heritabilities for the same corresponding traits were .14, .34, .38, .84, and .80, respectively. For bulls, the heritabilities were much lower. The only traits that were moderately heritable were the two RTU measured traits. The genetic correlation between carcass fat depth and RTU determined fat depth was reported as ≅ 1. The genetic correlation, on an age constant basis, between chemically determined intramuscular fat and RTU determined intramuscular fat was quite high at .95. The genetic correlation reported between RTU measured intramuscular fat and USDA marbling score was .83.

Shepard et al. (1996) conducted a study aimed at determining degree of genetic variability in RTU measured fat depth and longissimus muscle area and their subsequent relationships with weaning weight. Ultrasonic measures were taken on 805 Angus bulls and 877 Angus heifers. There were six different RTU dates used. Calves ranged from 250 to 550 days of age during this time with some calves receiving multiple measurements. For use in this study, the only measurements of interest were those taken closest to 365 days of age. Additional information regarding weaning weight and post-weaning average daily gain was received from the American Angus Association. Heritability estimates for RTU measured fat depth and longissimus muscle area were .56 and .11, respectively. The heritability for RTU measured fat depth was higher than reported in some studies, but similar to others (DeRose et al., 1988; .49, Robinson et al., 1993; .38). The heritability estimate for RTU measured longissimus muscle area was lower than that reported in other studies (Moser et al., 1998 and Johnson et al., 1993).

Table 1. Heritability and genetic correlation estimates for live animal ultrasound measures on seedstock cattle (Bertrand et al., 2001).

	Source[a]									
Parameter, trait(s)[b]	1	2	3	4	5	6	7	8	9	10	AVE
h^2, REA		.25	.40	.46	.11	.29	.50	.19	.39	.31	.32
h^2, FAT	.24	.26	.14	.50	.56	.11	.01	.27	.44	.26	.28
h^2, %IMF									.42	.39	.41
r_g ,REA-FAT		.48	.12	.38		.13	.76	.08	.23	.59	.35
r_g ,REA-%IMF									-.12	-.01	-.07
r_g ,REA-WWT		.55	.29		.42					.68	.49
r_g ,REA-YWT		.57	.38			.49	.78	.06			.46
r_g ,FAT-%IMF									.17	-.02	.08
r_g ,FAT-WWT	.13	.22	-.17		.19					.54	.18
r_g ,FAT-YWT		.29	-.53			.11	.36	-.02			.04

[a]Sources are as follows: 1) Lamb et al., 1990; 2) Arnold et al., 1991; 3) Johnson et al., 1993; 4)Evans et al., 1995; 5) Shepard et al, 1996; 6) Moser et al., 1998, 7) Meyer, 1999; 8) Meyer and Graser, 1999; 9) Wilson et al., 1999; 10) Unpublished analysis of American Hereford Association Ultrasound data.
[b]REA = longissimus muscle area, FAT = 12-13th rib fat depth, %IMF = % intramuscular fat, WWT = weaning weight, YWT = yearling weight, r_g = genetic correlation.

With data from 2,101 Brangus calves, Johnson et al. (1993) conducted a study to estimate variance components of RTU measured live animal traits. The genetic correlation between RTU measured longissimus muscle area at a year of age and post-weaning gain was reported as .43, whereas the genetic correlation between RTU measured fat depth and post-weaning gain was .44. Heritabilities were also estimated for RTU measured longissimus muscle area at a year of age and RTU measured fat depth at a year of age at .40 and .14, respectively.

Robinson et al. (1993) used RTU measurements to estimate heritabilities and genetic correlations in Angus, Hereford, and Polled Hereford cattle. It was necessary to split the Angus and Hereford data into two subsets to enable a complete multivariate animal model to be fit. The resulting number of animals represented in the first Angus, second Angus, first Hereford, second Hereford, and Polled Hereford data subsets were 1,910, 1,818, 1,860, 1,497, and 2,047, respectively. Heritabilities reported for RTU determined longissimus muscle area in the corresponding subsets were .25, .22, .18, .20, and .19, respectively. Heritabilities reported for RTU measured fat depth in the corresponding subsets were .34, .42, .42, .16, and .15, respectively. Average heritabilities over all subsets for live weight, estimated kilograms of saleable meat, and percent saleable meat were all moderate to high at .46, .44, and .36, respectively. The genetic correlation between longissimus muscle area and fat depth was quite low at .05. However, the genetic correlation reported between longissimus muscle area and live weight as well as the genetic correlation between fat depth and live weight were higher at .45 and .12, respectively.

Table 2. Age-adjusted estimates of heritability, genetic, and environmental correlations among carcass and real-time ultrasound traits[a] in Angus steers (Kemp et al., 2001)

Trait[b]	HCW	LMA	FAT	MARB	YWT	ULMA	UFAT	UEE
HCW	**0.48**	0.32	0.49	0.01	0.81	0.40	0.37	0.02
LMA	0.58	**0.45**	0.09	-0.01	0.28	0.27	0.15	0.01
FAT	0.17	-0.20	**0.35**	0.01	0.47	0.03	0.55	0.03
MARB	0.27	-0.10	0.38	**0.42**	-0.03	-0.04	-0.03	0.06
YWT	0.96	0.45	0.10	0.30	**0.55**	0.46	0.40	-0.01
ULMA	0.78	0.69	0.15	0.30	0.71	**0.29**	0.23	-0.02
UFAT	0.33	-0.24	0.82	0.45	0.33	0.23	**0.39**	0.02
UEE	0.14	-0.19	0.33	0.90	0.19	0.16	0.38	**0.51**

[a]Heritability estimates on diagonal, genetic correlations below diagonal, environmental correlations above diagonal.
[b]HCW = carcass weight, kg; LMA = carcass longissimus muscle area, cm^2; FAT = 12-13 rib carcass fat thickness, cm; MARB = marbling score, 4.0 = Slight^{00}, 5.0 = Small^{00}, etc.; YWT = weight at the time of real-time ultrasound, kg; ULMA = ultrasonically scanned longissimus muscle area, cm^2; UFAT = ultrasonically scanned 12-13 rib fat thickness, cm; UIMF = ultrasonically predicted percentage ether extract.

Arnold et al. (1991) reported heritabilities and genetic correlations for RTU measured traits and actual carcass data. Two separate data sets were used. The first was a group of 2,411 Hereford steers, from a progeny test, with growth and carcass measurements. The second group consisted of Hereford bulls (3,089) and Hereford heifers (393) that had been RTU measured for fat depth and longissimus muscle area. Carcass trait heritabilities for carcass weight, ribeye area, fat depth, and marbling were .24, .46, .49, and .35, respectively. Heritability estimates for RTU measured fat depth and longissimus muscle area, both on a weight constant basis, were .26 and .25, respectively. Heritability estimates for RTU measured fat depth and longissimus muscle area, both on an age constant basis, were .26 and .28, respectively. When using actual carcass data, genetic correlations between actual ribeye area and fat depth, marbling, and carcass weight were -.37, -.01, and .09, respectively. Genetic correlations between fat depth and marbling as well as fat depth and carcass weight were .19 and .36, respectively.

With more integrated production systems emerging, use of RTU data from feedyard steers and heifers may become more available. Using this approach would allow for progeny testing by measuring offspring at a single time and then subsequently marketing the offspring across multiple harvest dates. If this approach was feasible, carcass data would not need to be collected. Kemp et al. (2001) estimated heritabilities and genetic correlations among RTU and carcass traits in Angus steers from a designed progeny test (Table 2). These researchers determined that RTU data gathered from feedlot steers would rank sires the same as if EPD were calculated from carcass data alone.

The literature indicates that carcass traits and RTU predictions of carcass traits are heritable. In addition, individual carcass traits and their RTU determined predictors tend to be positively correlated. This indicates that selection for these traits can be realized and that the use of RTU offers an effective alternative to traditional carcass data collection.

STATUS OF EPD CALCULATION OF CARCASS MERIT

Table 3. U.S. breed registries with carcass or ultrasound EPD

	U.S. Breed Associations[a]							
Trait	AAA	AHA	AGA	AICA	ASA	IBBA	NALF	RAAA[b]
Carcass								
Weight	X		X	X	X		X	
Marbling	X		X	X	X		X	X
REA	X		X	X			X	X
12-13th Rib fat	X		X	X			X	X
% Retail product	X				X			
Tenderness					X			
Ultrasound								
IM Fat	X	X				X		
REA	X	X				X		
12-13th Rib Fat	X	X				X		
Rump Fat	X							

[a]AAA=American Angus Association, AHA=American Hereford Association, AGA=American Gelbvieh Association, AICA=American-International Charolais Association, ASA=American Simmental Association, IBBA=International Brangus Breeder's Association, NALF=North American Limousin Foundation, RAA=Red Angus Association of American

[b]Uses ultrasound and carcass data in a multi-trait genetic model for carcass EPD calculation

The International Brangus Breeder's Association was the first U.S. breed registry to incorporate RTU data from breeding stock into its genetic evaluation programs. Today, they, along with the American Angus Association and American Hereford Association, compute RTU EPD based on data from breeding stock. These data are taken at yearling measurement time. The resulting EPD are therefore expressed in RTU trait units on the same scale of expression as from which those data originate. In other words, if all the data for RTU fat thickness were obtained from yearling bulls, the spread in EPD would be narrower than if collected on fed steers at harvest.

The Red Angus Association of American uses both RTU and carcass data in their genetic evaluation program. However, they utilize a multi-trait genetic model that allows for the generation of only one EPD for the same carcass or RTU trait.

CONCLUSIONS

Ultrasound technology provides a credible description of carcass merit when using appropriate equipment, software and technicians. These RTU data from seedstock and fed cattle, along with other carcass data allow for a broader and more accurate genetic evaluation program that should shorten the generation interval when selecting for carcass merit.

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