

**PREDICTION OF CARCASS TRAITS USING LIVE  
ANIMAL ULTRASOUND****D. E. Wilson, H.-U. Graser, G. H. Rouse, V. Amin****Summary**

Research of real-time ultrasound technologies at Iowa State University (ISU) has focused on software and application systems for measuring the percentage of intramuscular fat (PIMF) in the longissimus dorsi muscle in both live beef cattle and in hot beef carcasses. The developed software has been licensed to a commercial marketing firm and has been used by ultrasound technicians in two different proficiency testing programs held at ISU. Relationships between prediction biases and standard errors of prediction (SEP) for PIMF with actual carcass measures are summarized in this paper using Spearman rank correlations. Reasonable genetic progress for the PIMF trait in beef cattle should be possible using this technology. Good technician-machine systems achieved SEP of less than 1%, rank correlations of greater than .7, and with biases of less than .5%.

Keywords: Beef cattle, carcass traits, marbling, ultrasound.

*Introduction*

Research of real-time ultrasound (RTU) technologies at Iowa State University (ISU) has focused on software and application systems for measuring the percentage of intramuscular fat (PIMF) in the longissimus dorsi (*Id*) muscle in both live beef cattle (Zhang et al. 1995) and in hot beef carcasses (Amin et al. 1995). The goal of this research is to provide the beef cattle industry with an objective measure of meat quality as determined by the amount of intramuscular fat (marbling) in the *Id* muscle. Accurate measurements of this trait in live animals can be used in genetic improvement

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programs in seed stock operations, as a management tool in feedlot operations, and in carcass value-based marketing programs. The objective of this paper is to report on results of two RTU proficiency testing programs for technicians using ISU developed RTU-PIMF technology. The ISU technology is licensed to Critical Vision, Inc. (430 Tenth St., NW, Suite N-110, Atlanta, GA 30318) for marketing and service. This report also includes results from one proficiency testing program for RTU-PIMF software called Quality Ultrasound Index Program (QUIP) calculator developed by Classic Ultrasound Equipment (Classic Medical Supply, Inc., 19900 Mona Road, Suite 105, Tequesta, FL 33469) for the Pie Scanner 200.

### *Materials and methods*

*Proficiency Testing.* Annual proficiency testing and evaluation programs for RTU technicians have been conducted at ISU for the years 1993 through 1997. Proficiency testing for PIMF was first initiated in 1996. Technicians scan 20+ beef animals to obtain images for measuring fat thickness, ribeye area and PIMF. The majority of the animals scanned are steers. A limited number of heifers and intact males are used in each certification. The animals average 14 months of age. After technicians have obtained images for the animals, the animals are scanned again in different order and each with a different identification number to test interpretation repeatability. Immediately after the proficiency testing scanning, the test animals are slaughtered at a commercial packing facility. Following a 24-hour chill, the carcasses are subjectively graded by a United States Department of Agriculture (USDA) grader for marbling score A 6.4 mm 12<sup>th</sup> rib facing is removed from each carcass and chemically analyzed for total lipid content using an n-hexane method. The carcass measures and the chemically determined PIMF (C-PIMF) serve as the reference from which to evaluate technician proficiency.

For each of the three traits, a standard error of prediction (SEP) (adjusted for individual technician-system bias), a standard error of repeatability (SER) and bias is calculated for each technician. At least two previously certified technicians scan the same cattle, and their proficiency statistics are used to help in setting standards for passing. Although not a current part of the testing criteria, additional analysis has been done to determine the product moment and rank correlation between RTU-PIMF and C-PIMF measures for each technician.

For RTU measurements to be of value to the beef cattle industry, they must be accurate enough to determine differences between animals undergoing genetic evaluation. In the case of feedlot animals, the measurements must be



accurate enough to have a high correlation with actual carcass measures. An accuracy assessment for the genetic evaluation scenario is presented in this paper by looking at the effect of an increasing standard error of prediction ( $(\sigma_{RTU}^2)^{1/2}$ ) associated with RTU-PIMF. Accuracy is defined as  $(n/(n+k))^{1/2}$ , where,  $n$  = effective progeny number for a sire,  $k = (\sigma_e^2/\sigma_a^2)$  or  $k = (4-h^2/h^2)$ . Heritability ( $h^2$ ) is defined as  $\sigma_a^2/(\sigma_a^2 + \sigma_e^2)$ . The subscripts  $a$ ,  $s$  and  $e$  represent additive, sire and error variances, respectively. The error variance is partitioned into two components,  $\sigma_{RTU}$  and  $\sigma_e^2$ . The genetic evaluation accuracy assessment is developed for Case 1 where feedlot steers are undergoing a progeny test for sire carcass merit and for Case 2 where young bulls are measured directly for PIMF.

*Case 1 - Angus Steers.* The baseline steer  $h^2$  estimate is .37 and comes from an analysis of the national carcass data base of the American Angus Association (Wilson 1997). The majority of steers in this data base average 485 days at slaughter with 13.9 mm of 12-13<sup>th</sup> ribs external fat. The mean marbling score is  $5.81 \pm 1.18$  which translates into a mean PIMF of  $5.5 \pm 1.88\%$ . The  $h^2$  estimate is for USDA marbling score, where  $(\sigma_e^2 = .64, \sigma_s^2 = .065$  and  $\sigma_a^2 = 4 * \sigma_s^2$ ). Although marbling score and C-PIMF are not perfectly correlated, the correlation has been high at .94 and .82 for the 1996 and 1997 proficiency testing, respectively. The scaling factor to convert PIMF  $\sigma_{RTU}^2$  to a marbling score equivalent is: 1% fat = .63 marbling score units within the "slight" "small" and "modest" degrees of marbling. The marbling score unit used in the carcass data base is one unit = one degree of marbling. For example, the marbling score for a "slight" amount of marbling ranges from 4.0 to 4.9; the marbling score for a "small" amount of marbling ranges from 5.0 to 5.9.

*Case 2 - Angus Bulls.* The baseline bull  $h^2$  estimate for RTU-PIMF is .26. This estimate comes from RTU research done on cattle which are a part of the ISU beef cattle breeding project (Izquierdo 1996). From this analysis, estimates obtained for  $\sigma_e^2$  and  $\sigma_s^2$  were  $1.0249\%^2$  and  $.07125\%^2$ , respectively. There were 229 Angus bulls involved in this study. The bulls were spring born, weaned in the fall at 200 days of age and fed an 85% concentrate corn-corn silage diet for approximately an eight-month period. They were slaughtered at an average age of 440 days. The mean level of C-PIMF was approximately  $3.5 \pm 1.3\%$  with a range of 1.4-8.2%.

## Results

*Proficiency Testing.* Table 1 summarizes the descriptive statistics for C-PIMF and USDA marbling score for animals used in the 1996 and 1997

proficiency testing. The mean level of PIMF was significantly higher in the 1996 group of cattle as well as the overall variation. The greater variation would account for why the correlation between C-PIMF and marbling score was higher in 1996 than in 1997. Research at ISU strongly suggests that RTU-PIMF, C-PIMF and Marbling Score are the same trait as genetic correlation estimates range from .83-.99 between the three (Izquierdo 1996).

Table 1. - DESCRIPTIVE STATISTICS FOR THE PIMF TRAIT AND USDA MARBLING SCORE IN TEST ANIMALS

Trait	n	Mean	SD	Minimum	Maximum	Correlation <sup>A</sup>
Year - 1996						
C-PIMF, %	39	4.44	1.79	1.40	9.08	.94
Marbling score <sup>B</sup>	39	1027	124	810	1280	
Year - 1997						
C-PIMF, %	43	3.81	1.54	1.46	7.97	.82
Marbling score	43	989	73	830	1170	

<sup>A</sup>Correlation between C-PIMF and marbling score.

<sup>B</sup>Marbling score by degree: traces=800, slight=900, small= 1000, modest= 1100 moderate=1200.

Table 2 summarizes the PIMF proficiency testing results for each of the two years. Figures 1, 2 and 3 graphically show the relationship between the SEP achieved by individual technicians and corresponding Spearman rank correlation (SAS 1989). The SEP criteria for passing in 1996 were  $\leq 1.2\%$ ; the criteria for passing in 1997 were  $\leq 1.4\%$ . Technicians shown as not passing, but having better SEP than these criteria failed, because of SER or bias criteria. General performance as measured by rank correlation was significantly worse in 1997 than in 1996. This is probably due in part to the smaller variation of C-PIMF in the 1997 cattle. For ISU developed software, the general tendency is for Spearman rank correlation to improve as SEP decreases. For this proficiency test, there is no indication that Spearman rank correlation and SEP are related in the RTU-PIMF QUIP software.

The relationships shown between rank correlations and the SEP statistic in Figures 1-3 suggest that SEP (along with SER and bias) are not sufficient statistics for RTU proficiency testing. The minimum acceptable level of rank correlation for passing proficiency testing will be a debated topic.

Figure 1. - RTU-PIMF SEP AND SPEARMAN RANK CORRELATION FOR THE 1996 PROFICIENCY TESTING FOR ISU DEVELOPED SOFTWARE

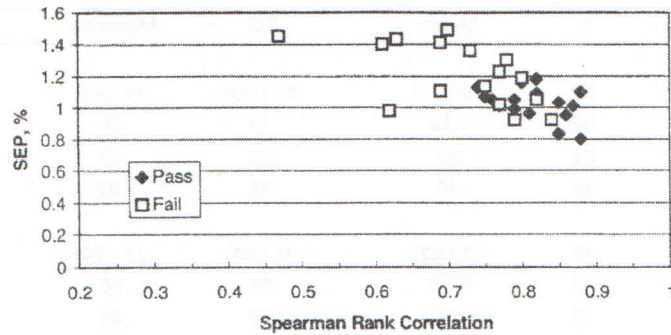


Figure 2. - RTU-PIMF SEP AND SPEARMAN RANK CORRELATION FOR THE 1997 PROFICIENCY TESTING FOR ISU DEVELOPED SOFTWARE

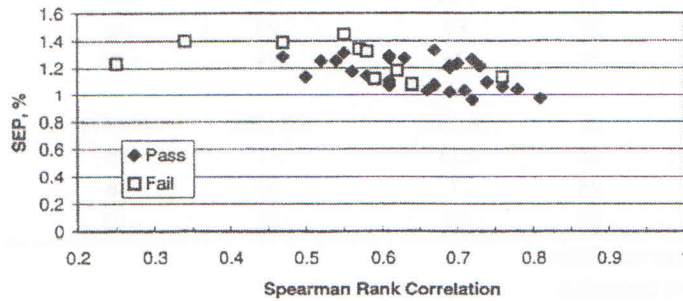


Figure 3. - RTU-PIMF SEP AND SPEARMAN RANK CORRELATION FOR THE 1997 PROFICIENCY TESTING FOR THE QUIP SOFTWARE

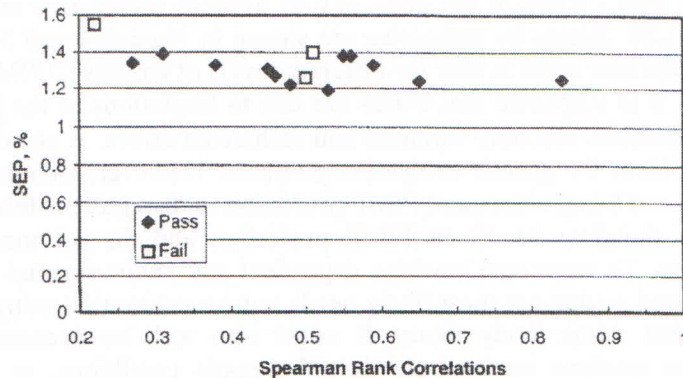




Table 2. - DESCRIPTIVE STATISTICS FOR RTU-PIMF PROFICIENCY TESTING IN 1996 AND 1997 FOR ISU DEVELOPED SOFTWARE

	n	Mean	SD	Minimum	Maximum
Overall - 1996					
$r_p^A (r_s^B)$	32	.76 (.77)	.11 (.09)	.37 (.47)	.90 (.88)
SEP, %	32	1.12	.18	.80	1.49
SER, %	32	.98	.42	.43	2.12
Bias, %	32	.46	.44	-.37	1.27
Passing -1996					
$r_p (r_s)$	16	.82 (.82)	.05 (.05)	.73 (.74)	.90 (.88)
SEP, %	16	1.03	.11	.80	1.18
SER, %	16	.74	.17	.43	1.07
Bias, %	16	.23	.31	-.37	.67
Overall - 1997					
$r_p (r_s)$	37	.61 (.61)	.12 (.12)	.24 (.25)	.85 (.81)
SEP, %	37	1.19	.13	.96	1.45
SER, %	37	.83	.29	.48	1.74
Bias, %	37	.74	.44	-.23	1.89
Passing -1997					
$r_p (r_s)$	26	.64 (.65)	.08 (.09)	.46 (.47)	.85 (.81)
SEP, %	26	1.16	.11	.96	1.33
SER, %	26	.7	.09	.48	.88
Bias, %	26	.60	.33	-.23	1.0

<sup>A</sup>Product moment correlation.

<sup>B</sup>Spearman rank correlation.

*PIMF Prediction Bias.* From Table 2 it is obvious that the current available software used by the average technician tends to overestimate PIMF by about 0.5 to 0.7% with a standard deviation of 0.44 between technicians and a range of -0.37 to 1.89. Biases by technician are shown in Figures 4 and 5. There is also a very definite trend in bias for different levels of carcass C-PIMF as seen in Figure 6. It is suspected that biases are due to limitations in the prediction regression formula, machine variation and technician errors. A consistent bias is of no problem for genetic evaluation purposes. However, technicians with large biases can bring ultrasound PIMF prediction in disrepute, if feedlot cattle are sent to slaughter based on PIMF prediction and do not meet market specifications. To overcome machine dependent and environmental causes of bias ultrasound equipment most likely needs regular calibration using standard phantoms that mimic body tissue. It might also well be necessary to re-calibrate the machine on a single day if climatic conditions, in particular

temperature, fluctuate greatly. Changing the gain settings on the machine and using the phantom image as a reference can possibly perform such calibration. For high accuracy over the whole range of PIMF observed in seed stock and feedlot cattle, two phantoms mimicking body tissue with vastly different PIMF might be useful.

Figure 4. - RTU-PIMF BIAS AND SPEARMAN RANK CORRELATION FOR THE 1997 PROFICIENCY TESTING FOR ISU DEVELOPED SOFTWARE

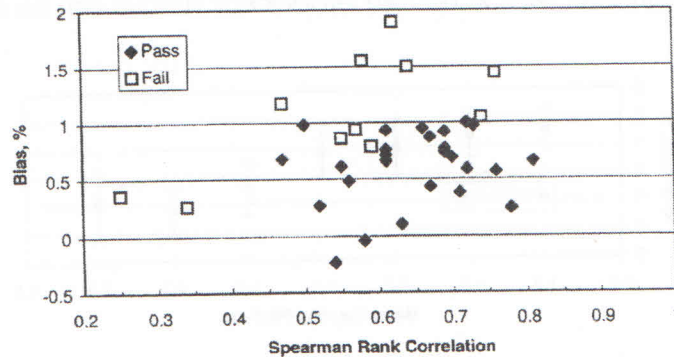
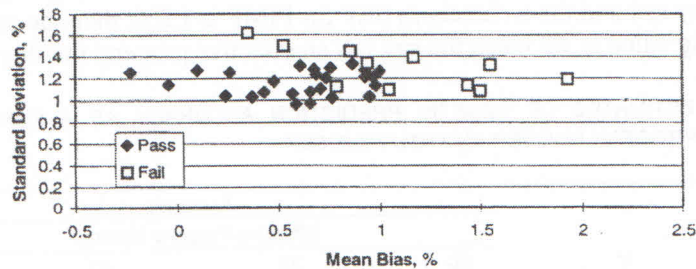


Figure 5. - RTU-PIMF MEAN BIAS AND STANDARD DEVIATIONS FOR TECHNICIANS IN THE 1997 PROFICIENCY TESTING USING ISU DEVELOPED SOFTWARE



The tissue-mimicking phantoms provide a simple, well-defined scattering medium which simulates important ultrasonic properties for soft tissues. Since the phantom is made of an artificial material and remains stable in different weather conditions, its ultrasound properties remain constant and provide an excellent means of standardizing measurement procedures. Images from the phantom can be used to calibrate image texture processing algorithms and to standardize measurements across scanning sessions. Using a reference phantom, one can study and possibly develop calibration curves for effects of different gain settings and different temperature on the image texture

parameters. This could lead to a standardized measurement procedure for more accurate results under different conditions. Such an approach could also allow an easy quantitative comparisons between different commercial equipment. The tissue-mimicking phantoms are available commercially for calibrating medical ultrasound machines the same could be used for animal ultrasound purposes. Additional research in this area is required.

Figure 6. - RTU-PIMF MEAN BIAS AND STANDARD DEVIATIONS ACROSS DIFFERENT LEVELS OF CARCASS C-PIMF IN THE 1997 PROFICIENCY TESTING FOR ISU DEVELOPED SOFTWARE

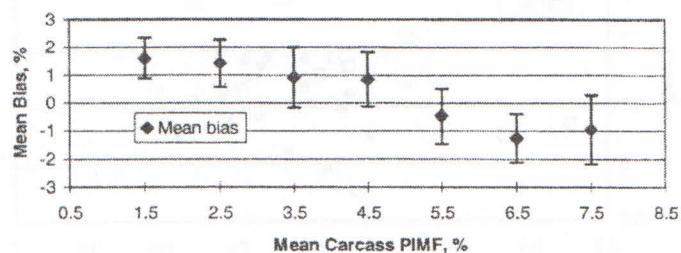


Table 3 summarizes genetic prediction accuracy (the correlation between estimated and true breeding value) as a function of RTU-PIMF SEP and sire effective progeny number. For example, if a breeder is scanning Angus steers in a progeny test and the technician's SEP for PIMF is 1.2%, then the accuracy of the breeding value is .69 when the sire has an effective progeny number of 20.

Table 3. - ESTIMATES OF GENETIC PREDICTION ACCURACY AS A FUNCTION OF EFFECTIVE PROGENY NUMBER AND RTU-PIMF SEP

SEP, %	h <sup>2</sup>	Accuracy			
		Effective Progeny Number			
		20	30	40	50
.0	.29 <sup>A</sup> (.22) <sup>B</sup>	.78 (.73)	.84 (.80)	.87 (.83)	.89 (.86)
.8	.23 (.15)	.74 (.66)	.80 (.73)	.84 (.78)	.87 (.81)
.9	.21 (.13)	.73 (.64)	.79 (.71)	.83 (.76)	.86 (.80)
1.0	.20 (.12)	.72 (.62)	.78 (.70)	.82 (.75)	.85 (.78)
1.1	.19 (.11)	.71 (.61)	.77 (.68)	.81 (.73)	.84 (.77)
1.2	.18 (.10)	.69 (.59)	.76 (.67)	.81 (.72)	.84 (.76)
1.3	.17 (.10)	.68 (.57)	.75 (.65)	.80 (.70)	.83 (.74)
1.4	.16 (.09)	.67 (.56)	.74 (.63)	.79 (.69)	.82 (.73)

<sup>A</sup>Case 1 - Angus steers.

<sup>B</sup>Case 2 - Angus bulls, in parenthesis.



The use of RTU technology offers a tremendous potential to producers interested in the genetic improvement in PIMF, as potential seed stock animals can be measured directly without the need for long-term and expensive progeny testing programs. Good technician-machine combinations achieve SEP of 1.0% or less. Such a technician would require scanning 30 effective progeny to achieve the same accuracy of the estimated breeding value as we can achieve with 20 effective carcass marble scores. This does not include the information that can be collected on relatives of the bull in seed stock herds.

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#### PREDVIĐANJE OSOBINA TRUPLA PRIMJENOM ULTRAZVUKA NA ŽIVOJ ŽIVOTINJI

##### Sažetak

Istraživanje real-time tehnologija ultrazvuka na Državnom sveučilištu u Iowi (ISU) usmjerena su na software i primjenu sustava za mjerenje postotka međumišićne masnoće (PIMF) u dugom leđnom mišiću na živom govedu (beef cattle) i toplim goveđim truplima. Licenca za razvijeni software data je poduzeću za trgovački marketing i njime se služe tehničari za ultrazvuk u dva različita programa za testiranje stručnosti na ISU. Odnosi između kosina predviđanja i standardnih pogrešaka predviđanja (SEP) za PIMF sa stvarnim mjerama trupa sažeti su u ovom radu primjenom Spearman položaja korelacije.

Primjena ove tehnologije trebala bi omogućiti umjeren genetski napredak za PIMF osobinu u goveda. Dobri sustavi tehničar-aparat postigli su SEP manji od 15, korelacije položaja veće od 7 i kosine manje od 5%.

Ključne riječi: govedo, osobine trupa, mramoriranje, ultrazvuk

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