Prediction of Carcass Traits Using Live Animal Ultrasound

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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 achieve SEP of less than 1%, rank correlations of greater than .7, and biases of less than .5%.

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 (ld)* 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 *ld* muscle. Accurate measurements of this trait in live animals can be used in genetic improvement 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 12th 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 are calculated for each technician. At least two previously certified technicians scan the same cattle, and their proficiency statistics are used to help set 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 among 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 ($[\sigma^2_{RTU}]^{1/2}$) associated with RTU-PIMF. Accuracy is defined as $[n/(n+k)]^{1/2}$, where, n=effective progeny number for a sire, $k=(\sigma^2_e/\sigma^2_s)$ or $k=(4-h^2/h^2)$. Heritability (h^2) is defined as $\sigma^2_a/(\sigma^2_a+\sigma^2_e)$. The subscripts a, s, and e represent additive, sire, and error variances, respectively. The error variance is partitioned into two components: σ^2_{RTU} and $\sigma^2_{e'}$. 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 12-13th ribs external fat. The mean marbling score is 5.81±1.18, which translates into a mean PIMF of 5.5±1.88%. The h^2 estimate is for USDA marbling score, where σ^2_e=.64, σ^2_s=.065, and σ^2_a=4*σ^2_s. 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 σ^2_{RTU} 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 σ^2_e and σ^2_s 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±1.3% with a range of 1.4 - 8.2%.

Results and Discussion

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 was the overall variation. The greater variation would account for the higher correlation between C-PIMF and marbling score in 1996 than in 1997.

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 was ≤1.2%; the criteria for passing in 1997 was ≤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.

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 consequence for genetic evaluation purposes. However, technicians with large biases could mar the reputation of ultrasound PIMF prediction, if feedlot cattle are send to slaughter based on PIMF prediction and don't 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 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 can 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.

The tissue-mimicking phantoms provide a simple, well-defined scattering medium which simulates important ultrasonic properties for soft tissues. Because 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. This also allows one to study and calibrate effects of different gain settings on the image parameters. Such an approach could lead to a measurement procedure that allows 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.

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.

Implications

The use of RTU technology offers a tremendous potential to producers interested in the genetic improvement of 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. An accurate technician would require scanning 30 effective progeny to achieve the same accuracy of the estimated breeding value that 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.

References

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Table 1. Descriptive statistics for the PIMF trait and USDA marbling score in test animals.

Trait	n	Mean	SD	Minimum	Maximum	Correlation[a]
Year - 1996						
C-PIMF, %	39	4.44	1.79	1.40	9.08	.94
Marblingscore[b]	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	

[a] Correlation between C-PIMF and marbling score.

[b] Marbling score by degree: traces=800, slight=900, small=1000, modest=1100, moderate=1200.

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

[a] Product moment correlation.

[b] Spearman rank correlation.

Table 3. Estimates of genetic prediction accuracy as a function of effective progeny number and RTU-PIMF SEP.

		Accuracy			
		Effective Progeny Number			
SEP, %	h^2	20	30	40	50
.0	.29[a] (.22)[b]	.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)

[a] Case 1 - Angus steers.

[b] Case 2 - Angus bulls, in parenthesis.

Figure 1. RTU-PIMF SEP and Spearman rank correlation for the 1996 proficiency testing for ISU-developed software.

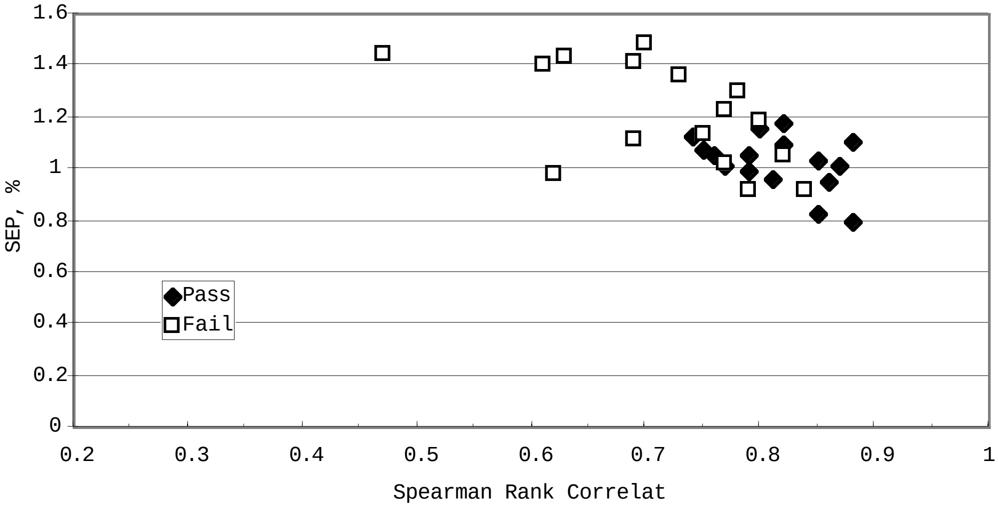

Figure 2. RTU-PIMF SEP and Spearman rank correlation for the 1997 proficiency testing for ISU-developed software.

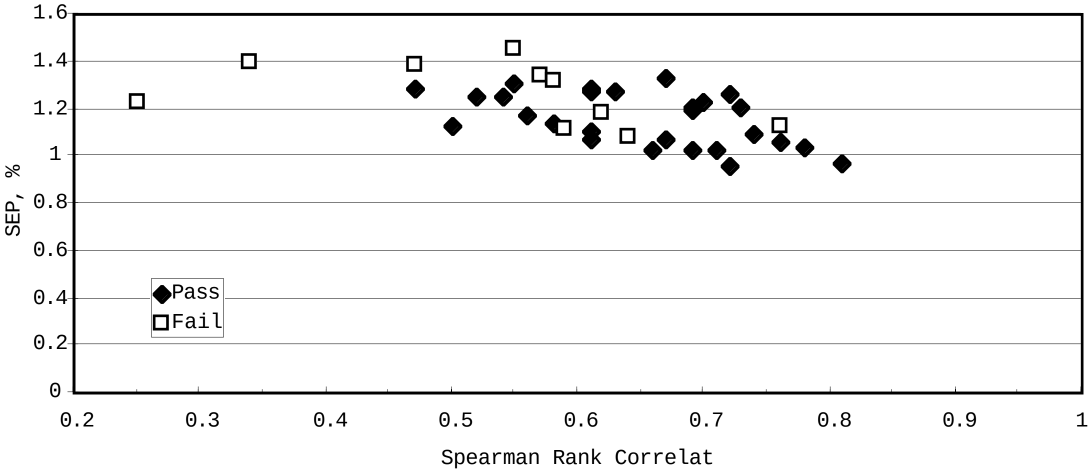

Figure 3. RTU-PIMF SEP and Spearman rank correlation for the 1997 proficiency testing for the QUIP software.

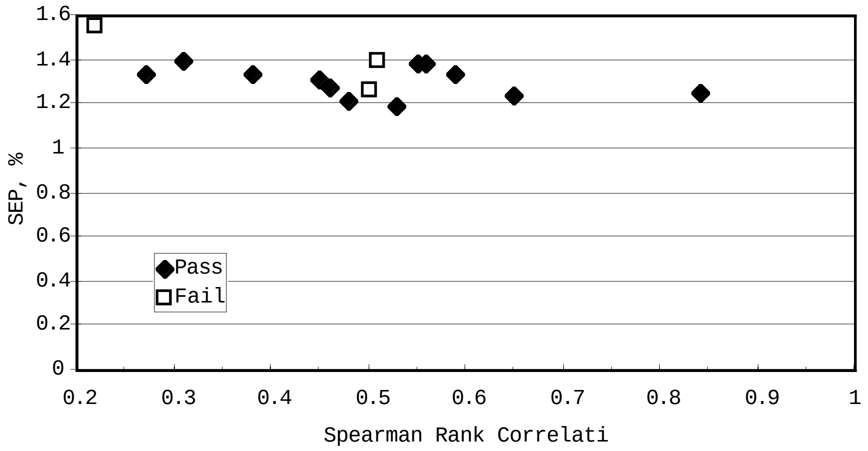

Figure 4. RTU-PIMF bias and Spearman rank correlation for the 1997 proficiency testing for ISU-developed software.

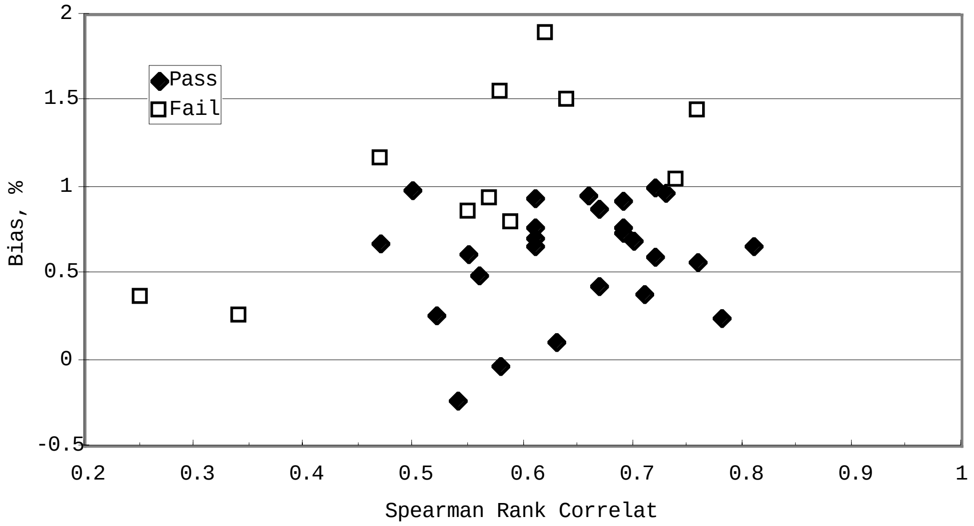

Figure 5. RTU-PIMF mean bias and standard deviations for technicians in the 1997 proficiency testing using ISU-developed software.

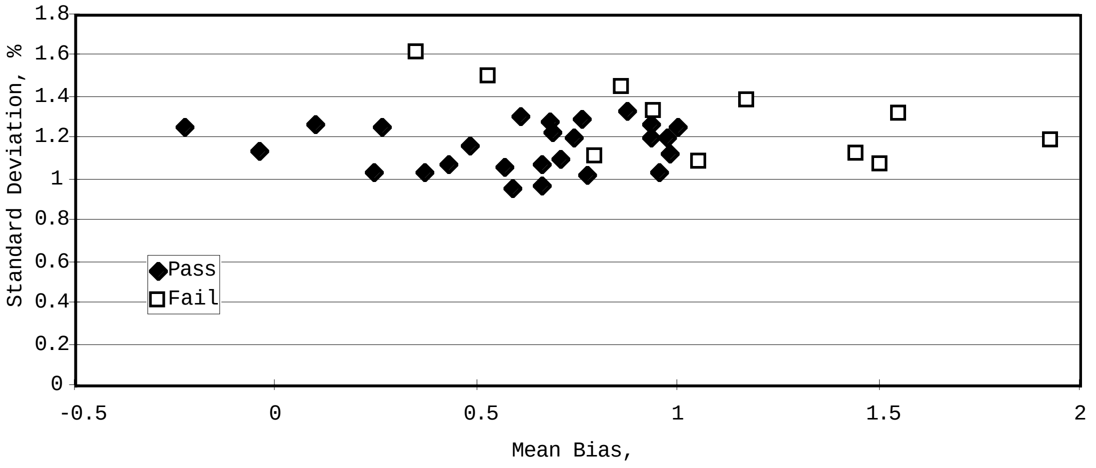

Figure 6. RTU-PIMF mean bias and standard deviations (SD) across different levels of carcass C-PIMF in the 1997 proficiency testing for ISU-developed software.