Evaluation of Ultrasound Measurements of Fat Thickness and Ribeye Area, I. Assessment of Technician Effect on Accuracy

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Summary

Data from two feeding trials were used to estimate accuracy of ultrasound measurements of fat thickness and ribeye area. In each trial, steers were scanned three or four times by one technician. Two beef improvement federation (BIF)-certified technicians with different levels of experience interpreted images from the last scan taken just before slaughter. Each technician interpreted the image of an individual steer twice on two different days. Accuracy of interpretation was evaluated using simple statistical measures, including means, standard deviations, regression and correlation coefficients, RMSE, and ESD. The overall technician biases for ultrasound measurements of fat thickness and ribeye area were -0.17 cm and 0.63 cm^2, respectively. Mean bias by technician indicated a similar direction and amount of bias (-0.14 vs -0.20 cm). However, bias in the measurement of ribeye area by the two technicians took an opposite direction (-1.28 vs 2.54 cm^2). In all cases, technician bias was within the acceptable range for BIF certification. Pearson product moment correlations between carcass and ultrasound measurements of fat thickness and ribeye area were 0.70 and 0.40, respectively. In general, fat thickness for 52% of the steers was measured within ±0.254 cm and for 85.2 % of the steers, fat thickness was measured within ±0.508 cm. For ribeye area, ±51.2 % and ±71.4 % of the steers had measurements within ±6.65 cm^2 and ±12.99 cm^2, respectively.

Introduction

With the advent of improved real-time ultrasound equipment such as the Aloka 500, ultrasound imaging may be a valuable opportunity to evaluate carcass merit in beef cattle. In feedlot operations, the technique provides an accurate estimate of ribeye area and fat thickness, allowing sorting of cattle into more uniform feeding groups. Through the use of serial scans and the application of simple regression techniques, it is possible to predict the number of feeding days needed to reach a particular fat cover and also to predict final retail product percentage. In the field of animal genetics, real-time ultrasound technique is now being considered a reliable means of developing breed databases for carcass traits.

Accuracy of ultrasound prediction varies with the type of instrument and the skill of technicians collecting and interpreting images, as well as with the species of animal. Hence, if the beef industry is to benefit further from this technology, several aspects need additional investigation. In ultrasound measurement of ribeye area and fat thickness, errors of varying magnitude may be introduced during image acquisition and interpretation of the captured images. Few reports have been made regarding the relative importance of these processes. Some reports indicated major interpreter error. The level of technician experience also impacts accuracy.

If interpretation effect contributes significantly to the accuracy of ultrasound measurement, a major emphasis needs to be given to a comprehensive evaluation of technician differences in the interpretation of the same image and how such differences relate to personal experience. The objective of this study was to evaluate the accuracy of real-time ultrasound measurements of ribeye area and fat thickness when interpreted by two technicians with different levels of experience.

Materials and Methods

Source of data and steers

Data for this analysis were from two separate feeding trials (Trial I and Trial II). The complete description of experimental animals and aspects of data acquisition for Trial I have been discussed elsewhere (R1217). In Trial I, data were collected on 164 cross-bred steers of uniform age (10-12 months at the start of feeding). The steers were fed in two separate groups involving different treatments and duration of feeding (Slaughter I and Slaughter II). Sixty-four of these steers were used to compare effects of four diets containing urea or soybean meal supplements with or without implants; they were fed for 148 days. The remaining 100 steers (Slaughter-II) were allotted to six treatment combinations. That is, in addition to the same treatments received by Slaughter I, steers in Slaughter II received treatments including diets containing raw soybean meal with implant and extruded soybean meal with implant. Steers in Slaughter II were fed 20 days longer than those in Slaughter I.

Trial II involved 144, 11-12 month-old cross-bred (Simmental and Charolais crosses) steers with an average weight of 395 kilograms at the start of the experiment. Steers in this experiment were randomly assigned to eight different treatments from weight-outcome groups. Steers were fed three different kinds of control diets including 1.04% urea, 5% soybean meal and urea, or 10 % soybean meal and urea. Implant steers were fed 1.04% urea, 1.97% urea, 5% soybean meal and urea, 10% soybean meal and urea, or cattle were started on 10% soybean meal and urea for 62 days and then changed to a diet containing 1.04% urea. The implanted steers were given Revalor-S implants on days 6 and 93. This experiment was started in April and lasted for 140 days (see R1235).

During each trial, steers were ultrasonically scanned three or four times by one technician. The transducer was located laterally between the 12th and 13th ribs for image collection. Measurements were made by an Aloka 500V unit (Corometrics Medical System, Inc., Wallingford, Connecticut), equipped with 3.5 mhz, 17-cm linear-array transducer. Each image was identified by specific animal identification number, and all images were saved on VHS video tape for interpretation. Steers were slaughtered within two days following the last scan. After a 24-hour chill, carcass fat thickness and ribeye area were measured between the 12th and 13th ribs.

In the present study, two technicians interpreted the images of the last scan from both trials. Both technicians were BIF certified. Technician A had more experience at the time of the study than Technician B. Each image was traced twice by each technician on two different days; neither of the technicians was involved in the image capturing.

Statistical analysis

Preliminary evaluation of ultrasound measurements of ribeye area and fat thickness was based on means and standard errors of carcass-measured traits, ultrasound-measured traits, and newly created variables. The newly created variables were,

- Difference in fat cover (DF) = Ultrasound fat thickness (Ufat) - Carcass fat thickness (Cfat)
- Absolute difference in fat cover (ADF) = |DF|
- Ratio of the difference in fat cover (PDF) = DF/Cfat
- Difference in ribeye area (DA) = Ultrasound ribeye area (Urea) - Carcass ribeye area (Crea)
- Absolute difference in ribeye area (ADA) = |DA|
- Ratio of the difference in ribeye area (PDA) = DA/Crea.

Technician effect on accuracy was further evaluated using a linear model which included fixed effect of technician**,** day of measurement, animal, and all possible interactions. In all cases, effects of low significance ($p > .05$) were deleted after being tested against the appropriate error term. Finally, a reduced model including the above main effects and two-way interactions was used. None of the high-order interactions were significant($p > .05$). Other measures of accuracy included were Pearson product moment and Spearman rank correlation. The use of correlation as a measure of accuracy is often criticized due to its dependency on the sample variance; hence, root mean square error (RMSE) and error standard deviation (ESD) were used as additional measures. These values, unlike correlation coefficients, help evaluate accuracy independent of variances. These statistics are defined as:

$$\mathbf{RMSE} = \sqrt{\Sigma(X_2 - X_1)^2/\mathbf{n}},$$

$$\mathbf{ESD} = \sqrt{\Sigma\,[(X_2 - \bar{X}_2) - (X_1 - \bar{X}_1)]^2/\mathbf{n-1}}$$

where, X_1 and X_2 are the respective carcass and ultrasound measurements of the trait in question. Although both RMSE and ESD allow measurement of accuracy independent of the sample variance, ESD data are adjusted for technician bias, as each measurement is deviated from its respective mean.

Results

The descriptive statistics for steers used in both trials are shown in Table 1. Both groups of cattle had a similar end weight and dressing percentage of 61% to 62 %.

The means for ultrasound-measured fat thickness, ribeye area, and the newly formed variables are given in Table 2. Generally, the DF value indicates the direction of bias created in measuring fat thickness of an individual or a group of animals. Thus, a mean value of -0.17 cm for DF indicates more frequent under-prediction of fat thickness among steers. It should be noted that a technician bias of this magnitude is well within the accepted range for certification of technician, which is $\pm$ 0.3 cm (Rouse, 1994). In the process of computing averages, there is always the cancellation of negative and positive deviations; consequently, a mean DF value closer to zero may not necessarily imply accurate estimations. Instead, the amount of error could be assessed in terms of the mean absolute difference between ultrasound and carcass measurements. In light of this argument, the calculated mean for ADF was 0.28 cm, which is reasonably accurate.

For ribeye area, mean bias was 0.63 cm^2, indicating a more repeated over-measurement. However, according to the standards set for technician certification, a bias of this magnitude represents a high level of accuracy (ISU, 1994). The mean error as measured by ADA was 7.65 cm^2. One other important point is the relative accuracy with which fat thickness and ribeye area were measured. That is, often it seems that fat thickness is measured with a relatively higher degree of accuracy than ribeye area. But the ratio of the error to the actual Cfat and Crea showed a percentage error of 25% and 8.5 % for fat thickness and ribeye area, respectively, indicating the opposite.

Evaluation of ultrasound measurement means by technician indicates almost the same amount and direction of bias (DF) by both technicians. Additionally, there was no apparent difference in the amount of error (ADF) involved as shown in Table 3. However, bias introduced in the measurement of ribeye area took an opposite direction. Mean DA indicates that Technician A often under-predicted ribeye area of steers, whereas steer ribeye area was often over-predicted by Technician B. The ADA, however, indicated a similar error.

In further evaluations, data were subjected to an analysis of variance procedure to test whether a true difference existed between technicians and if re-tracing images had any effect on accuracy. Consequently, the above mentioned newly created variables were analyzed according to a linear model that included fixed effects of technician, day of measurement, and animal and technician*animal interactions. Mean squares for technician and animal were tested against technician*animal mean squares, and the residual mean square was used to test the significance of day of measurement and technician*animal mean squares. The results of this analysis are shown in Table 4. There was a highly significant ($p < .05$) difference between technicians for DF and DA. However, no true differences were observed between technicians when evaluated for the magnitude of error (ADF, ADA). Day of measurement had no significant effect on all parameters except for DA. This indicates that re-tracing the same image did not improve the accuracy of ribeye area or fat thickness measurements.

Animal effect in this model represented effects of the amount of fat cover and size of ribeye area of an animal on the relative accuracy. If technicians were able to measure ribeye area and fat thickness with a bias independent of the amount of fat thickness and size of ribeye area, animal effect could be considered non-significant. However, for all measures of bias (DF, DA) and error (ADF, ADA), animal effect was highly significant ($p < .01$). This demonstrates the apparent association of bias and error with the sizes of ribeye area and the amount of fat cover. Additionally, it was interesting to note a highly significant ($p < .01$) interaction between animal and technician for all parameters considered. This indicates that the difference in the amount of bias and error introduced by technicians in measuring a particular steer varies with size of ribeye area and amount of fat cover.

Pearson product moment and Spearman rank correlation are presented in Table 5. As has been the case in several reports, coefficients were higher for fat thickness measurements than for ribeye area. Observation of correlation coefficients by technician and day of measurement has generally showed no major change in the accuracy of fat thickness. However, there was a marginal improvement in ribeye area measurement for Technician B, as indicated by a relatively better correlation coefficient and a smaller RMSE and ESD on the second day of measurement. The general understanding from Table 5 is that there is not a major difference between the two technicians in the accuracy of fat thickness and ribeye area measurement, and that there was some marginal improvement in ribeye area measurement by Technician B.

In a separate evaluation, the regression of DF on Cfat gave a slope of -0.47, which is significantly different ($p < .01$) from zero. As the Cfat of steers increased beyond 0.72 cm, Ufat was consistently underestimated, and the reverse was true for steers having a lesser amount of Cfat. Similarly, the slope for the regression of DA on Crea was significant -0.62($p < .01$). Ultrasound measurement of steers with ribeye area of above 92 cm^2 was consistently underestimated. For steers with a ribeye area of less than 92 cm^2, the estimates were inflated. In both analyses, about 42% to 46% of the variation in DF and DA was attributable to the linear association with Cfat and Crea, respectively. A quadratic relationship was non-existent.

Steer data were divided further into eight sub-classes based on the amount of Cfat. In order to create sub-classes with the least possible within-class variability and with enough animals per class, data were divided by half-standard deviation units. The mean and standard deviation for DF, ADF, and PDF are shown in Figure 1. There was a distinct change in the mean DF and ADF and also in the dispersion of observation within classes. The mean DF values were more negative and dispersed as the mean Cfat increased from 0.44 cm (class I) to 2.11 cm (class 8).

Dividing steer carcass ribeye area data into eight sub-classes also showed a distinct trend in the mean values and an increase in standard deviation at extreme classes (Figure 2.). Similarly, the mean PDF (Figure 1) and PDA (Figure 2) values assumed the same shape as the mean DF and DA, respectively. This indicates that bias in the measurement of fat thickness and ribeye area is definitely related to the amount Cfat and size of Crea, respectively.

Figures 3 and 4 represent the graph for DA, PDA, and ADA by Cfat class. According to Duello (1993), technicians often claim a reduction in the accuracy of ribeye area measurements due to the difficulty of acquiring good ultrasound images in fatter cattle. From the relationship observed in this particular study, there is not a clear trend to support this claim.

The cumulative frequency distribution of the absolute differences between ultrasound and carcass measurement is another way to evaluate precision of ultrasound measurements, and hence, to rank technicians. Overall, fat thickness for about 52% of feedlot steers was measured within 0.254 cm, and for 85.2% of the steers, fat thickness was measured within ±0.508 cm. When these values are evaluated on a within technician basis, technician A measured fat thickness within ±0.254 cm and ±0.508 cm, respectively, for 55.4% and 86.1 % of the steers. These values for Technician B were 57% and 84.3%, respectively. For ribeye area, 51.2% and 71.4% of the ribeye areas were measured within ±6.45 cm^2 and 12.99 cm^2, respectively. For measurements made by Technician A, 51.8% and 80.6% of the ribeye areas were measured with ±6.54 cm^2 and ±12.99 cm^2, respectively. The corresponding values for Technician B were 52.3% and 78.8%, respectively.

Implications

Through the use of advanced real-time ultrasound machines, fat thickness and ribeye area of live steers can be accurately measured. Particularly, the use of trained and certified technicians helps keep up and even improve today's level of accuracy. Considering effects of image interpretation on the overall accuracy of estimates, the ultimate goal should be to develop the technology to perform interpretation automatically.

References

Iowa State University (ISU), 1994. Real-time ultrasonic evaluation of beef cattle. Study guide. Department of Animal Science, Ames, Iowa.

Rouse, G., 1994. Proc. 26th research symposium and annual meeting, Beef Improvement Federation, Des Moines, Iowa, June 1-4, 1994.

Duello, D. A., 1993. The use of real-time ultrasound measurements to predict composition and estimates of genetic parameters of carcass traits in live beef cattle. Ph. D. Diss., Iowa State University, Ames, Iowa.

Table 1. Characterstics of feedlot steers used in the experiment*.

Trait	Mean	sd	Minimum	Maximum
Trail - I				
Slaughter weight	616.45	55.66	439.77	762.95
Carcass weight	379.44	37.08	258.18	465.00
Yield grade	2.65	0.70	1.00	4.00
KPH fat, %	3.04	0.45	2.00	4.50
Marbling score	1015.34	62.70	870	1180
Trial -II				
Slaughter weight	621.84	47.96	515.91	759.09
Carcass weight	378.64	29.83	306.36	458.64
Yield grade	2.49	0.68	1.00	4.00
KPH fat, %	2.89	0.45	1.50	3.50
Marbling score	1003.4	67.19	850.00	1180

* All weight traits are in kg.
Marbling score : Trace=800, Slight = 900, Small = 1000, Modest = 1100, Moderate = 1200, Slightly abundant = 1300.

Table 2. Statistics for carcass and ultrasound measures of fat thickness and ribeye area and of the newly created variables*.

Trail	Mean	Standard deviation	Minimum	Maximum
Fat thickness				
Carcass	1.11	0.46	0.20	2.60
Ultrasound	0.94	0.35	0.27	2.54
DF	-0.17	0.33	-1.93	1.04
ADF	0.28	0.24	0.00	1.93
Ribeye area				
Carcass	90.28	10.53	63.87	128.52
Ultrasound	90.91	8.14	58.76	115.24
DA	0.63	9.72	-30.59	33.48
ADA	7.65	6.01	0.00	33.48

*Fat thickness measurements are in cm. Rea measurements are in cm^2.

Table 3. Mean carcass- and ultrasound-measured fat thickness and ribeye area of steers and the actual and the absolute differences.

	Technician A				Technician B			
	Mean	sd	Min	Max	Mean	sd	Min	Max
Fat thickness								
UFAT	0.98	0.38	0.28	2.54	0.91	0.33	0.27	2.19
DF	-0.14	0.34	-1.88	1.04	-0.20	0.32	-1.92	0.62
ADF	0.28	0.24	0.00	1.88	0.29	0.24	0.00	1.93
Ribeye area								
UREA	89.00	9.06	58.76	111.37	92.82	6.58	72.75	115.24
DA	-1.28	9.68	-30.59	29.31	2.54	9.37	-27.42	33.48
ADA	7.59	6.14	0.02	30.59	7.72	5.88	0.02	33.48

* Fat thickness measurements are in cm. Rea measurements are in cm^2.

Table 4. Least squares means by technician and day of measurement* .

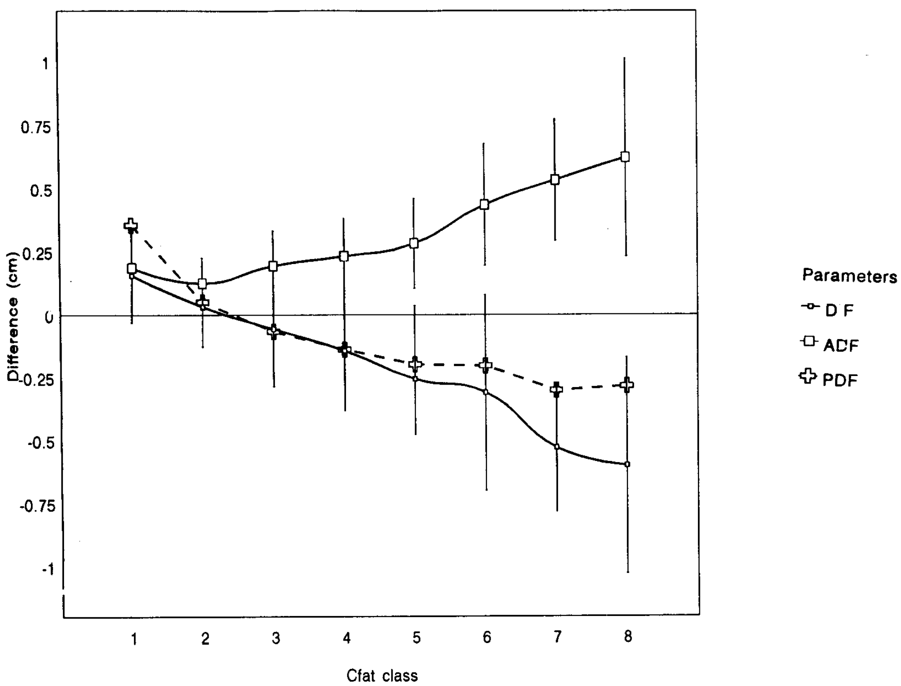
	DF± SE	ADF±SE	DA±SE	ADA±SE
Overall	-0.17±.00	0.28±.002	0.63±.08	7.65±.01
Technician				
A	-0.14±.01[a]	0.28±.01	-1.28±0.37[a]	7.59±0.30
B	-0.20±.01[b]	0.29±.01	2.53±0.37[b]	7.72±0.30
Measurement day				
1	-0.17±.00	0.29±.00	0.45±0.11[a]	7.70±0.10
2	-0.16±.00	0.28±.00	0.80±0.11[b]	7.61±0.10

*Means within column with different superscripts are significantly different ($p < .05$).

Table 5. The correlation between carcass and ultrasound measurements of fat thickness and ribeye area by technician and day of measurement.

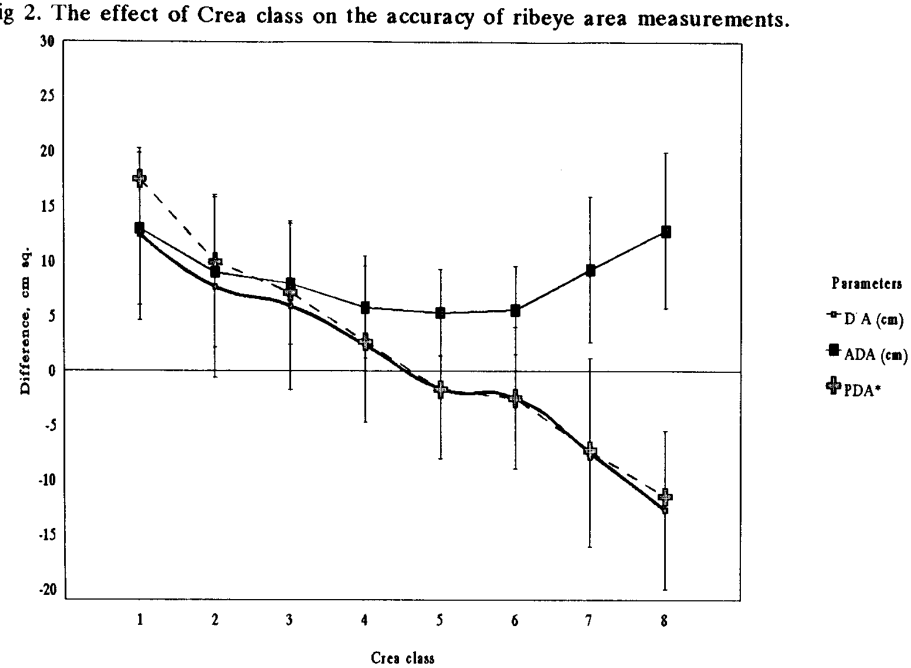
	r		RMSE	ESD
	Pearson	Spearman		
Overall				
Fat thickness	0.70	0.71	0.33	0.33
Ribeye area	0.48	0.44	9.73	9.52
Technician-measurement day				
Fat thickness				
A-1	0.70	0.70	0.36	0.34
B-1	0.72	0.72	0.38	0.32
A-2	0.68	0.69	0.37	0.34
B-2	0.71	0.72	0.38	0.33
Ribeye area				
A-1	0.53	0.49	9.55	9.55
B-1	0.45	0.41	9.99	9.71
A-2	0.51	0.49	9.87	9.83
B-2	0.52	0.48	9.41	9.04

Fig 1. The effect of Cfat class on the accuracy of fat thickness measurements



Mean Cfat (in cm), class 1 = 0.44, class 2 = 0.64, class 3 = 0.85, class 4 = 1.04
class 5= 1.3, class 6= 1.26, class 7 = 1.76, class 8 = 2.11

Fig 2. The effect of Crea class on the accuracy of ribeye area measurements.



Mean Crea (cm sq.), class 1 = 71.4, class 2 = 77.4, class 3 = 83.0, class 4= 87.5
class 5 = 92.5, class 6 = 97.5, class 7 = 102.5, class 8 = 111.2
***Multiplied by 100.**

Fig 3. The effect of Cfat class on the accuracy of ribeye area measurements.

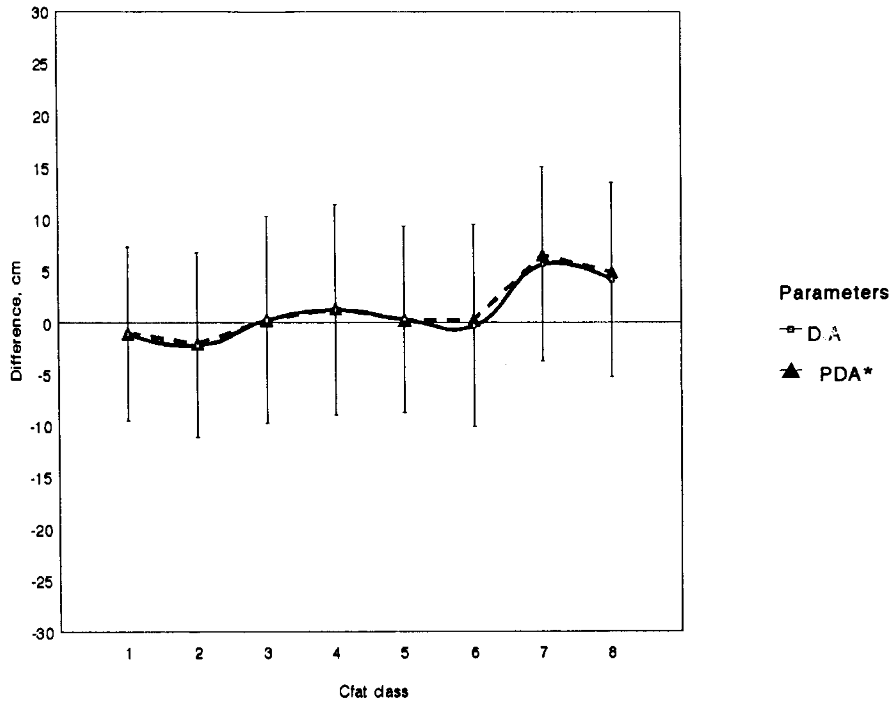


Fig 4. The effect of Cfat class on the accuracy of ribeye area measurements.