Predicting Percentage of Intramuscular Fat Using Two Types of Real-Time Ultrasound Equipment

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Summary

A total of 500 steers were used to develop models for prediction of percentage of intramuscular fat (PIMF) in live beef cattle. Prior to slaughter, steers were scanned across the 11th and 13th ribs using Aloka 500V and PIE scanner 200 machines. After slaughter, a cross-sectional slice of the longissimus dorsi muscle from the 12th rib facing was used for chemical extraction to determine carcass intramuscular fat measures (CIMF). Texture analysis software was used by two interpreters to define image parameters, which included Fourier, gradient, histogram, and co-occurrence parameters. A total of four prediction models were developed for each machine. These included, models developed without transformation of CIMF (model-I), models based on logarithmic transformation of CIMF (model-II), ridge regression (model-III), and principal components regression (model-IV) models. Model R^2 and root mean square error (RMSE) of Aloka models I, II, III and IV were .72, .84%; .72, .86%; .69, .91%; and .71, .86%; respectively. The corresponding R^2 and RMSE value of PIE models I, II, III, and IV were .68, .87%; .70, .85%; .64, .94%; and .65, .91%; respectively. All models were validated on an independent data set from 71 feedlot steers. The overall mean bias, standard error of prediction (SEP), and rank correlation coefficient across the four Aloka models were .42%, .84%, and .88, respectively. For PIE models the corresponding values were .67%, .81%, and .91, respectively. Both Aloka and PIE equipment can be used to accurately predict PIMF in live cattle. Further improvement in the accuracy of prediction could be achieved through increasing the development data set and the variation in PIMF of cattle used.

Introduction

At present, operation technicians use two main types of ultrasound machines to capture images for prediction of percentage of intramuscular fat (PIMF) in live cattle. These include the Aloka 500V and PIE scanner-200 machines. Earlier results showed important system differences in the accuracy of predicting PIMF in live steers. System proficiency differences may be caused by variations in the magnitude of errors introduced during image capture and/or interpretation using different technicians, image-processing software, and perhaps ultrasound machines. Thus far attempts have not been made to evaluate possible effects of extraneous factors, including machine type, on the accuracy of predicting PIMF. As a result, technicians often ask if a general accuracy criterion exists for the choice of ultrasound machines. Therefore, the objective of this study was to evaluate effects of machine type on the accuracy of predicting PIMF when images from Aloka 500V and PIE scanner-200 machines are processed using Iowa State technology.

Materials and Methods

Source of data

Animals and scanning procedure. Data in the present study came from 571 crossbred steers from five different farms located in central (Rhodes and Van meter), southern (McNay), northwestern (Sioux City) and southwestern (Armstrong) Iowa. Steers were scanned in the spring of 1999 by a Beef-Improvement Federation (BIF)-certified technician. At the time of the study steers averaged 455 d of age, with an average of 248 d on feed. Each individual steer was scanned using two ultrasound machines: an Aloka 500V (Corometrics Medical Systems, Inc., Wallingford, CT), equipped with a 3.5-MHz, 17.2-cm linear array transducer, and a PIE scanner-200 (classic ultrasound equipment, Tequesta, FL), equipped with a 3.5 MHZ, 18 cm transducer. Once the scanning site was determined by palpation, each steer was scanned on the right side four to five times using each machine. Each image was identified by a specific animal identification number, digitized at the scanning site, and saved on a personal computer for later processing.

Image processing. In the ultrasound laboratory, images were processed using the USOFT software package. Initially, the same technician who captured the images in the field interpreted all images (interpreter-I). In addition, images were interpreted by another technician with limited experience (interpreter-II). For each image, percentage intramuscular fat was predicted by placing a 100 × 100 pixels region of interest box (ROI) between the 12th and 13th ribs.

After processing each batch of images the software provided a ROI parameter file with 10 columns of image parameters. These parameters were calculated from the ROI based on four major image-processing techniques including Fourier based parameters, gradient image based parameters, Histogram parameters, and co-occurrence parameters.

Meat samples and chemical analysis. Steers were slaughtered within 2 to 5 days after scanning, and carcasses were chilled for 24 hours. A .635-cm-thick facing was removed from the 12th rib of the carcasses, returned to the ISU meat laboratory, and trimmed to contain only the longissimus muscle. The sample was freeze-ground in a blender with liquid nitrogen. Sub-samples were taken to determine actual percentage intramuscular fat (CIMF) using an n-hexane chemical extraction procedure.

Data analysis

Image parameters from repeated scans were averaged by steer-machine-interpreter subclass. These means were then used in the development and validation of prediction models. Data from a total of 500 steers were used for model development (data set-I). The rest of the data from 71 steers (data set-II) were used to validate candidate models.

Model development. Initially data were subjected to correlation analysis to study the linear association between CIMF and image parameters and also between image parameters themselves. For both machines, a preliminary examination of the correlation matrix demonstrated a strong linear association between image parameters. In further evaluation, the scatter diagram of residuals from a simple linear regression of CIMF on image parameters showed a clear increase in the scattering of points as the predicted PIMF values increased (data not shown). In general, four prediction models for each machine were developed based on data from the Aloka and PIE machines. These were: model-I, based on simple regression of CIMF on image parameters; model-II, based on simple regression after logarithmic transformation of CIMF values; Model-III, based on a ridge regression procedure; and model-IV, based on the principal components procedure. All prediction models were developed using regression procedures of SAS.

Model validation. The four models per machine were validated using independent data from 71 steers (data-II). Models were ranked using parameters commonly used in BIF ultrasound technician certification programs. These included: the difference (DIF) between ultrasound predicted percentage of intramuscular fat (UIMF) and CIMF, the absolute difference (ADIF) between UIMF and CIMF, standard error of prediction (SEP), and product moment and rank correlation coefficients.

In further evaluation, steers in data set-II were divided into 8 classes based on the CIMF values. Classes were created by grouping steer CIMF values by nearly half standard deviation units (.85%). This was done to study any possible relationship between the amount of CIMF and the system's prediction capability. Effects of machine type, type of prediction equation (I, II, III, and IV), and CIMF groups on DIF and ADIF were tested based on a linear mixed model that included fixed effects of machine, equation type, CIMF group, machine×group interaction, random effects of steer within group, and an error term. Another created variable included in this analysis was the absolute difference between UIMF and CIMF corrected for the mean bias. That is,

$$\text{CADIF} = |\text{UIMF} - \text{CIMF} - \text{mean DIF}|$$

Results and Discussion

Means and standard deviations of CIMF measures and image parameters are shown in Table 1. The overall mean of CIMF was 4.44% (SD = 1.75%). Individual CIMF values ranged from 1.08 to 11.2%, but the majority (85%) of steers' CIMF values fell between 2% and 6.5% (figure not shown). A brief description of image parameter values is also shown in Table 1. A total of four Fourier-based parameters and two parameters each from the rest of the image processing techniques were used.

Regardless of machine type, the correlation between image parameters and CIMF followed the same direction (table not shown). For Aloka data, image parameters showed important linear associations ($P < .05$) with CIMF ranging from .13 to .53. For PIE data, correlations with CIMF ranged from -.06 to -.56, and except for the correlation of P5 and P10 with CIMF, all other values were different from zero ($P < .05$).

Model development

Model R^2 and RMSE values are shown in Table 2. For each machine type, models were developed based on data pooled within and across interpreters. The overall R^2 and RMSE of Aloka-based models were .71 and .87%, respectively. Except for model-III, prediction models showed comparable R^2 and RMSE values. For PIE models, the overall R^2 and RMSE were .67 and .89%, respectively. Like the Aloka machine, model-III showed the lowest R^2 and the highest RMSE.

Regardless of machine type, corresponding models based on data from Interpreter-I and -II showed comparable R^2 and RMSE values. The major exception to this was the low R^2 and high RMSE of PIE model-IV of Interpreter-I. However, the reason for this particular result was not understood.

Model validation

Initially, corresponding Aloka and PIE prediction equations from interpreters I and II were compared. However, all validation criteria did not show major differences between interpreters. Therefore, the following discussion includes validation results of Aloka- and PIE-based equations pooled across interpreters.

The overall mean CIMF for data set-II was 3.66 % (SD= 1.73%). The mean DIF for Aloka and PIE models were .42 and .67%, respectively (Table 3). This indicates that both systems often overpredicted steer PIMF values. Comparing models within machine type, Aloka models II and III showed a lesser mean bias than the rest of the models. However, the smallest mean bias for PIE models came from model-IV. Although the present level of accuracy is encouraging, due to the cancellation of negative and positive values, a mean bias closer to zero may not guarantee a perfect ranking. Furthermore, a difference in mean bias may not be the best criterion in ranking ultrasound systems for use with breeding cattle because the use of contemporary grouping in today's sire evaluation programs can effectively remove measurement bias common to all members of a group.

The overall average error as measured by ADIF was similar for both systems ranging from .83% to .86%. For Aloka models, model-II showed the smallest mean ADIF followed by model-III. However, PIE models-II and -IV ranked almost equally.

The overall SEP for Aloka models is slightly higher (.84%) than that of PIE models (.81%). For both Aloka and PIE models, Model-II outranked the rest of the models.

Besides other factors, the overall mean DIF, ADIF, and SEP included errors made during image capture and/or interpretation, and the experimental protocol used in this study does not allow partitioning of these components. However, relative differences between machines, type of prediction equation, and other effects could be tested to validate preliminary results shown hitherto.

Results from the analysis of variance table (not shown) indicated an important ($P < .05$) effect of machine type on DIF. However, differences between machines for ADIF and CADIF were not important ($P > .05$). Differences between prediction models for the three created variables were not important ($P > .05$). There was a significant ($P < .01$) effect of CIMF group on DIF and CADIF. The mid-CIMF values for classes 1 through 8 were, 1.43, 2.28, 3.13, 3.98, 4.83, 5.68, 6.53, and 7.38%. The respective number of steers per group was 7, 11, 19, 11, 9, 2, 7, and 5. The important effect of CIMF group on DIF suggests that the amount of bias introduced during prediction is related to the level of marbling. Even after correcting for mean bias, CIMF group seems to have an influence on the amount of prediction error (CADIF). However, the significance of group on CADIF seems to have resulted from relatively larger CADIF values in the last few groups represented by the few numbers of steers.

Machine×group interaction was important ($P<.01$) for all the three created variables. This important interaction effect suggests differences in the ranking order and/or in the relative difference between machines for DIF, ADIF, and CADIF at different CIMF groups.

The overall rank and product moment correlation coefficients ranged from .88 (Aloka) to .91 (PIE). However, differences in correlation coefficient between models within machine were not large and consistent enough to allow a clear ranking of models. The present correlation coefficients are generally encouraging. However, correlation coefficients as measures of system proficiency need to be used with caution due to their sensitivity to changes in sample variances.

System ranking is also evaluated based on the cumulative frequency of individual steer ADIF values. When averaged across the four Aloka models, about 34%, 54%, and 71% of steer PIMF values were measured within ±.5%, ±.75%, and ±1% error, respectively. The respective percentages of steers for each error category for PIE models were, 31%, 53%, and 69%. However, this interpretation of cumulative frequency results rests on the assumption of a perfectly normal distribution of errors with zero mean and some constant variance. But, as shown in previous discussions steer PIMF values were often over predicted.

Generally, the present results clearly indicate no true and consistent difference between Aloka 500V and PIE scanner-200 systems on prediction capability. Therefore, in the choice of ultrasound system, image processing software and prediction models may be more important than concerns over machine type. In addition, use of certified technicians and strict follow up of scanning and image interpretation procedures are of prime importance.

Implications

With the present technology, ultrasound techniques could be used to accurately predict PIMF in live cattle. In this endeavor, validation and updating of software used for the processing of Aloka and PIE images is critical. Major improvement in the accuracy of prediction could be achieved through increasing the development data set and the variation in PIMF of cattle used.

Table 1. Description of data used for model development

Item	Description	Aloka Mean	Aloka SD	PIE Mean	PIE SD
CIMF	Carcass intramuscular fat	4.44	1.75	4.44	1.75
Image parameters					
P1	Fourier parameter-1	11.88	1.87	7.58	1.67
P2	Fourier parameter-2	792.89	127.83	942.78	181.48
P3	Fourier parameter-3	101.26	16.81	64.61	11.05
P4	Fourier parameter-4	27.90	6.10	15.64	3.86
P5	Gradient parameter-1	20.16	2.27	22.23	3.56
P6	Gradient parameter-2	1.34	.14	1.29	.17
P7	Histogram parameter-1	.60	.27	.89	.34
P8	Histogram parameter-2	43.40	14.93	14.40	10.62
P9	Co-occurrence parameter-1	124.17	22.97	101.12	24.01
P10	Co-occurrence parameter-2	1.57	.05	1.52	.08

CIMF = carcass intramuscular fat.

Table 2. Regression parameters by machine and interpreter

Analysis by machine

	Aloka R2	Aloka RMSE	PIE R2	PIE RMSE
Overall	.71	.87	.67	.89
Model				
I	.72	.84	.68	.87
II	.72	.86	.70	.85
III	.69	.91	.64	.94
IV	.71	.86	.65	.91

Analysis by machine and interpreter

	Aloka				**PIE**			
	Interpreter-I		**Interpreter-II**		**Interpreter-I**		**Interpreter-II**	
Model	**R^2**	**RMSE**	**R^2**	**RMSE**	**R^2**	**RMSE**	**R^2**	**RMSE**
I	.73	.83	.71	.85	.69	.85	.68	.87
II	.72	.87	.72	.86	.71	.83	.70	.85
III	.70	.91	.68	.92	.65	.92	.63	.95
IV	.73	.84	.71	.86	.40	1.17	.64	.92

Table 3. Means of parameters used for validation of prediction models

	DIF		ADIF		SEP	Correlation	
Model	Mean	SD	Mean	SD		r_P	r_r
Aloka Models							
Overall	.42	.82	.83	.51	.84	.88	.88
I	.55	.85	.86	.52	.85	.87	.87
II	.32	.82	.68	.55	.82	.88	.89
III	.32	.85	.74	.52	.85	.88	.89
IV	.47	.85	.83	.51	.85	.87	.87
PIE models							
All	.67	.81	.86	.60	.81	.89	.91
I	.71	.76	.86	.59	.76	.90	.92
II	.70	.73	.82	.60	.73	.91	.90
III	.72	.86	.94	.60	.86	.87	.90
IV	.55	.87	.83	.61	.87	.89	.90

DIF = the difference between ultrasound and carcass intramuscular fat; ADIF = the absolute difference between ultrasound and carcass intramuscular fat ; SEP = standard error of prediction; r_p = product moment correlation; r_r = rank correlation.