

Use of Real-Time Ultrasound in % IMF Prediction for Swine

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November 27, 2007

Introduction

For the past 20 years, the swine industry has made a concerted effort to genetically reduce the amount of backfat and increase the percent lean yield on market hogs. The resulting dramatic reduction in backfat and increased loin eye area significantly reduced the percent of intramuscular fat (% IMF) because % IMF is genetically correlated with both of these traits (+.35 to +.45 with backfat and -.20 to -.25 with loin eye area). With numerous taste panel studies demonstrating that % IMF or marbling is positively associated with juiciness, flavor and tenderness, a growing part of the swine industry now wants to return some of the lost marbling.

Existing genetic improvement programs in swine for growth and carcass characteristics using EPD, coupled with the ultrasound live animal measurement program, provide an established vehicle to easily and quickly adopt intramuscular fat (IMF) measurement and prediction tools for producers. The goal of Biotronics is to capitalize on several years of research experience with ultrasound and prediction of IMF for the beef cattle industry and directly participate in the introduction of this technology on a national scale in a similar program for the swine industry.

In 2005, Biotronics submitted a proposal for the USDA Small Business Innovative Research (SBIR) Phase I grant program. Phase I research was focused on proof of concept. One of the objectives of this research project was to determine if improvements could be made to existing percentage intramuscular fat (% IMF) prediction models using real-time ultrasound images captured from live swine. Biotronics was successful in this grant application and was able to demonstrate improvements in % IMF. Biotronics then sought funding for the USDA/SBIR Phase II project and was successful in that venture as well. The two-year Phase II full scale research and development efforts are to complete the research initiated in Phase I. If the research continues to prove out, then Phase III will be commercialization of the technology. Many of the technological concepts being pursued under Phase II are proprietary in nature and will not be addressed in this paper. However, prediction results from the 9-month Phase I study are presented in this paper.

Research Components

There were two major research components associated with Technical Objective 1. The first component involved developing a fairly sizeable image/carcass data base that could be used for texture analysis and statistical analysis in % IMF prediction model development. The second component involved analysis of the data base to determine if new texture parameters could be defined that have % IMF predictive merit for swine tissue.

Database and Model Development

The procedure involved developing a database of ultrasound images captured on market-ready pigs, chemically determining the % IMF in the *longissimus dorsi (ld)* muscle for each animal scanned, and

performing a regression analysis to arrive at a % IMF prediction model using the texture parameters as the independent set of variables. After a prediction model is developed, it must be tested on multiple independent data sets to evaluate its robustness and accuracy. Several prediction models were developed and tested during the Phase I research.

Data

Biotronics subcontracted with Iowa State University (ISU) to supply the pigs used in the Phase I study and to assist with the scanning of the pigs by certified swine ultrasound technicians. All scanned pigs were of market weight (254±17 lb) and were harvested within 36 hours of scanning. There were 501 pigs scanned that were sampled to determine % IMF chemical analysis for use in model development and validation. Pigs came from both the ISU Swine Breeding Project and the National Barrow Show Progeny Test conducted in Ames, IA. Seven (7) different groups of pigs were scanned, beginning on May 4, 2006 and ending on September 7, 2006. Pigs from the ISU Swine Breeding Project were of primarily Duroc crossbred pigs with Yorksire being the predominant second breed. Pigs from the National Barrow Show Progeny Test included a mixture of different breeds being represented in each scanning group. Breeds included: Berkshire, Chester White, Duroc, Hampshire, Landrace, Poland China, Yorksire and a few crossbred pigs. Sexes included barrows and gilts.




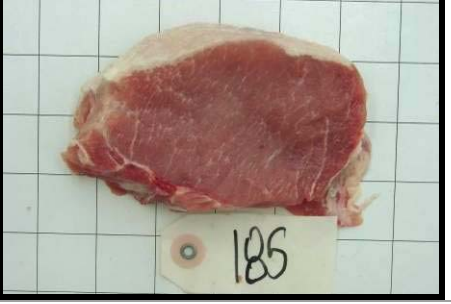
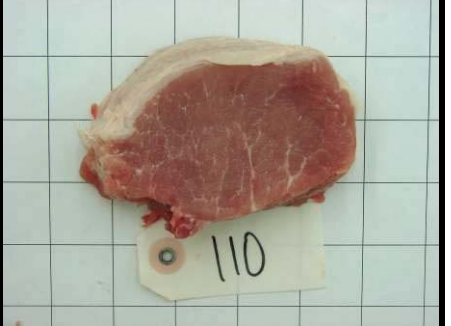
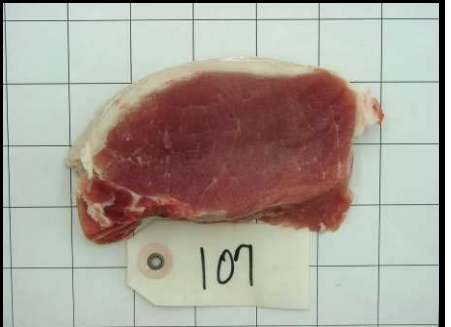
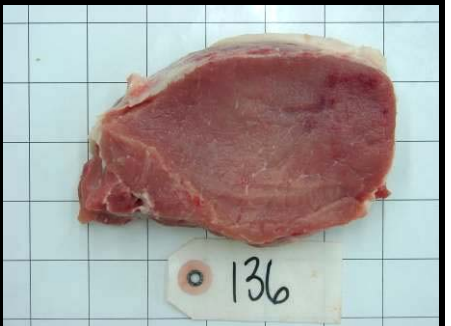
Figure 1 Scanning a live pig for % IMF.

Table 1. Carcass and Chemical % IMF for each of the Phase I scanning groups.

Scan Date (No. of Head)	Carcass weight, lbs±STD	Loin Muscle area, in ² ±STD	10 Rib Fat Depth, in. ±STD	Marbling Score±STD	Chemical Fat,% ±STD
05/04/2006 (80)	197±21	7.33±1.10	.72±.28	2.51±1.59	2.62±1.82
05/23/2006 (77)	192±21	7.40±0.90	.74±.27	3.05±1.16	2.41±1.07
06/26/2006 (37)	191± 9	6.14±0.86	1.05±.23	3.24±1.01	2.59±0.82
07/10/2006 (80)	190± 7	7.04±1.03	.95±.23	2.15±0.82	2.48±0.89
07/18/2006 (80)	186± 5	6.56±1.05	.95±.28	2.99±0.92	2.41±0.73
07/28/2006 (78)	192± 6	6.49±0.87	.98±.28	2.40±0.87	2.51±1.04
08/07/2006 (69)	181± 9	6.39±0.98	.79±.27	2.68±1.02	2.37±1.00

Table 2 is provided to give the reader an appreciation for the visual differences between loins with varying levels of intramuscular fat. The table also demonstrates that the subjective Marbling Score is not always in agreement with the actual chemical fat extracted from the tissue sample (for example, sample # 183).

Table 2. Pictures of loins from Validation Group 5 with accompanying Marbling Score and actual chemical % IMF values (the grid lines represent 1 in. x 1 in.)

<p>Chemical % IMF = 5.11% Marbling Score = 4</p>	
<p>Chemical % IMF = 4.10% Marbling Score = 4</p>	
<p>Chemical % IMF = 3.04% Marbling Score = 3</p>	
<p>Chemical % IMF = 2.03% Marbling Score = 2</p>	
<p>Chemical % IMF = 1.21% Marbling Score = 1</p>	

Scanning was done using three different ultrasound scanners, Aloka SSD 500V (Corometrics Medical Systems, Wallingford, CT) with a 12 cm transducer, Sonovet 2000 (Universal Medical, Bedford, NY) with an 18 cm transducer, and Aloka 900 with a 9 cm transducer. The transducer was aligned parallel to the midline of the animal, centered over the 10th rib, and approximately 6-7 cm off the midline. In most longitudinal images, one is able to easily see reflections off the 9-12 ribs.

The scanning technique is shown in the Figure 1 photo. The technician is holding the 12 cm transducer in his right hand, and he is also holding a freeze button in his left hand. When the technician believes the transducer is properly positioned, clicking the button will capture the image into the memory of the ultrasound scanner. A minimum of 4 independent images were captured for each pig.

Images were captured using the Biotronics, Inc. Blackbox Pro 5000 image capturing system (a notebook based system) shown in Figure 2. Images were stored on the hard drive of this system and then later transferred to a CD. [The Blackbox Pro 5000 image capturing software can be used with any notebook computer if the system has at least 1 USB port, a CD writer, and a type II PCMCIA card slot.]



Figure 2 BioSoft Toolbox® for Swine image capturing system.

During interpretation of each captured longitudinal image, a ROI box measuring 100 x 100 pixels was placed between the 10-11th ribs, above reflections of the rib tops and *intercostal* muscles, and below the hide and external fat tissue. Care was taken to make sure that the ROI was not placed within a region of the *longissimus dorsi* muscle that could be influenced by ultrasound signal loss or backscatter from the *trapezius* or *spinalis dorsi* muscles.

Priority in the Phase I analysis was given to the Aloka 500 images because this is the ultrasound technology currently being used by the majority of field technicians. The databases developed for each of three equipment types (Aloka SSD 500V, Sonovet 2000, and Aloka 900) are large and will be a valuable resource in the continued texture analysis research planned for Phase II. Each equipment type contained at least 4-5 images per animal on 500 animals, along with all of the carcass and chemical extract data. Images from the Sonovet 2000 and Aloka 900 will be incorporated into the Phase II research.

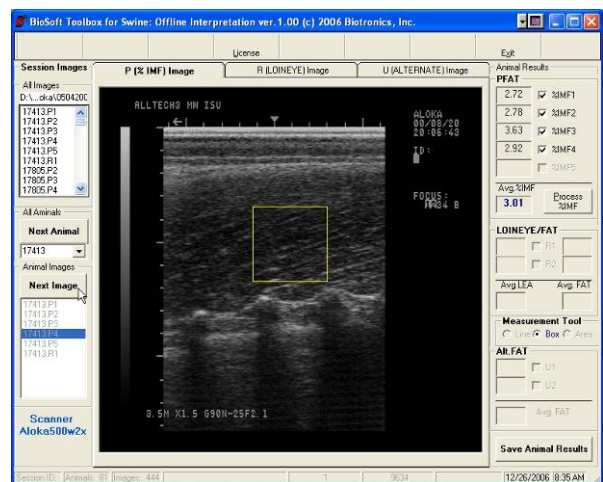


Figure 3 BioSoft Toolbox® for Swine Offline Interpretation software.

Each carcass was weighed and measured for carcass length, 10th rib backfat, last rib backfat, last lumbar backfat, and loin muscle area. After the carcasses were chilled, a three-rib section was removed and brought to the ISU meat laboratory for dissection, quality evaluation and chemical analysis for % IMF by the method of Bligh and Dyer (1959). Each sample was taken from between the 10th and 11th ribs to select a sample as close as possible to the ROI used in the image analysis.

The tissue sample (Figure 4) was trimmed so as to not contain loin muscle ends and was approximately 1 in. thick, 2.5 in. wide and 2 in. high. The objective was to ensure that the sample represented the same region of the *longissimus dorsi* that was captured with ultrasound. Additional loin muscle measurements included: subjective color score, subjective marbling score (1-10), subjective firmness score (1-3), pH measured at 48 hrs post-mortem, Minolta reflectance measured at 48 hrs (% reflectance) and Hunter L score measured at 48 hrs (1-100).



Figure 4 Tissue sample for chemical fat % determination of the scanned region of interest.

Statistics

Within the ROI, a series of ten (10) image texture parameters were calculated. These parameters have been shown to have varying degrees of correlation with % IMF in the *ld* muscle.

Correlations of individual texture parameters with actual chemical % IMF ranged from -.45 to +.54. Using RSQUARE, STEPWISE, and GLM procedures of SAS (SAS Institute, Inc.), alternative regression prediction models were defined and tested for prediction accuracy. The RSQUARE was used to identify potential models for further study using maximum R^2 and Mallow's C_p statistic. We used Mallow's statistic to help identify good model candidates by looking for submodels where C_p is both (i) small (suggesting small total error) and (ii) \leq number of parameters (suggesting small bias). Both first and second order polynomial models were considered. Accuracy statistics used were primarily model R^2 , RMSE, and distribution of residuals. The model is of the general form:

$$y_i, \% \text{ IMF} = b_0 + b_1 * p_{i1} + b_2 * p_{i2} + \dots + b_{10} * p_{i10} + e_i,$$

where,

y_i = chemical % IMF for the i^{th} animal meat sample,

b_j = regression estimates,

p_{ij} = j^{th} texture parameter values for the i^{th} animal (1st and 2nd order), and

e_i = random residual error for the i^{th} animal.

At least three classification or fixed effects (scanning date, animal sex, and breed) and other random effects (animal backfat depth and loineye muscle area) potentially have predictive power for % IMF. Excepting scanning date, these effects were not included in the model development because the objective was to develop a robust model that will work across a wide range of animal classification and body composition differences without the need to specify these effects when making predictions.

Results

The procedure was to develop potential prediction models from a subset of the data (scanning groups), and then apply those models against five independent data sets (scanning groups) not used in the model development. One model was optimized within each of three ranges of the independent variable actual chemical % IMF: $\leq 6\%$ (Model I); $\leq 4\%$ (Model II); and $\leq 3\%$ (Model III). The statistical properties for these models are presented in Table 3.

Table 3. Three prediction models developed for testing and validation.

Model	Ave. Actual % IMF,	No. Animals in Development Data Set	No. Parameters	C_p	R^2	RMSE, %
I	2.26	147	5	1.8	.66	.46
II	2.13	139	6	5.5	.53	.41
III	2.00	125	5	1.9	.42	.34

Correlations between predicted % IMF, actual chemical % IMF and visual Marbling Score for validation group 5 are summarized in Table 4. The correlations in Table 4 are representative of the other validation groups as well. The distribution of predicted % IMF values against actual chemical % IMF values for validation group 5 is shown in Figure 5.

Table 4. Correlation comparison of Model II predicted % IMF, chemical % IMF and visual marbling score.

	Model II % IMF	Chemical % IMF	Marbling Score
Model II % IMF	1.00	.64	.59
Chemical % IMF		1.00	.73
Marbling Score			1.00

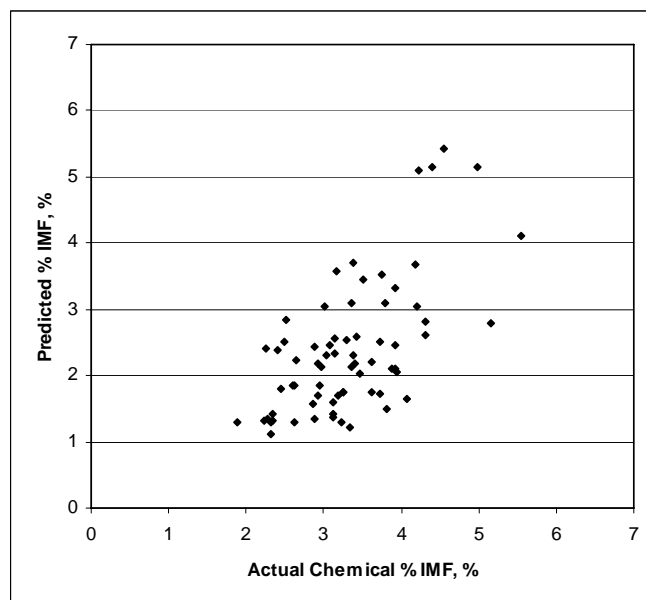


Figure 5. Distribution of predicted % IMF values plotted against actual chemical % IMF values for Validation Scanning Group 5.

Table 5. Validation analysis of two prediction models for % IMF in live swine.

	No. Animals	R ²	RMSE, %	Product Moment Correlation, r
Model II:				
Group 1	37	.35	.67	.59
Group 2	76	.26	.76	.51
Group 3	79	.08	.70	.29
Group 4	77	.29	.88	.54
Group 5	69	.42	.77	.66
Model III:				
Group 1	37	.32	.69	.56
Group 2	76	.32	.74	.56
Group 3	79	.13	.69	.36
Group 4	77	.26	.90	.51
Group 5	69	.47	.73	.69

Discussion

Newcom et al. (2002) reported on a swine % IMF prediction model that incorporated both animal ultrasound backfat and five image texture parameters. The R² and RMSE for their model were .32 and 1.02%, respectively. Schwab and Baas (2006) report on a % IMF prediction model for swine that used only ROI image texture parameters. The corresponding R² and RMSE for their model were .36 and 1.31%, respectively. The % IMF prediction models reported on this paper have similar R² values to both of the Newcom et al. and Schwab and Baas models when run on independent validation groups, with the exception of the Group 3 set of pigs. However, the RMSE results from the Biotronics research are smaller for all of the validation groups, which would indicate that model improvements are possible.

Phase II research is continuing to explore methods of improving the RMSE associated with prediction of % IMF in live animals and carcasses. A significant part of this research is the study of texture parameters that are being derived from the Phase I developed database. To this date, the prediction models for % IMF have relied solely upon texture parameters developed from beef cattle ultrasound data. As both muscle tissue characteristics and marbling distribution are significantly different from a visual perspective, it can be expected that we will be successful in the identification of additional texture parameters that can be used in % IMF prediction for swine.

References

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Acknowledgements

Biotronics, Inc. gratefully acknowledges the USDA/SBIR program for financial support and guidance from many of the reviewers on the Phase I and Phase II plans of work. Biotronics, Inc. also gratefully acknowledges the support of Iowa State University in the scanning and collection of the ultrasound and carcass data that are being used in this ongoing research project as well as Ohio State University for the use of their ultrasound equipment.