SOFTWARE PACKAGE AND APPLICATION SYSTEMS IN MEAT QUALITY EVALUATION AND PREDICTION FOR LIVE ANIMALS AND CARCASSES

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INTRODUCTION

There are three economically important traits under the current U. S. Beef Grading System: the distribution and amount of intramuscular fat (or marbling), the subcutaneous fat thickness, and the ribeye muscle size. These traits are also major factors used in evaluating body composition for genetic improvement. The marbling scores are visually graded by certified inspectors under the current USDA Beef grading system. There is a increased demand for an objective quality evaluation system from livestock producers, meat industries, and consumers.

In the past several years, our research efforts have been focusing on the development of on-line image analysis technologies and application systems in quality evaluation and prediction for live meat animals and carcasses.

In this paper, three aspects of our research and development will be described:

1. On-line image analysis for tissue characterization in the prediction of intramuscular percentage fat (%fat) from real-time ultrasound images.
2. Development of the software package - Quality Evaluation and Prediction (QEP) - for live meat animals and carcasses.
3. Application systems development: Model I and II for on-line applications and for research.

IMAGE AND DATA COLLECTION

Real-time ultrasound equipment Aloka 500v with a 3.5 MHz 17 cm linear array transducer was used to scan live beef animals. Two scan images were collected on each animal: one on the cross-sectional position with the transducer located between the 12th and 13th ribs; the other position with the transducer aligned parallel to the longitudinal direction across the 11-12-13th ribs.

For beef carcasses and swine, a 12.5 cm 3.5 MHz linear array transducer and Aloka 500v were used to do scans. For each carcass, the overlying subcutaneous fat layer was slit first, and then an image from the ribeye muscle across the 12-13th ribs was collected.

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Before the new system was developed, ultrasound images were recorded on video tapes and then digitized in the laboratory. With the software QEP part 1, the images can be digitized and saved directly on the hard drive of a portable computer on farms and at packing plants. This greatly saved time and also significantly improved the image quality .

The animals were slaughtered within one day after scanning, and a USDA marbling score was graded by certified inspectors for each carcass. A cross-sectional slice of the ribeye muscle between the 12th and 13th ribs on each animal/carcass was used to obtain the actual percentage of fat (called actual %fat) by using an n-hexane chemical extraction.

From 1991 to 1993, more than 5,000 live beef animals were scanned on farms; of these, 800 used to collect the chemically determined actual %fat after slaughtered. One thousand and five hundreds beef carcasses were scanned in a packing plant and actual %fat data were obtained for 860 of them. One hundred and fifty images and related data were collected from swine in Kansas (DEKALB Swine Breeders, Inc.). All these images and data built up a valuable data base for research.

The images were randomly divided into two groups. The first group of images were used to develop prediction models for %fat and the remaining images in the second group was used to test the accuracy of the prediction models.

For each image, an optimal region of interest above the 12th and 13th ribs was selected to do image analysis for tissue feature extraction in the development of prediction models.

IMAGE ANALYSIS AND PREDICTION MODELS DEVELOPMENT

Image analysis, signal processing, and ultrasound techniques have proved to be effective tools for meat quality grading.[1,2]

The approaches used in our research are image analysis for tissue characterization first, and then the development of prediction models of %fat for live animals and carcasses.

Different image analysis approaches, both in the frequency spectrum domain and in the gray-scale intensity domain, were investigated for their ability to extract tissue features for the prediction of %fat. Four of them are: gray-scale statistical analysis, gray-scale spatial texture analysis,[3] frequency spectrum texture analysis, and moment description.[4]

All the parameters derived from the image analysis were further analyzed and the prediction models for the %fat were developed by statistical analysis using SAS software.[5] Person's product moment correlation and Spearman's rank correlation procedures were used to detect the correlations between the parameters and the chemically determined actual %fat. Only the parameters that showed significant correlation with %fat and were not mutually highly correlated were considered for further analysis for prediction models.

Multiple regression analysis and a neural network were applied for the development of prediction models. The first group of data was used to develop multi-variable prediction models. The second group with the remaining images was used for validation testing of the prediction models. Correlation, regression, and residual analysis were performed on the predicted %fat versus actual values for all models in the validation testing.

Root mean square error (RMSE) and correlation coefficients describe the accuracy of the prediction. For live beef animals, correlation coefficients between predicted %fat and actual %fat ranged from .65 to .90 and the RMSE ranged from 1.10 to 1.14 on 64 to 70 percent of the population depending on the prediction models and different data sets used.

For carcasses, correlation coefficients between predicted %fat and actual %fat ranged from .70 to .81, and the RMSE ranged from .93 to 1.12 depending on different prediction

models and the data sets used. The RMSE is improved over that for live animals. One of the possible reasons is that removing the hide and fat layer could enhance the quality of ultrasound images.

Another test of fit, particularly for bias, is to regress predicted %fat on actual %fat and look at the intercept and slope of the regression. An optimum fit would be an intercept of zero and a slope of one.

Figure 1 presents the results from residual frequency analysis of one of the models for beef carcasses. From the figure, it can been seen that about 88 percent of the carcasses were predicted to within 1.5 percent residual error and about 99 percent fell within 2.0 percent. The frequency analysis results of residuals are especially encouraging.

Research on the prediction in swine is progressing, with preliminary results expected soon.

DEVELOPMENT OF THE SOFTWARE PACKAGE - QEP

In order to transfer the research results and technologies into practical applications, the software package - Quality Evaluation and Prediction (QEP) - were developed for live meat animals and carcasses.

This software package includes three independent programs:

- QEP-1: On-line image digitization and collection from video resources, such as VCR, ultrasound equipment, and cameras.
- QEP-2: Quantitative measurement for fat/hide thickness and ribeye/loin muscle size. Erasing traced line and re-tracing are available while measuring muscle size.

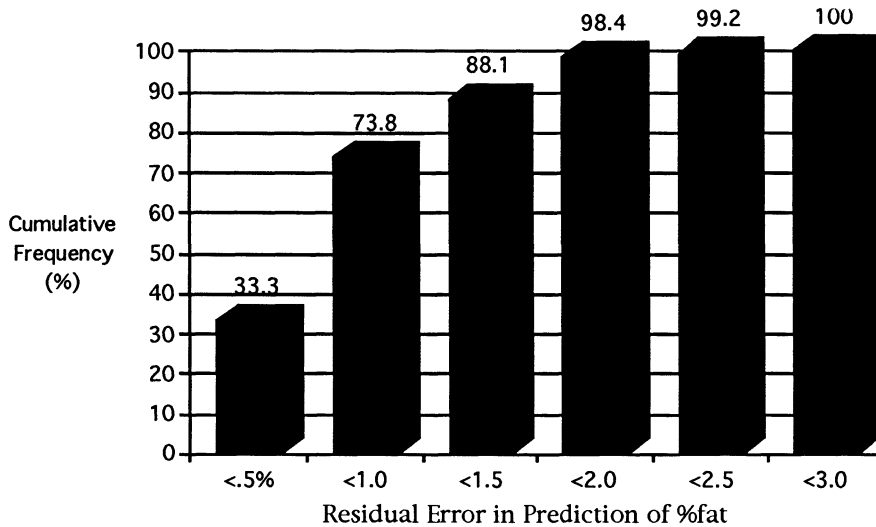

Figure 1. Cumulative frequency (%) versus residual errors of %fat prediction for validation testing of prediction model for carcasses.

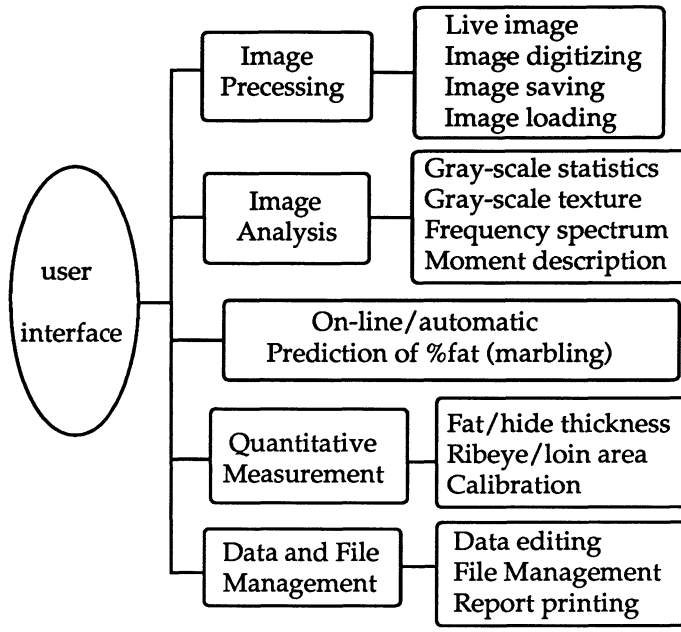

Figure 2: Functional diagram of the QEP.

- QEP-3: On-line/automatic prediction of intramuscular percentage fat for live beef animals and carcasses. All the image analysis functions for tissue characterization are included in this program.

The functional diagram of the QEP is illustrated in Figure 2.

The QEP is a menu-driven flexible software written in C/C++ and Assembly languages. Assembly language is used to directly access the hardware and memory, so the program can run very fast.

APPLICATION SYSTEMS FOR DIFFERENT USERS

To reduce cost and increase efficiency, the high-performance and low-cost application systems are developed for on-line applications and research. The application systems are designed for using on IBM or compatible personal computers with one half length expansion slot available for a video frame grabber board. Portable PCs are recommended for on-line applications. The QEP is a independent software package. No special software and no MS windows are required to support the QEP. The video resources can be VCR, camera, or ultrasound equipment, such as Aloka 210/500. The video monitor can be black/white or RGB color. The computer monitor can be a LCD display.

Two distinct models will be available depending on the application environment and requirement. Model I displays images on a video monitor screen. It is designed for the users with an external video monitor or some machines with video screen, such as the ultrasound equipment Aloka 500v. Model II, which displays the images on the computer screen, is for

the applications without an external video monitor. Most of the functions of the two models are the same. Model I is also suitable for use in research and in laboratories.

With the portable systems, users can process the images and get the fat thickness, ribeye muscle size, and predicted %fat directly on farms or at packing plants. The images and processed results can also be easily transferred to other computers or workstations for further processing or analysis.

RESULTS AND DISCUSSIONS

Using the real-time ultrasound technique and the QEP systems, the accuracies of %fat prediction shown in table 1 can be obtained for live beef animals and carcasses on 64 to 70 percent of the population. The accuracies of measurement for fat thickness and ribeye muscle area is shown in table 2.[6]

In all, to June 1994, more than 5,600 images have been collected from live beef animals, 1,500 from beef carcasses, and 150 from swine, and the prediction of %fat has been done for more than 4,000 live animals.

The automatic prediction of %fat for beef carcasses started to be used in a packing plant in Minnesota on May 26, 1994, opening a new application area for the first time. To use the automatic prediction program, users need only give the directory name for the images and the desired output file name for the predicted results. All the on-line image analysis and %fat prediction can be done automatically in a few seconds for each carcass.

Although the QEP was developed primarily for live beef animals and carcasses, the prediction of %fat can also be used for other species, such as swine, as long as an appropriate prediction model is available. The distance and area measurement can be used for any kind of image, as long as the active image window is adequate. The on-line image analysis procedures can also be used for many different purposes and applications.

The QEP system is expandable and flexible. More hardware, such as A-mode signal processing and/or image processing boards, can be integrated into the system as long as enough extension slots are available in the computer. Some new features or options can also be added along with the hardware or updated alone.

The field-portable systems can quantitatively evaluate all three important traits on live animals, namely intramuscular fat, subcutaneous fat thickness, and ribeye muscle size. The systems have been effectively used for thousands of live animals since 1993 and also used for carcasses in on-line/automatic prediction of intramuscular fat. The results indicate that the software package QEP and the on-line application systems are valuable tools in meat quality evaluation and prediction for livestock producers and meat industries.

Table 1. Accuracies of %fat prediction.

	Correlation	RMSE, %
Live anmals	.65 - .90	± 1.10 - 1.14
Carcasses	.78 - .81	± .93 - 1.12

Table 2. Accuracies of measurement.

	Correlation	RMSE
Fat thickness	.84	64.2% < 0.1 in.
Ribeye area	.77	69.7% < 1.0 sq.in.

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