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Predicting Aged Beef Tenderness with a Hyperspectral Imaging System

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Summary

A hyperspectral imaging apparatus was developed to predict, at 2-day postmortem, the 14 day aged tenderness of beef. USDA Choice and Select grade longissimus steaks (n = 314) from between the 12th and 13th ribs were scanned at 2 days postmortem, vacuum packaged, aged to 14 days, and frozen. For tenderness determination, steaks were thawed overnight, scanned, cooked in an impingement oven, and slice shear force values were obtained. The model predicted three tenderness categories (tender, intermediate, tough) with 77.1% accuracy, and two tenderness categories (acceptable, tough) with 93.7% accuracy. This hyperspectral imaging system was effective in predicting 14-day aged beef tenderness from 2-day scans.

Introduction

The development of an accurate, noninvasive, on-line beef tenderness predictor has been a long time interest of the beef industry because tenderness is commonly cited among consumers as a major concern, and they are willing to pay a premium for guaranteed tender product. The prediction device would need to accurately forecast 14-day aged tenderness from scans of the product at 2-day postmortem, since product typically reaches the consumer at 14-day postmortem.

Hyperspectral imaging captures multiple reflectance images, giving each pixel in an image its own spectral data. These imaging systems have been used to determine nutrient deficiency in plants, fecal contamination in chicken, and fungal/bacterial contamination in fruits. In the *2007 Nebraska Beef Report*, pp. 97-99, our research group reported a 96.4% accuracy in predicting 14 day beef tenderness from 14-day scans. Due to the success of the previous research, the objective of this research was to develop and validate an accurate, non-invasive tenderness instrument that accurately predicts 14-day aged beef tenderness from scans of 2-day aged beef.

Procedure

Hyperspectral imaging apparatus

A hyperspectral imaging apparatus (Figure 1) was constructed by integrating an InGaAs digital video camera and a spectrograph. The spectrograph has a spectral range of 900-1700 nm. Complete system specifications are described in *2007 Nebraska Beef Report*, pp. 97-99.

Data Collection

USDA Choice and Select grade longissimus steaks from between the 12th and 13th ribs at 2 day postmortem were cut to 1-inch thickness and scanned by the imaging system. Prior to the first scan, and periodically throughout data collection, a reference measure was obtained by measuring a 100% and 0% reflectance plate. Steaks were placed on a Teflon-coated plate mounted on a linear slide that utilized a stepper motor for movement. The steak was then scanned by the camera to obtain a three-dimensional data cube (reflectance by two-dimensional position). Images were obtained at wavelength intervals of 2 nm. After imaging, 2 day aged steaks were vacuum packaged, aged to 14 days and frozen. Steaks were later thawed overnight, scanned and cooked immediately on an impingement oven to an internal temperature of 157-162°F. Slice shear force (**SSF**) values were obtained by an Instron Texture Analyzer.

Statistical Analysis

From each image, a region-of-interest (**ROI**) was selected corresponding to the approximate shear

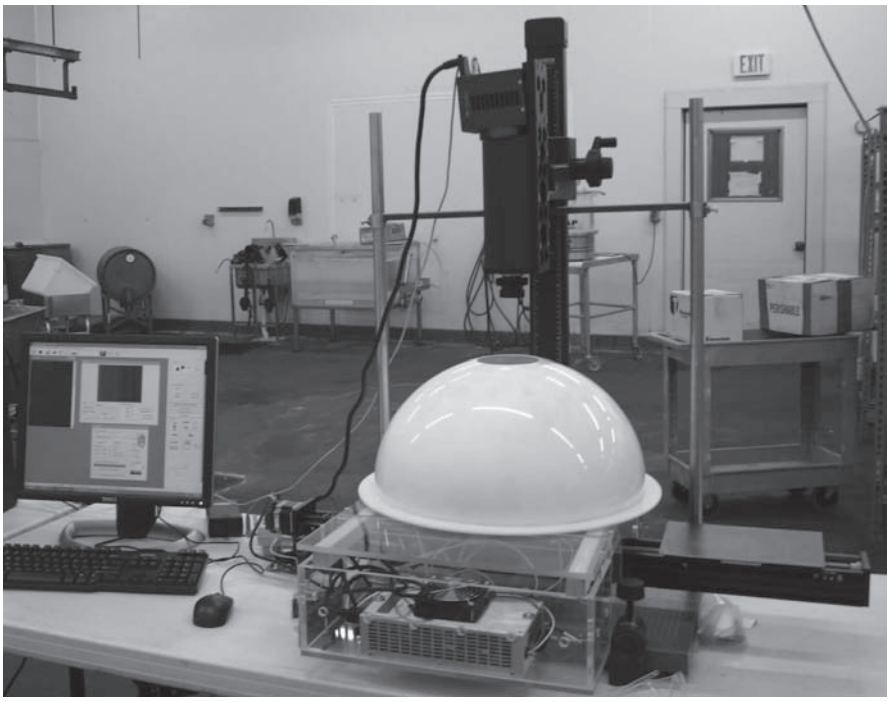

Figure 1. Hyperspectral imaging apparatus.

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Table 1. Hyperspectral tenderness prediction vs. actual shear force tenderness.

	Predicted Categories			
Actual Categories	Tender[a]	Intermediate[b]	Tough[c]	Total
Tender[a]	200	47	9	256
Intermediate[b]	8	32	2	42
Tough[c]	3	3	10	16
Total	211	82	21	314

[a]≤ 46.30 lb SSF.
[b]46.31-57.1 SSF.
[c]≤ 57.32 lb SSF.

location, and further image processing was performed on the ROI. By averaging the spectra of all ROI pixels, a mean spectrum of the ROI was obtained. The mean spectra (n = 314) were then analyzed with partial least squares (**PLS**) regression, and the loading vector was obtained. Each pixel of the ROI was then multiplied by the loading vector, thus generating PLS bands. To extract the textural features from the PLS bands, textural co-occurrence matrix analysis was conducted, and from these extracted textural features, a canonical discriminant model was developed. By implementing a leave-one-out cross-validation procedure, the developed model (from 2 day scans) predicted the three tenderness categories (defined by 14 day SSF), which are: tender $\leq$ 46.30 lb; 46.31 $\leq$ intermediate $\leq$ 57.31 lb; tough $\geq$ 57.32 lb.

Results

Of the 256 tender SSF steaks, 200 were accurately classified by the system as tender, 47 were misclassified as intermediate and 9 were misclassified as tough, for an accuracy of 78.1%. From the 42 intermediate SSF steaks, the system correctly classified 32, but misclassified 8 as tender and 2 as tough, for an accuracy of 76.2%. Of the 16 tough SSF steaks, 10 were classified by the system as tough, while 3 were misclassified as tender and 3 were misclassified as intermediate, for an accuracy of 62.5%. These results yielded an overall accuracy of the imaging system to be 77.1%. Intermediate SSF values are actually "acceptable" in tenderness to consumers. By merging the tender and intermediate groups together, thus only sorting two categories (acceptable from tough), this system correctly classified 287 out of 298 consumer acceptable steaks (96.3%). This yields an overall accuracy of 93.7% for sorting acceptable from tough. Table 1 shows the classification of steaks by the hyperspectral imaging system vs. the actual SSF categories of those steaks.

Implications

This hyperspectral imaging system was effective at predicting 14 day tenderness of beef longissimus steaks from 2-day postmortem scans. Implementation of a noninvasive tenderness prediction system may result in "guaranteed tender" premiums for beef products that may benefit producers and the industry as a whole.

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