Project Summary

Augmentation of Near Infrared (NIR) and In-plant Beef Video Image Analysis (VIA) Systems to Sort Carcasses into Tenderness Categories

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Study Completed
May 2008

Funded by The Beef Checkoff

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Background

As part of its effort to implement value-based marketing, the beef industry began investigating the use of instruments to improve characterization, sorting and pricing of cattle and beef carcasses nearly three decades ago.

Work continues to enhance video image analysis systems, so that they can more accurately sort carcasses for various attributes. Accurate tenderness prediction could be one of the most valuable aspects of video image analysis and would create more value-based marketing opportunities for producers.

The objectives of this study were:

1. To validate the effectiveness of augmenting an in-plant, video image analysis (VIA) system with a near-infrared (NIR) system to obtain an accurate 14-day tenderness prediction;
2. To determine the combined effect of near-infrared and video image analysis on the effectiveness of predicting seven-day and 14-day tenderness from four subprimals in various quality grades, observe if a relationship exists between predicted *longissimus* shear force and tenderness of short-term muscles, and obtain consumer perceptions of *longissimus* steaks that were categorized as "tender," "intermediate," or tough.

Methodology

This project was conducted in two phases. In the first phase, steer and heifer carcasses (n = 191) from USDA Prime (n = 5), Premium Choice (n = 28), Low Choice (n = 60), Select (n = 89) and Standard (n = 9) quality grades were randomly selected from a commercial processing facility.

Following a 24-hour chill period, carcasses were ribbed between the 12^{th} and 13^{th} ribs and were allowed to bloom for approximately 15 minutes before reaching the grading stand. The *longissimus thoracis* (LT) right sides were scanned with an in-plant VIA camera on the 12^{th}-13^{th} rib interface. NIR scanning was also done on the same *longissimus thoracis* surface that had been scanned with the VIA camera. Reflectance measurements were also taken with a spectral device.

After NIR scanning, carcass grade data factors were collected for preliminary yield grade, adjusted backfat thickness, kidney, pelvic and heart fat percentage (KPH), lean maturity, skeletal maturity, and marbling score. Hot carcass weight and carcass identification numbers were also collected. Once grade data collection was complete, a 7.5 centimeter ribeye section was removed from the right side of each carcass, individually bagged and transported to the Oklahoma State University Food and Agricultural Products Research Center for further analysis. At approximately 48-hour postmortem, the *longissimus thoracis* sections were cut perpendicular to the muscle fiber orientation to produce one 2.54 cm steak, which was designated for a 14-day aging period.

Slice shear force was used to evaluate tenderness. The researchers classified any steaks with a 14-day slice shear force value greater than 25 kilograms as "tough," 19-25 kilograms as "intermediate," and less than 19 kilograms as "tender."

In Phase II, native beef steer and heifer (n = 193) from upper two-thirds Choice (n = 38), Low Choice (n = 75), Select (n = 76) and Standard (n = 4) quality grades were randomly selected at a commercial processing facility. After the carcasses were ribbed between the 12th and 13th rib, the *longissimus thoracis* on the right side of the carcasses were scanned with an in-plant VIA camera on the 12th rib interface.

The researchers noted that between the time that Phase I and Phase II of the project was conducted, the commercial beef processing facility replaced the existing in-plant VIA camera with one from a different manufacturer. As a result, some variables that were examined during Phase I could not be evaluated in the second phase of the project.

NIR scanning was conducted on the same LT surface that had been scanned with the VIA camera. Reflected light was also collected through a spectral device.

Carcass grade data factors were collected for lean maturity, skeletal maturity and marbling score by USDA graders. Hot carcass weight and carcass identification numbers were recorded.

Ribeye rolls (*m. longissimus thoracis*; NAMP/IMPS 112), clods (*m. triceps brachii*; NAMP/IMPS 114), top sirloins (*m. gluteus medius*; NAMP/IMPS 184) and inside rounds (*m. semimembranosus*; NAMP/IMPS 169A) were fabricated. Seven days postmortem, two steaks were fabricated from the anterior end of each subprimal and individually identified for seven-day or 14-day aging periods, and were subsequently analyzied for shear force. Additional steaks were fabricated for use in a consumer study.

In the consumer study, steaks were categorized based on their respective NIR predicted 14-day slice shear force values:

- ≤ 18.99 kg (tender)
- 19.00 to 24.99 kg (intermediate)
- ≥ 25 kg (tough)

The steaks were prepared in-home by the consumer panelists and were evaluated through a questionnaire provided by the researchers.

Findings

Phase I

Significant differences in slice shear force values were observed between quality grades. Prime and upper two-thirds Choice steaks had slice shear force values that were significantly different from low Choice, Select and Standard steaks. In spite of the majority of steaks falling into the expected tenderness categories, there were a few tough samples observed in both the Prime and premium Choice categories. The researchers observed that even though superior quality was achieved based on grading factors, other intrinsic factors such as water holding capacity, connective tissue and state of the myofibril played very significant roles in steaks' overall tenderness outcome.

Steaks in the low Choice and Select grades had slice shear force values associated with tender beef and some associated with tough beef, illustrating the need for a non-invasive system to sort out those steaks and place them into classifications that more accurately reflect their tenderness rating.

After obtaining slice shear force values for each steak, they were combined with VIA data and a regression equation was developed. The resulting equation generated 16 significant independent variables that could be used to predict 14-day slice shear force value. Five components were deemed highly significant ($P < 0.0001$) in the prediction of slice shear force value. As a result, the researchers concluded that the data generated by the NIR camera was highly significant in providing information about traits that may be linked to overall tenderness ratings.

In addition to hot carcass weight, video image ribeye length, area, a*and b* color values, marbling and adjusted marbling of specific sections were shown to contain information about tenderness and reflect their significant role in tenderness prediction. The importance of a* values might be a reflection of the amount and state of myoglobin, which can be related to an estimation of the overall lean maturity of the animal. As an animal gets older, myoglobin deposition increases and overall meat tenderness tends to decrease.

Overall, 141 out of 191 samples (73.8 percent) were correctly predicted and placed into their tenderness category. Most of the 50 incorrect classifications were due to slice shear force values approaching the tender/intermediate and intermediate/tough boundaries. The researchers also noted that there were some samples that the regression analysis completely missed and the researchers hypothesized that this was due to variances during data collection by the camera, over-cooking during slice shear force analysis, or physiochemical traits (background toughness, extreme cook loss, etc.) that were made more prevalent during the aging and cooking periods. The researchers felt that these inaccuracies were minimal.

Table 1. Accuracy of VIA and NIR systems to correctly place samples into tenderness categories

Actual SSF Category	Predicted SSF Category	# Predicted Correctly	Total # of Samples	% Predicted Tenderness
Tender	Tender	42	63	66.6
Intermediate	Intermediate	63	80	78.8
Tough	Tough	36	48	75.0
Total		141	191	73.8

Of significance was the fact that no steaks were predicted to be tender and were actually tough, and no steaks were predicted as tough and were actually tender. Overall, the researchers felt the system was effective in sorting samples into correct tenderness groups.

Color data generated by the VIA camera was more useful in tenderness prediction than NIR visible data. The researchers hypothesized that this may be due to the VIA camera's ability to more precisely analyze L*, a* and b* color values for lean and fat.

Phase II

In this phase of the project, 145 out of 191 samples (75.9 percent) of the samples aged for seven days were correctly predicted and placed into their tenderness category.

Table 2. Accuracy of VIA and NIR systems to correctly place samples aged for seven days into tenderness categories.

Actual SSF Category	Predicted SSF Category	# Predicted Correctly	Total # of Samples	% Predicted Tenderness
Tender	Tender	73	91	80.2
Intermediate	Intermediate	54	71	76.1
Tough	Tough	18	29	62.1
Total		145	191	75.9

Similar to Phase I, the largest number of incorrect predictions was observed in samples that were predicted to be intermediate when they should have been classified as tender. The researchers attributed this to a majority of the samples having slice shear force values very close to 19 kilograms of force. The results indicate that the regression equation developed as part of this project had an easier time predicting and sorting tough samples compared to tender samples.

In the samples aged for 14 days, 110 out of 191 samples (57.6 percent) were correctly predicted and placed into their tenderness category. Unlike Phase I of the project, the largest number of incorrect predictions was observed in samples that were predicted to be intermediate when they should have been classified as tough. This result was unexpected by the researchers as the results of Phase I implied that NIR and VIA systems had an easier time sorting out the tough samples. However in this set of 14-day aged steaks, the majority of the observed tough samples had slice shear force values that were between 25.00 and 25.99 kilograms. This seemed to cause the equation to classify more samples as intermediate when they were actually tough.

Table 3. Accuracy of VIA and NIR systems to correctly place samples aged for 14 days into tenderness categories.

Actual SSF Category	Predicted SSF Category	# Predicted Correctly	Total # of Samples	% Predicted Tenderness
Tender	Tender	57	81	70.4
Intermediate	Intermediate	44	71	62.0
Tough	Tough	9	39	23.1
Total		110	191	57.6

Results observed from Phase I and Phase II of this project indicate that there is some promise in incorporating NIR spectroscopy into VIA scanning technology already in use in commercial beef processing facilities. Based on the results of this project, tough steaks were easier to identify and correctly predict than tender or intermediate steaks. Eliminating tough steaks from the retail population would give retailers the ability to market beef as a premium quality product that is guaranteed.

The ultimate goal of this research was to accurately predict *longissimus* tenderness which would translate into carcass tenderness. Inherent variation in the vision scanning systems could be further minimized by regularly testing a percentage of carcasses for slice shear force (SSF) values predicted to be tough. The researchers felt the advantages of doing so would outweigh the costs of conducting SSF analyses on a certain number of carcasses per day. Based on the results of Phase II, the researchers felt that SSF validation would only need to be conducted on 90 carcasses per day at a facility that processes 6,000 head daily.

Correlations between the beef quality attributes studied and NIR data suggest that this non-destructive technique has the potential to produce useful predictive models, especially in the case of slice shear force. However, prediction of other subprimals using one equation generated at the grading line was not successful. Additionally, NIR spectroscopy of the ribeye provided beneficial data about other subprimals, but when combined with ribeye VIA data, could not accurately place subprimal steaks into the correct tenderness categories.

Implications

This study indicates that the combination of NIR spectroscopy and VIA has the feasibility to predict shear force values of beef steaks during the aging process up to 14 days. Continued work to more accurately sort carcasses based on their quality attributes will help advance industry goals to provide more consistent beef products, and ultimately increase consumer demand.

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