Project Summary

High-resolution Imaging and Beef Tenderness

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Background
Since the beginning of beef quality grading, subjective evaluation of marbling and maturity has attempted to categorize beef carcasses into groups based on predicted eating quality. Utilizing conventional grading systems, over 75% of carcasses fall into a narrow range of quality grade (USDA Select through low Choice). Within this range, it has been proven that marbling alone is not sufficient to explain the majority of the variation that is seen in palatability traits, specifically with regard to tenderness. Consequently, during meetings of the National Beef Instrument Assessment Plan (NBIAP) held in 2002 and 2007, the need was identified for a technology that could rapidly identify differences in predicted tenderness of carcasses during grading.

Through the use of high resolution imaging, scientists may be able to better explain the effect of the specific features on muscle color, and ultimately augment current prediction equations for beef tenderness. High resolution imaging possesses the capability to obtain information on the microscopic level related to muscle structure. Specifically, the technology is able to obtain information related to muscle fiber size and potentially muscle connective tissue content. The Tenera Technology system represents the first technology able to function and obtain these variables within a commercial setting.

Methodology
Carcasses (N = 150) were selected from three beef processing facilities in Colorado, Nebraska and Texas. Carcasses were selected such that approximately one-third came from USDA Standard through the bottom half of the Select grade (Marbling Score (**MS**) ≤ Slight^{40}), one third from the upper half of the Select grade (MS ≥ Slight^{50}) through USDA low Choice and one third from upper two-thirds choice and better. Carcasses supplemented with Zilpaterol hydrochloride (n = 25) were noted based on harvest facility records. A sample of the *Longissimus dorsi* was taken immediately posterior to the 12th/13th rib interface. Samples were imaged under the Tenera Technology High Resolution Imaging system (Tenera Technologies, Boulder, CO). This system utilized a Canon 5D camera with a 15 megapixel imager (4770 x 3177 pixels) – by comparison, a television screen is approximately 300 x 500 pixels. The camera and lens were mounted to a ZenBot 1216 CNC router (Zenbot CNC, Tulare, CA). Three-axis (x, y and z) movement of the router was controlled via custom developed ZARMT software (Tenera Technology, Boulder, CO). The ZARMT software allowed for automated focus of the camera through control of movement on the z-axis. Illumination was accomplished using a small battery powered LED system mounted at approximately a 45^{0} angle to the sample surface. Color measurements (L^*, a^* and b^*) were obtained (Miniscan XE Model 45/0-L, Hunter Laboratories, Reston, VA).

Samples were transported in vacuum package bags on ice packs within coolers to the Colorado State University Meat Laboratory where they were fabricated into equal portions and assigned to a 7-day and 14-day aging period. Following completion of the aging period, samples were frozen, and then fabricated into 1 inch thick steaks using a band saw (Model 400, AEW-Thurne, AEW Engineering

Co. Ltd, Norwich, England). Steaks were thawed at 2^0C for 36-hours prior to Warner-Bratzler shear force (WBSF) determination. Steaks were cooked on a belt grill (model TBG-60, MagiGrill, MagiKitch'n, Inc., Quakertown, PA) for 6 minutes, 28 seconds at a setting of 163^0C for the top and bottom heating plates, to a target internal temperature of 71^0C. Following cooking, steaks were permitted to equilibrate to room temperature (22^0C). Cores (one or two, 1.27 cm in diameter) were removed from six locations on each steak in a manner such that each core was parallel to the orientation of muscle fibers. These locations were approximately the same regions from which images were obtained during sample collection. Cores were sheared perpendicular to the muscle fiber orientation using a universal testing machine (model 4443, Instron Corp., Canton, MA). Images were analyzed in a multistep procedure in which all non-muscle components of the image were first removed, followed by conversion of the final image into a 1-dimensional waveform from which features could be extracted. The predictive ability of the variables generated by the Tenera Technology High Resolution imaging system was determined by developing regressive prediction models.

Findings

Simple correlation coefficients demonstrating the relationship between all variables and 7-day and 14-day WBSF are presented in Table 1. Marbling score (MS) exhibited the greatest predictive capability for both 7-day and 14-day WBSF. Color variables (*L**, *a** and *b**) all showed some predictive ability for 7- and 14-day WBSF, however, some of the relationships between these variables and WBSF are in contrast to several previously published experiments. Reasons for this may include differences in pre- and post-harvest interventions currently employed that were not available at the time of the previous work, as well as differences in sample size and sample selection criteria. The correlation between the variables generated by the Tenera Technology High Resolution Imaging system and color variables was low, indicating that the traits measured by the software program are indeed new attributes that have not been associated (through color measurement) with WBSF previously. This is essential to the merit of the technology as it indicates potential for an enhanced tenderness prediction model utilizing color measurement and variables such as those generated by the Tenera Technology High Resolution Imaging system.

Utilizing several of the high resolution variables, a small and additive increase in the WBSF predictive capability resulted. The 14-day equation was accurately able to classify 94.7% of tender steaks and 81.8% of tough steaks; the best performance that Colorado State University researchers have ever achieved with a tenderness prediction technology. Within the 7-day population, use of high resolution variables increased the capability in the classification of "tough" from "tender" by approximately 10%. This may be due to substantially greater influence of muscle structure on WBSF at this aging period. Typical of any bench-top device, numerous issues surrounded the initial use of the Tenera Technology High Resolution Imaging system. Most critically, the sample population was such that there were very few "tough" samples to allow for ideal algorithm development. Mechanical issues with the system specifically related to illumination resulted in less than ideal image output. Moreover, given a chance to better analyze the images collected, researchers may be able to extract further variables form the muscle surface that may prove relevant to tenderness prediction. Nonetheless, the technology was able to produce variables that had an additive effect when coupled with color measurement. These results indicate that variables generated by the Tenera Technology system are measuring muscle qualities that have not previously been assessed by traditional measures of muscle color. With increased development of the equipment, the usefulness of these variables should be greatly improved.

Implications

In seeking to provide a uniform, consistent and highly palatable product to the consumer, technologies such as the Tenera Technology High Resolution Imaging system could prove essential information to better classify the majority of the beef carcass population that falls into a narrow range of USDA quality grade. Prediction of palatability attributes such as tenderness is vital to growing consumer demand for beef and ultimately the sustained profitability of our nation's beef producers

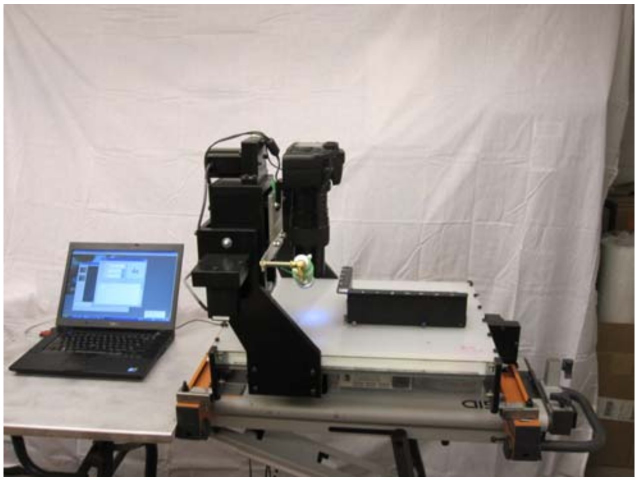
Table 1. Correlation coefficients of traits with 14-day and 7-day Warner-Bratzler shear force (WBSF, kg).

	Subset A[b]		Subset B[c]	
Trait[a]	14-day WBSF	7-day WBSF	14-day WBSF	7-day WBSF
Marbling score	-0.31	-0.37	-0.65	-0.44
L*	0.08	0.17	0.38	0.46
a*	-0.17	-0.16	-0.53	-0.28
b*	0.12	0.18	-0.66	-0.39
lensSml	0.04	0.06	-0.02	-0.12
areaSml	0.04	0.06	-0.01	-0.11
lensLrg	-0.02	-0.04	-0.03	0.13
areasLrg	-0.04	-0.05	-0.003	0.16
ratLen	-0.03	-0.05	-0.02	0.12
ratArea	-0.04	-0.05	-0.02	0.11
medLen	-0.06	-0.07	0.01	0.16
medArea	-0.06	-0.08	-0.03	0.11
lensNormMax	-0.11	-0.07	0.24	0.33
areasNormMax	0.06	-0.003	-0.01	0.01

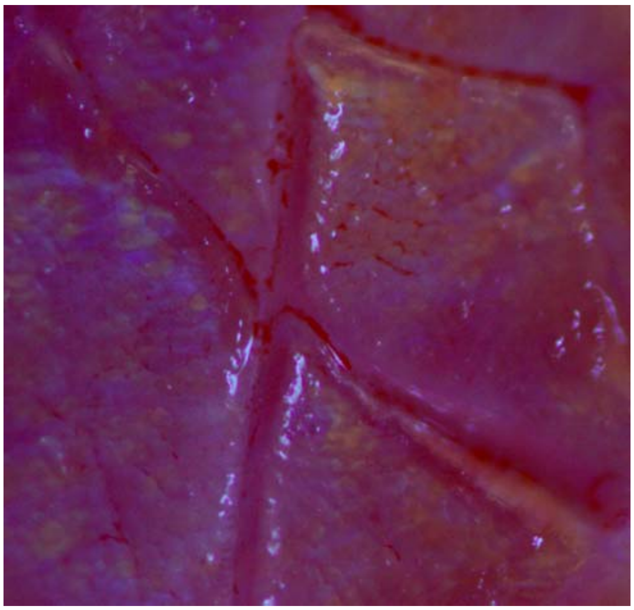
[a]Marbling score = as determined by official USDA grader on A-maturity carcasses; CIE L* = 0 = black, 100 = white; CIE a* = -60 = green, 60 = red; CIE b* = -60 = blue, 60 = yellow; lensSml = length fraction of the data that was in the range of 40 to 60 microns; areasSml = area fraction of the data (i.e., treating the lengths as diameters giving rise to area) that was in the range of 40-60 microns; lensLrg = length fraction of the data that was in the range of 65 to 90 microns; areasLrg = area fraction of the data (i.e., treating the lengths as diameters giving rise to area) that was in the range of 65-90 microns; ratLen = the ratio of lensSml to lensLrg; ratArea = the ratio of areasSml to areasLrg; medLen = the median length in the range of 40-90 microns; medArea = the median area in the range of diameters 40-90 microns; lensNormMax/areasNormMax = 10[th] percentile at each diameter histogram position was obtained, resulting in a baseline curve. This curve was subtracted from the histogram to give the excursions from the baseline. The position of the maximum excursion was recorded, and was adjusted in the case of areasNormMax for the area versus the linear dimension

[b]Subset A derived from cattle not known to be supplemented with beta-adrenergic agonists. $|r| > 0.18$ ($P < 0.05$)

[c]Subset B derived from cattle known through plant records to be supplemented with Zilpaterol hydrochloride. $|r| > 0.41$ ($P < 0.05$)



Tenera Technology High Resolution Imaging system



Raw image generated by the Tenera Technology High Resolution Imaging system

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