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AN INNOVATIVE APPROACH TO PREDICTING MEAT TENDERNESS USING BIOMECHANICAL PROPERTIES OF MEAT

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Introduction

Variation in beef tenderness is one of the largest problems facing the meat industry. Current techniques for predicting beef tenderness lack accuracy, are time consuming, destructive and require a cooked sample. The most utilized instrumental method for predicting tenderness is the Warner-Bratzler shear (WBS), but correlations of WBS with trained sensory panel are variable. Development of a non-destructive, objective method with superior accuracy, speed and repeatability would alleviate this problem.

This study was conducted to develop a non-destructive, more rapid and accurate tenderness assessment method using the technique and mathematical models developed by Spadaro (1996) and Spadaro et al. (2000), and verified by Marburger (1999). Initial studies by Spadaro (1996) used samples of raw, bovine *Longissimus dorsi* cubed (2.54 cm) to orient the fibers in a parallel and perpendicular direction to predict muscle tenderness. Cubed samples were compressed for 240 s using a flat platen. Spadaro (1996) and Spadaro et al. (2000) observed that biomechanical properties, stiffness and total energy dissipated, were highly correlated to overall sensory panel tenderness scores (R^2 = 0.74 and R^2 = 0.83, respectively). Marburger (1999) observed similar results for energy dissipated (parallel to fibers) and initial stiffness (perpendicular to fibers) (R^2 = 0.73 and R^2 = 0.73, respectively) and concluded these values to be effective predictors of sensory tenderness.

Objectives

The specific objectives of this study were to:

1. Evaluate the influence of muscle fiber orientation and sample temperature for predicting beef tenderness using the compressive cube method of Spadaro (1996).
2. Compare the cube (destructive) and probe compressive (non-destructive) methods at varying temperatures for predicting beef tenderness.

Methodology

Forty beef *Longissimus dorsi* muscles were randomly selected 24 hr post-slaughter from a commercial processing plant. Three steaks, 2.54 cm thick were cut from the anterior end of the loin. One 5.08 cm steak was removed for compressive testing using the TA.XT2 Texture Analyzer (TA) (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK). Steaks were assigned to the following analyses: 1 – chemical analysis; 2 – sensory evaluation; 3 – probe compression TA test; 4, 5 – cubed compression TA test. All analyses were performed on fresh (2 day post-mortem) samples.

Compressive Testing - Texture Analyzer (TA)

USDA Choice and Select quality grade samples were randomly distributed between measurement temperatures of -6.6º (n=14), 4.4º (n=13) and 10ºC (n=13). Due to insufficient samples, not all loins were treated to every testing temperature.

Cubed Compressive Testing

A compressive test as described by Spadaro (1996) was performed on 2.54 cm cubed portions of the raw *Longissimus dorsi* samples at either -6.6º, 4.4º or 10ºC of the sample temperature. Compressive measurements were performed perpendicular and parallel to the muscle fiber orientation using a TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY/Stable Micro Systems, Godalming, Surrey, UK) with samples being compressed for 240 s at 3% of sample height. Data were saved in ASCII file format for further analysis using the software package Matlab v4.2c1 (The MathWorks, Inc., Natick, MA). to obtain initial stiffness (ISTF), final stiffness (FSTF) and energy dissipated (ED) for parallel (PLC) and perpendicular (PPC) fiber orientation values for all samples.

Probe Compressive Testing

A modified, non-destructive compressive test was also performed on intact samples equilibrated to either -6.6º, 4.4º or 10ºC. A 2 mm diameter probe was compressed 0.635 cm into the sample and held for 0.25 s, with four compressions obtained at different locations on the surface of each sample. Data were saved in ASCII file format for further analysis using the software package Matlab v4.2c1 (The MathWorks, Inc., Natick, MA) to obtain initial stiffness (ISTFPR), final stiffness (FSTFPR) and energy dissipated (EDPR) for each compression reading.

Revised mathematical models were developed from the initial Spadaro (1996) and Spadaro et al. (2000) models to calculate stiffness (initial and final) and energy dissipated values using the Matlab v4.2c1 (The MathWorks, Inc., Natick, MA) software package.

Sensory Evaluation

Companion loin steaks were evaluated by a trained descriptive attribute sensory panel using an 8-point scale for juiciness (8=extremely juicy, 1=extremely dry), muscle fiber tenderness (8=extremely tender, 1=extremely tough), overall tenderness (8=extremely tender, 1=extremely tough) and connective tissue amount (8=none, 1=abundant) as defined by AMSA (1995).

Statistical Analysis

Data were analyzed using the PROC MIXED procedure as described by the Statistical Analysis System (SAS, 1985) to assess if sample temperature during compression had an effect on biomechanical properties. Data were then separated on the basis of compression temperature and regression models to predict overall sensory tenderness from biomechanical measurements were derived for each temperature using the PROC REG procedure. PROC REG was run with a selection option of STEPWISE and RSQUARE to help distinguish which variables contributed to prediction equations with higher R-square values. Once the most favorable prediction equations were selected, the model was run under PROC REG to derive the appropriate β-values.

Results & Discussion

The effect of sample temperature during compression on biomechanical properties was analyzed and no significant differences between temperature treatments were observed. A prediction equation using biomechanical values for energy dissipated perpendicular to fibers of the cubed sample (EDPPC) and final stiffness of probe compression (FSTFPR) had the greatest prediction potential for overall sensory tenderness ($R^2 = 0.3953$). This formula incorporates a destructive and non-destructive measurement. To evaluate the non-destructive method, a formula using the probe compression biomechanical variables of initial stiffness (ISTFPR), final stiffness (FSTFPR) and energy dissipated (EDPR) was evaluated and resulted in a less effective predictor of overall tenderness ($R^2 = 0.1417$) than the equation that utilized a cubed sample and probe compression measurements.

Although sample temperature was not significant, data were still segregated based on sample temperature at compression. TA measurements for each temperature were regressed against overall sensory tenderness scores (Tables 1 and 2).

Cubed Compressive Testing

For TA cubed compressions, samples compressed at higher temperatures produced better prediction equations than those samples compressed at lower temperatures (Table 1). As compression temperature decreased from 10°C to 4.4° to –6.6°C, so did predictability. At –2.2°C muscle freezes, steaks held at –6.6°C would have had a proportion of water in the frozen state that would have affected compression values. Interestingly, the prediction equations at 4.4°C and 10°C both used a parallel fiber and perpendicular fiber orientation variable. The 4.4°C prediction equation utilized EDPLC and EDPPC while the 10°C prediction equation used the relationship between FSTFPLC and EDPPC.

Probe Compressive Testing

Probe compression data was segregated based on sample temperature at compression and regression models predicting overall sensory tenderness were derived for each temperature. R-square values (Table 2) for equations using ISTFPR, FSTFPR and EDPR were higher for samples compressed at 4.4° and 10°C than equations using the same TA variables and compressing at -6.6ºC. These results indicate that compression at refrigerated temperatures (4.4º and 10ºC) proved to produce better predictability of overall tenderness than lower temperatures (-6.6ºC). This may be the result of ice crystal formation affecting compression values. Reducing the number of variables in the prediction equation was evaluated. An equation using ISTFPR and FSTFPR at 10ºC proved to be an acceptable predictor of tenderness, but an equation incorporating the same variables for 4.4ºC lacked the same predictability (Table 2). It was expected that prediction equations with identical variables would have similar intercept values, which was not observed in this study (Table 2). The intercepts and the coefficients for each variable were different at each testing temperature. Perhaps effective utilization of probe compressive testing on a large-scale production would have to include prediction equations over a common range of temperatures expected during the chilling process post-mortem.

Conclusions

The overall goal of this study was to develop a more rapid, accurate and non-destructive objective instrumental method for measuring the tenderness of raw beef loins using the compressive technique developed by Spadaro (1996) and Spadaro et al. (2000) and to verify this new technique. Spadaro's (1996) technique was adapted to produce a non-destructive objective tenderness method. The most effective predictive models for tenderness were derived when steaks were assessed at 4.4ºC and 10ºC, rather than –6.6ºC, using either the destructive compression test or the non-destructive probe method. This study verified the use of biomechanical probe measurements to more rapidly and effectively predict overall sensory tenderness of raw steaks without sample destruction. This innovative technique could guarantee tenderness to consumers, be integrated into on-line grading systems and be utilized as a powerful research tool.

References

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Tables and Figures

TABLE 1. Prediction equations for overall sensory tenderness utilizing TA cubed sample compression values[1] at various compression temperatures.

Equation	β value	R^2	MSE
<u>-6.6ºC</u>			
Intercept	9.15711	0.4769	0.66982
FSTFPPC	-0.00027935		
<u>4.4ºC</u>			
Intercept	7.45088	0.5361	0.35166
EDPLC	-0.66424		
EDPPC	0.37355		
<u>10ºC</u>			
Intercept	4.88366	0.7075	0.40263
FSTFPLC	-0.00021298		
EDPPC	0.91179		

[1] FSTFPLC = final stiffness of parallel fiber orientation in cubed samples; FSTFPPC = final stiffness of perpendicular fiber orientation in cubed samples; EDPLC = energy dissipated of parallel fiber orientation of cubed samples; EDPPC = energy dissipated of perpendicular fiber orientation of cubed samples; R^2 = R-square; MSE = Mean Square Error.

TABLE 2. Prediction equations for overall sensory tenderness utilizing TA probe compression values[1] at various compression temperatures.

Equation	β value	R^2	MSE
-6.6ºC			
Intercept	-1.35095	0.2936	1.08535
ISTFPR	0.02317		
FSTFPR	-0.01307		
EDPR	634.61514		
4.4ºC			
Intercept	15.60995	0.7073	0.22409
ISTFPR	0.14377		
FSTFPR	-0.20226		
EDPR	-427.06157		
Intercept	8.22752	0.4710	0.36447
ISTFPR	0.11554		
FSTFPR	-0.14687		
10ºC			
Intercept	8.11712	0.7019	0.47954
ISTFPR	0.25924		
FSTFPR	-0.31144		
EDPR	-89.94746		
Intercept	6.65498	0.6912	0.44699
ISTFPR	0.26102		
FSTFPR	-0.30943		

[1] Variable abbreviation explanation: ISTFPR = initial stiffness for intact samples compressed with probe; FSTFPR = final stiffness for intact samples compressed with probe; EDPR = energy dissipated for intact samples compressed with probe; R^2 = R-square; MSE = Mean Square Error.