MECHANICAL FORCE MEASURES ON UNCOOKED BEEF *LONGISSIMUS* MUSCLE CAN PREDICT TENDERNESS OF STRIP LOIN STEAKS

R. R. Timm, J. A. Unruh, M. E. Dikeman, M. C. Hunt, T. E. Lawrence, J. E. Boyer, Jr.[1], and J. L. Marsden

Summary

We investigated mechanical force measurements on uncooked *longissimus* muscle as a means to predict Warner-Bratzler shear force (WBSF) and trained sensory panel tenderness (SPT) of cooked strip loin steaks. Uncooked steaks from 24 USDA Select strip loins (IMPS 180) were evaluated at 2 and 14 days postmortem using plumb bob and needle probe devices attached to an Instron Universal Testing Machine. Cooked steaks aged 14 days were then evaluated for WBSF and SPT. Regression models to predict SPT from needle probe and plumb bob measurements individually taken at 2 days postmortem had R^2 of 0.54 and 0.51, respectively. Combining needle probe and plumb bob measurements resulted in an R^2 of 0.76; however, when quadratic terms for both variables were in the model, R^2 was 0.80. Regressing needle probe and plumb bob measurements at 2 days postmortem with WBSF produced R^2 of 0.51 and 0.45, respectively. When linear terms of both probes were combined, R^2 improved to 0.77. An equation to predict WBSF including both the linear and quadratic terms of needle probe and plumb bob measurements resulted in R^2 of 0.84. Using plumb bob and needle probe combined on uncooked *longissimus* muscle at 2 days postmortem can predict cooked WBSF and SPT of strip loin steaks aged for 14 days.

(Key Words: Beef, *Longissimus dorsi*, Instrument, Tenderness.)

Introduction

Tenderness is the most important factor of beef palatability, and consumers are willing to pay a premium for tender beef. In 1995, the National Beef Quality Audit listed inadequate tenderness as the second most important concern of the beef industry. The USDA currently uses marbling as the primary predictor of beef palatability but often it does not accurately sort carcasses for tenderness, especially in intermediate marbling scores (Slight and Small). Despite many attempts, researchers have not developed a mechanical method for use on uncooked meat that will successfully predict cooked meat tenderness. In a preliminary study, we found the force required to insert a plumb bob into uncooked steaks at 14 days postmortem was correlated (r=-0.48) to SPT. Therefore, our objective was to further investigate two mechanical methods applied to *longissimus* muscle of uncooked USDA Select steaks to predict cooked WBSF and SPT.

Experimental Procedures

Twenty-four USDA Select strip loins (IMPS 180) were obtained at 2 days postmortem from a commercial slaughter facility. Loins were trimmed of external fat, faced, and two *longissimus* muscle steaks

[1]Department of Statistics

were fabricated from the anterior end of each strip loin. The first uncooked steak (1 in.) was used for the plumb bob measurement and the second (2 in.) was assigned to the needle probe assessment. The remaining strip loin was vacuum packaged and stored at 32 ± 2°F. At 14 days postmortem, the strip loins were further fabricated into steaks, starting at the anterior end. The first steak (2 in.) was assigned to the needle probe measurement and the remaining steaks (1 in.) were randomly assigned to plumb bob measurement (one steak), sensory panel evaluation (three steaks), and WBSF (one steak). Sensory panel steaks were then vacuum packaged, frozen, and stored at –20°F. Uncooked steaks at 2 and 14 days postmortem were evaluated immediately after fabrication with the needle probe and plumb bob. Steak temperature at 2 days postmortem was 41 ± 2°F and at 14 days postmortem was 36.8 ± 1°F.

A brass plumb bob (model 27446, Hempe Manufacturing Co., Inc., New Berlin, WI) was attached to an Instron Universal Testing Machine with a 50-kg compression load cell using a crosshead speed of 250 mm/min. The plumb bob had an angle of 20°, a diameter ranging from zero to 1.38 in., and was 3.8 in. long. Uncooked steaks (1 in.) were positioned on an aluminum plate (4.1 × 3.9 × 0.5 in.) that had a 27° hole in the center (tapering from 0.87 to 0.63 in. in diameter). The plumb bob traveled 2.7 in. and penetrated the steak to a point where the diameter of the plumb bob at the top of the steak was 1 in. Plumb bob steaks were probed once each in the medial, center, and lateral sections, and peak force required for penetration was recorded.

A multi-needle probe was modified such that two rows of three needles each were attached to a 1 × 3 in. plate; rows were 1 in. apart and needles within a row were 0.75 in. apart. Each needle was 2.75 in. long and had a diameter of 0.12 in. with a 10° sharpened point. The needle probe was attached to an Instron Universal Testing Machine with a 50-kg compression load cell using a crosshead speed of 250 mm/min. Uncooked steaks (2 in.) were positioned on an aluminum plate (4.1 × 3.9 × 0.5 in.). The probe traveled 1.75 in., allowing it to penetrate 1.5 in. into each steak. Steaks were probed once in the medial and lateral sections. Peak force required for penetration was recorded.

Steaks for WBSF were cooked to a 158°F endpoint internally in a Blodgett forced-air convection gas oven preheated to 325°F. Steak temperature was monitored using a 30-gauge, type T thermocouple inserted into the geometric center of each steak. Following refrigeration overnight at 37°F, six ½-in. diameter cores were taken parallel to muscle fiber orientation. Two cores were taken from each of the medial, center, and lateral sections of each steak. Cores were sheared perpendicular to muscle fiber orientation using an Instron Universal Testing Machine with a WBSF V-blade attachment. A 50-kg compression load cell and a crosshead speed of 250 mm/min were used.

Sensory panel steaks were thawed for 24 to 36 hours at 37°F and cooked using the same procedures as for WBSF steaks. Cooked steaks were trimmed of epimysial connective tissue and any remaining external fat, cut into ½ × ½ in. × steak thickness cubes, and placed in preheated double boilers. Medial, center, and lateral sections were evaluated separately and averaged. The center section consisted of a 2-in. × steak width section centered at the point where the medial and lateral muscle fibers conjoin. Sensory panels were conducted in individual booths having a mixture of red and green lighting. Duplicate samples for each steak section were presented to panelists in a statistically randomized order.

Samples were evaluated for overall tenderness using an 8-point scale (1=extremely tough, 8=extremely tender) and scored to the nearest 0.5.

Correlations were determined using the CORR procedure of SAS (2000). Regression models were developed to predict trained SPT and WBSF values from the plumb bob, needle probe, and their respective quadratic terms. Preliminary models were selected using the PROC RSQUARE procedure (SAS, 2000) and final models were developed using the PROC REG procedure (SAS, 2000). Models were selected based on the best combination of R^2, root mean square error, and model simplicity.

Results and Discussion

Means, SD, and ranges for plumb bob, needle probe, WBSF, and SPT measurements are presented in Table 1. At 14 days postmortem, the plumb bob and needle probe values were higher than at 2 days postmortem, probably because the 14-day steaks were approximately 4.1ºF colder, resulting in a firmer muscle and higher probe values. Plumb bob measurements at 2 days postmortem were correlated to SPT (r=−0.71) and WBSF (r=0.78). In contrast, plumb bob values at 14 days postmortem were not correlated (P>0.05) to SPT or WBSF. Needle probe values at 2 days postmortem were correlated to SPT (r=−0.74) and WBSF (r=0.67). Needle probe values at 14 days postmortem were correlated to SPT (r=−0.61) and WBSF (r=0.53).

Regression models to predict SPT from needle probe and plumb bob measurements individually had R^2 of 0.54 and 0.51, respectively (Table 2). By combining independent needle probe and plumb bob measurements, the R^2 increased to 0.76, and when quadratic terms for both variables were in the model, the R^2 value was 0.80.

Utilizing needle probe and plumb bob measurements individually at 2 days postmortem to predict WBSF values resulted in R^2 of 0.45 and 0.51, respectively. By combining linear terms of both probes, the R^2 improved to 0.77. Including both the linear and quadratic terms for needle probe and plumb bob measurements to predict WBSF had an R^2 of 0.84.

We speculate that although needle probe and plumb bob measurements in preliminary regression models were both found to predict tenderness, each probe might have a different mode of action that when combined contributes to the improved prediction. We postulate that the plumb bob may have applied both compression and tensile strength forces to the connective tissue matrix and may have caused muscle fibers or bundles to separate. We speculate that the needle probe may measure more of the muscle fiber component of tenderness. Because of their small diameters, the needle probes may be piercing through the muscle bundles, thus measuring the strength needed to separate the muscle fibers.

The combination of needle probe and plumb bob measurements at 2 days postmortem can accurately predict WBSF and SPT on steaks aged 14 days. Future development and refinement may provide a method to accurately predict cooked meat tenderness from fresh uncooked muscle. Potentially, subprimal cuts or intact carcasses could be sorted into tenderness categories, with premiums for guaranteed tender steaks.

Table 1. Plumb Bob and Needle Probe Values of Uncooked Steaks, and Sensory Panel Tenderness (SPT) and Warner-Bratzler Shear Force (WBSF) Values of Cooked Steaks

Trait	Day[a]	Mean	SD	Minimum	Maximum
Plumb bob, kg	2	3.62	0.56	2.75	5.24
	14	4.34	0.60	3.32	5.7
Needle probe, kg	2	2.96	0.69	1.36	4.47
	14	3.08	0.67	1.65	4.58
WBSF, kg	14	4.50	1.21	2.33	8.33
SPT[b]	14	5.4	1.0	3.5	6.8

[a]Steaks evaluated at 2 or 14 days postmortem.

[b]Sensory panel tenderness evaluated on an 8-point scale (1=extremely tough, 8=extremely tender).

Table 2. Multivariate Regression Equations Predicting Sensory Panel Tenderness and Warner-Bratzler Shear Force of Cooked Steaks Aged for 14 Days Using Plumb Bob (PB) and Needle Probe (NP) Measurements Taken at 2 Days Postmortem

			Parameter Estimate				
Item	R^2	Intercept	PB	PB^2	NP	NP^2	Root MSE[a]
Sensory Panel Tenderness							
	0.54	8.63			-1.08		0.69
	0.51	10.07	-1.28				0.72
	0.76	11.02	-0.89		-0.79		0.52
	0.58	6.70			0.33	-0.24	0.68
	0.51	10.03	-1.26	-0.003			0.74
	0.76	10.97	-0.89		-0.76	-0.005	0.53
	0.79	18.15	-4.52	0.47	-0.91		0.49
	0.80	18.32	-5.24	0.58	-0.09	-0.15	0.49
Warner-Bratzler Shear Force							
	0.45	0.99			1.19		0.92
	0.51	10.07	-1.28				0.77
	0.77	-2.57	1.33		0.76		0.61
	0.47	2.38			0.17	0.17	0.93
	0.70	10.24	-4.57	0.81			0.70
	0.78	-4.59	1.45		1.96	-0.21	0.61
	0.79	4.55	-2.28	0.47	0.64		0.59
	0.84	4.99	-4.22	0.75	2.83	-0.40	0.54

[a]Root mean square error.