Tenderness Classification of Beef: II. Design and Analysis of a System to Measure Beef Longissimus Shear Force Under Commercial Processing Conditions[1]

S. D. Shackelford[2], T. L. Wheeler, and M. Koohmaraie

Roman L. Hruska U.S. Meat Animal Research Center, USDA, ARS, Clay Center, NE 68933-0166

ABSTRACT: The objectives of this study were to evaluate the efficacy of a system for classifying beef for tenderness based on a rapid, simple method of measuring cooked longissimus shear force. Longissimus steaks (2.54 cm thick) were trimmed free of s.c. fat and bone and rapidly cooked using a belt grill. A 1-cm-thick, 5-cm-long slice was removed from the cooked longissimus parallel with the muscle fibers for measurement of shear force. Slices were sheared with a flat, blunt-end blade using an electronic testing machine. The entire process was completed in less than 10 min. Therefore, in commercial application, this process could be completed during the 10- to 15-min period that carcasses are normally held to allow the ribeye to bloom for quality grading. In Exp. 1, the repeatability of slice shear force (SSF), as determined by evaluation of duplicate samples from 204 A-maturity carcasses, was .89. In Exp. 2, A-maturity carcasses (n = 483) were classified into three groups based on SSF (< 23, 23 to 40, and > 40 kg) at 3 d postmortem that differed ($P < .001$) in mean trained sensory panel tenderness ratings (7.3 ± .04, 6.4 ± .06, and 4.4 ± .20) and the percentages (100, 91, and 28%) of samples rated "Slightly Tender" or higher at 14 d postmortem. Therefore, this tenderness classification system could be used to accurately segregate beef carcasses into expected tenderness groups. Further research is needed to test the feasibility and accuracy of this system under a variety of commercial processing conditions.

Key Words: Beef, Classification, Tenderness

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Introduction

The final report of the 1995 National Beef Quality Audit listed low overall uniformity and consistency of beef, low overall palatability, and inadequate tenderness among the top 10 concerns of the beef industry (Smith et al., 1995). Thus, there is growing interest in implementing steps to control variation in beef palatability. This led the National Cattlemen's Association to list "development of an instrument or procedure that can adequately measure quality, cutability and tenderness in beef carcasses in modern packing plants" as a top priority of the beef industry (NCA, 1995).

We (Shackelford et al., 1997b) have shown that beef longissimus Warner-Bratzler shear force measured at the time of carcass grading (1 to 2 d postmortem) is a valid predictor of beef longissimus Warner-Bratzler shear force at 14 d postmortem. Herein we outline a system for measuring beef longissimus tenderness under commercial processing conditions using a simplified method of shear force determination. The present experiments were designed to evaluate the potential efficacy of this system.

Materials and Methods

Experiment 1: Repeatability of Slice Shear Force

Two adjacent longissimus steaks (2.54 cm thick) were acquired from beef carcasses (n = 204) at a commercial packing plant. Samples were transported to the U.S. Meat Animal Research Center (**MARC**) and evaluated at either 2 (n = 74) or 3 (n = 130) d postmortem. Steaks were rapidly cooked with a belt

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[1]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of other products that may also be suitable. The authors are grateful to Patty Beska, Kathy Mihm, and Pat Tammen for their assistance in the execution of this experiment and to Marilyn Bierman for her secretarial assistance.

[2]To whom correspondence should be addressed (phone: 402-762-4223; fax: 402-762-4149; E-mail: shackelford@email.marc.usda.gov).

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grill (TBG-60 Magigrill, MagiKitch'n, Quakertown, PA). With the belt grill (Wheeler et al., 1998a) operating at its highest temperature setting (260°C), approximately 7.33 min of total cooking time was required to cook each steak from an internal temperature of 5°C to a final internal temperature of 70°C. Total cooking time included the time required for the steak to enter the grill (1 min), to pass between the platens (4.33 min), and to exit the grill (.42 min), and time for temperature rise after cooking (1.58 min). Specific belt grill settings were as follows: preheat = disconnected, top heat = 260°C, bottom heat = 260°C, height (i.e., gap between platens) = 2.16 cm, and cook time = 4.33 min.

Immediately after cooking, a 1-cm-thick, 5-cm-long slice was removed from each steak parallel to the muscle fibers. The slice was acquired by first cutting across the width of the longissimus at a point approximately 2 cm from the lateral end of the muscle. Using a sample sizer, a cut was made across the longissimus parallel to the first cut at a distance 5 cm from the first cut. Using a knife that consisted of two parallel blades spaced 1 cm apart, two parallel cuts were simultaneously made through the length of the 5-cm-long steak portion at a 45° angle to the long axis of the longissimus and parallel with the muscle fibers.

The 5-cm-long, 1-cm-thick slice was sheared perpendicular to the muscle fibers using an electronic testing machine equipped with a flat, blunt-end blade. The slice shear force blade was designed to replace the Warner-Bratzler shear blade on a universal testing machine (Instron Corp., Canton, MA). The slice shear force blade has the same thickness (1.016 mm) and degree of bevel (half-round) on the shearing edge as Warner-Bratzler shear blades. The crosshead speed was set at 500 mm/min to minimize the time required for measurement of shear force.

Repeatability of slice shear force was calculated as the proportion of the total variance that could be attributed to animal variance: repeatability = $\sigma^2_{animal}/(\sigma^2_{animal} + \sigma^2_{error})$. Variance components were estimated with the MIVQUEO option of the VARCOMP procedure of SAS (1988).

Experiment 2: Evaluation of the Tenderness Classification System

Animals. A-maturity beef carcasses (n = 483) were selected for this experiment at a commercial packing plant. At 36 h postmortem, carcasses were ribbed between the 12th and 13th ribs and USDA quality and yield grade traits were evaluated (USDA, 1997). The wholesale rib was obtained from the right side of each carcass, placed in a plastic-lined cardboard container (combo bin), and transported (2°C) to MARC.

Assignment of Steaks. At 3 d postmortem, the ribeye roll (IMPS #112) containing the longissimus thoracis was removed from each wholesale rib. A 12.7-cm-long section was removed from the posterior end of the ribeye roll, vacuum-packaged, aged (2°C) until 14 d postmortem, and frozen (–30°C). The remainder of the ribeye roll was vacuum-packaged and immediately frozen (–30°C).

Using a band saw, each frozen ribeye roll section was sliced to yield four steaks (2.54 cm thick). Beginning at the posterior end of the ribeye roll, steaks were numbered 1 through 8; steaks 1 through 4 came from the section that was frozen at 14 d postmortem and steaks 5 through 8 came from the section that was frozen at 3 d postmortem. Steak 1 was used for assessment of Warner-Bratzler shear force at 14 d postmortem, steaks 3 and 4 were used for trained sensory panel evaluation at 14 d postmortem, steak 5 was used for tenderness classification at 3 d postmortem based on slice shear force, steak 7 was used for assessment of Warner-Bratzler shear force at 3 d postmortem, and steaks 2, 6, and 8 were not used in this experiment.

Tenderness Classification. Steaks were thawed (24 h at 5°C) until an internal temperature of 5°C was reached. Steaks were cooked and slice shear force testing was conducted as in Exp. 1. A sample was classified as "Tender," "Intermediate," or "Tough" if its slice shear force value at 3 d postmortem was less than 23 kg, 23 to 40 kg, or greater than 40 kg, respectively.

Warner-Bratzler Shear Force. Steaks were thawed and cooked as above except that the temperature of the belt grill was decreased and total cooking time was increased to prevent excessive crust formation (top heat = 163°C, bottom heat = 163°C, cook time = 5.7 min). Cooked steaks were placed in plastic bags and cooled for 24 h at 4°C before removal of six cores (1.27 cm in diameter) parallel to the longitudinal orientation of the muscle fibers. Each chilled (4°C) core was sheared once with a Warner-Bratzler shear force attachment using an Instron Universal Testing Machine (Instron Corp.). The crosshead speed was set at 200 mm/min to conform to standard Warner-Bratzler shear force procedures (AMSA, 1995; Wheeler et al., 1997a,b). With the protocol used in this experiment, Warner-Bratzler shear force is measured with a repeatability of .85 (Wheeler et al., 1998a).

Trained Sensory Panel Analysis. For descriptive attribute sensory panel analysis, steaks were thawed and cooked as described for Warner-Bratzler shear force. Steaks were sliced and served immediately after cooking. Each panelist received three cubes (1.3 cm × 1.3 cm × cooked steak thickness) from each sample. Sensory panelists scored steaks for tenderness, ease of fragmentation, amount of connective tissue, juiciness, and beef flavor intensity on 8-point scales (1 = extremely tough, extremely difficult, abundant, extremely dry, or extremely bland and 8 = extremely tender, extremely easy, none, extremely juicy, or extremely intense). Sensory panelists scored steaks for off-flavor on a 4-point scale (1 = intense and 4 =

none). The eight-member sensory panel was selected and trained according to Cross et al. (1978). With the protocol used in this experiment, the eight-member sensory panel has been reported (Wheeler et al., 1998a) to measure each sensory trait with a high degree of repeatability: tenderness (.87), ease of fragmentation (.88), amount of connective tissue (.66), juiciness (.51), beef flavor intensity (.52), and off-flavor (.51).

Statistical Analysis. Using the GLM procedure of SAS (1988), one-way ANOVA was conducted to determine the effect of tenderness classification on Warner-Bratzler shear force at 3 and 14 d postmortem and sensory traits at 14 d postmortem (SAS, 1988). Mean separation was accomplished with Tukey's test (Steel and Torrie, 1980).

Variances were not homogenous among tenderness classes for Warner-Bratzler shear force at 14 d postmortem and sensory panel tenderness, ease of fragmentation, and amount of connective tissue ratings. Box-Cox transformations (Box and Cox, 1964) were conducted for each trait and ANOVA was conducted. Results of analyzing transformed data did not differ from results of analyzing untransformed data. Therefore, results of analyzing untransformed data are presented.

Correlation and frequency analyses were conducted to more fully determine the efficacy of tenderness classification. The overall accuracy of tenderness classification was evaluated for both Warner-Bratzler shear force values and trained sensory panel tenderness ratings at 14 d postmortem. To calculate the overall accuracy of tenderness classification for predicting Warner-Bratzler shear force at 14 d postmortem, carcasses that were classified as "Tender" or "Intermediate" at 3 d postmortem and that had "Low" (≤ 5 kg) Warner-Bratzler shear force values at 14 d postmortem were considered accurately classified. Also, carcasses that were classified as "Tough" at 3 d postmortem and that had "High" (> 5 kg) Warner-Bratzler shear force values at 14 d postmortem were considered accurately classified. To calculate the overall accuracy of tenderness classification for predicting trained sensory panel tenderness ratings at 14 d postmortem, carcasses that were classified as "Tender" or "Intermediate" at 3 d postmortem and that were rated "Slightly Tender" or higher by the trained sensory panel at 14 d postmortem were considered accurately classified. Also, carcasses that were classified as "Tough" at 3 d postmortem and that were rated less than "Slightly Tender" by the trained sensory panel at 14 d postmortem were considered accurately classified. In each case, overall accuracy was calculated as the total number of accurate predictions divided by the total number of carcasses tested.

Linear regression was used to determine the percentage of the total variation in Warner-Bratzler shear force and trained sensory panel ratings accounted for by slice shear force value at 3 d postmortem and marbling score singularly and combined.

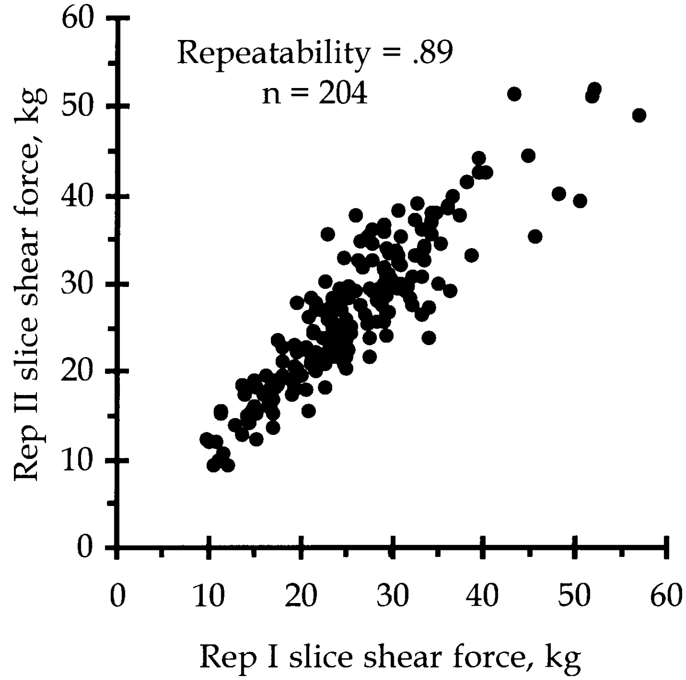

Figure 1. Repeatability of slice shear force.

Results and Discussion

Experiment 1: Repeatability of Slice Shear Force

Slice shear force was highly repeatable (Figure 1). In fact, the repeatability of slice shear force (.89) exceeded repeatability estimates (.53 to .86) that we have reported for longissimus Warner-Bratzler shear force (Wheeler et al., 1996, 1997a). The higher repeatability of slice shear force may be due to improved consistency of cooking associated with the belt grill as compared with open-hearth electric broilers (Wheeler et al., 1998a), improved sampling

Table 1. Simple statistics of carcass traits

Trait	Mean	SD	Min	Max
Hot carcass weight, kg	315.3	40.6	206.8	456.8
Adjusted fat thickness, cm	1.0	.5	.1	2.8
Longissimus area, cm^2	78.4	9.3	54.2	114.2
Kidney, pelvic, and heart fat, %	3.0	.7	.5	4.5
Yield grade	2.8	.8	.3	5.5
Marbling score[b]	414	62.3	290.0	710

[a]100 = A^0; 200 = B^0; 300 = C^0.
[b]200 = $Traces^0$; 300 = $Slight^0$; 400 = $Small^0$; 500 = $Modest^0$; 600 = $Moderate^0$; 700 = Slightly $Abundant^0$; 800 = Moderately $Abundant^0$.

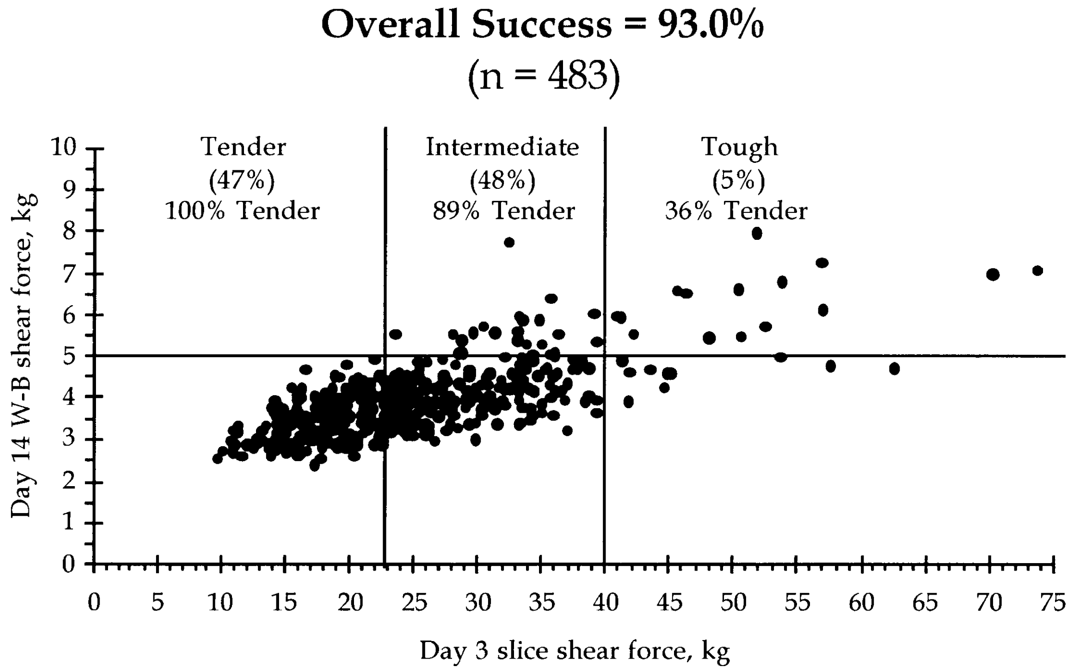

Figure 2. Use of manual tenderness classification at 3 d postmortem to predict longissimus Warner-Bratzler shear force at 14 d postmortem (r = .72). For 93.0% of the samples evaluated at 3 d postmortem, tenderness classification accurately predicted whether the sample would have a "low" (≤ 5 kg) Warner-Bratzler shear value at 14 d postmortem. All of the samples in the "Tender" class had "low" Warner-Bratzler shear values at 14 d postmortem, most (89%) of the samples in the "Intermediate" class had "low" Warner-Bratzler shear values at 14 d postmortem, and few (36%) of the samples in the "Tough" class had "low" Warner-Bratzler shear values at 14 d postmortem. Parenthetical values below the class names indicate the percentage of the total population in each class.

technique for slice shear force vs Warner-Bratzler shear force, or a combination of these factors.

Experiment 2: Evaluation of the Tenderness Classification System

Although the carcasses sampled for this experiment represented a substantial range in yield grade factors and marbling score, all carcasses were A-maturity (Table 1). For the present experiment, 47, 48, and 5% of the carcasses were classified as "Tender," "Intermediate," and "Tough," respectively. The relative frequency of the various tenderness classes should be considered when interpreting the results of the present experiment. However, these frequencies may not be representative of national averages because this experiment was limited to carcasses from one packing plant. It is highly likely that these percentages will vary among and within packing plants due to differences in carcass handling practices, cattle types, and management regimens. Whereas 0, 3, and 6% of top loin, ribeye, and rib steaks were found to have sensory panel tenderness ratings less than slightly tender in the National Beef Tenderness Survey (Morgan et al., 1991), 8% of ribeye steaks were found to have sensory panel tenderness ratings less than slightly tender at 14 d postmortem in the present experiment.

Although the present data set contained a low percentage of "Tough" samples, slice shear force at 3 d postmortem was strongly correlated with Warner-Bratzler shear force (r = .84; $P < .001$; Figure 2) and trained sensory panel tenderness rating (r = –.81; $P < .001$; Figure 3) at 14 d postmortem. The effects of tenderness class on the simple statistics of Warner-Bratzler shear force and trained sensory panel ratings are shown in Table 2. Tenderness class affected ($P < .001$) mean Warner-Bratzler shear force and trained sensory panel ratings for tenderness, ease of fragmentation, amount of connective tissue, and juiciness. Moreover, the SD of Warner-Bratzler shear force and trained sensory panel ratings for tenderness, ease of fragmentation, and amount of connective tissue was smaller for "Tender" than for "Intermediate," which, in turn, was less variable than "Tough." Tenderness class did not affect beef flavor intensity or off-flavor scores.

For 93.0% of the samples evaluated at 3 d postmortem, tenderness classification accurately predicted whether the sample would have a "low" (≤ 5 kg) Warner-Bratzler shear value at 14 d postmortem (Figure 2). All of the samples in the "Tender" class had "low" Warner-Bratzler shear values at 14 d postmortem, most (89%) of the samples in the "Intermediate" class had "low" Warner-Bratzler shear values at 14 d postmortem, and few (36%) of the

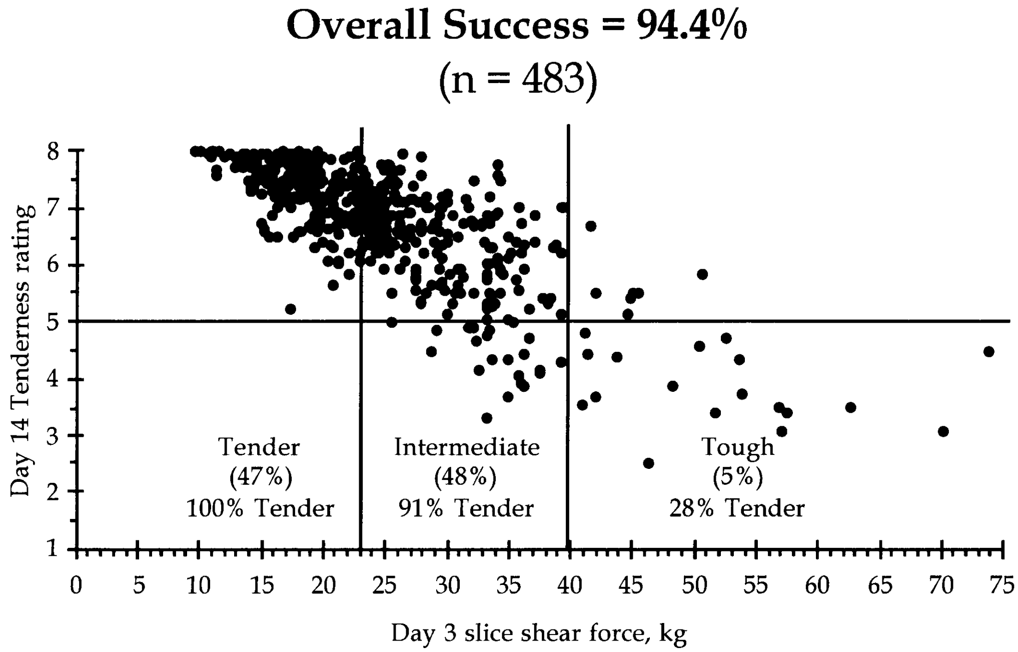

Figure 3. Use of manual tenderness classification at 3 d postmortem to predict longissimus tenderness ratings at 14 d postmortem (r = –.78). For 94.4% of the samples evaluated at 3 d postmortem, tenderness classification accurately predicted whether the trained sensory panel would rate the sample as "Slightly Tender" or higher at 14 d postmortem. All of the samples in the "Tender" class were rated "Slightly Tender" or higher, most (91%) of the samples in the "Intermediate" class were rated "Slightly Tender" or higher, and few (28%) of the samples in the "Tough" class were rated "Slightly Tender" or higher by the trained sensory panel at 14 d postmortem. Parenthetical values below the class names indicate the percentage of the total population in each class.

samples in the "Tough" class had "low" Warner-Bratzler shear values at 14 d postmortem.

For 94.4% of the samples evaluated at 3 d postmortem, tenderness classification accurately predicted whether the trained sensory panel would rate the sample as "Slightly Tender" or higher at 14 d postmortem (Figure 3). All of the samples in the "Tender" class were rated "Slightly Tender" or higher, most (91%) of the samples in the "Intermediate" class were rated "Slightly Tender" or higher, and few (28%) of the samples in the "Tough" class were rated "Slightly Tender" or higher by the trained sensory panel at 14 d postmortem. Although the degree of tenderness difference between "Tender" and "Intermediate" steaks was small relative to the level of tenderness difference between "Intermediate" and "Tough" steaks, it is likely "Tender" steaks would result in greater consumer satisfaction (Boleman et al., 1997), particularly for those consumers who prefer their steaks well done (Wheeler et al., 1999a). Thus, there may be potential to market "Tender" steaks as a premium product line in much the same manner as "Prime" steaks are currently marketed.

Linear regression was used to determine the percentage of the total variation in Warner-Bratzler shear force and trained sensory panel ratings accounted for by slice shear force value at 3 d postmortem and marbling score singularly and combined (Table 3). Slice shear force value at 3 d postmortem accounted for a much higher proportion of the variation in Warner-Bratzler shear force and trained sensory panel tenderness, ease of fragmentation, amount of connective tissue, and juiciness ratings than did marbling score. Marbling score accounted for a higher proportion of the variation in trained sensory panel beef flavor intensity ratings than did slice shear force value at 3 d postmortem. Within a given tenderness class, marbling score subcells did not differ ($P > .05$) in tenderness or juiciness; however, within "Tender" and "Intermediate," beef flavor intensity ratings increased with marbling score (Table 4). In a companion paper (Wheeler et al., 1999b), we compared the sensory characteristics of well-done (80°C) rib steaks from "Tender" carcasses differing in marbling level (Low Slight vs Modest/Moderate) and found that, under those conditions, juiciness and beef flavor intensity ratings increased ($P < .05$) with increased levels of marbling.

This report documents a rapid, simple method for measuring longissimus shear force that allowed for accurate classification of carcasses into three classes that differed in longissimus tenderness. Processing plants that process fewer than 100 carcasses per hour probably could conduct tenderness classification manually in much the same manner as described in the present experiments. However, large-scale beef processors would likely require a fully automated version of this system.

We have evaluated tenderness classification based on segregation of carcasses into three groups. These three tenderness groups are similar to the three tenderness groups that Boleman et al. (1997) used to evaluate the value of tenderness to consumers. They reported that consumers can distinguish tenderness differences between longissimus steaks with Warner-Bratzler shear values of 3.0 vs 4.7 kg and 4.7 vs 6.4 kg. Correspondingly, consumer ratings for overall satisfaction differed among each successive shear force category in their study. Thus, the three tenderness classes created in the present experiment seem to represent meaningful differences in tenderness and satisfaction to consumers. However, it is not known how many different tenderness classes should be used to maximize carcass value and consumer satisfaction or where the lines should be drawn to segregate the classes most effectively. Consumers in the United States tend to cook beef steaks to an advanced degree of doneness (NLSMB, 1995), which may be detrimental to tenderness. Thus, the degree of tenderness associated with the "Tender" class might be required to satisfy some consumers, whereas others might be satisfied with the degree of tenderness associated with the "Intermediate" category.

Because longissimus constitutes a higher proportion of total carcass value than any other muscle and there is more carcass-to-carcass tenderness variation in longissimus than any other major beef muscle (Shack-

Table 2. Effect of tenderness class on simple statistics of Warner-Bratzler shear force and trained sensory panel ratings

Tenderness class	Mean ± SEM	SD	Minimum	Maximum
	Warner-Bratzler shear force at 3 d postmortem, kg			
Tender[a]	4.2^z ± .04	.7	2.6	6.6
Intermediate	5.5^y ± .03	.8	3.6	8.2
Tough	7.9^x ± .23	1.2	6.3	11.1
	Warner-Bratzler shear force at 14 d postmortem, kg			
Tender	3.5^z ± .03	.5	2.4	4.9
Intermediate	4.2^y ± .05	.7	3.0	7.8
Tough	5.7^x ± .22	1.1	3.9	8.0
	Tenderness[b]			
Tender	7.3^x ± .04	.5	5.2	8.0
Intermediate	6.4^y ± .06	.9	3.3	7.9
Tough	4.4^z ± .20	1.0	2.5	6.7
	Ease of fragmentation[b]			
Tender	7.3^x ± .04	.5	5.0	8.0
Intermediate	6.3^y ± .06	.9	3.3	7.9
Tough	4.2^z ± .21	1.1	2.5	6.7
	Amount of connective tissue[b]			
Tender	7.7^x ± .02	.2	6.6	8.0
Intermediate	7.4^y ± .03	.4	6.1	8.0
Tough	6.7^z ± .11	.6	5.6	7.8
	Juiciness[b]			
Tender	6.0^x ± .02	.3	4.8	6.8
Intermediate	5.8^y ± .02	.3	4.8	6.6
Tough	5.5^z ± .07	.4	4.9	6.3
	Beef flavor intensity[b]			
Tender	5.0^x ± .02	.3	4.3	5.9
Intermediate	5.0^x ± .02	.3	3.9	5.6
Tough	4.8^x ± .06	.3	4.1	5.3
	Off-flavor[c]			
Tender	3.0^x ± .02	.3	2.0	3.8
Intermediate	3.0^x ± .02	.2	1.9	3.6
Tough	2.9^x ± .04	.2	2.4	3.2

[a]N = 225, 233, and 25 for Tender, Intermediate, and Tough, respectively. Please note that the SEM is influenced by both the number of observations and the degree of variation in each tenderness class.

[b]1 = extremely tough, extremely difficult, abundant, extremely dry, or extremely bland and 8 = extremely tender, extremely easy, none, extremely juicy, or extremely intense.

[c]1 = intense and 4 = none.

[x,y,z]Means within a trait that do not share a common superscript differ ($P < .05$).

Table 3. Percentage of total variation in Warner-Bratzler shear force and trained sensory panel ratings accounted for by slice shear force value at 3 d postmortem and marbling score singularly and combined

Trait	Slice shear force value at 3 d postmortem	Marbling score	Combined
Warner-Bratzler shear force at 3 d postmortem	69	4	71
Warner-Bratzler shear force at 14 d postmortem	51	2	52
Tenderness	61	0	61
Ease of fragmentation	61	0	61
Amount of connective tissue	39	1	41
Juiciness	15	2	16
Beef flavor intensity	4	7	10
Off-flavor	4	0	4

elford et al., 1995, 1997a), the need for tenderness classification is greatest for longissimus. Clearly, it would be desirable if longissimus tenderness could be predicted by evaluating a lower-value muscle. However, the relationship between longissimus tenderness and the tenderness of other muscles has been reported to be weak to moderate (Knutson et al., 1966; Slanger et al., 1985; Shackelford et al., 1995). Thus, a direct evaluation of longissimus seems to be needed to accurately characterize longissimus tenderness.

The effect of tenderness classification on customer satisfaction will likely be greater for cuts that contain the longissimus than for other cuts. Even if there were no effect of tenderness classification on the palatability of other muscles of the carcass, tenderness classification is warranted because the longissimus represents about 20% of carcass value, and consumers are willing to pay a premium for consistently tender beef (Boleman et al., 1997). Further research is needed to test the feasibility and accuracy of this system under a variety of commercial processing conditions.

Implications

Tenderness classification will allow packers and processors to accurately classify beef carcasses for

Table 4. Trained sensory panel ratings as stratified by tenderness class and marbling score

	Tender	Intermediate	Tough
		n	
Modest or higher	14	14	—
Small	118	100	8
Slight	89	115	17
Traces	4	4	—
		Tenderness[b]	
Modest or higher	7.4 ± .11[a]	6.3 ± .29	
Small	7.3 ± .05	6.3 ± .09	4.7 ± .45
Slight	7.4 ± .05	6.4 ± .08	4.2 ± .22
Traces	7.1 ± .37	6.5 ± .50	
		Juiciness[b]	
Modest or higher	6.1 ± .05	5.9 ± .12	
Small	6.0 ± .03	5.8 ± .03	5.7 ± .13
Slight	6.0 ± .03	5.8 ± .03	5.5 ± .08
Traces	6.1 ± .26	5.6 ± .28	
		Beef flavor intensity[b]	
Modest or higher	5.1 ± .07	5.1 ± .09	
Small	5.1 ± .03	5.0 ± .03	4.8 ± .11
Slight	5.0 ± .03	4.9 ± .02	4.8 ± .06
Traces	4.6 ± .12	4.7 ± .18	

[a]Please note that the SEM is influenced by both the number of observations and the degree of variation in each tenderness class.
[b]1 = extremely tough, dry, or bland and 8 = extremely tender, juicy, or intense.

longissimus tenderness. This system should allow identification and marketing of a portion of the beef supply with consistently tender longissimus cuts. In turn, marketing of a more consistent product should increase consumer satisfaction with beef. Use of tenderness classification data in a value-based marketing system should result in clearer economic signals throughout the beef production chain.

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