Relationship of beef longissimus tenderness classes to tenderness of gluteus medius, semimembranosus, and biceps femoris[1]

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ABSTRACT: The objective of this study was to determine the relationship of longissimus tenderness classes to tenderness of three other major muscles. Ninety-eight crossbred steers and heifers (14 to 17 mo of age) were humanely slaughtered over 9 wk and the carcasses were chilled 48 h at 0°C. At 48 h postmortem, carcasses were assigned to one of three tenderness classes (tender = < 26 kg, intermediate = 26 to 42 kg, tough = > 42 kg) using slice shear force from the MARC Beef Classification System (n = 20, 67, and 11, respectively). The longissimus thoracis, gluteus medius, semimembranosus, and biceps femoris were removed, aged at 2°C, and frozen at −30°C at 14 d postmortem. Two 2.54-cm-thick steaks were obtained from each muscle, thawed to 5°C, cooked with a belt grill at 163°C for 5.5 min, and served warm to an eight-member trained descriptive attribute panel. Panelists evaluated each sample for tenderness, connective tissue amount, juiciness, and beef flavor intensity on 8-point scales. The mean 2-d longissimus slice shear force values were 20.7, 34.4, and 46.3 kg, respectively, for the "tender," "intermediate," and "tough" classes. Tenderness ratings were lowest ($P < 0.05$) for the "tough" class and highest ($P < 0.05$) for the "tender" class for all muscles except the gluteus medius, for which the "tender" and "intermediate" classes were not different ($P > 0.05$; longissimus, 7.7, 7.1, 6.3, and 7.1; semimembranosus, 6.4, 5.8, 5.1, and 5.8; biceps femoris, 5.9, 5.4, 4.8, and 5.4; gluteus medius, 6.8, 6.5, 5.8, and 6.5 for the "tender," "intermediate," "tough," and "unsorted" classes, respectively). The magnitude of the differences in tenderness ratings between the "tender" and "intermediate" classes and between the "intermediate" and "tough" classes was similar for all muscles. The percentages of tenderness ratings greater than 5.0 (slightly tender) for the "tender" and "unsorted" classes, respectively, were as follows: longissimus, 100 and 95%; semimembranosus, 95 and 85%; gluteus medius, 100 and 94%; and biceps femoris, 95 and 81%. The simple correlations between longissimus and the other muscles for tenderness ratings were as follows: semimembranosus, 0.58; biceps femoris, 0.43; and gluteus medius, 0.68. These data indicate that early-postmortem longissimus slice shear force could be used to classify top sirloin, top round, and bottom round cuts for tenderness.

Key Words: Beef, Carcass Grading, Classification, Meat Quality, Muscles, Tenderness

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Introduction

An accurate, instrumental method for classifying beef carcasses based on longissimus tenderness has been developed (Shackelford et al., 1997b, 1999; Wheeler et al., 1999a). Efforts have been focused on prediction of longissimus tenderness, because the longissimus comprises a higher proportion of total carcass value than any other muscle and there is more carcass-to-carcass tenderness variation in longissimus than in other major muscles (Shackelford et al., 1995, 1997a). Furthermore, there are many potential ways to use longissimus slice shear force to classify beef carcasses for tenderness. However, for illustrative purposes we have evaluated the results of creating three tenderness classes (Shackelford et al., 1997b, 1999; Wheeler et al., 1999b).

It would be desirable if an accurate prediction of longissimus tenderness also could be used to classify other muscles into tenderness groups. The relationship between tenderness of the longissimus and tenderness of other muscles has been reported to be weak to moderate (Slanger et al., 1985; Shackelford et al., 1995). However, the effectiveness of applying classification based on longissimus tenderness to other muscles has not been adequately evaluated. Thus, the objective of this experiment was to determine the relationship of longissimus tender-

[1]Names are necessary to report facually 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 others thay may also be suitable.

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ness classes to tenderness of gluteus medius, semimembranosus, and biceps femoris.

Materials and Methods

Animals. The Roman L. Hruska U.S. Meat Animal Research Center (**MARC**) Animal Care and Use Committee approved the use of animals in this study. One hundred fourteen (Angus, Hereford, and Piedmontese crossbred) steers and heifers (14 to 17 mo of age) were weaned at approximately 200 d of age and fed a corn and corn silage diet for 215 to 278 d. All animals were genotyped (Fahrenkrug et al., 1999) for the inactive myostatin allele that causes the double-muscling phenotype. Analyses indicated that genotype did not affect the results of this experiment; nonetheless, only muscles from carcasses of the 98 animals with zero or one copy of the inactive myostatin allele were used. Animals were humanely slaughtered and processed at the MARC abattoir in four groups during a period spanning 63 d. Carcasses were not electrically stimulated. Carcasses were chilled for 48 h at 0°C. At 48 h postmortem, right carcass sides were ribbed between the 12th and 13th ribs and USDA quality and yield grade factors were measured by experienced MARC personnel (USDA, 1997).

At 48 h postmortem, carcasses were assigned to one of three tenderness classes (tender = < 26 kg, intermediate = 26 to 42 kg, tough = > 42 kg) based on longissimus slice shear force values from the left carcass sides using the MARC Beef Classification System (Shackelford et al., 1999). These criteria differ slightly from those reported by Shackelford et al. (1999) because classification was conducted at 2 rather than 3 d postmortem. An "unsorted" class, represented by all 98 samples, was used to compare tenderness classification to doing no sorting for tenderness. The longissimus thoracis, gluteus medius, semimembranosus, and biceps femoris from the right carcass sides were aged at 2°C (muscles were removed from the carcass and vacuum-packaged at postmortem times ranging from 2 to 13 d) and then frozen at –30°C at 14 d postmortem. The frozen muscles were cut (from the anterior end of the longissimus thoracis and from the center of the other muscles) into 2.54-cm-thick steaks using a band saw. Two steaks from the longissimus (steaks two and three) and one steak each from the gluteus medius, semimembranosus, and biceps femoris were evaluated by a trained sensory panel.

Cooking. Steaks were thawed and cooked as described by Wheeler et al. (1998) with the following exceptions. The preheat platen on the belt grill was set at 149°C,

Table 1. Simple statistics for carcass traits

Class/trait	Mean	SD	Minimum	Maximum
Unsorted (n = 98)[a]				
Hot carcass weight, kg	310	38	235	409
Adjusted fat thickness, cm	0.74	0.05	0.13	2.50
Longissimus area, cm^2	86.5	11.6	65.8	118.1
Kidney, pelvic, and heart fat, %	2.2	0.7	0.5	4.0
USDA yield grade	2.0	1.0	0.0	4.8
Marbling score[b]	472	59	290	650
Tender (n = 20)[c]				
Hot carcass weight, kg	309	29	253	353
Adjusted fat thickness, cm	0.71	0.05	0.38	2.50
Longissimus area, cm^2	87.1	12.3	66.5	111.6
Kidney, pelvic, and heart fat, %	1.8	0.7	1.0	3.0
USDA yield grade	1.8	1.0	0.0	4.8
Marbling score[b]	449	75	340	650
Intermediate (n = 67)[d]				
Hot carcass weight, kg	311	38	235	409
Adjusted fat thickness, cm	0.76	0.05	0.13	2.16
Longissimus area, cm^2	87.1	11.6	65.8	118.1
Kidney, pelvic, and heart fat, %	2.3	0.7	0.5	4.0
USDA yield grade	2.0	1.0	0.1	4.3
Marbling score[b]	476	54	290	590
Tough (n = 11)[e]				
Hot carcass weight, kg	305	50	238	373
Adjusted fat thickness, cm	0.79	0.06	0.25	1.78
Longissimus area, cm^2	79.4	7.1	67.1	93.5
Kidney, pelvic, and heart fat, %	2.3	0.5	1.5	3.0
USDA yield grade	2.3	0.9	1.1	3.7
Marbling score[b]	489	52	410	580

[a]All 98 samples.
[b]200 = "Practically Devoid," 400 = "Slight," 600 = "Modest."
[c] "Tender" = < 26 kg longissimus slice shear force at 2 d postmortem.
[d] "Intermediate" = 26 and 42 kg longissimus slice shear force at 2 d postmortem.
[e] "Tough" = > 42 kg longissimus slice shear force at 2 d postmortem.

rather than disconnected. That change required that cooking time be reduced to 5.5 min, rather than 5.7 min. The means and SD for cooked temperature (°C) for longissimus, gluteus medius, semimembranosus, and biceps femoris were 70.6 (1.5), 71.2 (1.3), 70.8 (2.1), and 70.8 (1.3), respectively.

Trained Sensory Panel Analysis. Cooked steaks were evaluated by an eight-member trained descriptive attribute panel as described by Wheeler et al. (1998).

Statistical Analysis. Data were analyzed by analysis of variance for a completely randomized design (SAS Inst. Inc., Cary, NC). The main effect was tenderness class (tender, intermediate, tough, and unsorted). Mean separation for significant ($P < 0.05$) muscle effects was accomplished by the PDIFF option (a pairwise t-test) of the least squares means procedures (SAS Inst. Inc.). The PROC CORR procedure of SAS (SAS Inst. Inc.) was used for simple correlations. Mantel-Haenszel chi-square analysis was used to analyze the frequency data.

Results and Discussion

Carcass traits characterizing the sample are shown in Table 1. Ninety percent of carcasses had Small or Slight marbling scores that would qualify them for Low Choice or Select quality grades, respectively (USDA, 1997). The most recent beef carcass quality audit indicated that 83% of fed steer and heifer carcasses had Slight or Small marbling scores (Boleman et al., 1998). Wulf et al. (1997) reported that it was in this narrow range of marbling scores, which includes a majority of fed beef, that more precise methods for distinguishing palatable from unpalatable beef were needed.

Based on longissimus slice shear force values at 2 d postmortem, 20 carcasses were assigned to "tender," 67

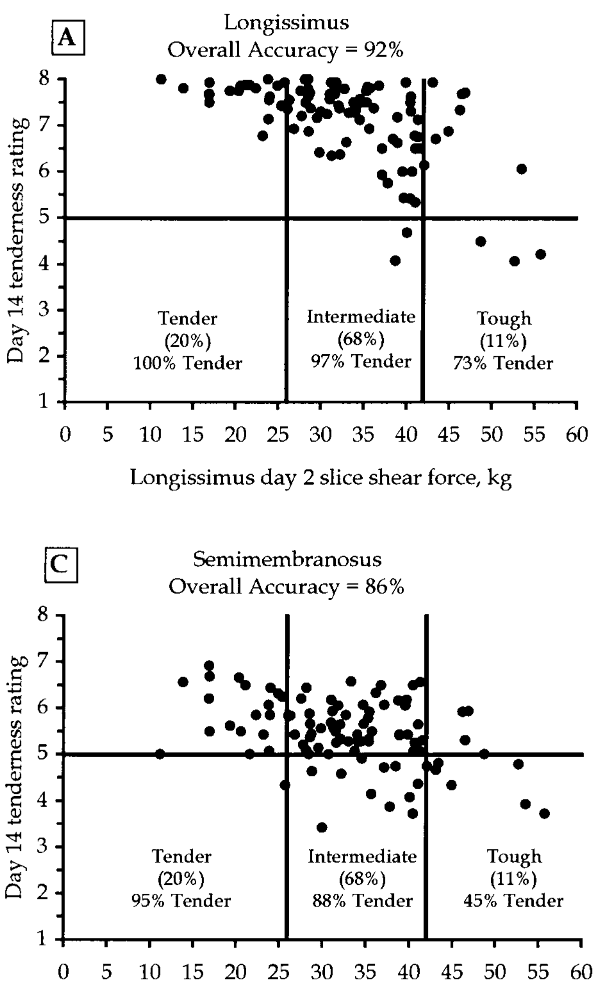

Figure 1. Classification of longissimus, gluteus medius, semimembranosus, and biceps femoris into three tenderness classes based on d-2 postmortem longissimus slice shear force (Tender = < 26 kg, Intermediate = 26 to 42 kg, and Tough = > 42 kg). Accuracy of classification is based on d-14 postmortem trained sensory tenderness ratings. Overall accuracy is based on the percentage of "tender" and "intermediate" with a tenderness rating at 14 d postmortem > 5.0 (slightly tender) and the percentage of "tough" with a tenderness rating at 14 d postmortem < 5.0. The number in parentheses is the percentage of the total that was in that class. The percentage "tender" is the percentage of that class with a tenderness rating at 14 d postmortem > 5.0.

to "intermediate," and 11 to "tough" classes (Figure 1A). The mean slice shear force values were 20.7, 34.4, and 46.3 kg, respectively, for "tender," "intermediate," and "tough." The distribution among the three tenderness classes differed from that previously published (Shackelford et al., 1999) due to a greater proportion of carcasses in the "intermediate" and "tough" classes in this study. However, the level of accuracy of assigning carcasses to classes, based on d-14 trained sensory tenderness rating of "slightly tender," was 92%, which was similar to the accuracy reported by Shackelford et al. (1999). Carcasses in the "tender" and "intermediate" classes were considered accurately classified if 14-d tenderness rating was "slightly tender" or greater, and carcasses in the "tough" class were considered accurately classified if 14-d tenderness rating was less than "slightly tender." For the longissimus, the proportions of each class that were "tender" after aging were similar for "tender" and "intermediate" classes and higher for the "tough" class than was reported by Shackelford et al. (1999). These statistics are likely to vary depending on cattle type, management practices, and carcass processing conditions.

The accuracy of classifying the gluteus medius into one of three tenderness classes based on longissimus d-2 slice shear force was slightly lower (89%) than the 92% for the longissimus and slightly higher than for semimembranosus (86%) or biceps femoris (85%; Figures 1B, 1C, and 1D). Percentages of individual tenderness classes rated as "tender" for gluteus medius classification were more similar to those of the longissimus muscle than to those of the semimembranosus or biceps femoris (Figure 1). For gluteus medius, 100, 96, and 73% of the samples, respectively, for the "tender," "intermediate," and "tough" classes were rated "tender" by the trained sensory panel at 14 d postmortem. For semimembranosus and biceps femoris, 95% of the "tender" class (all but one sample) was rated "tender." For semimembranosus, 88% of the "intermediate" class and 45% of the "tough" class were rated "tender." For biceps femoris, 84% of the "intermediate" class and 36% of the "tough" class were rated "tender."

For longissimus and biceps femoris, tenderness ratings were highest ($P < 0.05$) for the "tender" class (Table 2). For gluteus medius and semimembranosus, tenderness ratings were not different ($P > 0.05$) between the "tender" and "intermediate" classes. For all four muscles, tenderness ratings were lowest ($P < 0.05$) for the "tough" class. The magnitude of the difference in tenderness ratings between the "tender" and "tough" classes was similar in all four muscles (1.0 to 1.4 units). For all muscles except gluteus medius, tenderness ratings were higher ($P < 0.05$) for the "tender" class than for the "unsorted" class. Connective tissue amount ratings were higher ($P < 0.05$) for the "tender" class (less connective tissue) than for the

Table 2. Trained sensory descriptive attribute ratings by tenderness class and muscle with 14 d of postmortem aging[a]

Class	Tenderness[b]	Connective tissue[c]	Juiciness[d]	Beef flavor intensity[e]
		Longissimus		
Tender[f]	7.7 ± 0.20[g]	7.9 ± 0.05[g]	5.6 ± 0.07	4.6 ± 0.07
Intermediate[f]	7.1 ± 0.11[h]	7.7 ± 0.03[h]	5.5 ± 0.04	4.7 ± 0.04
Tough[f]	6.3 ± 0.27[i]	7.6 ± 0.07[h]	5.5 ± 0.09	4.7 ± 0.09
Unsorted[f]	7.1 ± 0.09[h]	7.7 ± 0.02[h]	5.5 ± 0.03	4.7 ± 0.03
		Gluteus medius		
Tender[f]	6.8 ± 0.18[g]	7.2 ± 0.12[g]	5.4 ± 0.07	4.5 ± 0.05
Intermediate[f]	6.5 ± 0.10[g]	7.0 ± 0.06[g]	5.3 ± 0.04	4.5 ± 0.03
Tough[f]	5.8 ± 0.25[h]	6.5 ± 0.16[h]	5.2 ± 0.09	4.4 ± 0.07
Unsorted[f]	6.5 ± 0.08[g]	7.0 ± 0.05[g]	5.3 ± 0.03	4.4 ± 0.02
		Semimembranosus		
Tender[f]	6.4 ± 0.18[g]	6.3 ± 0.13[g]	5.2 ± 0.07	4.5 ± 0.05
Intermediate[f]	5.8 ± 0.10[gh]	6.1 ± 0.07[g]	5.3 ± 0.04	4.5 ± 0.03
Tough[f]	5.1 ± 0.25[i]	5.7 ± 0.17[h]	5.2 ± 0.10	4.5 ± 0.07
Unsorted[f]	5.8 ± 0.08[h]	6.1 ± 0.06[g]	5.3 ± 0.03	4.5 ± 0.02
		Biceps femoris		
Tender[f]	5.9 ± 0.16[g]	5.7 ± 0.12[g]	5.3 ± 0.07	4.5 ± 0.05
Intermediate[f]	5.4 ± 0.09[h]	5.4 ± 0.07[gh]	5.4 ± 0.04	4.5 ± 0.03
Tough[f]	4.8 ± 0.21[i]	4.9 ± 0.17[i]	5.3 ± 0.09	4.4 ± 0.07
Unsorted[f]	5.4 ± 0.07[h]	5.4 ± 0.06[h]	5.4 ± 0.03	4.5 ± 0.02

[a]Mean ± SEM.
[b]1 = extremely tough, 8 = extremely tender.
[c]1 = abundant, 8 = none.
[d]1 = extremely dry, 8 = extremely juicy.
[e]1 = extremely bland, 8 = extremely intense.
[f]Based on 2 d postmortem longissimus slice shear force: tender = < 26 kg, intermediate = 26 to 42 kg, tough = > 42 kg, and unsorted = all 98 samples.
[g,h,i]Within a column and muscle, means lacking a common superscript letter differ ($P < 0.05$).

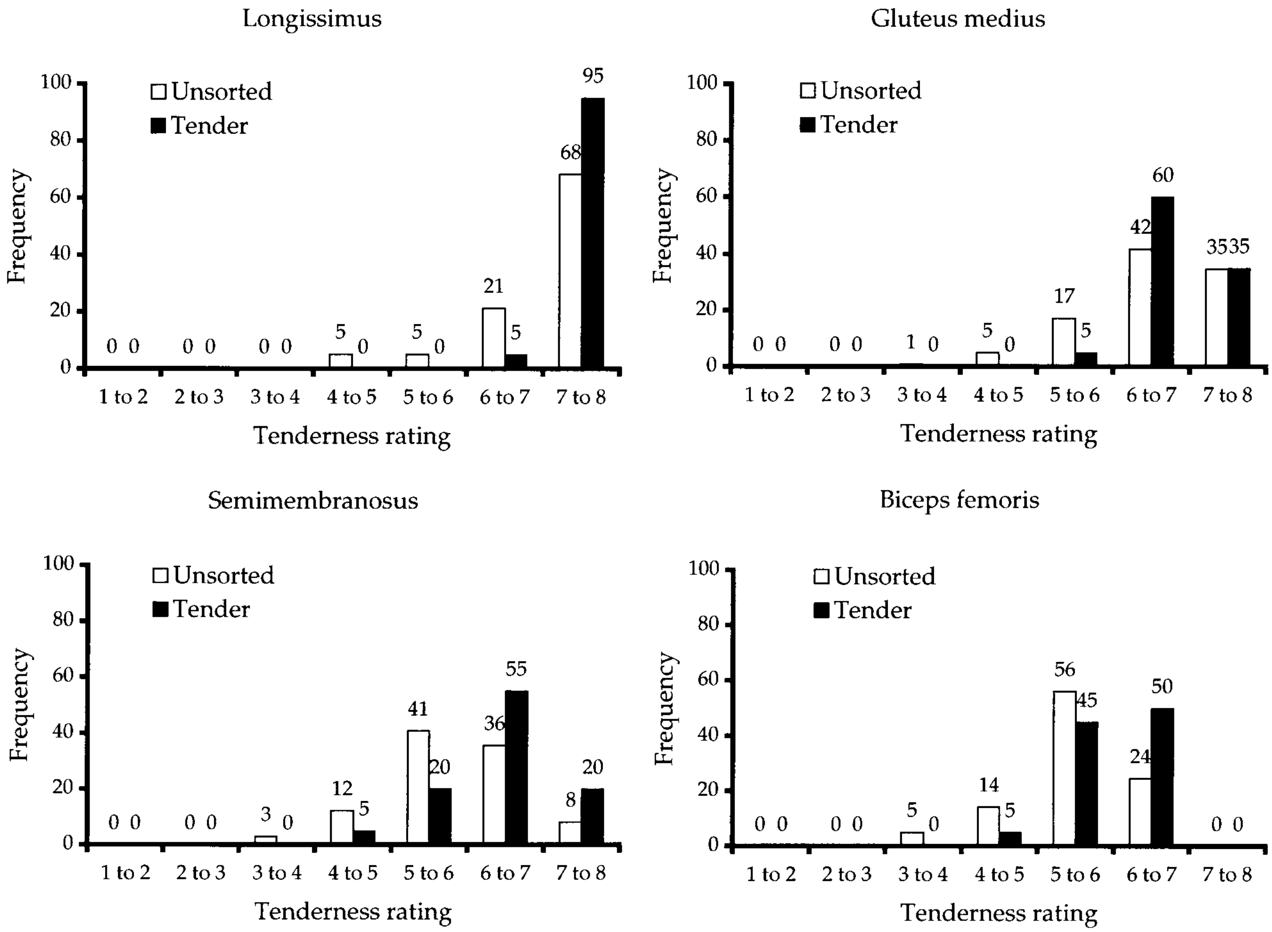

Figure 2. Frequency distribution of trained sensory panel tenderness ratings for "tender" and "unsorted" classes for each muscle. "Unsorted" includes all samples. "Tender" includes those samples with d-2 postmortem longissimus slice shear force < 26 kg. Chi-square analysis indicated the "tender" distribution was different ($P < 0.05$) from the "unsorted" distribution for all muscles except the gluteus medius.

"tough" class in all muscles. Connective tissue amount ratings were not different ($P > 0.05$) between the "tender" and "intermediate" classes, except in longissimus. Connective tissue amount ratings were higher ($P < 0.05$) for the "tender" class than for the "unsorted" class in longissimus and biceps femoris. The "intermediate" class was not different ($P > 0.05$) from the "unsorted" class in tenderness or connective tissue ratings for all four muscles. Juiciness and beef flavor intensity ratings were not affected ($P > 0.05$) by tenderness class in any muscle.

For all four muscles, the improvement in tenderness of the "tender" class compared to the "unsorted" class is further illustrated by the distribution of tenderness ratings (Figure 2). The distributions for the "tender" class were shifted ($P < 0.05$) toward higher tenderness ratings in all muscles except the gluteus medius.

The simple correlation coefficients between d-2 longissimus slice shear force and d-14 tenderness rating of the four muscles were significant but moderate in magnitude (Table 3). The simple correlation coefficients for d-14 postmortem tenderness rating among all muscles were significant. The correlations among muscles for tenderness rating were moderate in magnitude but generally higher than can be found in the literature. Previously reported correlations among these muscles for trained sensory tenderness rating were 0.20 to 0.32 in beef (Joseph and Connolly, 1979) and 0.17 to 0.54 in pork (Wheeler et al., 2000). Correlations among these muscles in beef for Warner-Bratzler shear force were 0.26 to 0.43 (Shackelford et al., 1995) and 0.40 (Slanger et al., 1985). Because previously reported correlations among muscles for mea-

Table 3. Simple correlation coefficients among muscles for d-14 postmortem tenderness rating and d-2 longissimus slice shear force

Muscle	Gluteus medius	Semi-membranosus	Biceps femoris	Longissimus d-2 SSF[a]
Longissimus	0.68**	0.58**	0.43*	–0.58**
Gluteus medius		0.62**	0.60**	–0.31*
Semi-membranosus			0.61**	–0.47*
Biceps femoris				–0.41*

[a]SSF = slice shear force.
*$P < 0.05$.
**$P < 0.01$.

sures of tenderness were relatively weak, it has been assumed that tenderness classification of the longissimus would do little to segregate other muscles into groups differing in tenderness (Shackelford et al., 1995, 1999). Joseph and Connolly (1979) concluded that using one muscle as an index of carcass toughness would not be feasible.

However, the present experiment indicates that at least three other muscles can be segregated into tenderness groups using early-postmortem longissimus tenderness classification. In support of this finding, Tipton et al. (1998) reported that consumer overall like scores were greater for "Guaranteed Tender Select" and "Guaranteed Tender Top Choice" (based on MARC longissimus tenderness classification at 2.5 d postmortem) strip, top sirloin, and top round, but not clod steaks, than for control steaks. Furthermore, Tatum et al. (1999) found that application of a "quality system" that included 1.5-d longissimus muscle Warner-Bratzler shear force to identify those that were "tender" and subsequent treatment with calcium chloride of those that were not "tender" reduced the probability of nonconformance to tenderness specification (< 4.54 kg Warner-Bratzler shear force) of both strip (0.26 to 0.12) and top sirloin (0.23 to 0.13) steaks.

The beef industry has made the development of an accurate instrument for meat tenderness measurement a high priority (NCA, 1994a, 1995). It has been suggested by industry leaders (NCA, 1994b) that sorting beef based on tenderness would result in increased consumer satisfaction by enabling the industry to manage and reduce the variation in tenderness. The current experiment indicates the cost of implementing a system for this purpose (Shackelford et al., 1997b, 1999; Wheeler et al., 1999a) could be greatly reduced and the amount of beef marketable as "tender" greatly increased by classifying other major muscles, in addition to the longissimus, into groups differing in tenderness. This does not mean that all muscles from "tender" carcasses will be as tender as longissimus muscle. It means they will be more tender than average for that muscle, which likely would warrant marketing in some way as superior in tenderness.

Implications

These results indicate that, in addition to the longissimus, it may be possible to market some other major beef cuts from a carcass identified as "tender" based on an early-postmortem measure of longissimus tenderness. By classifying tenderness of other muscles in addition to the longissimus, the cost of implementing a system for this purpose could be greatly reduced and the amount of beef marketable as "tender" greatly increased.

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