National Beef Tenderness Survey–1998[1]

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ABSTRACT: Fifty-six retail stores representing 15 retail chains and 14 foodservice facilities in eight U.S. cities were sampled to determine the tenderness of beef steaks at retail and foodservice levels based on Warner-Bratzler shear (WBS) values and consumer evaluation panels. Retail consumer panels were conducted at five universities. Each retail and foodservice steak was evaluated using 10-point scales. Steaks were divided into the following quality groups for statistical analysis: Prime, Top Choice, Choice, Select, and Lean or No Roll. Quality group had no effect on WBS values of retail clod, chuck roll, top round, bottom round, eye of round, top loin, top sirloin, or ribeye steaks but did ($P < .05$) affect values for the T-bone/porterhouse. The percentages of retail top round, eye of round, and bottom round steaks with a WBS force > 3.9 kg were 39.6, 55.9, and 68.0, respectively. Foodservice ribeye, top loin, and top sirloin steaks had WBS values less than 3.4 kg for all quality groups, with Prime ribeye steaks having lower ($P < .05$) WBS values than ribeyes from the other quality groups. With the exception of the retail ribeye steak, quality group did not affect consumer sensory ratings of retail and foodservice steaks. Average postfabrication aging times were 32 d for foodservice subprimals and 19 d for retail cut subprimals. These data indicate that improvements in the tenderness of retail cuts from the round are needed. Finally, quality group had little or no effect on consumer sensory evaluations and WBS values of retail and foodservice steaks used in this study.

Key Words: Beef, Consumer Panels, Market Survey, Tenderness

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Introduction

In 1990, Texas A&M University conducted the National Beef Tenderness Survey (Morgan et al., 1991). The purpose of that survey was to determine the tenderness of beef in the retail case based on Warner-Bratzler shear force values and trained sensory panels. That survey, in general, showed problems with the tenderness of beef from the chuck and round subprimals and with the top sirloin steak.

The Beef Customer Satisfaction Study (Neely et al., 1998, 1999; Lorenzen et al., 1999; Savell et al., 1999) showed that tenderness can be a major and contributing factor to consumers' perception of taste. Moreover, other investigations have suggested that consumers are willing to pay more for guaranteed tender beef products (Boleman et al., 1997). These studies have established the importance of tenderness to consumers who purchase beef products.

Because of the higher price of beef compared to other protein sources, the importance of a good eating experience is crucial to maintaining or improving current beef buying trends. With the tenderness problems found in the National Beef Tenderness Survey–1990 (Morgan et al., 1991) and the elapsed time since that survey was conducted, it became clear that it was important to update the information on beef tenderness on a nationwide basis. In addition, whereas the previous survey concentrated on beef from the retail sector, the growth in foodservice servings of beef (Neel et al., 1994) through the decade of the 1990s makes it imperative that this segment be evaluated for baseline tenderness information. Thus, the project had two objectives: 1) to determine the tenderness of beef from the retail case based on Warner-Bratzler shear (**WBS**) force and consumer

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evaluation panels and 2) to determine the tenderness of beef from the foodservice industry based on Warner-Bratzler shear force and consumer evaluation panels.

Materials and Methods

Sampling of Cities. Texas A&M University personnel and collaborators from Iowa State University, Oklahoma State University, Pennsylvania State University, and University of Florida sampled eight U.S. cities once, during the period from January 1998 to May 1998. The cities sampled were Atlanta, GA; Chicago, IL; Denver, CO; Houston, TX; Los Angeles, CA; New York, NY; Philadelphia, PA; and San Francisco, CA. In each city, two to three retail chains were sampled by auditing four stores per retail chain. For this study, the retail sector is defined as retail chains representing one-third of total market share in their area (Directory of Supermarket, Grocery and Convenience Store Chains, 1997). The retail chains were identified and Texas A&M personnel contacted each company to obtain permission to sample the stores. Cold storage areas were audited in at least two stores from each retail chain to obtain the code dates (to determine postfabrication times as a measure of postmortem aging), establishment numbers, grades, and company names of the boxed subprimals representing the retail cuts sampled in the retail case. Retail cuts were shipped for overnight delivery to Texas A&M University in insulated bags containing commercial ice packs and processed under refrigerated conditions (2 to 4°C) to obtain the following information: city, date, cut, chain, store number, price per pound, grade/brand, full- or self-service, external fat thickness (cm), and steak thickness (cm). Each steak was identified individually. Approximately 20% of the steaks representing each retail cut and grade/brand at each store were vacuum-packaged and frozen for consumer sensory panels.

While in each city, the collaborators sampled at least one foodservice facility. For this study, foodservice facilities were defined as operations that portioned steaks for commercial operators (restaurants, fast food outlets, hotel/motel, country clubs, etc.). The facilities were chosen based on their willingness to participate in the study. Each USDA quality grade or branded beef product that the facility portioned into steaks was evaluated. University personnel gathered information on each cut regarding postfabrication times (as a measure of postmortem aging), type of aging, processing temperatures, and use of mechanical tenderization methods. Type of aging was described as “wet” if beef subprimals were aged (postmortem) in sealed vacuum-packaged bags before fabrication into steaks and “dry” if subprimals were aged unpacked and under controlled conditions. Steaks were shipped to Texas A&M University and processed as described above. Approximately 20% of the steaks (from each grade) were selected randomly, vacuum-packaged, and frozen at −10°C for foodservice consumer panel evaluation.

Steaks. The following cuts were sampled from the self-serve retail case: chuck roll steak (UPC #1158 and #1102), clod steak (UPC #1133), ribeye steak (UPC #1203 and #1209), top loin steak (UPC #1404), T-bone/porterhouse steak (UPC #1369/#1330), top sirloin steak (UPC #1422), bottom round steak (UPC #1466), top round steak (UPC #1553), and eye of round steak (UPC #1481) (URMIS, 1995). Sampling of the full-service retail cuts involved cuts common to this type of service: ribeye steaks, top loin steaks, T-bone/porterhouse steaks, top sirloin steaks, and top round steaks. Two steaks from each retail cut, within each grade, were sampled randomly from full- and self-service. The clod steak, ribeye steak, top sirloin steak, and top round steak were the focus of the retail consumer panel analysis. At the foodservice facilities, ribeye steaks (IMPS #1112), top loin steaks (IMPS #1180), and top sirloin steaks (IMPS #1184B) (NAMP, 1997) were sampled. Eight steaks from each cut, within each grade represented in the facility, were obtained. The ribeye, top loin, and top sirloin steaks were evaluated by consumers.

Warner-Bratzler Shear Force. Steaks were held at 4°C to allow for temperature equilibration after shipping. The fresh steaks were held no longer than 48 h before cooking for Warner-Bratzler shear analysis. Farberware Open Hearth electric broilers (Kidde, Bronx, NY) were used to cook the retail cuts. The metal housing and drip pans of each broiler were covered with aluminum foil and pre-heated for 15 min. During cooking, all steaks were turned after reaching an internal temperature of 40°C and cooked to a 70°C final internal temperature. Cooking time, initial and final internal temperature, raw weight, and final cooked weight were recorded for each steak. Internal temperature was monitored by .02-cm-diameter, copper-constantan thermocouple wire attached to a microprocessor thermometer (Model HH21, Omega, Stamford, CT), which was inserted into the geometric center of each steak. If steaks were approximately 1.3 cm thick or less, temperature was monitored by temperature probe (Model HH21 microprocessor thermometer with a Type T temperature probe attachment, Omega). After the desired internal temperature was reached, steaks were removed from the broiler, weighed, and wrapped individually with Saran wrap film. Steaks then were cooled at 4°C for at least 10 h. After cooling, steaks were trimmed free of visible connective tissue to expose the muscle fiber orientation. Six 1.3-cm cores were removed from each muscle. Both the longissimus lumborum muscle (four cores) and the psoas major muscle (two cores) were used to represent the T-bone and porterhouse steaks. Each chuck roll steak was viewed by personnel before coring. The muscles were ranked from largest to smallest, based on their area of exposed lean. The number of cores taken from each muscle was adjusted so muscles with the largest area of exposed lean comprised the majority of the cores taken. The cores were removed parallel to the muscle fiber orientation and sheared once, perpendicular to the muscle fibers, on a Warner-Bratzler shear machine (G-R Electric Manufacturing Co., Manhattan, KS). The peak force (kg) needed to shear each core was recorded, and the mean of the six cores was used in the statistical analysis.

Warner-Bratzler shear force values obtained on the foodservice cuts were conducted as described above with a few exceptions. Steaks were prepared on a flat-top griddle (Model TMM-36B, Wolf Range Co., Compton, CA) to simulate industry practice. The griddle temperature was set at 177°C and allowed to preheat for 30 min. Steaks cooked on the griddle were monitored by temperature probe (Model HH21 microprocessor thermometer with a Type T temperature probe attachment, Omega).

Consumer Panels. Frozen retail steaks were divided into groups (based on retail cut and the number of each retail cut being sampled) and assigned to Texas A&M University, Iowa State University, Oklahoma State University, Pennsylvania State University, and University of Florida. Panelists were recruited from the surrounding communities and within the universities. Steaks were thawed at 2 to 5°C in vacuum-packaged bags for at least 24 h, and stacking or overlapping of the steaks was avoided. All steaks were broiled on Open Hearth electric broilers as described earlier, or in a broiler oven (Model CN02, General Electric, Fairfield, CT) preheated to 232°C for 30 min. Steaks were served randomly to individual panelists in sensory booths under white light and were provided with water and an expectorant cup. Testing was conducted at a central location. Each panelist evaluated eight steaks. Two samples (measuring approximately $1 \times 1 \times 2.5$ cm) from each steak were evaluated by each panelist. Samples were characterized using a 10-point scale for overall like (1 = dislike extremely; 10 = like extremely), flavor (1 = dislike extremely; 10 = like extremely), beef flavor (1 = none at all; 10 = an extreme amount), juiciness (1 = not at all juicy; 10 = very juicy), and tenderness (1 = not at all tender; 10 = very tender). Before sampling, each panelist completed a demographic questionnaire and a consent form. All foodservice cuts were evaluated at Texas A&M University in the Product Sensory Laboratory. Foodservice consumer panelists used the same ballots, and samples were served under the same conditions as the retail panels, with one exception. The foodservice steaks were prepared on the flat-top griddle using the same cooking procedures used to prepare foodservice steaks for Warner-Bratzler shear force determination. Data were averaged across panelists for each steak, and the mean was used in the analysis to determine the least squares means represented in each quality group. This study was approved by the Institutional Human Use Committee at Texas A&M University.

Statistical Analysis. Before analysis, the steaks were divided into groups based on USDA grade/brand and the number of samples. The groups consisted of steaks graded USDA Prime, Choice, and Select, as well as those that were not graded (termed "No Roll"). USDA-certified, branded beef programs with carcass specifications focusing on marbling scores of Small^{50} or higher were termed "Top Choice." USDA-certified, branded beef programs centered on subprimals from USDA Select or lower carcasses were grouped as "Lean." Warner-Bratzler shear values and consumer panel responses were analyzed using the general linear model procedure of SAS (1990). Cook loss was included in the model as a covariate for the Warner-Bratzler shear and foodservice consumer panel analysis. Retail consumer panel analysis was conducted using group as a main effect, with university included in the model as a block effect. Least squares means were separated using the P-diff option of SAS (1990) and tested to a 5% significance level. Means and standard deviations were analyzed using PROC MEANS and PROC UNIVARIATE of SAS (1990). The percentages of steaks with shear values > 3.9 and 4.6 kg (Shackelford et al., 1991) were analyzed using PROC FREQ of SAS (1990).

Results and Discussion

Product Information. The external fat thickness and steak thickness of retail cuts are presented in Table 1. Retail steaks originating from the beef full-loin (top loin, T-bone, porterhouse, and top sirloin) had significantly more external fat than other retail cuts. The chuck roll, top round, and eye of round steaks possessed the least ($P < .05$) amount of external fat compared to the other retail cuts. Mean external fat levels for all retail steaks was .28 cm (data not reported in tabular form). The National Beef Market Basket Survey (Savell et al., 1991) reported external fat levels of .38 cm on the steaks sampled in that survey. The decrease in external fat thickness values since 1991 indicates the meat industry's shift toward closely trimmed retail cuts.

Retail stores fabricated steaks from the rib and loin wholesale cuts thicker ($P < .05$) than the chuck and round. There was no difference in the thickness of the

Table 1. Least squares means and standard errors for external fat thickness and steak thickness of retail cuts

Steak	n	External fat thickness, cm	Steak thickness, cm
Clod	68	.24 ± .03^{bc}	1.81 ± .07de
Chuck roll	135	.15 ± .02^{d}	1.87 ± .05^{cd}
Ribeye	200	.24 ± .02^{b}	2.28 ± .04^{b}
Top loin	269	.39 ± .02^{a}	2.39 ± .03^{a}
T-bone	147	.41 ± .02^{a}	2.29 ± .04^{ab}
Porterhouse	56	.44 ± .03^{a}	2.34 ± .07^{ab}
Top sirloin	118	.41 ± .02^{a}	2.23 ± .05^{b}
Top round	91	.15 ± .03^{d}	2.00 ± .06^{c}
Bottom round	97	.25 ± .03^{b}	1.62 ± .05^{f}
Eye of round	177	.18 ± .02^{cd}	1.74 ± .04^{ef}

^{a,b,c,d,e,f}Within a column, means lacking a common superscript letter differ ($P < .05$).

Table 2. Least squares means and standard errors for external fat and steak thickness of foodservice steaks

Cut	n	External fat thickness, cm	Steak thickness, cm
Ribeye	212	.30 ± .02[a]	2.59 ± .04[a]
Top loin	262	.33 ± .01[a]	2.98 ± .04[b]
Top butt	79	.04 ± .02[b]	3.43 ± .07[c]

[a,b,c]Within a column, means lacking a common superscript letter differ ($P < .05$).

top loin, T-bone, and porterhouse steaks, and the thickness of the ribeye and top sirloin steaks was similar to that of the T-bone and porterhouse. However, there was a significant difference ($P < .05$) in the thickness of these steaks compared to the other retail cuts surveyed. The eye of round and bottom round steaks were the thinnest steaks sampled ($P < .05$), but the thickness of the clod steak was statistically similar to that of the eye of round steak. The effect of steak thickness on tenderness is inconclusive. Simmons et al. (1985) showed that increasing the thickness of pork loin chops from 1.27 cm to 1.90 or 2.54 cm significantly lowered their WBS values by .3 kg. However, Neely et al. (1995) showed that beef loin steaks cut 2.54 cm thick were tougher ($P < .05$) than steaks cut 1.27, 1.91, or 3.81 cm thick. More research is needed to determine the effect of steak thickness on beef tenderness.

External fat thickness and steak thickness of foodservice cuts are shown in Table 2. The external fat thickness of top sirloin steaks was significantly less than that of ribeye and top loin steaks. The role, if any, that external fat thickness has on tenderness is not well researched. Berry (1993) showed that external fat of .6 cm had little to no effect on the peak load of top loin steaks compared to steaks with no external fat. Coleman et al. (1988) reported that external fat thicknesses of .6 and 1.3 cm had no effect on trained sensory panel muscle fiber tenderness scores of broiled top loin steaks. Additionally, top sirloin steaks were thicker than top loin steaks, which were thicker than ribeye steaks ($P < .05$).

Comparisons of steak thickness and external fat thickness of ribeye, top loin, and top sirloin steaks were made between retail and foodservice steaks (data not shown). The retail data were divided into full-service and self-service for a more detailed analysis. Ribeye steaks from foodservice and retail self-service did not differ in external fat thickness but did have more ($P < .05$) external fat than retail full-service ribeye steaks. Ribeye and top loin steaks from self-service counters were thinner ($P < .05$) than full-service retail and foodservice steaks. However, there were no differences in ribeye and top loin steak thickness between full-service retail and foodservice steaks. Foodservice top sirloin steaks had significantly less external fat than full- and self-service retail top sirloin steaks. This difference is the result of different fabrication styles. The biceps femoris muscle is removed from foodservice top sirloin steaks, which removes the external fat on the subprimal. Foodservice top sirloin steaks were cut thicker than full-service retail steaks, which were thicker than self-service retail top sirloin steaks ($P < .05$).

Table 3. Postfabrication times (d) for subprimal cuts audited in the cold storage facilities of retail stores

Subprimals	Mean	SD	Min[a]	Max[b]	% < 14 d[c]
Chuck[d]	19	8.2	6	50	26.7
Ribeye, boneless	21	13.5	6	59	41.9
Ribeye, bone-in	22	9.9	5	43	31.1
Short loins	18	7.8	7	37	30.2
Strip loin, boneless	20	11.5	5	61	28.6
Strip loin, bone-in	14	5.1	7	22	45.5
Top sirloin butt	19	9.5	5	48	31.0
Round[e]	18	9.1	2	52	39.0
Overall	19	9.7	2	61	34.1

[a]Min = minimum value.
[b]Max = maximum value.
[c]% < 14 d = percentage of subprimals aged less than 14 d.
[d]Chuck = includes all subprimals from the chuck.
[e]Round = includes all subprimals from the round.

Postfabrication Aging Times. Subprimal postfabrication times at the retail level averaged 19 d (Table 3). Bone-in strip loins had the shortest postfabrication aging times, whereas bone-in ribeye rolls had the longest postfabrication times. Postfabrication aging times ranged from 2 to 61 d; 34.1% of the subprimals had postfabrication age times less than 14 d.

Postfabrication age times for foodservice subprimals are presented in Table 4. Overall, foodservice steaks were subjected to a postfabrication time of 32 d. Interestingly, top sirloins were aged an average of 32 d with a minimum of 20 d before fabrication in an effort to maximize tenderness. However, Harris et al. (1992) reported that aging top sirloins up to 35 d postmortem had no effect on WBS values.

Postfabrication storage of meat at temperatures above freezing to improve tenderness has been well established. Recently, Lorenzen et al. (1998) reported that postmortem aging times of 14 d maximized the tenderness of steaks from the chuck roll, rib, and shortloin. Based on this information, approximately one-third of retail subprimals sampled were not aged adequately. Approximately one of every five subprimals

Table 4. Postfabrication times (d) for subprimal cuts audited at the foodservice level

Subprimal	Mean	SD	Min[a]	Max[b]	% < 14 d[c]
Ribeye, boneless	39	21.5	10	67	20.0
Ribeye, bone-in	15	5.1	11	21	33.3
Strip loin, boneless	31	17.5	5	61	26.7
Top sirloin	32	12.5	20	55	0
Overall	32	17.6	5	67	19.4

[a]Min = minimum value.
[b]Max = maximum value.
[c]% < 14 d = percentage of subprimals aged less than 14 d.

Table 5. Least squares means and standard errors for Warner-Bratzler shear values (kg) of retail steaks from the rib and loin subprimals

	Group				
Steak	Prime	Top Choice	Choice	Select	Lean
Ribeye	2.93 ± .33	2.76 ± .09	2.88 ± .09	2.87 ± .08	3.01 ± .19
Top loin	3.20 ± .29	2.59 ± .10	2.84 ± .08	2.75 ± .07	2.92 ± .14
T-bone/porterhouse	3.26 ± .32[b]	2.47 ± .09[a]	2.75 ± .08[b]	2.76 ± .07[b]	—
Top sirloin	3.77 ± .34	2.88 ± .15	3.01 ± .12	3.05 ± .10	3.23 ± .23

[a,b]Within a row, means lacking a common superscript letter differ ($P < .05$).

aged at foodservice facilities would be subjected to insufficient aging periods.

Information obtained from the cold storage rooms at retail stores was summarized (data not shown). Data were gathered on boxed subprimals reflecting the retail cuts sampled in the full- and self-serve cases. A total of 38 U.S. and Canadian facilities supplied subprimals to the retail stores evaluated in the survey. Temperature of the storage facilities ranged from –2.2 to 6.1°C. The following quality groups were represented: Prime, Top Choice, Choice, Select, Lean, and No Roll. However, none of the No Roll product in the cold storage rooms could be identified in the retail case.

Evaluations of the type of aging, use of alternative tenderization methods other than aging, temperature while aging, and quality groups found at the foodservice level were condensed (data not shown). Of the 14 facilities sampled, all used some form (wet, dry, or both) of aging. Wet aging, dry aging, and a combination of both represented 58%, 14%, and 28% of the foodservice facilities sampled, respectively. Mechanical tenderization of wet-aged product was used in addition to aging at 8 of the 14 establishments. Only one establishment mechanically tenderized dry-aged subprimals. The target aging times for wet- and dry-aged subprimals ranged from 10 to 40 d, with a majority targeting 21 d of aging. Ambient temperature during wet aging ranged from –2.2°C to 3.3°C, whereas dry aging temperatures ranged from 1.1°C to 6.7°C. The following quality groups were represented at the foodservice level: Prime, Top Choice, Choice, Select, and No Roll. Finally, most establishments noted that aging time and mechanical tenderization schemes were often subject to their customers' requests.

Warner-Bratzler Shear Force. Least squares means for Warner-Bratzler shear force values for retail cuts from the rib and loin and the chuck and round are presented in Tables 5 and 6, respectively. For the cuts from the rib and loin, quality group affected ($P < .05$) WBS values for T-bone/porterhouse steaks but had no effect on ribeye steaks, top loin steaks, or top sirloin steaks. These results are consistent with findings of Harris et al. (1992), who showed that ether-extractable fat did not account for tenderness differences between top sirloin and top loin steaks. Perhaps the lack of a quality group effect on the WBS values of ribeye and top loin steaks is because of the presence of tender beef in each quality group. Miller et al. (1998) reported a 100% consumer acceptance of top loin steaks with WBS values of 3.0 kg or less. With the exception of the top loin steaks in the Prime quality group, all ribeye and top loin steaks in each quality group had WBS values ≤ 3.0 kg.

For the cuts from the chuck and round, quality group had no effect on WBS values of the clod, chuck roll, top round, bottom round, or eye of round steaks. These results are consistent with those of Smith et al. (1984), who reported that differences in marbling had little or no effect on percentage incidence of round steaks with shear values ≤ 4.99 kg.

Least squares means for WBS values of foodservice cuts are presented in Table 7. Quality group had no effect on WBS values of top loin steaks. However, all mean WBS values for top loin steaks were < 2.62 kg. These results are consistent with those of Wheeler et al. (1999), who showed that quality grade had little effect on tenderness of steaks from beef longissimus muscle that were inherently tender. Quality group did have an effect ($P < .05$) on WBS values for foodservice ribeye steaks. Ribeye steaks from the Prime group had significantly lower WBS values than those from all other groups. This is consistent with Smith et al. (1984), who showed that beef loin steaks from highly marbled carcasses were more likely to have low (≤ 3.63 kg) shear values when a wide range in marbling was represented in the steaks. There were no differences in WBS values of Top Choice, Choice, and No Roll ribeye steaks. However, Select ribeye steaks had higher ($P < .05$) WBS values than steaks from the Prime, Top Choice, or Choice groups. Quality group also had an effect on WBS

Table 6. Least squares means and standard errors for Warner-Bratzler shear values (kg) of retail steaks from the chuck and round subprimals[a]

	Group	
Steak	Choice	Select
Clod	3.14 ± .14	2.97 ± .10
Chuck roll	3.30 ± .12	3.30 ± .09
Top round	4.04 ± .19	3.60 ± .15
Bottom round	5.06 ± .31	5.19 ± .28
Eye of round	4.55 ± .18	4.08 ± .10

[a]None of the means in a row was statistically different ($P > .05$).

Table 7. Least squares means and standard errors for Warner-Bratzler shear values (kg) of foodservice steaks

	Group				
Steak	Prime	Top Choice	Choice	Select	No roll
Ribeye	2.35 ± .12[a]	2.73 ± .07[b]	2.95 ± .07[b]	3.39 ± .15[c]	3.00 ± .26[bc]
Top loin	2.44 ± .09	2.31 ± .06	2.34 ± .05	2.47 ± .12	2.62 ± .16
Top sirloin	2.76 ± .19[ab]	2.47 ± .30[a]	3.11 ± .19[b]	—	3.37 ± .28[b]

[a,b,c]Within a row, means lacking a common superscript letter differ ($P < .05$).

values of foodservice top sirloin steaks. Top Choice sirloin steaks had lower ($P < .05$) WBS values than top sirloin steaks from Choice and No Roll groups, but Top Choice did not differ ($P > .05$) from Prime top sirloin steaks.

Warner-Bratzler shear values, and the distribution of WBS values > 4.6 or > 3.9 kg of retail cuts with all quality groups combined, are presented in Table 8. Retail ribeye, porterhouse, T-bone, and top loin steaks had lower ($P < .05$) WBS values than other steaks sampled. The National Beef Tenderness Survey (Morgan et al., 1991) reported WBS values of 3.39 and 3.25 kg for ribeye and top loin steaks broiled to a 65°C internal temperature. The improvements in WBS values between the two studies can be attributed to numerous possibilities. First, there were fewer No-Roll and many more higher-quality (Top Choice, etc.) steaks than in the 1991 survey. Second, in the decade of the 1990s, beef packers moved to 36 to 48 h chilling of carcasses between slaughter and presenting for grading. In the past, most carcasses were chilled for 20 to 24 h before grading, which meant that rate of chilling had to be very rapid. In the current system that uses longer chilling times, the rate of chilling is much more gradual. It is well documented that cold shortening/cold toughening can play a part in causing beef toughness (Locker, 1960; Marsh and Leet, 1966; Honikel et al., 1983). We believe that these longer and more gradual chilling methods may be benefiting meat tenderness.

Table 8. Least squares means for Warner-Bratzler shear (WBS) force and the percentage distribution of steaks with WBS values > 4.6 or > 3.9 kg

			Percentage	
Steak	n	WBS, kg	> 4.6	> 3.9
Clod	68	3.01[ef]	5.9	7.4
Chuck roll	135	3.35[d]	5.2	25.2
Ribeye	200	2.84[efg]	1.5	5.5
Porterhouse	56	2.69[g]	1.8	7.1
T-bone	147	2.71[g]	0.0	2.0
Top loin	269	2.77[fg]	0.7	5.9
Top sirloin	118	3.04[e]	0.8	11.0
Top round	91	3.74[c]	15.4	39.6
Eye of round	177	4.19[b]	26.6	55.9
Bottom round	97	5.09[a]	52.6	68.0

[a,b,c,d,e,f,g]Within the WBS column, means lacking a common superscript letter differ ($P < .05$).

The retail top sirloin steak had a WBS value similar to that of the ribeye and clod steaks but was significantly more tender than steaks from the round ($P < .05$). The top sirloin steak had lower WBS force values in the current study than in the Morgan et al. (1991) survey. Research conducted since 1990 revealed the incidence of injection-site blemishes in top sirloins is linked to the toughness of top sirloin steaks (George et al., 1996). Efforts to reduce this problem as monitored by scientists at Colorado State University have documented the major decline of injection-site lesions in the top sirloin over the past decade.

Clod steaks had lower WBS values than chuck roll steaks, which were more tender than top round and eye of round steaks ($P < .05$). Morgan et al. (1991) reported WBS values for clod, chuck roll, top round, and eye of round to be 4.01, 4.15, 5.23, and 4.67 kg, respectively. However, those steaks were braised to an internal temperature of 85°C (Jones, 1988), whereas those cuts were broiled to 70°C in our study. The bottom round steak had the highest WBS force value of all steaks evaluated ($P < .05$). Morgan et al. (1991) reported a WBS value of 4.38 kg for braised, bottom round steaks.

The percentage of cuts with WBS > 4.6 or > 3.9 kg is based on research conducted by Shackelford et al. (1991). Threshold WBS values were determined by regression analysis of WBS values and trained sensory panel tenderness ratings. Guidelines were based on 50 and 68% confidence levels for a tenderness rating of "slightly tender." Fewer than 2.0% of the ribeye, porterhouse, T-bone, and top sirloin steaks had WBS values greater than 4.6 kg. These percentages are lower than those reported by Morgan et al. (1991), who showed percentage of steaks having WBS values > 4.6 or > 3.9 kg were 10.2 and 23.5, 4.9 and 13.0, and 8.2 and 29.4 for broiled ribeye, top loin, and top sirloin steaks, respectively. The same research reported percentage of steaks having WBS values > 4.6 or > 3.9 kg were 70.1 and 86.6, 56.4 and 87.2, and 41.3 and 67.0 for top round, eye of round, and bottom round braised steaks, respectively. With the exception of the bottom round steaks, the current study reported lower percentages of WBS values > 4.6 or 3.9 kg for the top round and eye of round steaks. Nonetheless, the percentages of steaks with WBS values > 4.6 or > 3.9 kg indicate that improvements in the tenderness of retail cuts originating from the round are still needed. The utilization of one cooking method allowed for the determination of relative ten-

Table 9. Age, income, gender, and beef use of consumers that participated in the retail (universities combined) and foodservice sensory panels

	Retail		Foodservice	
Item	n	%	n	%
Age, yr				
< 20	19	5.7	38	26.4
20–29	130	38.7	63	43.8
30–39	63	18.8	13	9.0
40–49	60	17.9	13	9.0
50–59	41	12.2	10	6.9
60 and over	23	6.8	7	4.9
Income, US $				
< 25,000	133	39.9	83	57.6
25,000–50,000	96	28.8	20	13.9
> 50,000	104	31.2	41	28.5
Gender				
Male	159	47.3	69	47.9
Female	177	52.7	75	52.1
Beef use				
> 5 times/week	80	23.8	36	25.0
2–4 times/week	162	48.2	76	52.8
1–2 times/week	85	25.3	24	16.7
< 1 time/week	9	2.7	8	5.6

derness between all of the retail cuts sampled in 1998. However, the single cooking method did not allow for the use of other cooking methods that may optimize the palatability of cuts that contain higher connective tissue levels. Efforts should be made to emphasize cooking methods that optimize the palatability of all beef cuts to consumers.

Consumer Sensory Evaluations. The demographic information obtained from each panelist who participated in the retail and foodservice sensory panels is given in Table 9. Information obtained from the collaborating universities was combined and presented as the retail data. No efforts were made to target a specific group of individuals before evaluation of the steaks.

Least squares means for sensory panel ratings for the retail ribeye are presented in Table 10. The Prime group received higher ($P < .05$) panel ratings for "overall like" than the other groups evaluated. These results are supported by Smith et al. (1984), who showed that higher marbling scores were associated with higher palatability scores when a wide range in marbling scores was evaluated. However, when marbling scores narrowed, there was little to no difference in palatability scores attributed to marbling (Smith et al., 1984). All other quality groups (Top Choice, Choice, Select, and Lean) did not differ in overall like ratings. Overall flavor scores for ribeye steaks were significantly affected by quality group. Prime steaks received the highest overall flavor scores and Choice steaks had the lowest scores. Cross et al. (1979) reported higher marbling scores significantly attributed to higher sensory flavor intensity scores in broiled top loin steaks. A trend ($P = .058$) similar to the quality group effect on "overall like" scores was observed for retail ribeye tenderness scores.

Sensory ratings for retail top sirloin steaks, clod steaks, and top round steaks did not differ across quality groups for any of the sensory panel traits evaluated (data not presented). The lack of grade-related differences for the top sirloin steak and clod steak agrees with findings of the Beef Customer Satisfaction Project (Neely et al., 1998; Goodson et al., 1999). However, Neely et al. (1998) found that Top Choice top round steaks received higher ($P < .05$) "overall like" ratings than Low Choice, High Select, or Low Select top round steaks.

The least squares means for "overall like" sensory panel ratings of foodservice top loin, top sirloin, and ribeye steaks are presented in Table 11. "Overall like" scores for top loin, top sirloin, and ribeye steaks were not significantly different across quality groups. Moreover, sensory panel ratings for tenderness, juiciness, flavor, and beef flavor did not differ across quality groups for the top loin, top sirloin, and ribeye steak (data not shown). The results for top loin differ from those noted by Lorenzen et al. (1999), who showed that "overall like" and juiciness score were higher ($P < .05$) for Top Choice and lowest ($P < .05$) for Low Select steaks. Lorenzen et al. (1999) also showed that desirable flavor scores for top loin steaks were higher for Top Choice and Low Choice than for High Select and Low Select steaks. The results for foodservice top sirloin steak are consistent with Savell et al. (1999), who showed that

Table 10. Least squares means and standard errors for sensory panel ratings for retail ribeye steaks (n = 105 steaks)

	Group				
Sensory rating[a]	Prime	Top Choice	Choice	Select	Lean
Overall like	7.50 ± .48[b]	6.12 ± .19[c]	5.95 ± .18[c]	6.42 ± .16[c]	5.99 ± .30[c]
Tenderness	8.15 ± .56	6.47 ± .22	6.45 ± .21	6.67 ± .19	6.48 ± .35
Juiciness	6.68 ± .61	5.63 ± .24	5.45 ± .23	5.79 ± .20	5.38 ± .39
Overall flavor	7.27 ± .46[b]	6.05 ± .18[cd]	5.92 ± .17[d]	6.39 ± .15[bc]	6.16 ± .29[cd]
Beef flavor	6.90 ± .41	5.97 ± .16	5.89 ± .15	6.28 ± .13	6.08 ± .26

[a]Overall like: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; overall flavor: 10 = like extremely, 1 = dislike extremely; and beef flavor: 10 = extreme amount, 1 = none at all.

[b,c,d]Within a row, means lacking a common superscript letter differ ($P < .05$).

Table 11. Least squares means and standard errors for overall like[a] ratings of foodservice steaks[b]

		Group				
Steak	n	Prime	Top Choice	Choice	Select	No roll
Top loin	90	6.20 ± .31	5.79 ± .21	6.05 ± .19	5.22 ± .48	5.87 ± .87
Top sirloin	34	6.43 ± .71	4.89 ± .34	5.86 ± .45	—	6.49 ± 1.04
Ribeye	67	6.30 ± .36	5.43 ± .21	5.55 ± .19	5.93 ± .45	6.06 ± .72

[a]Overall like: 10 = like extremely, 1 = dislike extremely.
[b]None of the means in a row was statistically different ($P > .05$).

quality grade had no effect on consumer sensory scores for "overall like," juiciness, desirable flavor, or flavor intensity of broiled top sirloin steaks.

In this study, quality group had little to no effect on the variability in WBS values and consumer sensory ratings. However, all beef steaks, regardless of quality group, were highly rated by consumers. The lack of quality group effects on sensory evaluations is expected because of the highly desirable and low WBS values observed for steaks from the chuck, rib, and loin.

Implications

Retail cuts from the round still require more attention in processing and preparation to ensure acceptable tenderness. Reducing the number of cuts that are not sufficiently aged before consumption may help increase tenderness ratings and further reduce beef tenderness problems. Information from this audit can serve as a baseline for the tenderness of beef available at retail and foodservice levels and can be used to support further research to improve the tenderness of beef steaks.

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