Characterization of Certified Angus Beef steaks from the round, loin, and chuck

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ABSTRACT: Beef carcasses (n = 150) of A-maturity were selected randomly to determine baseline shear force and sensory panel ratings, assess variation in tenderness, and evaluate mean value differences between Certified Angus Beef (CAB), commodity Choice, and Select steaks. Three steaks were removed from the triceps brachii (TB), longissimus lumborum (LL), gluteus medius (GM), semimembranosus (SM), biceps femoris (BF), and quadriceps femoris complex (QF), and assigned to Warner-Bratzler shear (WBSF) and sensory panel analyses. As anticipated, marbling score and measured percentage of i.m. fat were greatest ($P < 0.05$) for CAB, intermediate ($P < 0.05$) for Choice, and least ($P < 0.05$) for Select carcasses. A muscle × quality level interaction ($P < 0.05$) was observed for WBSF values and sensory panel tenderness ratings. The TB, LL, GM, and BF steaks from CAB carcasses had lower ($P < 0.05$) WBSF than Select steaks from the same muscles. Even though WBSF values did not differ ($P > 0.05$) between CAB and Choice QF and TB steaks, the LL and GM steaks from CAB carcasses were more tender ($P < 0.05$) than Choice-grade LL and GM steaks. The TB from Select carcasses had higher ($P < 0.05$) WBSF values than TB steaks from CAB or Choice carcasses, but sensory panel ratings indicated that quality level showed little consistency among the GM, SM, BF, and QF. Trained sensory panelists rated CAB LL steaks more tender ($P < 0.05$) than LL steaks from Choice and Select carcasses, and Choice LL steaks were evaluated as more ($P < 0.05$) tender than those from Select carcasses. These results demonstrate that the influence of marbling on tenderness was more evident in muscles of middle meats than in end cuts, particularly in muscles of the round.

Key Words: Beef, Marbling, Quality Grade, Tenderness

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Introduction

Insufficient marbling, inadequate tenderness, and low overall palatability were the top "quality" concerns noted by beef purveyors, restaurateurs, retailers, and packers in the 2000 National Beef Quality Audit (NCBA, 2001). These concerns coupled with the fact that consumers are able to discern differences in beef tenderness and are willing to pay a premium for "guaranteed tender" beef (Boleman et al., 1997) creates a challenge for beef industry. One approach to solving the beef palatability dilemma has been the development of branded beef programs. The beef industry is experiencing a gradual transition from commodity-based to value-based marketing, and branded beef programs attempt to add value to a raw commodity.

One of the first branded beef programs introduced was Certified Angus Beef. The American Angus Association established the Certified Angus Beef program at a time when "premium quality" beef seemed to be decreasing (Hildebrand and Ward, 1994). Although it has been reported that consumers recognize Certified Angus Beef steaks to be more tender, juicy, and flavorful than USDA Choice (commodity) and Select strip loin steaks (Claborn, 1996), there is currently limited information relative to the palatability of end cuts (i.e., cuts from the round, loin, and chuck). The current research was conducted to 1) determine baseline tenderness values and sensory panel ratings; 2) assess variation in tenderness; and 3) compare the mean values and variation for tenderness and sensory characteristics among Certified Angus Beef, USDA Choice (commodity), and Select steaks from the round, loin, and chuck.

Materials and Methods

Sample Collection. Carcasses (n = 150) from steers of unknown origin were selected randomly over a 6-mo

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Table 1. Marbling score by yield grade consist of carcasses

Quality level[a]	Marbling score	Yield grade	No. of sides
Certified Angus Beef			
(n = 50)	Moderate	1	1
		2	5
		3	6
	Modest	1	2
		2	18
		3	18
USDA Choice			
(n = 50)	Moderate	1	1
		2	2
		3	0
	Modest	1	1
		2	4
		3	4
	Small	1	3
		2	17
		3	18
USDA Select			
(n = 50)	Slight +	1	3
		2	9
		3	5
	Slight 0	1	3
		2	7
		3	4
	Slight –	1	4
		2	10
		3	5

[a]Selected Choice and Select carcasses were A-maturity, displayed no *Bos indicus* characteristics, and did not qualify for the Certified Angus Beef program on a live animal-specification basis.

period at a commercial meat-processing facility to fit predetermined USDA yield and quality grade criteria. Fifty Certified Angus Beef (**CAB**), USDA Choice, and USDA Select carcasses were selected to follow the marbling score by yield grade criteria (USDA, 1997) defined in Table 1. The basis for the carcass selection criteria was the yield grade by quality grade distribution reported in the National Beef Quality Audit (Boleman et al., 1998), and hot carcass weights were maintained between 272 and 408 kg. Two trained Oklahoma State University personnel collected carcass data, and the average score for each trait was recorded. Factors used to determine quality grade were monitored so as to remain consistent with the onsite USDA grading personnel. After carcass data collection, carcasses were fabricated according to Institutional Meat Purchasing Specifications (IMPS; USDA, 1996), and the chuck clod (IMPS #114), strip loin (IMPS #180), top sirloin butt (IMPS #184), inside round (IMPS #168); outside round flat (IMPS #171a), and knuckle (IMPS #167a) were collected from the left sides; vacuum packaged; and aged 14 d postmortem at approximately 2°C. After the aging period, three 2.54-cm-thick steaks were removed from the following muscles: the triceps brachii (**TB**) from the chuck clod; the longissimus lumborum (**LL**) from the strip loin; the gluteus medius (**GM**) from the top sirloin butt; the semimembranosus (**SM**) from the inside round; the biceps femoris (**BF**) from the outside round; and the quadriceps femoris complex (**QF**) from the knuckle. Steaks from each muscle were assigned to either Warner-Bratzler shear force (WBSF) determination or sensory panel evaluations. Before the removal of LL steaks, a 1.27-cm-thick section, free of external fat and connective tissue, was removed from the anterior end of the strip loin and placed in whirlpack bags for proximate analysis. After being vacuum-packaged, steaks and proximate analysis samples were subsequently stored at –28°C.

Warner-Bratzler Shear Force. Steaks were assigned randomly to a cooking order within subprimal. Seventy-five steaks were allowed to temper for 24 h at 4°C before cooking. Steaks were broiled in an impingement oven (model 1132-000-A; Lincoln Impinger, Fort Wayne, IN) at 180°C to an internal temperature of 70°C. Internal steak temperatures were monitored with copper constantan thermocouples (model OM-202; Omega Engi-

Table 2. Selected carcass and meat traits

Trait	Mean	Minimum	Maximum	SD
Carcass maturity[a]				
Skeletal	156.6	110.0	200.0	21.21
Lean	149.7	110.0	205.0	15.56
Overall	153.2	120.0	185.0	15.30
Marbling score[b]	466.7	305.0	670.0	100.55
Fat thickness, cm	1.04	0.25	2.08	0.42
Adjusted fat thickness, cm	1.25	0.51	1.88	0.37
Ribeye area, cm^2	86.3	64.8	111.9	9.32
KPH, %[c]	2.3	1.1	4.8	0.48
Hot carcass weight, kg	347.3	273.5	403.7	29.80
Yield grade	2.8	1.0	3.9	0.63
Shear force, kg	4.15	1.85	7.28	0.82
Cook loss, %	26.7	5.1	51.9	3.1

[a]100 to 199 = A-maturity (approximately 9 to 30 mo chronological age at time of slaughter; (USDA, 1997).
[b]300 to 399 = Slight; 400 to 499 = Small; 500 to 599 = Modest; and 600 to 699 = Moderate degree of marbling (USDA, 1997).
[c]Kidney, pelvic, and heart fat.

Table 3. Carcass traits and longissimus muscle proximate analysis stratified by quality level

Trait	Quality level			SE
	CAB[a]	Choice	Select	
No. of carcasses	50	50	50	
Carcass maturity[b]				
Skeletal	160.4	155.9	153.3	2.99
Lean	146.9[e]	148.1[e]	154.2[d]	2.17
Overall	153.7	153.0	153.8	2.17
Marbling score[c]	570.3[d]	480.9[e]	348.8[f]	6.00
Quality grade, %				
High Choice	24.0	6.0	—	
Average Choice	76.0	18.0	—	
Low Choice	—	76.0	—	
High Select	—	—	34.0	
Average Select	—	—	28.0	
Low Select	—	—	38.0	
Fat thickness, cm	1.14[e]	1.07[e]	0.90[f]	0.062
Adjusted fat thickness, cm	1.35[e]	1.27[ef]	1.14[f]	0.063
LM area, cm^2	84.2[e]	87.2[ef]	87.5[f]	1.31
KPH, %[d]	2.3	2.2	2.3	0.07
Hot carcass weight, kg	343.7	355.1	343.1	4.17
Yield grade	2.99[e]	2.84[ef]	2.62[f]	0.090
1, %	6.0	10.0	20.0	
2, %	46.0	46.0	52.0	
3, %	48.0	44.0	28.0	
Lipid, %	6.2[e]	4.9[f]	3.0[g]	0.22
Protein, %	21.2[e]	21.9[f]	22.4[g]	0.13
Moisture, %	71.4[e]	71.9[e]	73.6[f]	0.20
Cook loss, %	26.5	26.7	26.8	0.16

[a]Certified Angus Beef.
[b]100 to 199 = A-maturity (approximately 9 to 30 mo chronological age at time of slaughter; USDA, 1997).
[c]300 to 399 = Slight; 400 to 499 = Small; 500 to 599 = Modest; and 600 to 699 = Moderate degree of marbling (USDA, 1997).
[d]Kidney, pelvic, and heart fat.
[e,f,g]Within a row, least squares means without a common superscript letter differ ($P < 0.05$).

neering, Inc., Stamford, CT). Individual steak weights were recorded before and after cooking to determine cook loss percents. After steaks had cooled for at least 2 h to 25°C, a minimum of six 1.27-cm-diameter cores were removed parallel to the muscle fiber orientation, and each core was sheared once by a Warner-Bratzler head attached to an Instron Universal Testing Machine (model 4502; Instron Corp., Canton, MA) at a crosshead speed of 200 mm/min. Peak force (in kilograms) of cores was recorded by an IBM PS2 (model 55 SX) using software provided by the Instron Corp. and the mean peak force of six cores was used for statistical analyses.

Sensory Analysis. Seventeen potential panel members were trained for sensory analysis as outlined by AMSA (1995) guidelines. Following training, at least 10 panelists were identified. Subprimal sensory ratings were obtained in the order of strip loin, clod, inside round, knuckle, round flat, and top sirloin butt. Steaks were assigned randomly to a cooking order within subprimal. No more than 16 steaks per day were tempered at 4°C 24 h before cooking. Steaks were broiled in an impingement oven (model 1132-000-A; Lincoln Impinger) at 180°C to an internal temperature of 70°C and immediately placed into a foil pouch. Two cubed sections (1.3 cm × 1.3 cm × cooked steak thickness) from each steak were served warm to the panelists and the average for each section was recorded. Samples from eight steaks were served consecutively, after which panelists were allowed to rest for at least 10 min before serving the remaining steak samples. The attributes assessed were juiciness, beef fat flavor, overall tenderness, and connective tissue amount (1 = extremely dry, extremely bland, extremely tough, and abundant to 8 = extremely juicy, extremely intense, extremely tender, and none), as well as flavor intensity (0 = none detectable to 2 = very strong) and off-flavor (1 = intense to 4 = none).

Chemical Analyses. Analyses of LL samples were performed in duplicate, and averaged according to procedures outlined by AOAC (1990). Each sample was frozen individually in liquid nitrogen and pulverized to a powder in a Waring blender (Dynamics Co. of America; New Hartford, CT). Three grams of the powdered sample was placed in glass thimbles, dried at 100°C for 24 h, desiccated for 1 h, and reweighed to determine moisture. Following moisture determination, each sample was placed in a Soxhlet apparatus for 24 h for ether extraction of lipid, followed by drying at 100°C for no more than 12 h. Each sample was then desiccated and reweighed to calculate lipid content. Using a Leco Nitro-

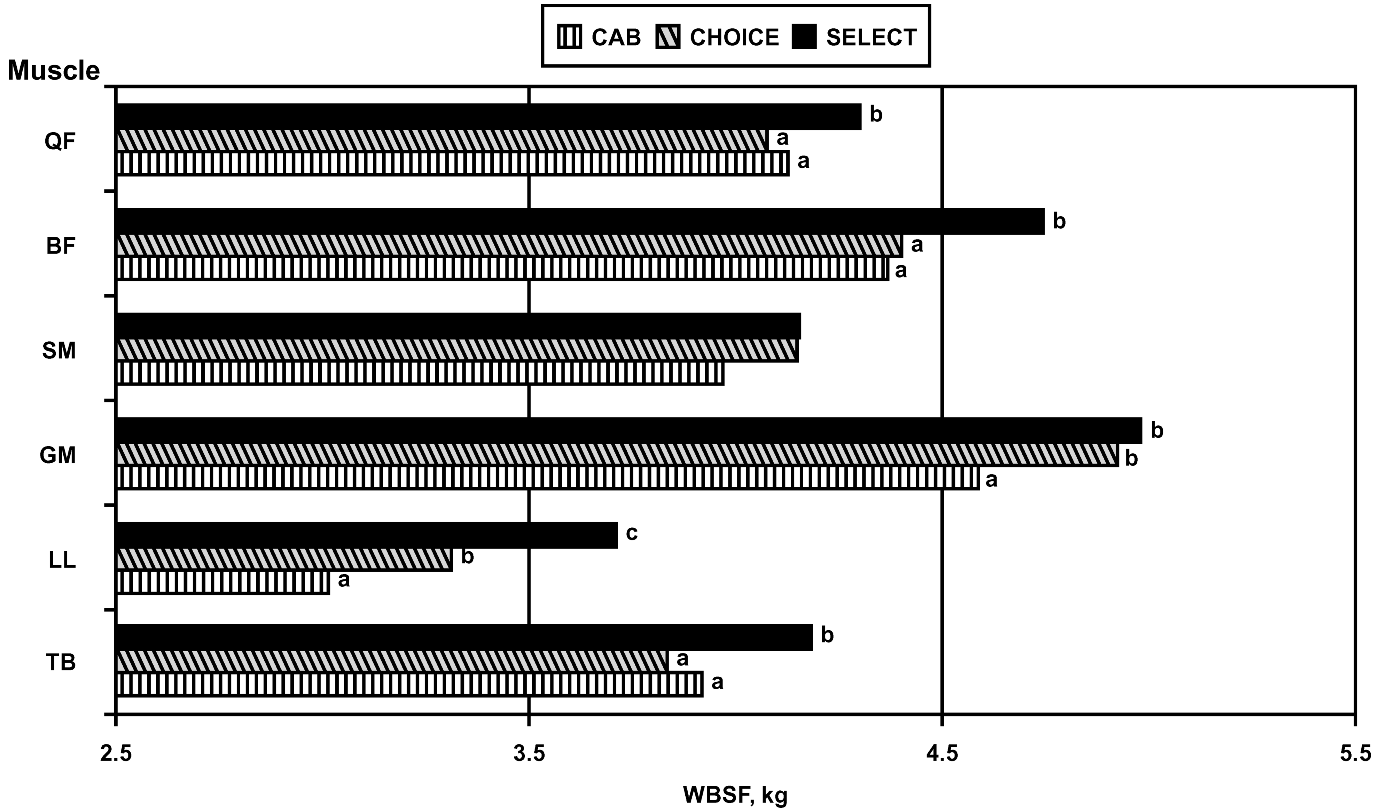

Figure 1. Least squares means for Warner-Bratzler shear force (WBSF) by quality level and muscle (TB = triceps brachii; LL = longissimus lumborum; GM = gluteus medius; SM = semimembranosus; BF = biceps femoris; and QF = quadriceps femoris complex). Within a muscle, bars without a common letter differ ($P < 0.05$).

gen Determinator (model FP-428; Leco Corp., St. Joseph, MI), crude protein content was determined and recorded from a separate 0.5-g pulverized sample.

Data Analyses. Data were analyzed as a split-plot design using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with carcass as the experimental unit. Quality level was the lone main effect in the whole plot, and carcass nested within quality level was the error term used to test whole-plot effects. Main effects in the subplot included muscle and the muscle × quality level interaction, and residual error was used to test the subplot main effects. Least squares means were generated and separated ($P < 0.05$) using the PDIFF procedure of SAS. To investigate the relative importance and relationship of marbling level to sensory panel overall tenderness, simple correlations were determined for each subprimal using the correlation procedure (PROC CORR) of SAS.

Results and Discussion

Carcass Characteristics and Meat Traits. Carcass traits are presented in Tables 2 and 3. By design, marbling score differed ($P < 0.05$) among quality levels. Certified Angus Beef carcasses were slightly fatter and consequently had a higher ($P < 0.05$) numeric yield grade than Select carcasses. Both CAB and Choice carcasses had more ($P < 0.05$) youthful lean maturity scores than Select carcasses; however, overall maturity was similar ($P > 0.05$) among quality levels. No differences ($P > 0.05$) in carcass weight; longissimus muscle area; or percentage of kidney, pelvic, and heart fat were observed when stratified by quality level. Percentage of protein and ether-extractable fat differed ($P < 0.05$) across all quality levels, with CAB carcasses exhibiting the highest i.m. fat and lowest percentages of protein, followed by Choice and Select carcasses (Table 3). The relationships between mean marbling score and mean percentage of i.m. fat for CAB, Choice, and Select carcasses were comparable to those reported by Savell et al. (1986). Steaks from Select carcasses had the highest ($P < 0.05$) percentage of moisture, but no differences ($P < 0.05$) in moisture percents were noted between steaks from CAB and Choice carcasses. Weight loss during cooking was not affected ($P > 0.05$) by quality level (Table 3) but differed among four of the six muscles studied (data not in tabular form).

Steaks from the QF had the highest ($P < 0.05$) percentage of cook loss (29.0%), followed by steaks from the GM, SM, and TB (27.8, 26.8, and 26.0%, respectively). Although LL and BF steaks had the similar ($P > 0.05$) cooking loss percents (25.3 and 25.0%, respectively), steaks from these two muscles had the lowest ($P < 0.05$) cooking loss percents.

Table 4. Percent distribution of steaks within tenderness thresholds stratified by quality level and muscle

Muscle[a]	Quality level: Certified Angus Beef	Choice	Select
TB			
Less than 3.9 kg	44	54	40
3.9 to 4.5 kg	46	32	32
4.6 kg or greater	10	14	28
LL			
Less than 3.9 kg	90	84	70
3.9 to 4.5 kg	8	8	12
4.6 kg or greater	2	8	18
GM			
Less than 3.9 kg	8	2	4
3.9 to 4.5 kg	38	28	24
4.6 kg, or greater	54	70	72
SM			
Less than 3.9 kg	46	30	36
3.9 to 4.5 kg	38	52	40
4.6 kg or greater	16	18	24
BF			
Less than 3.9 kg	10	14	8
3.9 to 4.5 kg	56	52	34
4.6 kg or greater	34	34	58
QF			
Less than 3.9 kg	34	36	22
3.9 to 4.5 kg	46	42	46
4.6 kg or greater	20	22	32

[a]TB = triceps brachii; LL = longissimus lumborum; GM = gluteus medius; SM = semimembranosus; BF = biceps femoris; and QF = quadriceps femoris complex.

Warner-Bratzler Shear Force. A quality level × subprimal interaction ($P < 0.05$) was observed for WBSF (Figure 1). Within the LL, all quality levels differed ($P < 0.05$), with CAB being the most tender, Select the least tender, and Choice intermediate. In a similar study, Claborn (1996) reported that LL steaks from CAB carcasses were more tender than U.S. Choice and U.S. Select strip loin steaks. Steaks from Select carcasses in the present study were more ($P < 0.05$) variable in shear force than either CAB or Choice steaks, which agrees with previous results where WBSF increased in variability as marbling score decreased (Smith et al., 1984). Within the GM, CAB steaks had lower ($P < 0.05$) shear force values than either Choice or Select, but WBSF were similar ($P > 0.05$) between Select and Choice GM steaks. Select steaks from the TB and BF had higher ($P < 0.05$) shear force values than steaks from either CAB or Choice carcasses; however, no differences ($P > 0.05$) were noted between CAB and Choice for these two muscles. Furthermore, no differences ($P > 0.05$) were observed in shear force for SM or QF steaks, regardless of quality level.

Tenderness thresholds have been identified that represent a given level of confidence of a steak being rated least "slightly tender" (Shackelford et al., 1991). Based on sensory panel ratings compared to WBSF values of the same samples, steaks having a WBSF value less than 4.6 and 3.9 kg should have a 50 and 68% chance of being rated "slightly tender," respectively (Shackelford et al., 1991). Table 4 summarizes the percentage distribution of steaks within the predetermined tenderness thresholds for quality level, muscle, and quality level × muscle, respectively. Ninety percent of CAB LL steaks had WBSF values less than 3.9 kg (6 and 20% improvement over Choice and Select LL steaks, respectively). When all subprimals were pooled, CAB steaks had the lowest percentage of steaks with a shear force of greater than 4.6 kg, and the highest percentage of steaks with a shear force of less than 3.9 kg. Among muscles, the GM and BF muscles produced the greatest percentage of steaks with shear force values of 4.6 kg or greater; the QF, SM, and TB were intermediate; and the LL produced the least. Subprimal differences between CAB and Choice were most notable within the GM and BF. Top butt (GM) steaks from CAB-carcasses produced 16% fewer ($P < 0.05$) shear force values of 4.6 kg, or more, and SM steaks from CAB carcasses had 16% more ($P < 0.05$) shear force values of less than 3.9 kg. Compared with Select, CAB carcasses had lower percentages of frequencies in the 4.6 kg, or more, category for BF (–24%), GM (–18%), TB (–18%), LL (–16%),

Table 5. Least squares means of sensory attributes averaged for six subprimals stratified by quality level

Trait	Quality level: CAB[a]	Choice	Select	SE
Juiciness[b]	4.92[e]	4.91[e]	4.68[f]	0.031
Beef fat flavor[b]	0.50[e]	0.50[e]	0.41[f]	0.012
Overall tenderness[b]	4.87	4.79	4.65	0.034
Connective tissue amount[b]	5.06	5.07	5.01	0.030
Flavor intensity[c]	5.12[e]	5.12[e]	5.01[f]	0.025
Off-flavors[d]	3.94	3.94	3.94	0.006

[a]Certified Angus Beef.
[b]1 = extremely dry, extremely tough, abundant, and extremely bland to 8 = extremely juicy, extremely tender, none, and extremely intense.
[c]1 = extremely bland, 8 = extremely intense.
[d]1 = intense to 4 = none.
[e,f]Within a row, least squares means without a common superscript letter differ ($P < 0.05$).

Table 6. Least squares means and standard deviations of sensory attributes stratified by muscle

	Muscle[a]						
Trait	TB	LL	GM	SM	BF	QF	SE
Juiciness[b]	5.17[g]	5.39[f]	4.37[j]	4.39[j]	4.78[i]	4.91[h]	0.057
Beef fat flavor[c]	0.48[g]	0.68[f]	0.38[i]	0.35[i]	0.50[g]	0.43[j]	0.025
Overall tenderness[b]	5.06	5.70	4.51	4.44	4.02	4.88	0.041
Connective tissue[b]	5.44[g]	5.78[f]	5.00[i]	4.88[j]	4.01[k]	5.15[h]	0.040
Flavor intensity[b]	5.26[f]	5.32[f]	4.99[h]	4.81[i]	4.98[h]	5.16[g]	0.037
Off-flavors[d]	3.94[fg]	3.95[fg]	3.95[fg]	3.96[f]	3.89[h]	3.93[g]	0.009

[a]TB = triceps brachii; LL = longissimus lumborum; GM = gluteus medius; SM = semimembranosus; BF = biceps femoris; and QF = quadriceps femoris complex.
[b]1 = extremely dry, extremely tough, abundant, and extremely bland to 8 = extremely juicy, extremely tender, none and extremely intense.
[c]0 = none detectable to 2 = very strong.
[d]1 = intense to 4 = none.
[f,g,h,i,j,k]Within a row, least squares means without a common superscript letter differ ($P < 0.05$).

QF (–12%), and SM (–8%) steaks. Moreover, CAB had substantially higher ($P < 0.05$) percentages of steaks in the most tender category (less than 3.9 kg) for LL (+20%), QF (+12%), and SM (+10%) steaks than Select.

Sensory Analysis. Least squares means for sensory panel attributes within quality level and subprimal are listed in Tables 5 and 6, respectively. A quality level × muscle interaction ($P < 0.05$) was also observed for overall tenderness (Figure 2). Strip loin (LL) steaks were rated more ($P < 0.05$) tender than all other muscles. Within the LL, CAB steaks were the most tender ($P < 0.05$), Select steaks were the least tender ($P < 0.05$), and

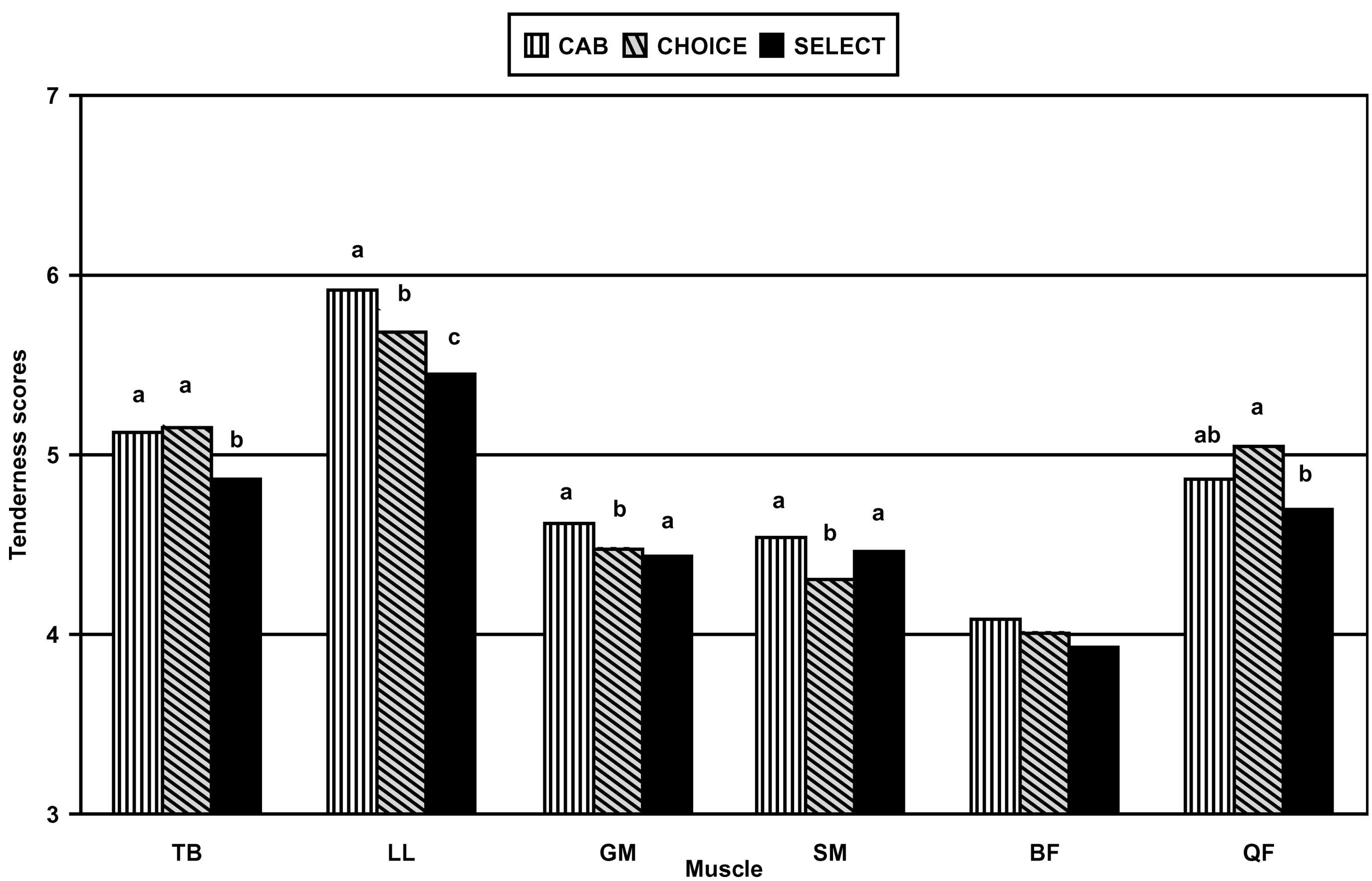

Figure 2. Least squares means for sensory means for sensory panel tenderness scores (1 = extremely tough to 8 = extremely tender) by quality level and muscle (TB = triceps brachii; LL = longissimus lumborum; GM = gluteus medius; SM = semimembranosus; BF = biceps femoris; and QF = quadriceps femoris complex). Within a muscle, bars without a common letter differ ($P < 0.05$).

Table 7. Selected Pearson correlation coefficients (r) across and within subprimals

	Comparisons[a]		
Subprimal	Marbling × WBSF	Marbling × Sensory	WBSF × Sensory
Overall	–0.19*	0.12*	–0.67*
Clod	–0.19*	0.17*	–0.61*
Strip loin	–0.33*	0.30*	–0.82*
Top butt	–0.24*	0.18*	–0.35*
Inside round	–0.13	0.03	–0.52*
Flat	–0.23*	0.09	–0.49*
Knuckle	–0.21*	0.17*	–0.49*

[a]Marbling = carcass marbling degree; WBSF = Warner-Bratzler shear force; sensory = sensory panel overall tenderness rating.
*$P < 0.05$.

Choice steaks were intermediate ($P < 0.05$); however, means for all quality levels were within the “slightly tender” category. Claborn (1996) found CAB LL steaks to be superior in sensory panel tenderness compared with U.S. Choice and U.S. Select steaks. Tenderness scores for TB steaks did not ($P > 0.05$) differ but were more tender ($P < 0.05$) than steaks from the GM, SM, and BF and more ($P < 0.05$) tender than CAB and Select QF steaks. Choice and CAB QF steaks received higher ($P < 0.05$) tenderness scores than Select QF steaks, and CAB and Choice QF steaks were more tender than GM, SM, and BF steaks, regardless of the quality level. Overall tenderness differences for the GM and SM were minimal. No differences ($P > 0.05$) were noted among quality levels within the GM; however, CAB steaks received numerically higher overall tenderness ratings than Choice and Select steaks. Steaks from the BF were the least tender ($P < 0.05$) of all muscles. Within the BF muscles, quality level did not ($P > 0.05$) affect sensory panel overall tenderness scores; yet the mean rating for Select BF steaks was in the “moderately tough” category whereas the mean ratings for CAB and Choice BF steaks were rated in the “slightly tough” category.

Choice and CAB steaks received higher ($P < 0.05$) juiciness, beef fat flavor, and beef flavor intensity scores than Select steaks, but scores were similar ($P > 0.05$) between Choice and CAB steaks (Table 5). No differences ($P > 0.05$) were apparent across quality level for connective tissue amount or off-flavors. When all quality levels were pooled, sensory panel attribute differences were most noticeable relative to connective tissue amount; all subprimals differed in the amount of detectable connective tissue amount. The BF received the highest ($P < 0.05$) connective tissue scores, followed by the SM, GM, QF, TB, and LL. Muscle effects on juiciness scores were slightly varied from those of tenderness and connective tissue. Steaks from the LL received the highest ($P < 0.05$) juiciness scores, whereas the SM and GM steaks were the driest ($P < 0.05$). Juiciness scores for TB, QF, and BF were intermediate, but all differed ($P < 0.05$) in a decreasing manner, respectively.

Simple correlation coefficients for marbling score, WBSF, and sensory panel overall tenderness ratings are presented in Table 7. Marbling score had a negative correlation ($P < 0.05$) with WBSF for all muscles except the SM. Marbling score and WBSF were most highly correlated within the LL, whereas the SM had the lowest coefficient. Sensory panel overall tenderness scores exhibited a generally weaker relationship when these ratings were compared against marbling score. Coefficients for this comparison (marbling score × sensory panel overall tenderness ratings) for all six subprimals were numerically lower than the marbling score × shear force coefficients. Similar to WBSF, the LL showed the strongest relationship between marbling score and sensory panel tenderness ratings. The sensory panel detected no relationship ($P > 0.05$) between marbling score and tenderness for two of the three round cuts (SM and BF). Smith et al. (1984) reported that marbling was much more influential on the palatability of loin steaks than that of round steaks. Even though the sensory panel generally less recognized the relationship between marbling and tenderness, sensory panel scores were moderately consistent with WBSF values, which may be explained by the effect of connective tissue amount among different muscles. Across all subprimals, sensory panel connective tissue amount and overall tenderness were highly related (r = 0.85; ($P < 0.05$); data not shown). The relationship between WBSF and sensory panel ratings was strongest within the LL, followed by the TB, SM, BF, and QF, and lowest for the GM. These relationships follow the same numerical rankings as shear force values (as WBSF values increased due to muscle, sensory panel ratings were less likely to reflect tenderness differences).

For the present study, the coefficient of determination revealed that marbling accounted for 3.6 and 1.4% of the observed shear force and sensory panel tenderness variability, respectively. This agrees with previous research indicating that marbling explains less than 10% of cooked beef tenderness and palatability variation (Crouse and Smith, 1978; Armbruster et al., 1983; Jones and Tatum, 1994), whereas other researchers have reported that marbling accounted for nearly 30% of beef palatability variation (Smith et al., 1984; May et al., 1992). Additionally, marbling explained 4.0, 2.4

and1.7% of the flavor, juiciness, and flavor intensity, respectively.

Implications

Branded beef programs exist to provide consumers with a favorable product that is consistent. The present study indicates that steaks from carcasses qualifying for the Certified Angus Beef program generally have improved tenderness and palatability ratings when cooked to a medium degree of doneness (70°C). Based on predetermined tenderness thresholds, the likelihood of receiving steaks rated at least "slightly tender" is greater for Certified Angus Beef carcasses and lowest for U. S. Select carcasses. Additionally, the effect of marbling on tenderness seems to be more evident in middle beef cuts than in end cuts, particularly in the round.

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