Palatability of beef chuck, loin, and round muscles from three USDA quality grades¹

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ABSTRACT: The objective of this study was to determine the palatability of various beef cuts from 3 USDA quality grades. Five different beef subprimals from USDA Prime, Choice, and Select ($n = 10/\text{quality grade}$) carcasses were utilized for the study, including: strip loins, inside rounds, bottom rounds, shoulder clods, and chuck rolls. Subprimals were fabricated into 9 retail cuts, which contained the following beef muscles: longissimus lumborum (LL); longissimus thoracis, complexus, and spinalis dorsi (LCS); infraspinatus (IF); serratus ventralis (SV); triceps brachii (TB); teres major (TM); adductor (AD); semimembranosus (SM); and biceps femoris (BF). The pH and percentage of fat, moisture, protein, and collagen was determined for each muscle on a raw basis. Additionally, cooked steak measurements included Warner–Bratzler shear force (WBSF) and slice shear force (SSF). Consumer and trained sensory panelists evaluated palatability traits of each cut and quality grade combination. A quality grade $\times$ muscle interaction was determined for trained panelists assessment of overall tenderness ($P = 0.03$), SSF ($P = 0.02$), proximate composition ($P < 0.01$),

and pH ($P < 0.01$). In all objective and subjective measurements of tenderness, the LCS was the most tender ($P < 0.05$), while cuts from the round (BF, AD, and SM) were among the toughest and least juicy ($P < 0.05$). Conversely, consumers and trained sensory panelists identified the LCS, IF, and SV to be juicier ($P < 0.05$) than all others. The TB, TM, and LL were perceived by consumers most often as being everyday quality. The LCS was found by consumers to be the most acceptable ($P < 0.05$) across all attributes, with the SM being the least ($P < 0.05$) acceptable muscle. For each muscle, fat percentage was the greatest ($P < 0.05$) in Prime cuts. Slice shear force determined Prime IF, LL, and SV to be more tender ($P < 0.05$) than Choice and Select. No SSF differences ($P > 0.05$) were found among quality grades for the AD, BF, and SM. The WBSF values decreased ($P < 0.05$) across all muscles, as quality grade increased (Prime $<$ Choice $<$ Select). The results of this study indicate that muscles from the chuck may be utilized to provide consumers with a positive eating experience. Meanwhile, muscles from the round are likely to provide consumers with a lower quality eating experience.

Key words: beef, marbling, muscles, palatability, quality grade, slice shear force

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INTRODUCTION

Consumer perception of beef products is closely related to liking of specific palatability

attributes, where the combination of tenderness, juiciness, and flavor influence overall liking (O'Quinn et al., 2018). Historically, beef whole-muscle retail steaks from loin and rib primals are marketed to consumers because of their desirable tenderness, juiciness, and flavor (Lepper-Blilie et al., 2014; Jung et al., 2016). By comparison, beef whole-muscle steaks from the chuck and round have been underutilized due to

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perceived lower eating quality in comparison to the loin and rib. Therefore, chuck and round cuts are historically marketed as ground products, low-end roasts, or low-quality steaks (Belew et al., 2003; Seggern et al., 2005; Lepper-Blilie et al., 2014). However, evidence indicates that specific muscles from the chuck have equivalent or greater eating quality as rib steaks (Kukowski et al., 2004). Previously, consumers have demonstrated a willingness to pay a premium for a beef with greater eating quality (Miller et al., 2001; Kukowski et al., 2005; Lepper-Blilie et al., 2014; Lucherik et al., 2016; Yeh et al., 2018). Therefore, opportunity exists to further add value to beef carcasses through the utilization of specific muscles from the chuck and round, which provide acceptable or superior eating quality (Kukowski et al., 2004; Lepper-Blilie et al., 2014).

In addition to muscle type, intramuscular fat content or USDA quality grade influences beef tenderness, juiciness, flavor, and overall palatability (Smith et al., 1985; O'Quinn et al., 2012; Emerson et al., 2013; Corbin et al., 2015), with increased eating quality observed in higher quality grades, such as USDA Prime and Upper 2/3 Choice. The majority of research has evaluated palatability impacts of USDA quality grade of strip steaks. However, some work has evaluated quality grade impacts as they relate to other beef muscles (Jeremiah et al., 2003; Gruber et al., 2006; Hunt et al., 2014; Lepper-Blilie et al., 2014; Jung et al., 2016; Yeh et al., 2018). Nevertheless, previous studies have not simultaneously evaluated extensive groups of muscles across the USDA quality grade range. Therefore, the objective of this study was to characterize the eating quality, composition, and objective tenderness of 9 beef cuts from the loin, chuck, and round, across 3 USDA quality grades.

MATERIALS AND METHODS

Product Selection and Fabrication

Beef subprimals were collected from USDA Prime ($\geq$ Slightly abundant⁰⁰), Choice (Small⁰⁰ to Small¹⁰⁰), and Select (Slight⁰⁰ to Slight⁵⁰) beef carcasses ($n = 10/\text{grade}$) by Texas Tech University (TTU) and Kansas State University (KSU) personnel at a commercial beef processing facility. Selected subprimals included: strip loins [Institutional Meat Purchasing Specification (IMPS) #180; North American Meat Processors Association, 2010] inside rounds (IMPS #169), bottom rounds (IMPS #171B), shoulder clods (IMPS #114), and chuck rolls (IMPS #116A).

All subprimals were transported under vacuum and refrigeration (4 to 6°C) to the TTU Gordon W. Davis Meat Science Laboratory in Lubbock, Texas, and wet-aged in darkness for 21-d postmortem (0 to 4°C under vacuum).

After aging, the collected chuck and round subprimals were fabricated into further subprimals. These subprimals were primarily made up of the following muscles: longissimus thoracis, complexus, and spinalis dorsi, (LCS; IMPS #116D); infraspinatus (IF; IMPS #114D); serratus ventralis (SV; IMPS #116G); triceps brachii (TB; IMPS #114E); teres major (TM; IMPS #114F); adductor (AD; 169A); semimembranosus (SM; 169A); and biceps femoris (BF; 171D). In addition, the longissimus lumborum (LL; IMPS #180) was not further fabricated prior to steak cutting.

Steaks were produced from the 9 cuts described above by cutting perpendicular to the long axis of the subprimal, across the grain, into 2.5-cm-thick steaks. The SV, however, due to shape and muscle fiber direction was cut ventral to dorsal with angle adjustments to ensure cutting occurred perpendicular to the grain. The first (wedge) steak was removed prior to steak cutting to allow for a uniform cutting surface for steak fabrication and was designated as steak zero. Following the wedge steak, steaks were then assigned a steak number (1 through 6) and assigned in a predetermined order for subjective or objective measurements. The BF, AD, SM, IF, TB, SV, and LL each used steak zero for proximate analysis and pH evaluation. Steaks 1 through 6 were assigned as followed: consumer sensory testing, trained sensory testing, slice shear force (SSF), and Warner–Bratzler shear force (WBSF) analysis. No LCS steaks were assigned to SSF analysis. For the TM, steaks were only assigned to consumer and trained sensory analysis due to product size limitations. All steaks were individually identified, vacuum-packaged, and frozen (−20°C) until subsequent analyses. Following freezing, steaks intended for consumer and trained sensory analysis were shipped frozen to KSU for evaluation. Objective measures (WBSF, SSF, proximate analysis, and pH measurement) were conducted at TTU.

Proximate and pH Analysis

The percentage of fat, moisture, protein, and collagen, as well as pH was determined for each raw sample. Steaks were thawed for 24 h at 4–6°C prior to analysis. Any exterior muscles present, heavy connective tissue and external fat was removed to leave only the muscles of interest designated above.

Samples were then cubed into approximately 2.5-cm size pieces and ground twice through a 4-mm plate (#12 2/3 HP Electric Meat Grinder, Model: MG-204182-13, Gander Mountain, Saint Paul, MN). Proximate analysis of raw steaks was conducted by an AOAC official method (Anderson, 2007) using a near infrared spectrophotometer (FoodScan, FOSS NIRsystems, Inc., Laurel, MD).

The pH was measured from a slurry created by combining 10 g of raw ground sample in 90 mL of distilled water and stirring with a glass rod until mixed. A filter paper (Qualitative P8 Fisherbrand Filter Paper, Fisher Scientific, Pittsburgh, PA) cone was placed in the slurry in order to prevent the electrode (Jenway Model-3510, 120 VAC, Cole-Parmer, Vernon Hills, IL) from being clogged by meat particles. All pH measurements were taken from the solution present inside the cone. The electrode was raised and cleaned between each pH measurement with distilled water and low-lint Kimwipes (Kimberly-Clark; 34120, Uline, Pleasant Prairie, WI).

Cooked Sample Preparation

Steaks were thawed at 2 to 4°C for 24 h prior to cooking. After thawing, steaks were trimmed to remove external fat. After trimming, initial raw weights and temperatures (Thermopen Mk4, Themoworks, American Fork, UT) were recorded before cooking. Steaks were then cooked using an electric clamshell grill (Cuisiart Griddler Deluxe, model GR150, East Windsor, NJ) and were removed from the grill at a designated temperature, based on prior cook tests, and allowed to rise to a temperature (71°C) which is considered a medium degree of doneness. Final steak peak temperature was recorded as the maximum temperature reached during a designated rest period after cooking. After peak temperature was reached, each steak was re-weighed to calculate cook loss. Cook loss percentage was calculated for each steak using the following equation: raw weight (g) subtracted by cooked weight (g), then divided by raw weight (g), multiplied by 100.

Warner–Bratzler Shear Force

Tenderness was evaluated using WBSF as described by the American Meat Science Association guidelines (2015). Each steak was cooked as described above, placed on a metal tray and overwrapped with polyvinyl chloride, and chilled for 24 h at 4–6°C. Following chilling, 4 to

6 cores (1.3-cm in diameter) were removed parallel to the muscle fibers, randomly throughout the steak. In the LCS, 2 to 3 cores (1.3 cm in diameter) were removed from each muscle. Individual cores were then sheared at 200 mm/min using a Warner–Bratzler shear machine (G-R Elec. Mfg., Manhattan, KS) with a calibrated digital force gauge attachment (Mecmesin BFG500N, G-R Elec. Mfg. Co.). The peak force (kg) was recorded for each core, and all cores for each steak were averaged to determine the WBSF value (kg) of each steak.

Slice Shear Force

Tenderness was evaluated using SSF as described by Shackelford et al. (1999) with the modifications outlined by USDA-ARS (2016) for multiple muscles. Each muscle followed a different method of cutting to obtain 2 or 3 slices for testing. Six of the seven muscles were cut according to the USDA-ARS SSF cutting protocol (USDA-ARS, 2016). A 5-cm-long section from the medial portion of each steak was used to obtain 2 to 3 slice samples using either a 45° or 90° slicing block, based on muscle fiber orientation. In addition, SSF analysis for the SV followed similar SSF protocols of muscles with the 45° fiber orientation. The anterior and posterior ends of the steak were removed to expose the muscle fiber orientation (45°). Following these initial cuts, two 5-cm by 1-cm thick cuts slices were made from both ends of the steaks using the 45° cutting guide and used for SSF determination. For each muscle, samples were sheared across the center, perpendicular to the muscle fiber orientation at 500 mm/min per slice using a slice shear analyzer (GR-152, Tallgrass Solution, INC., Manhattan, KS).

Consumer and Trained Sensory Panel Evaluation

Consumer panels were conducted similar to methods utilized in several previous works (Lucher et al., 2016; Wilfong et al., 2016; McKillip et al., 2017) and consistent with American Meat Science Association guidelines (AMSA, 2015). Consumer panelists ($n = 210$) were recruited from Manhattan, KS, and the surrounding communities and monetarily compensated for their participation. Panelists were provided with a ballot, plastic fork, toothpick, napkin, expectorant cut, cup of distilled water, and palate cleansers (unsalted crackers and apple juice) to use between samples. Data were gathered using electronic ballots (Model 5709

HP Stream 7; Hewlett-Packard, Palo Alto, CA) which included a digital survey (Version 2417833; Qualtrics Software, Provo, UT) containing a demographic questionnaire and 8 sample ballot pages. Before the start of each panel, panelists were given verbal instructions about the electronic ballot and the use of palate cleansers. Steaks were cooked as previously described and cubed into 1.27-cm pieces, with 2 pieces served immediately to each of 7 predetermined consumers. Consumers were served a total of 8 samples representing differences in muscles and quality grades in random order. The predetermined serving order was designed as an unbalanced, incomplete block design so that every muscle $\times$ quality grade combination was compared as close to an equal number of times as possible. Attributes for each sample were assessed on continuous-line scales for juiciness, tenderness, flavor liking, and overall liking. The zero anchors were labeled as: extremely dry, extremely tough, dislike flavor extremely, and dislike overall extremely; the 100 anchors were labeled as extremely juicy, extremely tender, like flavor extremely, like overall extremely, and neutral midpoints were provided for each scale. In addition, each consumer was asked to rate each sample as either acceptable or unacceptable for each palatability trait. Consumers also identified each sample as either unsatisfactory, everyday quality, better-than-everyday quality, or premium quality.

Trained sensory analysis was conducted at KSU using an 8-member panel (AMSA, 2015). Panelists were trained over a period of 2 wk prior to the evaluation of sample steaks. Panelists were trained using the anchors described by Lucherk et al. (2016) and Vierck et al. (2018). Thirteen sessions were conducted, where panelists evaluated 9 different samples, with a warm up steak sample served first for panelist palatability calibration. Panelists evaluated each sample based on initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, beef flavor intensity, off-flavor intensity, and overall tenderness on continuous-line scales with verbal anchors at each end (0 = extremely dry/tough/ none/bland, 100 = extremely juicy/tender/ abundant/intense) and neutral midpoints anchored at 50% of the scale. All cooking procedures were identical to those described above.

Statistical Analysis

Statistical analyses were conducted using the procedures of SAS (version 9.4; SAS Inst. Inc., Cary, NC). Treatment comparisons were tested

using PROC GLIMMIX with $\alpha = 0.05$. Subprimal was used as the experimental unit. A factorial arrangement with muscle, grade, and the quality grade $\times$ muscle interaction as fixed effects was used as the model. For sensory data, the model included the random effects of panel session, and for both sensory and shear force analysis, steak peak temperature was used as a covariate. The SLICE option was further used for data that consisted of a cut $\times$ quality grade interaction. A binomial error distribution model was used for acceptability and perceived quality data with peak temperature used as a covariate. Pearson correlation coefficients were determined among all variables measured via PROC CORR using a significance of ($P < 0.05$).

RESULTS

Objective Measurements

A quality grade $\times$ muscle interaction ($P < 0.01$) was detected for each proximate measurement, as well as pH ($P < 0.01$; Table 1). Within each muscle the fat percentage differed ($P < 0.05$) among each quality grade. However, for the AD and TB Prime had greater ($P < 0.05$) fat percent than Choice and Select, which did not differ ($P > 0.05$) from each other. The AD had the least range (2.81%) in fat percentage between Select and Prime, while the SV had the greatest range (11.98%). As quality grades decreased, moisture levels increased ($P < 0.05$), with Prime steaks having the lowest ($P < 0.05$) amount of moisture within each muscle. For many of the muscles, differences ($P < 0.05$) were found among quality grades for the percentage of protein, collagen, and pH; however, in most cases, these differences were in a more narrow range ($<3\%$ for protein, $<1\%$ for collagen, and <0.1 for pH). Yet, among pH levels, the SV was the only muscle that differed ($P < 0.05$) among each quality grade, with Prime having the greatest ($P < 0.05$) pH value.

An interaction of quality grade $\times$ muscle ($P = 0.02$) was determined for SSF (Table 2). No SSF differences ($P > 0.05$) were found among quality grades from all round cuts evaluated (AD, BF, and SM). Among the IF, SV, and LL, Prime steaks had lower ($P < 0.05$) SSF values than Choice and Select. Within the TB, both Prime and Select were rated more tender ($P < 0.05$) than Choice steaks.

There was no interaction for quality grade $\times$ muscle ($P = 0.95$) for WBSF values (Table 3). However, WBSF values were influenced by the main effects of muscle ($P < 0.01$) and quality grade ($P < 0.01$). Prime WBSF values were lower

Table 1. Least squares means for the interaction of USDA quality grade and muscle for proximate percentage ($P < 0.01$) and pH ($P < 0.01$)

Muscle/quality grade	Fat, %	Protein, %	Moisture, %	Collagen, %	pH
Longissimus lumborum					
Prime	14.07 ^a	21.63 ^c	63.79 ^c	2.37 ^a	5.70
Choice	6.13 ^b	23.59 ^b	69.81 ^b	1.79 ^b	5.82
Select	3.18 ^c	24.24 ^a	71.91 ^a	1.57 ^b	5.76
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.07
Infraspinatus					
Prime	14.82 ^a	18.71 ^c	65.23 ^c	2.44 ^a	5.89
Choice	7.42 ^b	20.17 ^b	70.87 ^b	1.96 ^b	5.90
Select	4.65 ^c	20.96 ^a	73.07 ^a	1.88 ^b	5.83
SEM ¹	0.70	0.22	0.59	0.10	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.39
Longissimus thoracis, Complexus, and Spinalis dorsi					
Prime	12.07 ^a	20.87 ^b	66.90 ^c	2.22 ^a	5.62
Choice	6.65 ^b	22.59 ^a	70.46 ^b	1.81 ^b	5.57
Select	4.06 ^c	22.63 ^a	73.30 ^a	1.67 ^b	5.63
SEM ¹	0.67	0.23	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.42
Serratus ventralis					
Prime	18.04 ^a	18.03 ^c	62.65 ^c	2.87 ^a	5.92 ^a
Choice	10.00 ^b	20.58 ^b	68.23 ^b	2.19 ^b	5.81 ^b
Select	6.06 ^c	21.44 ^a	71.25 ^a	1.93 ^c	5.70 ^b
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	<0.01
Triceps brachii					
Prime	7.62 ^a	20.77 ^b	70.55 ^b	2.41 ^a	5.83
Choice	3.87 ^b	21.87 ^a	73.07 ^a	1.95 ^b	5.84
Select	2.76 ^b	21.97 ^a	74.04 ^a	1.78 ^b	5.83
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.99
Adductor					
Prime	4.63 ^a	23.46 ^c	70.31 ^b	1.99 ^a	5.40
Choice	2.15 ^b	24.07 ^b	72.30 ^a	1.82 ^a	5.32
Select	1.82 ^b	24.81 ^a	72.67 ^a	1.53 ^b	5.44
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.07
Biceps femoris					
Prime	12.73 ^a	20.25 ^c	66.72 ^c	3.02 ^a	5.59
Choice	6.67 ^b	21.96 ^b	70.46 ^b	2.33 ^b	5.56
Select	3.54 ^c	22.56 ^a	72.69 ^a	1.69 ^c	5.61
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.64
Semimembranosus					
Prime	9.35 ^a	21.83 ^b	68.60 ^b	2.54 ^a	5.60
Choice	4.68 ^b	23.67 ^a	71.43 ^a	2.19 ^b	5.58
Select	2.68 ^c	24.03 ^a	72.52 ^a	1.66 ^c	5.60
SEM ¹	0.67	0.22	0.56	0.09	0.04
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	0.88

¹SE (largest) of the least squares means.^{abc}Least squares means in the same muscle and column without a common superscript differ ($P < 0.05$).

($P < 0.05$) than Choice and Select, which did not differ ($P > 0.05$). Among muscles, the LCS was the most tender ($P < 0.05$), while the SM was found

to be the toughest ($P < 0.05$). The IF, LL, and SV were similar ($P > 0.05$) in tenderness and had lower ($P < 0.05$) WBSF values than the AD, TB, and BF.

Table 2. Least squares means for the interaction ($P = 0.02$) of USDA quality grade and muscle for slice shear force (SSF)

Muscle/quality grade	SSF (kgf)
Longissimus lumborum	
Prime	11.14 ^b
Choice	13.63 ^a
Select	14.74 ^a
SEM ¹	0.82
<i>P</i> value	<0.01
Infraspinatus	
Prime	10.72 ^b
Choice	14.40 ^a
Select	13.69 ^a
SEM ¹	0.87
<i>P</i> value	<0.01
Serratus ventralis	
Prime	10.84 ^b
Choice	13.34 ^a
Select	14.85 ^a
SEM ¹	0.82
<i>P</i> value	<0.01
Triceps brachii	
Prime	13.75 ^b
Choice	16.81 ^a
Select	13.73 ^b
SEM ¹	0.83
<i>P</i> value	<0.01
Adductor	
Prime	14.86
Choice	14.87
Select	14.43
SEM ¹	0.83
<i>P</i> value	0.91
Biceps femoris	
Prime	20.76
Choice	20.29
Select	21.54
SEM ¹	0.83
<i>P</i> value	0.56
Semimembranosus	
Prime	16.53
Choice	17.11
Select	17.89
SEM ¹	0.83
<i>P</i> value	0.51

¹SE (largest) of the least squares means.^{abc}Least squares means within the same muscle without a common superscript differ ($P < 0.05$).

Consumer Demographics

The demographic profile of consumers tested in Manhattan, KS, for this study is presented in Table 4. Slightly more males (54.1%) participated in the study than females (45.9%). The age of the consumers was distributed from 18 to 65, with most

Table 3. Least squares means for Warner–Bratzler shear force (WBSF) of the longissimus lumborum, chuck, and round beef muscles from 3 USDA quality grades

Treatment	WBSF (kgf)
Quality grade	
Prime	2.27 ^b
Choice	2.51 ^a
Select	2.63 ^a
SEM ¹	0.05
<i>P</i> value	<0.01
Muscle	
Longissimus lumborum	1.99 ^d
Infraspinatus	2.16 ^d
Longissimus thoracis, Complexus, and Spinalis dorsi	1.76 ^e
Serratus ventralis	2.04 ^d
Triceps brachii	2.69 ^c
Adductor	2.54 ^c
Biceps femoris	3.00 ^b
Semimembranosus	3.57 ^a
SEM ¹	0.16
<i>P</i> value	<0.01
Quality grade × muscle	
<i>P</i> value	0.95

¹SE (largest) of the least squares means.^{abcde}Least squares means in the same main effect (quality grade or muscle) without a common superscript differ ($P < 0.05$).

(34%) of the consumers falling in the 20 to 29 age range. The majority (84.1 %) of consumers were Caucasian. Each annual household income bracket was represented by consumers tested, but the largest number of participants (21.6 %) was represented in the \$50,000 to \$74,999 range. A majority of consumers had at least a college level degree (63.2%). When asked how many times a week they consumed beef, the most frequent response was at least 3 times a week (19.9%). The majority (63.6%) of consumers indicated they preferred steaks cooked to a medium-rare degree of doneness. Consumers identified flavor (50.7 %), followed by tenderness (36.4%) as the most important palatability trait when consuming steaks.

Consumer Sensory Analysis

Consumer ratings for juiciness, tenderness, flavor liking, and overall liking are shown in Table 5. There were no quality grade × muscle interactions for the consumer traits evaluated ($P \geq 0.28$), indicating the impact of quality grade was consistent across all of the muscles evaluated. Prime was rated greater ($P < 0.05$) than Choice and Select for all traits evaluated. No difference ($P > 0.05$) was

Table 4. Demographics characteristics of consumers who participated in consumer sensory panels ($n = 210$)

Characteristic	Response	Percentage of consumers
Gender	Male	54.1
	Female	45.9
Household size	1 People	21.4
	2 People	25.7
	3 People	11.9
	4 People	22.9
	5 People	10.0
	6 People	2.4
	> 6 People	5.7
Marital status	Married	57.4
	Single	42.6
Age, yr	Under 20	5.7
	20 to 29	34.0
	30 to 39	21.1
	40 to 49	23.4
	50 to 59	12.9
	Over 60	2.9
Ethnicity	African-American	3.4
	Asian	1.4
	Caucasian/White	84.1
	Hispanic	7.7
	Native American	1.0
	Other	0.5
	Mixed Race	1.9
Annual household income, \$	<25,000	11.8
	25,000–34,999	12.8
	35,000–49,999	12.8
	50,000–74,999	21.6
	75,000–99,000	18.1
	100,000–149,999	18.1
	150,000–199,999	4.4
	>199,999	0.5
Highest level of education completed	Non-high school graduate	1.9
	High school graduate	11.5
	Some college/Technical school	23.4
	College graduate	40.2
	Post-college graduate	23.0
Most important palatability trait	Flavor	50.7
	Juiciness	12.9
	Tenderness	36.4
	Very rare	1.0
Preferred degree of doneness	Rare	2.9
	Medium-rare	63.6
	Medium	26.3
	Medium-Well	0.0
	Well-Done	5.7
	Very Well Done	0.5
Weekly beef consumption, number of meals	1	2.4

Table 4. *Continued*

Characteristic	Response	Percentage of consumers
	2	9.2
	3	19.9
	4	11.2
	5	9.7
	6	10.2
	7	6.3
	8	3.4
	9	9.7
	10	5.3
	11	2.9
	12	5.3
	13	1.5
	14	0.5
	15	1.5
	17	0.5
	18	0.5

found between Choice and Select for tenderness and overall liking, however, Choice was rated greater ($P < 0.05$) than Select for both juiciness and flavor. Consumers rated the LCS, IF, and SV to have the greatest ($P < 0.05$) juiciness, while the LL rated similar ($P > 0.05$) to TB for juiciness. The AD, BF, and SM did not differ ($P > 0.05$) in juiciness ratings, with each muscle rating lower ($P < 0.05$) than the LL, LCS, IF, and SV. The LCS and IF were the most tender ($P < 0.05$), followed by SV, which was more tender ($P < 0.05$) than all others. The LL was rated similar ($P > 0.05$) in tenderness to the TM and TB. The BF was tougher ($P < 0.05$) than all other muscles, except the SM ($P > 0.05$). The LCS and IF had greater ($P < 0.05$) flavor liking than all other muscles, except the SV which was similar ($P > 0.05$) to the IF. Muscles from the round (AD, BF, and SM) had the lowest ($P < 0.05$) overall liking ratings, while the LCS had greater ($P < 0.05$) overall liking than all other muscles, except the IF ($P > 0.05$).

Consumer Ratings of Acceptability

Consumer acceptability ratings of juiciness, tenderness, flavor, and overall liking are presented in Table 6. There was no quality grade $\times$ muscle interactions found among consumer acceptability ratings of palatability traits ($P \geq 0.34$), demonstrating the variation of quality grade affected all muscles evaluated the same. The LCS, IF, and SV had a greater ($P < 0.05$) percentage ($> 92\%$) of steaks rated acceptable for juiciness than all other cuts. The BF had the lowest ($P < 0.05$) percentage for tenderness acceptability compared with all other

Table 5. Least squares means for consumer ($n = 210$) ratings¹ of the palatability traits of longissimus lumborum, chuck, and round beef muscles from 3 USDA quality grades

Treatment	Juiciness	Tenderness	Flavor	Overall like
Quality grade				
Prime	68.8 ^a	66.8 ^a	64.9 ^a	66.2 ^a
Choice	56.6 ^b	56.3 ^b	58.9 ^b	57.9 ^b
Select	51.4 ^c	54.5 ^b	54.6 ^c	55.0 ^b
SEM ²	1.3	1.3	1.3	1.3
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Muscle				
Longissimus lumborum	59.8 ^b	63.2 ^c	59.2 ^c	61.8 ^c
Infraspinatus	73.7 ^a	75.9 ^a	67.8 ^{ab}	72.7 ^{ab}
Longissimus thoracis, Complexus, and Spinalis dorsi	71.6 ^a	78.4 ^a	71.5 ^a	74.2 ^a
Serratus Ventralis	72.6 ^a	69.1 ^b	65.4 ^b	67.4 ^b
Teres major	53.0 ^{cd}	62.9 ^c	57.9 ^c	59.9 ^c
Triceps brachii	56.3 ^{bc}	57.6 ^c	58.4 ^c	59.2 ^c
Adductor	47.2 ^{de}	46.6 ^d	50.6 ^d	48.3 ^d
Biceps femoris	51.0 ^{cde}	38.4 ^e	54.4 ^{cd}	47.4 ^d
Semimembranosus	45.1 ^e	40.9 ^{de}	50.0 ^d	46.4 ^d
SEM ²	2.4	2.4	2.1	2.3
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Quality grade × muscle				
<i>P</i> value	0.38	0.63	0.28	0.59

¹Sensory scores: 0 = extremely dry/tough/dislike extremely; 100 = extremely juicy/tender/like extremely.

²SE (largest) of the least square means.

^{abcde} Least squares means without a common superscript within the same main effect (quality grade or muscle) and sensory attribute differ ($P < 0.05$).

Table 6. Least squares mean percentages of longissimus lumborum, chuck, and round beef muscles from 3 USDA quality grades rated acceptable by consumers ($n = 210$) for juiciness, tenderness flavor, and overall liking

Treatment	Juiciness acceptability	Tenderness acceptability	Flavor acceptability	Overall acceptability
Quality grade				
Prime	93.0 ^a	90.9 ^a	87.2 ^a	87.7 ^a
Choice	81.5 ^b	82.4 ^b	82.9 ^b	82.3 ^b
Select	75.9 ^c	81.7 ^b	78.8 ^b	78.4 ^b
SEM ¹	2.0	2.0	2.1	2.0
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Muscle				
Longissimus lumborum	85.3 ^b	89.4 ^{bc}	79.5 ^{cde}	83.4 ^c
Infraspinatus	93.6 ^a	93.8 ^{ab}	86.2 ^{abc}	88.5 ^{bc}
Longissimus thoracis, Complexus, and Spinalis dorsi	92.6 ^a	96.4 ^a	91.4 ^a	96.4 ^a
Serratus ventralis	96.6 ^a	91.6 ^{abc}	88.0 ^{ab}	90.7 ^b
Teres major	79.5 ^{bc}	90.8 ^{bc}	83.5 ^{bcd}	84.4 ^{bc}
Triceps brachii	82.8 ^b	87.0 ^c	83.9 ^{bc}	81.5 ^c
Adductor	71.1 ^{cd}	65.6 ^d	75.2 ^{de}	67.4 ^d
Biceps femoris	70.3 ^{cd}	51.7 ^e	81.7 ^{bcd}	60.5 ^d
Semimembranosus	65.9 ^d	65.1 ^d	73.4 ^e	69.4 ^d
SEM ¹	3.6	3.9	3.5	3.9
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Quality grade × muscle				
<i>P</i> value	0.34	0.43	0.57	0.71

¹SE (largest) of the least square means.

^{abcde} Least squares means without a common superscript within the same main effect (quality grade or muscle) and sensory attribute differ ($P < 0.05$).

cuts. The LCS had the greatest ($P < 0.05$) percentage (96.4%) of steaks rated as acceptable for overall liking. In comparison with the LL, all cuts from the chuck (IF, LCS, SV, TB, and TM) had similar ($P > 0.05$) or greater ($P < 0.05$) percentages of samples rated as acceptable for overall liking. The AD, BF, and SM were similar ($P > 0.05$) and had the lowest ($P < 0.05$) percentage of samples rated as acceptable for overall liking. A greater ($P < 0.05$) percentage of Prime samples were rated acceptable for all palatability traits in comparison with Choice and Select. The percentage of steaks rated acceptable in Choice and Select cuts did not differ ($P < 0.05$) across traits, except juiciness, where a greater ($P < 0.05$) proportion of Choice steaks had acceptable juiciness compared with Select.

Consumer Perceived Quality Levels

Consumer perceived quality levels are presented in Table 7. Consumers found no quality grade $\times$ muscle interactions ($P \geq 0.11$) among perceived quality levels of the samples evaluated. The LCS had a greater percentage ($P < 0.05$) of steaks rated as premium and better-than-everyday quality than all cuts, other than the IF ($P > 0.05$). The AD, BF, and SM had the greatest ($P < 0.05$) percentage ($>30\%$) of steaks rated as unsatisfactory.

The LL and SV did not differ ($P > 0.05$) between each other for percentage of everyday quality rating. Comparing quality grades, Prime was rated premium quality most frequently ($P < 0.05$) and did not differ ($P > 0.05$) from Choice when rated as better-than-everyday quality. Select was determined by consumers to have the greatest ($P < 0.05$) percentage of steaks rated as unsatisfactory quality, compared to both Choice and Prime which did not differ ($P > 0.05$). Everyday quality ratings increased ($P < 0.05$) as quality grades decreased (Prime $<$ Choice $<$ Select).

Trained Sensory Analysis

There were no quality grade $\times$ muscle interactions for the traits evaluated ($P \geq 0.07$), except overall tenderness ($P = 0.03$). Trained sensory panel ratings are presented in Table 8 as main effect means, while the interaction quality grade $\times$ muscle for overall tenderness is presented in Table 9. Initial juiciness, myofibrillar tenderness, and beef flavor intensity were rated greater ($P < 0.05$) for Prime compared with Choice and Select, which were rated similar ($P > 0.05$) for the same traits. Select steaks had a greater ($P < 0.05$) amount of connective tissue than both Choice and Prime steaks. Panelists rated the LCS, IF, and SV greatest ($P < 0.05$) in

Table 7. Least squares mean percentages of the longissimus lumborum, chuck, and round beef muscles from 3 USDA quality grades identified as certain perceived quality levels by consumers ($n = 210$)

Treatment	Unsatisfactory quality	Everyday quality	Better-than-everyday quality	Premium quality
Quality grade				
Prime	11.0 ^b	34.0 ^c	29.8 ^a	15.2 ^a
Choice	15.2 ^b	41.5 ^b	24.9 ^a	2.0 ^b
Select	19.6 ^a	50.0 ^a	19.2 ^b	6.1 ^b
SEM ¹	1.8	2.1	1.9	2.1
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Muscle				
Longissimus lumborum	12.9 ^b	40.9 ^b	23.8 ^{cd}	15.1 ^{bc}
Infraspinatus	8.9 ^{bc}	26.0 ^c	36.7 ^a	22.0 ^{ab}
Longissimus thoracis, Complexus, and Spinalis dorsi	6.3 ^c	25.5 ^c	37.8 ^a	30.0 ^a
Serratus ventralis	6.0 ^c	40.8 ^b	34.2 ^{ab}	16.5 ^b
Teres major	15.0 ^b	46.8 ^{ab}	27.0 ^{bc}	8.7 ^{cd}
Triceps brachii	14.1 ^b	48.5 ^{ab}	25.9 ^{bcd}	6.9 ^d
Adductor	30.1 ^a	47.0 ^{ab}	18.3 ^{cd}	3.4 ^d
Biceps femoris	32.4 ^a	48.1 ^{ab}	15.1 ^c	3.8 ^d
Semimembranosus	31.1 ^a	56.0 ^a	11.4 ^c	0.0 ^d
SEM ¹	3.6	3.9	3.4	5.5
<i>P</i> value	<0.01	<0.01	<0.01	<0.01
Quality grade $\times$ muscle				
<i>P</i> value	0.82	0.11	0.26	0.13

¹SE (largest) of the least square means.

^{abcde}Superscripts within the same main effect (quality grade or muscle) and sensory attribute differ ($P < 0.05$).

Table 8. Least squares means for trained sensory panel ratings¹ of the longissimus lumborum, chuck, and round beef muscles from 3 USDA quality grades

Treatment	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue amount	Beef flavor intensity	Off-flavor intensity
Quality grade						
Prime	70.9 ^a	63.4 ^a	74.8 ^a	19.2 ^b	49.4 ^a	1.1
Choice	62.3 ^b	52.3 ^b	67.2 ^b	20.3 ^b	40.7 ^b	1.8
Select	60.3 ^b	48.9 ^c	65.1 ^b	22.8 ^a	39.1 ^b	1.8
SEM ²	0.9	1.1	0.8	1.0	0.7	0.3
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	<0.01	0.25
Muscle						
Longissimus lumborum	65.6 ^b	54.9 ^b	73.9 ^b	8.1 ^c	41.9 ^d	0.7
Infraspinatus	76.7 ^a	70.7 ^a	82.9 ^a	10.6 ^c	48.9 ^b	2.8
Longissimus thoracis, Complexus, and Spinalis dorsi	77.0 ^a	71.0 ^a	83.5 ^a	8.6 ^c	49.6 ^b	1.3
Serratus ventralis	78.4 ^a	72.2 ^a	76.4 ^b	21.5 ^{cd}	52.4 ^a	2.1
Teres major	61.5 ^{bc}	50.0 ^{bc}	64.2 ^c	17.7 ^d	41.5 ^d	0.9
Triceps brachii	58.6 ^c	49.0 ^c	75.6 ^b	7.9 ^e	37.6 ^e	2.0
Adductor	47.2 ^d	34.5 ^d	55.9 ^d	25.6 ^c	33.9 ^f	1.4
Biceps femoris	64.8 ^b	54.3 ^{bc}	58.8 ^d	50.2 ^a	45.5 ^c	1.2
Semimembranosus	50.4 ^d	37.4 ^d	50.3 ^e	37.1 ^b	36.2 ^{ef}	1.4
SEM ²	1.8	2.0	1.5	1.8	1.2	0.6
<i>P</i> value	<0.01	<0.01	<0.01	<0.01	<0.01	0.25
Quality grade × muscle						
<i>P</i> value	0.73	0.69	0.35	0.20	0.07	0.83

¹Sensory scores: 0 = extremely dry/tough/bland/none, 50 = neither juicy/dry/tough/tender, 100 = extremely juicy/tender/abundant/intense.

²SE (largest) of the least square means.

^{abcde}Least squares means without a common superscript within the same main effect (quality grade or muscle) and sensory attribute differ ($P < 0.05$).

initial and sustained juiciness, while the AD and SM rated lowest ($P < 0.05$) for these traits. For myofibrillar tenderness, the LCS and IF rated highest ($P < 0.05$), followed by the LL, SV and TM. The SM was rated the lowest ($P < 0.05$) for myofibrillar tenderness. The BF had the greatest ($P < 0.05$) rating for amount of connective tissue, followed by the SM, compared to all other muscles. For beef flavor intensity, the SV was rated the highest ($P < 0.05$), and the LCS and IF were greater ($P < 0.05$) than all remaining muscles. No differences ($P > 0.05$) were determined among muscles and quality grades for off-flavor intensity.

The interaction ($P < 0.05$) of quality grade × muscle on overall tenderness scores is reported in Table 9. Within Prime, the LCS was rated the most ($P < 0.05$) tender, and no differences ($P > 0.05$) were found among the LL, IF, SV, and TM. Whereas within Choice and Select, LCS was similar ($P > 0.05$) to the IF and TM for overall tenderness. Additionally, within Prime, no difference ($P > 0.05$) in overall tenderness was found among BF, AD, and SM. However, the AD was more tender ($P < 0.05$) than both the BF and SM in both Choice and Select.

Correlations

Table 10 shows Pearson correlation coefficients between consumer sensory traits, trained sensory analysis, and all objective measurements across all muscles. Consumer tenderness ratings were correlated ($P < 0.05$) with fat percent ($r = 0.42$), collagen percentage ($r = 0.13$), and pH ($r = 0.34$). Consumer tenderness was negatively correlated with WBSF ($r = -0.54$) and SSF ($r = -0.49$). Consumer juiciness ratings were correlated ($P < 0.01$) with fat, collagen, and pH ($r = 0.58, 0.38, 0.31$, respectively). Consumer flavor liking was correlated ($P < 0.01$) with fat, collagen, and pH ($r = 0.40, 0.24, 0.22$, respectively). Furthermore, consumer overall liking was correlated ($P < 0.01$) with fat percentage ($r = 0.42$), collagen ($r = 0.19$), and pH ($r = 0.31$).

Cook loss percentage was negatively correlated ($P < 0.01$) across all consumer attributes evaluated; tenderness ($r = -0.26$), juiciness ($r = -0.36$), flavor liking ($r = -0.30$), and overall liking ($r = -0.28$). Additionally, cook loss was negatively associated ($P < 0.01$) with trained panel attributes of initial juiciness ($r = -0.45$), sustained juiciness ($r = -0.44$), myofibrillar tenderness ($r = -0.35$),

Table 9. Least squares means for the interaction ($P = 0.03$) of USDA quality grade and muscle for trained sensory panel overall tenderness¹ rating

Treatment	Overall tenderness
Prime	
Longissimus lumborum	77.6 ^b
Infraspinatus	81.2 ^b
Longissimus thoracis, Complexus, and Spinalis dorsi	89.3 ^a
Serratus ventralis	77.2 ^b
Teres major	75.6 ^b
Triceps brachii	64.7 ^c
Adductor	45.1 ^d
Biceps femoris	41.8 ^d
Semimembranosus	37.7 ^d
SEM ²	2.8
<i>P</i> value	<0.01
Choice	
Longissimus lumborum	68.5 ^b
Infraspinatus	77.8 ^a
Longissimus thoracis, Complexus, and Spinalis dorsi	76.6 ^a
Serratus ventralis	65.9 ^b
Teres major	70.4 ^{ab}
Triceps brachii	51.7 ^c
Adductor	44.6 ^c
Biceps femoris	35.5 ^d
Semimembranosus	36.3 ^d
SEM ²	3.0
<i>P</i> value	<0.01
Select	
Longissimus lumborum	66.2 ^b
Infraspinatus	76.3 ^a
Longissimus thoracis, Complexus, and Spinalis dorsi	73.2 ^{ab}
Serratus ventralis	54.4 ^c
Teres major	69.8 ^{ab}
Triceps brachii	54.7 ^c
Adductor	42.8 ^d
Biceps femoris	29.3 ^e
Semimembranosus	29.8 ^e
SEM ²	3.2
<i>P</i> value	<0.01

¹0 = extremely tough; 50 = neither tough/tender; 100 = extremely tender.

²SE (largest) of the least square means.

^{abcde}Least squares means within the same grade without common superscript differ ($P < 0.05$).

overall tenderness ($r = -0.27$), and beef flavor identity ($r = -0.38$).

Table 11 shows Pearson correlation coefficients of cooked objective measures and fat percentage of each individual muscle. Consumer tenderness scores were correlated ($P < 0.01$) with fat percentage for the LL ($r = 0.53$), IF ($r = 0.65$), and BF ($r = 0.51$). Consumer juiciness liking was correlated

($P < 0.01$) with fat percentage for the same 3 muscles, LL ($r = 0.60$), IF ($r = 0.64$), and BF ($r = 0.59$). Additionally, consumer flavor liking was correlated ($P < 0.01$) with fat percentage for the LL ($r = 0.47$), IF ($r = 0.50$), and BF ($r = 0.62$). Finally, consumer overall liking was also correlated ($P < 0.01$) with fat percentage for the LL ($r = 0.48$), IF ($r = 0.44$), and BF ($r = 0.57$).

However, fat percentage was correlated ($P < 0.05$) with juiciness alone for the SV ($r = 0.51$), TB ($r = 0.44$), and SM ($r = 0.47$). Fat percentage of the LCS was only correlated ($P < 0.05$) with overall liking ($r = 0.37$). Finally, the fat percentage of AD was not correlated ($P > 0.05$) with any attribute evaluated by consumers.

Fat percent was correlated ($P < 0.05$) with trained panel attribute initial juiciness for the LL ($r = 0.72$), IF ($r = 0.38$), LCS ($r = 0.43$), SV ($r = 0.58$), TB ($r = 0.53$), and BF ($r = 0.45$). Fat percent was also correlated ($P < 0.05$) with trained panel measured sustained juiciness for the LL ($r = 0.78$), IF ($r = 0.53$), LCS ($r = 0.44$), SV ($r = 0.57$), TB ($r = 0.58$), and BF ($r = 0.53$). Furthermore, fat percent was correlated ($P < 0.05$) with trained panel measured myofibrillar tenderness for the LL ($r = 0.66$), IF ($r = 0.43$), LCS ($r = 0.59$), SV ($r = 0.68$), TB ($r = 0.52$), and BF ($r = 0.57$). Additionally, fat percent was correlated ($P < 0.05$) with trained panel overall tenderness for the LL ($r = 0.62$), LCS ($r = 0.68$), SV ($r = 0.62$), TB ($r = 0.50$), and BF ($r = 0.54$). Finally, fat percent was correlated ($P < 0.05$) with trained panel beef flavor identity for the LL ($r = 0.87$), IF ($r = 0.61$), LCS ($r = 0.65$), SV ($r = 0.71$), TB ($r = 0.57$), and BF ($r = 0.75$). The LCS was the only muscle to be negatively correlated ($P < 0.05$) with connective tissue content assessed by trained panelists ($r = -0.38$).

Negative correlations ($P < 0.05$) were determined between WBSF and trained attributes myofibrillar tenderness and overall tenderness for the LL ($r = -0.37$ and -0.39 , respectively) and BF ($r = -0.39$ and -0.44 , respectively). The WBSF values of the SV and SM were negatively correlated ($P < 0.05$) with trained panel overall tenderness ($r = -0.43$, -0.47 , respectively). Furthermore, SV and LCS WBSF values were negatively correlated ($P < 0.05$) to myofibrillar tenderness ($r = -0.55$ and -0.41 , respectively). A positive correlation ($P < 0.05$) was demonstrated for WBSF values and connective tissue in the LL and TB ($r = 0.48$ and 0.42 , respectively).

The BF was the only muscle with correlation ($P < 0.05$) between SSF and consumer measured tenderness ($r = -0.49$), juiciness ($r = -0.44$), flavor liking ($r = -0.40$), and overall liking

Table 10. Pearson correlation coefficients for sensory scores and objective measurements for the longissimus lumborum, chuck¹ and round² muscles of 3 different USDA quality grades (Prime, Choice, Select)

Measurement	Consumer panel rating				Trained panel rating						
	Tenderness	Juiciness	Flavor liking	Overall liking	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue	Overall tenderness	Beef flavor identity	Off-flavor
Cooked measurements											
WBSF, kg	-0.54**	-0.51**	-0.35**	-0.45**	-0.48**	-0.49**	-0.66**	0.60**	-0.72**	-0.39**	0.02
Slice shear force value, kg	-0.49**	-0.40**	-0.20**	-0.37**	-0.23**	-0.25**	-0.48**	0.65**	-0.63**	-0.20**	-0.07
Cook loss %	-0.26**	-0.36**	-0.30**	-0.28**	-0.45**	-0.44**	-0.35**	0.03	-0.27**	-0.38**	0.02
Raw measurements											
Fat %	0.42**	0.58**	0.40**	0.42**	0.58**	0.60**	0.53**	-0.16*	0.44**	0.71**	-0.06
Moisture %	-0.35**	-0.49**	-0.32**	-0.33**	-0.46**	-0.48**	-0.44**	0.13*	-0.36**	-0.60**	0.07
Protein %	-0.44**	-0.60**	-0.44**	-0.45**	-0.66**	-0.68**	-0.58**	0.16*	-0.48**	-0.71**	0.00
Collagen %	0.13*	0.38**	0.24**	0.19**	0.32**	0.33**	0.20**	0.12	0.09	0.48**	-0.09
pH	0.34**	0.31**	0.22**	0.31**	0.39**	0.38**	0.39**	-0.33**	0.44**	0.34**	0.03

¹Chuck muscles: Infraspinatus; chuck eye (Longissimus thoracis, Complexus, and Spinalis dorsi); Serratus ventralis; and Triceps brachii.

²Round muscles: Adductor; Biceps femoris; and Semimembranosus.

*Correlation coefficient differs from 0 ($P < 0.05$).

**Correlation coefficient differs from 0 ($P < 0.01$).

Table 11. Pearson correlation coefficients of cooked objective measures and fat percentage with consumer and trained sensory response for each muscle

Muscle/measurement	Consumer Panel rating				Trained Panel Rating						
	Tenderness	Juiciness	Flavor liking	Overall liking	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue	Overall tenderness	Beef flavor identity	Off-flavor
Longissimus lumborum											
WBSF	-0.27	-0.35	-0.33	-0.26	-0.41*	-0.42*	-0.37*	0.42*	-0.39*	-0.48**	-0.11
SSF	-0.28	-0.25	-0.23	-0.22	-0.41*	-0.49**	-0.39*	0.32	-0.40*	-0.66**	-0.02
Cook loss %	-0.59**	-0.65**	-0.57**	-0.61**	0.06	0.01	0.17	-0.13	0.18	0.08	0.07
Fat %	0.53**	0.60**	0.47**	0.48**	0.72**	0.78**	0.66**	-0.32	0.62**	0.87**	-0.23
Infraspinatus											
WBSF	-0.16	-0.19	-0.01	-0.01	0.14	0.13	-0.22	0.25	-0.19	0.02	-0.14
SSF	-0.28	-0.34	-0.24	-0.24	-0.21	-0.26	-0.54**	0.42*	-0.47*	-0.14	-0.16
Cook loss%	-0.11	-0.20	-0.19	-0.19	-0.20	-0.21	-0.42*	0.09	-0.36*	-0.34	-0.16
Fat %	0.65**	0.64**	0.50**	0.44**	0.38*	0.53**	0.43*	0.04	0.26	0.61**	-0.11
Longissimus thoracis, Complexus, and Spinalis dorsi											
WBSF	-0.27	-0.26	-0.21	-0.28	-0.29	-0.32	-0.41*	-0.02	-0.32	-0.35	0.29
Cook loss %	-0.36	-0.16	-0.09	-0.07	-0.58**	-0.67**	-0.55**	-0.04	-0.40*	-0.48**	0.39
Fat %	0.29	0.29	0.35	0.37*	0.43*	0.44*	0.59**	-0.38*	0.68**	0.65**	-0.24
Serratus ventralis											
WBSF	-0.35	-0.54**	-0.06	-0.25	-0.23	-0.22	-0.55**	0.25	-0.43*	-0.37	-0.13
SSF	-0.16	-0.31	0.14	-0.04	-0.27	-0.27	-0.58**	0.26	-0.52**	-0.51**	-0.18
Cook loss %	-0.38*	-0.48*	-0.20	-0.35	-0.08	-0.10	-0.21	0.21	-0.27	-0.27	0.12
Fat %	0.27	0.51**	-0.08	0.08	0.58**	0.57**	0.68**	-0.40*	0.62**	0.71**	0.07
Teres major											
Cook loss	-0.36	-0.12	-0.08	-0.04	-0.61**	-0.57**	-0.29	-0.16	-0.19	-0.34	-0.15
Triceps brachii											
WBSF	-0.08	-0.43*	-0.13	-0.13	0.07	0.05	-0.16	0.48**	-0.35	-0.03	-0.11
SSF	-0.13	-0.33	0.22	0.01	-0.12	-0.15	-0.15	0.16	-0.19	0.06	-0.05
Cook loss %	-0.09	-0.37	-0.13	-0.13	-0.44*	-0.43*	-0.57**	0.09	-0.54**	-0.25	0.05
Fat %	0.16	0.44*	0.25	0.32	0.53**	0.58**	0.52**	-0.23	0.50**	0.57**	0.07
Adductor											
WBSF	-0.05	-0.05	0.09	0.03	-0.20	0.19	-0.09	-0.09	-0.20	-0.26	0.46*
SSF	-0.05	-0.19	0.26	0.07	0.07	0.09	-0.22	0.37*	-0.50**	-0.04	0.04
Cook loss %	-0.52**	-0.54**	-0.46**	-0.60**	-0.37*	-0.26	-0.29	-0.16	-0.31	-0.19	0.02
Fat %	0.23	0.26	-0.06	0.00	0.30	0.27	0.20	0.02	0.15	0.34	-0.26
Biceps femoris											
WBSF	-0.38*	-0.41*	-0.31	-0.28	-0.39*	-0.37*	-0.39*	0.16	-0.44*	-0.10	0.17
SSF	-0.49**	-0.44*	-0.40*	-0.39*	-0.01	-0.04	-0.10	0.32	-0.23	0.10	0.09
Cook loss %	-0.47**	-0.56**	-0.50**	-0.52**	-0.48**	-0.45*	-0.29	-0.08	-0.18	-0.04	-0.31

Table 11. Continued

	Consumer Panel rating				Trained Panel Rating						
	Tenderness	Juiciness	Flavor liking	Overall liking	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue	Overall tenderness	Beef flavor identity	Off-flavor
Muscle/measurement											
Fat %	0.51**	0.59**	0.62**	0.57**	0.45*	0.53**	0.57**	-0.34	0.54**	0.75**	-0.20
Semimembranosus											
WBSF	0.13	-0.32	0.01	0.07	0.02	0.06	-0.09	0.25	-0.47**	-0.06	0.13
SSF	0.11	-0.19	0.06	0.01	0.08	0.26	0.22	0.40*	-0.65**	0.02	0.31
Cook loss %	-0.12	-0.02	-0.49**	-0.39*	-0.05	0.01	0.01	0.01	0.03	0.03	0.14
Fat %	0.09	0.47**	0.05	0.08	-0.06	-0.04	-0.08	0.01	0.34	0.08	-0.17

*Correlation coefficient differs from 0 ($P < 0.05$).

**Correlation coefficient differs from 0 ($P < 0.01$).

($r = -0.39$). The SSF values of LL, IF, and SV were negatively correlated ($P < 0.05$) with trained attributes of myofibrillar tenderness ($r = -0.39$, -0.54 , and -0.58 , respectively) and overall tenderness ($r = -0.40$, -0.47 , and -0.52 , respectively). The SSF values of the AD and SM were negatively correlated ($P < 0.05$) to overall tenderness ($r = -0.50$ and -0.65 , respectively). Finally, SSF values were positively correlated ($P < 0.05$) to trained panel assessment of connective tissue content for the IF ($r = 0.42$), AD ($r = 0.37$), and SM ($r = 0.40$).

DISCUSSION

Quality Grade Impacts

It is well established that the USDA quality grade system segregates beef into categories of expected eating experience. Numerous previous works have demonstrated that USDA Prime possesses greater eating quality in comparison to Choice and Select (Savell et al., 1987; O'Quinn et al, 2012; Emerson et al, 2013; Corbin et al, 2015). The influence of quality grade on palatability is largely due to variation in intramuscular fat content among grades. In this study, fat percent differed due to quality grade, as expected. However, this effect was muscle dependent as fat percent did not differ for AD and TB from Choice and Select. All other muscles differed in fat percent between each quality grade. Likewise, quality grade did not influence SSF tenderness for the AD, BF, and SM. Meanwhile, this interaction was not present for WBSF tenderness, consumer liking of attributes, consumer acceptability of attributes, consumer perceived quality level, and the majority of trained panelist attributes. In other words, the quality grade effect was determined to be similar across all muscles for the majority of the measurements in this study. Counter to this, others have observed an interaction between quality grade and muscle for consumer liking scores, where specific cuts did not differ between quality grades (Kukowski et al., 2004; Hunt et al., 2014). The results of the current study indicate that the USDA quality grading system does in fact segregate multiple beef muscles into categories of expected eating experience. Our results may differ from past research due to the inclusion of USDA Prime and a broader group of muscles.

Within this quality grade differentiation, USDA Prime was different from Choice and Select in each objective and subjective measurement of beef attributes (tenderness, juiciness, and flavor). Meanwhile,

there was less segregation between Choice and Select beef. Choice was similar to Select for several measurements, including: WBSF, consumer tenderness, consumer overall liking, consumer acceptability of tenderness, consumer acceptability of flavor, consumer overall acceptability, initial juiciness, myofibrillar tenderness, and beef flavor intensity. These results clearly indicate that Prime beef is a premium product with a consistently better eating quality compared with Choice and Select, as expected. More interestingly, these results indicate that there is less differentiation between Choice and Select for many measurements of palatability within the muscles evaluated.

In spite of similarities between Choice and Select product, strong correlations were determined in this study between fat percent and measurements of palatability, when all muscles were considered. Therefore, relationships between fat percent and eating attributes provide valid points of discussion toward quality grade impacts in this study. As previously described, fat percent was correlated with each consumer liking score, WBSF, SSF, and each trained panel attribute, except off-flavor intensity. These results support the overall conclusion that fat percent, and thus quality grade, influences beef eating quality. However, it should be noted that this strong relationship was in place when all muscle and quality grade combinations were included.

Chuck Muscles

Muscles from the rib and loin of beef carcasses, such as the LL, are marketed at a greater price point due to an expectation of greater eating quality. The chuck cuts evaluated in this study were determined to have similar or greater tenderness, flavor, and overall liking as evaluated by consumers. Furthermore, consumers determined the IF, LCS, and SV to have greater palatability than the LL. Interestingly, among these 3 cuts, fat percent did not appear to be highly related with consumer scores of palatability traits, where the IF was the only cut to have each palatability trait correlated with fat. This is in contrast to studies evaluating the LL (Corbin et al., 2015), and the results of our study where fat percent of the LL was correlated with each palatability traits measured by consumers. However, when these chuck cuts were evaluated by trained panelists there were strong correlations between fat percent and palatability traits. It is unclear why consumers did not find strong relationships between consumer measured palatability traits and fat percent for chuck muscles, meanwhile, the trained panelists measured traits were related with fat percent. It is

likely that other factors beyond fat percent influenced consumer liking scores.

When looking at WBSF tenderness values there was little segregation among chuck muscles. The SV (2.04 kgf) and IF (2.16 kgf) were similar to the LL (1.99 kgf), and the LCS (1.76 kgf) was considered to be more tender than the LL. However, as previously discussed, consumers deemed the SV, IF, and LCS to have greater tenderness, juiciness, flavor, and overall liking compared with the LL. With little variation in objective tenderness, at the halo effect of other attributes, such as flavor, may have impacted consumer perception of tenderness. Previously the composition of lipids and volatile flavor compounds were determined to vary between muscles (Hunt et al., 2016). Therefore, it may be speculated that alterations to flavor, in response to muscle specific flavor development, influenced consumer liking of all palatability traits.

From a monetary value standpoint, the evaluated chuck muscles be marketed as having similar or better palatability than the LL. Furthermore, consumers rated the IF, LCS, and SV as better-than-everyday quality or premium quality at a high frequency (50.7 to 58.7%). Meanwhile, the TM and TB were similarly rated as better-than-everyday quality in comparison with the LL. Current USDA Choice prices for the chuck shoulder clod (IMPS # 114), chuck roll (IMPS # 116A), and strip loin (IMPS # 180) are \$4.41, 6.31, and 14.27 per kg, respectively (USDA-AMS, 2018). While purchase of these subprimals will require further fabrication into retail cuts, there is unquestionably an opportunity for retailers to purchase beef subprimals from the chuck at a lower wholesale costs in comparison to the striploin. As demonstrated in this study, the resulting chuck muscles will possess greater or equal eating quality. Furthermore, pricing is also available for further fabricated chuck muscles. The IF (IMPS # 114D), TB (IMPS # 114E), TM (IMPS # 114F), and SV (IMPS # 116G) are each currently priced at \$8.40, 4.87, 13.98, and 12.15 per kg, respectively (USDA-AMS, 2018). Each of these presents further options for beef muscles that possess a quality eating experience at similar or lower pricing than the LL (\$14.27 per kg; USDA-AMS, 2018).

Round Muscles

Overall consumers rated round cuts lower in liking compared with the LL and chuck muscles. The lone exception being comparable flavor liking between the BF and LL. Furthermore, consumers rated round cuts most frequently as unsatisfactory quality (30.1 to 32.4%) compared with the

LL (12.9%) and chuck muscles (6.01 to 14.1%). Likewise, trained panelists determined that round muscles had lower juiciness, tenderness, and flavor in comparison to the LL and chuck muscles. These results strongly indicate that the eating quality of the evaluated round cuts is relatively low, in agreement with previous findings (Brooks et al., 2000; Nelson et al., 2004). Previously, it was stated that muscles from the round are less desirable due to lower tenderness ratings influenced by fiber type and an increased level of connective tissue (Anderson et al., 2012). Greater amount of perceived connective tissue was observed by the trained panelists in our study and is in agreement with results from Rhee et al. (2004) who determined the BF had twice as much collagen compared to the LL.

As previously described, there were few interactions between quality grade and muscle for palatability measurements in this study. Thus, indicating that muscle performance was independent of quality grade or fat percentage. When correlations between fat percent and palatability traits were carried out within muscles there were inconsistent relationships, similar to the chuck muscles. The only muscle to show any consistent correlation between fat percent and palatability measurements was the BF. As previously stated, the LL is frequently determined to have strong relationships between fat percent and palatability traits and other muscles beyond the LL seem to have additional factors influencing palatability more strongly than fat percent, most notably connective tissue content. This conclusion would also fit the round cuts of this study and is in agreement with other past works (Hunt et al., 2014).

Practically speaking for round cuts to be utilized as steaks, palatability interventions may be required. Previously, beef palatability of round cuts has been improved through enhancement or through the combination of mechanical tenderization and marination (Elam et al., 2002; Baublits et al., 2005). The need to improve the palatability of round cuts is not new or novel. However, this study does serve as a reminder that if round cuts are utilized for steaks and dry-heat cookery, consumer expectations for eating quality are likely not to be met.

CONCLUSIONS

Overall, this study supports past efforts to characterize the palatability of muscles from throughout the beef carcass. The implications from this study that may be drawn are first that the chuck possess muscles that are perceived to be as palatable or more palatable than high-value middle

meats. Therefore, the beef industry should continue current efforts toward utilization of cuts from the chuck. Secondly, muscles evaluated from the round are less palatable than the chuck and middle meats. Future efforts should be made to develop unique ways to improve the palatability of round cuts in order to further add value to beef carcasses. Lastly, this study supports the importance of intramuscular fat in beef palatability. Thus, supporting the need and on-going efforts toward increasing marbling accumulation in beef carcasses.

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