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Marbling Texture's Effects on Beef Palatability[1]

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Abstract: The objective of this study was to evaluate the effects of marbling texture on consumer and trained sensory panel ratings of beef strip loin steaks from 3 USDA quality grades. Beef strip loins ($n = 117$) were selected from 3 quality grades [Top Choice (Modest^{00} – Moderate^{100} marbling), Low Choice (Small^{00} – Small^{100} marbling), and Select (Slight^{00} – Slight^{100} marbling)] to equally represent three different marbling texture groups: fine, medium, and coarse, via visual appraisal. There were no quality grade × texture interactions ($P > 0.05$) for all of the traits evaluated. Consumers ($n = 104$) rated all marbling texture groups similar ($P > 0.05$) for tenderness, juiciness, flavor, and overall liking, as well as rated a similar ($P > 0.05$) percentage of samples from each marbling texture group acceptable for each palatability trait. Moreover, consumers indicated no preference ($P > 0.05$) among marbling texture groups for visual desirability or likelihood to purchase. However, trained sensory panelists rated coarse marbled steaks higher ($P < 0.05$) than fine or medium marbled steaks for both beef flavor intensity and sustained juiciness, as well as higher ($P < 0.05$) for initial juiciness than medium textured steaks. There were no differences ($P > 0.05$) among marbling texture groups for Warner-Bratzler shear force, slice shear force, and pressed juice percentage. Low Choice steaks were rated higher ($P < 0.05$) than Select steaks by consumers for tenderness, flavor liking, and overall liking, but similar ($P > 0.05$) to Top Choice. Results from this study indicate marbling texture had no impact on consumer evaluations of eating quality and only minimal effects on trained sensory panel palatability ratings and therefore provides no palatability-based evidence for the exclusion of coarse marbled carcasses from current and future branded beef programs.

Keywords: beef, consumer, marbling, marbling texture, palatability, quality grade
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Introduction

According to the USDA beef grading standards, USDA quality grade is derived from marbling level and maturity (USDA, 2017a). Marbling texture has not been an official consideration for quality grades and is not mentioned once in the official USDA beef grading standards (USDA, 2017a). Despite this, 75 percent of the 119 branded beef programs under the supervision of the USDA Agricultural Marketing Service require marbling to meet a fine or medium texture specification to qualify (USDA, 2017b). Carcasses that otherwise meet all specifications are eliminated from these programs, which impacts the potential supply and possible enhanced revenue that could be derived from them. However, this consideration of marbling texture is not just limited to the United States. In Japan, fine, frost-like marbling is preferred and priced higher than coarse marbled beef (Motoyama et al., 2016). This has resulted in researchers developing camera systems to objectively measure marbling texture in Wagyu cattle through the "New Fineness Index", which measures the perimeter of marbling flecks (Gotoh et al., 2014). However, similar to the United States, marbling texture is not mentioned in the Japanese beef grading standards (Polkinghorne and Thompson, 2010).

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Currently, only one published study has assessed the effects of marbling texture on beef palatability. Moody et al. (1970) reported coarse marbled rib roasts had significantly higher Warner-Bratzler shear force values in comparison to fine marbled rib roasts. However, when evaluated by trained sensory panelists, there were no differences reported for flavor, tenderness, juiciness, or overall satisfaction (Moody et al., 1970). Other researchers have evaluated marbling texture; however, comparisons were not made among the marbling texture groups in most of these studies (Goll et al., 1965; Cross et al., 1975; Cross, 1977; Dubeski et al., 1997; de Mello et al., 2012a, 2012b; Durunna et al., 2014). Therefore, the objective of the current study was to evaluate the effects of marbling texture on consumer and trained sensory panel ratings of beef strip loins varying in marbling texture (fine, medium, and coarse) from 3 USDA quality groups.

Materials and Methods

The Kansas State University (KSU) Institutional Review Board approved all procedures for use of human subjects in sensory panel evaluations (IRB 7740.3, November 24, 2016).

Sample collection and preparation

Beef strip loins (n = 117, IMPS #180) were collected from a Midwestern beef processor to equally represent 3 marbling textures (fine, medium, and coarse) from 3 quality groups [Top Choice (Modest^{00} – Moderate^{100} marbling), Low Choice (Small^{00} – Small^{100} marbling), and Select (Slight^{00} – Slight^{100} marbling)]. Kansas State University trained research team members selected carcasses for the 3 marbling texture groups by evaluating the marbling in the ribeye based on the USDA Marbling Texture reference card (USDA-AMS-LS-SB-02). Carcasses were visually scored for marbling texture using a 9-point scale where 1 = extremely fine marbling and 9 = extremely coarse marbling, with scores of 1 to 3 within the fine classification, 4 to 6 within the medium classification, and 7 to 9 within the coarse classification. In order for beef to have been selected for use in the study, 75% of the marbling within the ribeye had to meet the USDA visual standard. Following collection, strip loins were transported to the KSU Meat Laboratory under refrigeration (2°C) for steak cutting. Strip loins were cut into 2.54-cm thick steaks from anterior to posterior. The first "face" steak of each strip loin was used for instrumental color, proximate analysis, and pH. The next 4 steaks were assigned to muscle fiber and collagen characteristics analyses (steak 2; data reported by Vierck et al., 2018), consumer sensory analysis (steak 3), trained sensory panel evaluation (steak 4), and objective tenderness and juiciness testing (steak 5). Each steak was vacuum packaged, aged for 21 d at 2 to 4°C in the absence of light, and frozen at –20°C until subsequent analysis.

Consumer sensory panel evaluation

A total of 104 consumers were recruited from Manhattan, Kansas and the surrounding areas. Consumers were monetarily rewarded for their participation. Steaks evaluated by consumers were thawed at 2 to 4°C for 24 h preceding each panel. Immediately prior to cooking, external fat and accessory muscles were removed. Steaks were cooked on a clamshell grill (Cuisinart Griddler Deluxe, East Windsor, NJ) to a medium degree of doneness (71°C) with internal temperatures monitored using a thermometer (Thermapen Mk4, ThermoWorks, American Fork, UT), and final peak temperatures were confirmed using a probe thermometer (Model 450-ATT, Omega Engineering, Stamford, CT). Steaks then were sliced into 1 cm × 1 cm × steak thickness cuboids, and 2 cuboids were immediately served to eight consumer sensory panelists.

Panels took place at the KSU campus where consumers were placed into a lecture-style classroom and supplied with a ballot, napkins, toothpicks, expectorant cup, plastic knife, and fork as well as unsalted crackers, apple juice, and water to use as palate cleansers between samples. Each paper ballot contained a demographic survey, consumer purchasing motivator sheet, and nine sample ballots. Each sample ballot consisted of 100-mm line scales for overall liking, tenderness, juiciness, and flavor liking with verbal anchors at each end and midpoint, where 0 = extremely dislike/extremely tough/extremely dry; 50 = neither like or dislike/neither tough or tender/neither dry or juicy; 100 = extremely like/extremely tender/extremely juicy. Each trait was also rated as acceptable or unacceptable with yes/no questions. Additionally, consumers were asked to rate each sample's perceived quality level as unsatisfactory, everyday quality, better than everyday quality, or premium quality. At the beginning of each panel, panelists were given verbal instructions for panel procedures and filling out of ballot sheets. Each panelist was served 9 samples, 1 from each treatment, in a randomly assigned order.

Each panelist was also given an electronic tablet (Model 5709 HP Steam 7; Hewlett-Packard, Palo Alto, CA) with a digital survey (Version 2417833; Qualtrics Software, Provo, UT) that included the digital image of the bloomed face steak from each of the 9 samples to be

evaluated during the panel. The picture of each steak was edited to a dimension of 2.54 × 6.35 cm that only showed the center of the steak, in order to remove any muscling or external fat differences. Additionally, if any image had a darker color, lightness was adjusted to reduce color variation and color bias among the images as much as possible. Consumers were asked to rate the appearance of each steak with no regards to color on a continuous line scale with verbal anchors at each end and midpoint (0 = dislike extremely; 50 = neither like or dislike; 100 = like extremely), as well as asked to indicate how likely they would be to purchase the steak pictured, disregarding color, on a similar line scale (0 = extremely unlikely; 50 = neither likely or unlikely; 100 = extremely likely). Visual evaluations were completed prior to serving of cooked samples and each image was uniquely identified, with no identifiable connection to the cooked sensory samples.

Trained sensory panel evaluation

Sensory panelists were trained according to the American Meat Science Association (AMSA) sensory guidelines (American Meat Science Association, 2015). Panelists were trained in a series of 10 sessions held in the 2 weeks immediately prior to sample evaluations. Each session included samples representing a large amount of variation in the traits to be evaluated and panelists were trained consistent with the anchors described by Lucherk et al. (2016). Additional anchors for myofibrillar tenderness and connective tissue amount were provided as follows: beef tenderloin steak cooked to 71°C = 95 to 100 for myofibrillar tenderness and 0 for connective tissue amount; and USDA Choice beef strip loin steak cooked to 71°C = 70 to 75 for myofibrillar tenderness and 5 to 10 for connective tissue amount.

Panelists evaluated samples on continuous line scales for initial and sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off flavor intensity using a digital survey (Version 2417833; Qualtrics Software, Provo, UT) on an electronic tablet (Model 5709 HP Steam 7; Hewlett-Packard, Palo Alto, CA). Each scale was verbally anchored at both end and midpoints with descriptive terms (0 = extremely dry/tough/none/unbeef-like/bland, 50 = neither dry nor juicy, neither tough nor tender, and neither unbeef-like or beef like, 100 = extremely tender/juicy/abundant/beef-like/intense). Additionally, for off-flavor intensity, a box identified as "not applicable" was available for samples where no off-flavor was detected. Thirteen panels were conducted with 8 panelists during each session. Each session consisted of 9 samples, 1 from each treatment in the study, served in a random order. Additionally, a representative warm-up sample was served prior to sample evaluation for each panel in order to allow for panelist calibration. Steaks were cooked using the procedures previously described for consumer sensory evaluation to a medium degree of doneness (71°C) with internal temperature monitored using thermocouples (30 gauge copper-constantan; Omega Engineering, Stamford, CT). Panelists were served in individual booths under low-intensity red incandescent lights. During each panel session, panelists had deionized water, apple slices, and unsalted crackers for palate cleansers, as well as an expectorant cup and napkin.

Slice Shear Force

Slice Shear (SSF) values were determined using the protocol of Shackelford et al. (1999). Raw weights were taken prior to cooking for cook loss analysis. Steaks were cooked to a medium degree of doneness (71°C), then allowed to rest for 3 min, and reweighed. After the resting period, 1 cm of the lateral portion of the steak was removed to reveal the orientation of the muscle fibers. After the muscle fiber orientation was revealed, a 5 cm portion of the steak was cut using a double bladed knife and cutting guide, a 1 cm slice of the steak was removed at a 45° angle, and sheared using a SSF machine (GR-152; Tallgrass Solutions, Manhattan, KS) to measure the peak force (kg) required to shear through the center of the slice.

Pressed juice percentage

The protocol developed by Lucherk et al. (2017) was used for pressed juice percentage (PJP) determination. After removal of the 5-cm portion used for SSF, a 1-cm portion of the steak was removed immediately medial to the SSF sample removal (Lucherk et al., 2017). Using a double bladed knife, the 1 cm section was cut into three 1-cm portions, individually weighed on 2 pieces of filter paper (VWR Filter Paper 415, 12.5 cm, VWR International, Radnor, PA), and pressed at 78.45 N for 30 s using an Instron Model 5569 machine (Instron, Canton, MA). After the sample was pressed, a final weight was taken without the compressed sample. The 3 measures were averaged across for the PJP value for one steak. Pressed juice percentage was quantified as a percentage of the weight lost as a result of compression.

Warner-Bratzler Shear Force

After removal of both SSF and PJP samples, the remainder of the steak was chilled at 2 to 4°C for 24 h prior to Warner-Bratzler Shear Force (WBSF) analysis

using the protocol described by American Meat Science Association (2015). Six cores (1.27 cm diameter) were removed parallel to the muscle fiber orientation and sheared perpendicular to the muscle fiber orientation using an Instron Model 5569 (Instron, Canton, MA). Measurements were recorded as peak force (kg) and averaged across the 6 cores for each steak.

Proximate analysis, instrumental color, and pH

Instrumental color and pH measurements were obtained during fabrication prior to vacuum packaging and aging. Immediately after cutting, the face steak used for pH and instrumental color analyses was allowed to bloom for 20 m. Then, pH was measured at the geometric center of the steak with a pH meter (model HI 99163; Hanna Instruments, Smithfield, RI). After the blooming period, a HunterLab Miniscan EZ spectophotometer (Illuminant A, 2.54-cm diameter aperture, 10° observer; Hunter Associates Laboratory, Reston, VA) was used to obtain L*, a*, and b* measurements according to AMSA's *Meat color measurement guidelines* (American Meat Science Association, 2012). Three color measurements were taken from each steak, recorded, and averaged for analyses. Steaks were then vacuum packaged and stored (2 to 4° C) for the remainder of the 21 d aging period.

Following aging, the face steaks were diced, frozen in liquid nitrogen, homogenized using a Waring blender (Waring Products Division; Hartford, CT), and stored at –20°C until proximate analysis. Proximate analysis was performed at a commercial research lab (Ward Laboratories, Kearney, NE). Samples were analyzed for percent moisture (method 935.29; AOAC, 2016), crude protein (method 990.03; AOAC, 2016), percent fat (method 920.39; AOAC, 2016), and ash (method 942.05; AOAC, 2016).

Statistical analysis

Statistical analysis was performed using the PROC GLIMMIX procedure of SAS (SAS Version 9.4; SAS Inst. Inc., Cary, NC) with strip loin serving as the experimental unit. Data were analyzed as a completely randomized design with a 3 × 3 factorial arrangement, with quality grade, marbling texture, and the quality grade × texture interaction serving as fixed effects. Panel number was used as a random effect and steak peak temperature was used as a covariate. A model with a binomial error distribution was used for all acceptability data. For all analyses, the Kenward-Roger adjustment was used and α was set at 0.05.

Results

For all traits evaluated and analyses performed, there were no marbling texture × quality grade interactions ($P > 0.05$).

Consumer panel demographic characteristics and purchasing motivators

The demographic characteristics of the 104 consumers who participated in the sensory evaluation are presented in Table 1. The majority of participants were Caucasian/White (92.9%) and from households of 2 (22.3%) or 4 (23.3%). Additionally, 67.3% of consumers were male, whereas 32.7% were female. There was an even split of consumers that were married (50.0%) and single (50.0%). The largest age, income, and education categories were 20 to 29 years of age (34.6%), annual household income of $50,000 to $74,999 (28.9%), and had some college/technical school (45.5%). When consuming meat, 61.2% of consumers preferred the flavor of beef and 52.9% of consumers ate beef 1 to 3 times per week. Additionally, when consuming beef, most consumers considered flavor the most important palatability trait (50.0%), followed by tenderness (37.5%).

In addition to a demographics questionnaire, consumers were also asked to rate 15 different purchasing motivators for beef products (Table 2). Price, size, weight, thickness, and steak color were rated most important ($P < 0.05$) among the purchasing motivators. Moreover, marbling level, familiarity with cut, and nutrient content were rated as more important ($P < 0.05$) than local, antibiotic use, growth promotant use, animal welfare, packaging type, natural or organic claims, or brand of product. No difference ($P > 0.05$) was found among packaging type, local, antibiotic use, growth promotant, and animal welfare claims. Brand of the product was lower ($P < 0.05$) in importance than all traits evaluated, other than natural and organic claims.

Consumer sensory panel results

Marbling texture had no effect ($P > 0.05$) on the palatability traits evaluated (Table 3). Consumers rated all marbling texture groups similar ($P > 0.05$) for tenderness, juiciness, flavor liking, and overall liking. Additionally, marbling texture did not impact ($P > 0.05$) the coefficient of variation for consumer panelists' ratings of juiciness, tenderness, flavor liking, or overall liking (data not shown). Furthermore, when asked to rate each sample as acceptable or unacceptable for each palatability trait, consumers found a similar ($P > 0.05$)

Table 1. Demographic characteristics of consumers (n = 104) who participated in consumer sensory panels

Characteristic	Response	Percentage of consumers
Gender	Male	67.3
	Female	32.7
Household size	1 person	10.7
	2 people	22.3
	3 people	15.5
	4 people	23.3
	5 people	10.7
	6 people	5.8
	>6 people	11.7
Marital Status	Single	50.0
	Married	50.0
Age	Under 20	9.6
	20-29	34.6
	30-39	18.3
	40-49	16.4
	50-59	11.5
	Over 60	9.6
Ethnic Origin	African-American	2.0
	Asian	3.1
	Caucasian/White	92.9
	Hispanic	2.0
	Native American	0.0
	Other	0.0
Annual household income	Under $25,000	6.7
	$25,000 - $34,999	8.7
	$35,000 - $49,999	6.7
	$50,000 - $74,999	28.9
	$75,000 - $100,000	25.0
	More than $100,000	24.0
Education level	Non-high school graduate	0.0
	High school graduate	8.1
	Some college/ technical school	45.5
	College graduate	24.2
	Post graduate	22.2
Beef consumption per week	None	0.9
	1-3 times	52.8
	4-6 times	37.5
	7 or more	8.7
Most important palatability trait	Flavor	50.0
	Juiciness	12.5
	Tenderness	37.5
Degree of doneness preference	Very rare	0.0
	Rare	3.9
	Medium-rare	41.8
	Medium	25.2
	Medium-well	22.3
	Well-done	4.9
	Very well-done	1.9
Preferred meat product for flavor	Beef	61.2
	Chicken	13.6
	Fish	0.9
	Lamb	7.8
	Pork	8.7
	Shellfish	3.9
	Turkey	0.9
	Veal	0.9
	Venison	1.9

Table 2. Beef strip loin steak purchasing motivators[1] of consumers (n = 104) participating in consumer sensory panels

Trait	Importance
Price	78.0[a]
Size, weight, thickness	72.9[a]
Steak color	71.9[a]
USDA grade	63.5[b]
Marbling level	60.5[bc]
Familiarity with cut	59.1[bc]
Nutrient content	54.1[cd]
Eating satisfaction claims	48.6[ed]
Local	43.3[ef]
Antibiotic use in animal	43.2[ef]
Growth promotant use	42.0[fg]
Animal welfare	40.3[fg]
Packaging type	38.6[fg]
Natural or organic claims	36.3[gh]
Brand of product	31.5[h]
SEM[2]	2.8
P-value	< 0.01

[a–h]Least squares means without a common superscript differ ($P < 0.05$).

[1]Purchasing motivators: 0 = extremely unimportant, 100 = extremely important.

[2]Standard error (largest) of the least squares means in the same main effect.

Table 3. Least squares means for consumer (n = 104) panel ratings[1] of grilled beef strip loin steaks of 3 marbling texture groups and 3 USDA quality grades

Treatment	Tenderness	Juiciness	Flavor liking	Overall liking
Marbling texture				
Fine	66.6	63.8	65.0	67.7
Medium	63.0	60.9	62.1	64.2
Coarse	63.7	61.9	63.3	64.9
SEM[2]	2.2	2.2	1.8	1.8
P-value	0.29	0.53	0.35	0.22
Quality grade				
Top Choice[3]	64.6[ab]	63.2	64.3[a]	66.1[ab]
Low Choice[4]	67.5[a]	63.7	66.3[a]	68.3[a]
Select	61.2[b]	59.6	59.8[b]	62.4[b]
SEM[2]	2.2	2.2	1.8	1.8
P-value	0.04	0.24	0.01	0.02
Texture × QG				
P-value	0.51	0.46	0.78	0.62

[a,b]Least squares means in the same main effect (quality grade or marbling texture) without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely tough/dry/dislike flavor/dislike overall; 50 = neither dry nor juicy/neither tough nor tender/neither like nor dislike; 100 = extremely juicy/tender/like flavor/like overall.

[2]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[3]USDA marbling score of Modest[00]-Moderate[100].

[4]USDA marbling score of Small[00]-Small[100].

percentage of samples from each marbling texture group acceptable (> 83% for all traits; Table 4).

Consumers rated Low Choice steaks similar ($P > 0.05$) to Top Choice steaks for all palatability traits evaluated. Low Choice steaks were rated higher ($P < 0.05$) than Select for tenderness, flavor liking, and overall liking scores; however, were similar ($P > 0.05$) to Select for juiciness ratings. Moreover, both Top Choice and Low Choice were rated greater ($P < 0.05$) for flavor liking than Select samples. When consumers were asked to rate samples as acceptable or unacceptable, no differences ($P > 0.05$) were found among quality grades for the percentage of samples rated acceptable for tenderness, juiciness, and overall. However, a lower percentage ($P < 0.05$) of Select samples were rated acceptable for flavor than either Top Choice or Low Choice.

Marbling texture did not affect ($P > 0.05$) the percentage of steaks rated at certain quality levels when consumers rated each sample as either unsatisfactory, everyday quality, better than everyday quality, or premium quality (Table 5). However, there was a quality grade effect ($P < 0.05$) on the percentage of steaks rated as unsatisfactory. Select steaks were rated as unsatisfactory a higher ($P < 0.05$) percentage of the time than Low Choice steaks. But, Top Choice steaks were similar ($P > 0.05$) to both Low Choice and Select for the percentage of steaks rated as unsatisfactory quality. There were no significant differences ($P > 0.05$) among quality grades for the percentage of steaks rated as everyday quality, better than everyday quality, or premium quality.

When asked to visually appraise the desirability of raw steaks of each treatment, consumers rated all marbling texture groups similar ($P > 0.05$) for the desirability of the appearance of the pictured steak (Table 6). This trend continued when the consumers were asked about purchase intent, which also was not impacted ($P > 0.05$) by marbling texture. Additionally, quality grade did not affect ($P > 0.05$) the consumer panelists' ratings of the desirability of appearance of the steak or their purchase intent.

Table 4. Percentage of beef strip loin steaks of varying marbling texture groups and quality grades rated acceptable for tenderness, juiciness, flavor, and overall liking by consumer panelists ($n = 104$)

Treatment	Tenderness acceptability	Juiciness acceptability	Flavor acceptability	Overall acceptability
Marbling texture				
Fine	87.9	86.4	87.5	88.5
Medium	86.0	85.7	85.8	85.0
Coarse	86.6	83.7	85.1	85.2
SEM[1]	2.7	2.6	2.4	2.5
P-value	0.78	0.63	0.68	0.38
Quality grade				
Top Choice[2]	85.8	84.7	87.6[a]	87.5
Low Choice[3]	89.2	87.6	88.7[a]	87.8
Select	85.2	83.4	81.4[b]	83.2
SEM[1]	2.8	2.6	2.8	2.7
P-value	0.29	0.35	0.03	0.20
Texture × QG				
P-value	0.59	0.50	0.38	0.40

[a,b]Least squares means in the same main effect (marbling texture or quality grade) without a common superscript differ ($P < 0.05$).

[1]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[2]USDA marbling score of Modest[00] - Moderate[100].

[3]USDA marbling score of Small[00]-Small[100].

Table 5. Percentage of beef strip loin steaks of varying marbling texture groups and quality grades identified as different perceived quality levels by consumer panelists ($n = 104$)

Treatment	Unsatisfactory quality	Everyday quality	Better than everyday quality	Premium quality
Marbling texture				
Coarse	7.3	47.8	31.3	11.8
Medium	10.1	50.0	29.2	9.2
Fine	6.9	43.5	32.3	14.2
SEM[1]	1.9	3.0	2.7	2.4
P-value	0.28	0.27	0.72	0.18
Quality grade				
Top Choice[2]	7.4[ab]	48.0	29.6	12.6
Low Choice[3]	5.9[b]	42.8	35.1	14.0
Select	11.5[a]	50.5	28.3	8.7
SEM[1]	2.1	3.0	2.8	2.4
P-value	0.05	0.16	0.2	0.12
Texture × QG				
P-value	0.74	0.18	0.06	0.14

[a,b]Least squares means in the same main effect (marbling texture or quality grade) without a common superscript differ ($P < 0.05$).

[1]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[2]USDA marbling score of Modest[00]-Moderate[100].

[3]USDA marbling score of Small[00]-Small[100].

Trained sensory panel results

Panelists rated coarse marbled steaks higher ($P < 0.05$) than medium marbled steaks for initial juiciness, but rated them similar ($P > 0.05$) to fine marbled steaks for the same trait (Table 7). Coarse marbled steaks were also rated higher ($P < 0.05$) for sustained juiciness than both fine and medium marbled steaks. Additionally, beef flavor intensity of coarse marbled

Table 6. Least squares means for consumer panel visual ratings[1] of beef strip loin steaks of varying marbling texture groups and quality grades (n = 104)

Treatment	Visual desirability	Purchase intent
Marbling texture		
Coarse	63.4	63.5
Medium	64.8	65.1
Fine	63.1	63.7
SEM[2]	1.5	1.5
P-value	0.68	0.73
Quality grade		
Top Choice[3]	64.0	65.1
Low Choice[4]	63.6	63.1
Select	63.8	64.1
SEM[2]	1.5	1.5
P-value	0.98	0.65
Texture × QG		
P-value	0.35	0.49

[1]Visual ratings: 0 = dislike extremely/extremely unlikely to purchase; 50 = neither like nor dislike appearance/neither likely nor unlikely to purchase; 100 = like extremely/extremely likely to purchase.

[2]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[3]USDA marbling score of Modest[00]-Moderate[100].

[4]USDA marbling score of Small[00]-Small[100].

steaks was higher ($P < 0.05$) than both fine and medium marbled steaks. Fine and medium marbled steaks were rated similar ($P > 0.05$) for sustained juiciness and beef flavor intensity. All marbling texture groups were rated similar ($P > 0.05$) for myofibrillar tenderness, connective tissue amount, overall tenderness, and off-flavor intensity. Furthermore, marbling texture did not affect ($P > 0.05$) coefficients of variation for the trained sensory panel ratings of initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, or off-flavor intensity (data not shown).

Top Choice steaks were rated higher ($P < 0.05$) for both initial and sustained juiciness than Select steaks, but were similar ($P > 0.05$) to Low Choice steaks for the same traits. Furthermore, panelists rated all quality grades similar ($P > 0.05$) for myofibrillar tenderness, connective tissue amount, overall tenderness, and off-flavor intensity. However, Top Choice and Low Choice steaks were similar ($P > 0.05$) and more intense ($P < 0.05$) in beef flavor than Select steaks.

Instrumental tenderness and juiciness analyses

Marbling texture did not impact ($P > 0.05$) WBSF, SSF, PJP, or cooking loss (Table 8). Additionally, there were no differences ($P > 0.05$) in the coefficients of varia-

Table 7. Least squares means for trained panel ratings[1] of grilled beef strip loin steaks (n = 117) from varying marbling texture groups and quality grades

Treatment	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue amount	Overall tenderness	Beef flavor intensity	Off flavor intensity
Marbling texture							
Coarse	65.5[a]	54.5[a]	73.6	9.2	69.8	42.6[a]	1.8
Medium	60.3[b]	48.5[b]	71.5	8.2	68.4	38.5[b]	1.4
Fine	61.4[ab]	49.5[b]	74.1	8.8	70.8	39.6[b]	1.7
SEM[2]	1.8	2.0	1.6	0.7	1.6	1.1	0.7
P-value	0.04	0.03	0.17	0.55	0.53	0.01	0.88
Quality grade							
Top Choice[3]	65.8[a]	55.2[a]	74.7	8.3	71.5	42.2[a]	2.0
Low Choice[4]	62.4[ab]	50.6[ab]	73.3	8.2	69.9	40.5[a]	1.3
Select	59.1[b]	46.7[b]	71.2	9.8	67.6	38.0[b]	1.6
SEM[2]	1.8	2.0	1.6	0.7	1.6	1.1	0.7
P-value	0.01	< 0.01	0.34	0.22	0.18	0.01	0.67
Texture × QG							
P-value	0.33	0.38	0.83	0.81	0.89	0.85	0.18

[a,b]Least squares means in the same main effect (marbling texture or quality grade) without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/none/bland/no off-flavor; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/intense.

[2]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[3]USDA marbling score of Modest[00]-Moderate[100].

[4]USDA marbling score of Small[00]-Small[100].

Table 8. Least squares means of instrumental measures of tenderness and juiciness of grilled beef strip loin steaks (n = 117) from varying marbling texture groups and quality grades

Treatment	Warner-Bratzler Shear Force, kg	Pressed juice percentage, %[1]	Slice Shear Force, kg	Cook loss, %[2]
Marbling texture				
Coarse	2.53	20.44	12.29	15.81
Medium	2.46	21.60	11.57	16.47
Fine	2.37	21.41	12.06	16.47
SEM[3]	0.09	0.40	0.46	0.32
P-value	0.44	0.08	0.53	0.23
Quality grade				
Top Choice[4]	2.32[b]	21.29	12.09	16.28[ab]
Low Choice[5]	2.35[b]	20.93	11.88	15.64[b]
Select	2.70[a]	21.23	11.96	16.84[a]
SEM[3]	0.09	0.40	0.46	0.32
P-value	< 0.01	0.79	0.94	0.03
Texture × QG				
P-value	0.71	0.10	0.98	0.57

[a,b]Least squares means in the same main effect (marbling texture or quality grade) without a common superscript differ ($P < 0.05$).

[1]Percentage moisture lost during compression of sample between filter paper at 78.45 N of pressure for 30 seconds (Lucherk et al., 2017).

[2]Cook loss = [(raw weight – cooked weight) / raw weight] × 100.

[3]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[4]USDA marbling score of Modest[00]-Moderate[100].

[5]USDA marbling score of Small[00]-Small[100].

tion among texture groups for both WBSF and SSF (data not reported). Select steaks exhibited higher ($P < 0.05$) WBSF values than both Top Choice and Low Choice steaks, with Top Choice and Low Choice similar ($P > 0.05$) for WBSF (Table 8). There were no quality grade effects ($P > 0.05$) for PJP or SSF. Low Choice steaks had a lower ($P < 0.05$) percentage of cooking loss than Select steaks. Top Choice steaks were similar ($P > 0.05$) to both Low Choice and Select steaks for cooking loss percentage.

Proximate analysis, instrumental color, and PH results

There were no marbling texture effects ($P > 0.05$) for the percentage of moisture, protein, and ash measured (Table 9). Conversely, coarse marbled steaks exhibited a higher ($P < 0.05$) percentage of fat than both fine and medium marbled steaks, which were similar ($P > 0.05$) for fat percentage. As expected, there was a quality grade effect ($P < 0.05$) for fat content (Top Choice > Low Choice > Select), with fat percentages similar to previous reports (Emerson et al., 2013). The inverse was observed for protein content, with Select steaks having the most ($P < 0.05$) protein, followed by Low Choice and Top Choice.

There were no marbling texture effects ($P > 0.05$) for all instrumental color traits evaluated (Table 9). There was a quality grade effect on L* values, where Top Choice steaks were lighter ($P < 0.05$) than Select steaks, but similar ($P > 0.05$) to Low Choice steaks. Low Choice steaks were similar ($P > 0.05$) in L* values to both Top Choice and Select steaks. There were no quality grade effects ($P > 0.05$) for a* values. Additionally, Select steaks had lower ($P < 0.05$) b* values than Top Choice or Low Choice steaks. There was no quality grade effect ($P > 0.05$) for pH values (Table 9). Coarse marbled steaks had a higher ($P < 0.05$) pH than both fine and medium marbled steaks, though all treatments differed by less than 0.10 units.

Discussion

Quality grade

The role of marbling level on palatability as determined by consumers has been well established. In previous literature, increases in marbling level and quality grade have been associated with increased palatability scores (O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016). For many of these studies, a wider range in quality grade was used (often Prime to Standard) than was used in the current study. In our study, consumers rated Low Choice steaks higher for tenderness, flavor liking, and overall liking than Select steaks, yet Select steaks were similar to Top Choice steaks for both tenderness and overall liking. Other authors have reported similar results, with steaks with Modest and Moderate marbling found similar to steaks with Slight marbling for tenderness and overall liking (Savell et al., 1987; Wilfong et al., 2016). Consumers in the current study also rated a higher percentage of Select samples as acceptable for each palatability trait (> 81%) than has typically been reported by other authors (61 to 80%; O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016). But as stated previously, these studies have most often included a wider range of quality grades than the current study, perhaps creating larger perceived differences among samples to consumers when evaluating samples within the same panel session. The narrower range of quality grades used and the slightly higher ratings for Select samples than previous reports may have contributed to the non-significant differences observed between Select and Top Choice in the current study. Additionally, a significant amount of variation exists across the beef

Table 9. Least squares means for proximate analysis, pH, and instrumental color values for beef strip loin steaks (n = 117) of varying marbling texture groups and quality grades

	%							
Treatment	Fat	Moisture	Protein	Ash	pH	L*[1]	a*[2]	b*[3]
Marbling Texture								
Coarse	6.7[a]	60.2	23.9	1.3	5.64[a]	43.18	25.97	17.96
Medium	5.4[b]	62.0	23.9	1.4	5.59[b]	42.96	25.97	17.42
Fine	5.2[b]	64.2	24.0	1.3	5.57[b]	42.46	25.60	17.79
SEM[4]	0.3	1.2	0.2	0.04	0.01	0.54	0.23	0.22
P-value	< 0.01	0.06	0.90	0.18	< 0.01	0.63	0.43	0.20
Quality Grade								
Top Choice[5]	7.4[a]	61.6	23.4[c]	1.3	5.58	44.06[a]	25.76	18.03[a]
Low Choice[6]	6.0[b]	61.8	23.9[b]	1.3	5.60	42.95[ab]	26.02	17.88[a]
Select	3.8[c]	63.0	24.4[a]	1.4	5.61	41.60[b]	25.75	17.25[b]
SEM[4]	0.3	1.2	0.2	0.04	0.01	0.54	0.23	0.22
P-value	< 0.01	0.67	< 0.01	0.18	0.50	< 0.01	0.66	0.03
Texture × QG								
P-value	0.66	0.52	0.20	0.14	0.08	0.22	0.48	0.09

[a,b]Least squares means in the same main effect (marbling texture or quality grade) without a common superscript differ ($P < 0.05$).

[1]L*: Lightness (0 = black and 100 = white).

[2]a*: Redness (-60 = green and 60 = red).

[3]b*: Blueness (-60 = blue and 60 = yellow).

[4]Standard error (largest) of the least squares means in the same main effect (marbling texture or quality grade).

[5]USDA marbling score of Modest[00]-Moderate[100].

[6]USDA marbling score of Small[00]-Small[100].

industry within these quality grades that potentially may not be accounted for in these types of studies.

Nevertheless, trained sensory panelists in the current study reported results consistent with previous reports in which Top Choice samples were rated higher for juiciness and flavor traits than Select samples (Davis et al., 1979; Emerson et al., 2013). No differences in tenderness traits were observed by trained sensory panelists in our study, which is consistent with our SSF results. But for WBSF, Select samples had higher shear values than either Low Choice or Top Choice. Previous reports have also shown an increase in WBSF as marbling score decreases from Moderate to Slight (Tatum et al., 1980; Smith et al., 1985; Savell et al., 1987). These reports included beef that had an average WBSF of >3.1 kg, even in the Moderate marbling category, and thus typically reported differences in tenderness of > 0.5 kg between steaks with Moderate and Slight marbling, which is higher than the 0.38 kg observed in the current study on beef that was much more tender. More contemporary reports on tender beef more similar to the tenderness level of samples in the current study have reported no difference in WBSF between Select and Top Choice samples (Savell et al., 2016; Wilfong et al., 2016).

Results of the consumer visual panel from the current study indicate consumers did not visually prefer a specific quality grade over the others. When compared to prior studies using consumer visual panels, the results of the current study differ from those previously reported (Killinger et al., 2004; Claborn et al., 2011; DeVuyst et al., 2014). Killinger et al. (2004) reported consumers were willing to pay more for steaks with a low level of marbling and bright cherry-red color in comparison to those with high levels of marbling and similar color. Similarly, Claborn et al. (2011) reported consumer preference towards reduced marbling levels when purchasing steaks. However, in these 2 studies, raw steaks were viewed in a retail-style case in comparison to the images of the steaks used in the current study. In our study pictures were used as opposed to retail display to remove any differences and potential biases as a result of muscling and external fat differences. It is not clear how this difference in methodology may have impacted consumer visual ratings, however, our results indicate consumers do not prefer a specific quality grade visually.

Marbling texture

Although not a part of the formal USDA grading standards, coarse marbling texture is commonly discriminated against at both the grading chain and in meat evaluation, as fine marbling is rewarded and preferred at

both levels (Smith et al., 2001). Marbling texture is impacted by a variety of factors including breed (Albrecht et al., 2006; Yang et al., 2006; Albrecht et al., 2011) and animal diet (Dubeski et al., 1997; de Mello et al., 2012a, b; Durunna et al., 2014). But marbling texture's impact on beef palatability is unclear as it has not been the primary focus of much previous work. Yet, when evaluating the specifications for current USDA-AMS monitored branded beef programs, 75% require beef to contain fine or medium textured marbling in the ribeye at the time of grading in order to qualify (USDA, 2017b). This provides additional evidence of the perceived advantage of beef with finer marbling over coarse marbled alternatives.

Though the origins of this perception are unclear, a study by Goll et al. (1965) reported a negative correlation ($r = –0.359$) between marbling texture and distribution (measured as one trait) and WBSF, indicating that as marbling increased in fineness and was more evenly distributed, there was a reduction in WBSF. This was followed by a study by Moody et al. (1970), which was the first to evaluate the impact of marbling texture on beef eating quality. These authors reported a 15.4% increase in WBSF for coarse marbled rib roast samples when compared to fine marbled samples (Moody et al., 1970). These authors speculated this observed difference was due to differences in perimysial thickness, though no measure of perimysial thickness was provided. However, more recent studies have indicated perimysial thickness is a poor indicator of tenderness ($r = 0.21$), specifically of WBSF values (Nishimura et al., 1999; Brooks and Savell, 2004; Purslow, 2005). Results of the current study are in direct contrast to the shear force findings of Moody et al. (1970). Our results indicate no difference in either WBSF or SSF value exist among beef strip steaks ranging in marbling texture from fine to coarse, with means differing by no more than 0.16 kg for WBSF and 0.72 kg for SSF among all 3 texture groups. It is also noteworthy that the study by Moody et al. (1970) used a 2.54 cm diameter core as opposed to the 1.27 cm diameter core most commonly used today. This larger core diameter may have impacted the results of Moody et al. (1970) and been partially responsible for the observed difference between the 2 studies.

When evaluating the sensory characteristics of samples differing in marbling texture, no differences were found among marbling texture groups in the current study for any of the consumer panel measures of palatability, the percentage of samples rated acceptable for the individual sensory traits, or for consumer perceptions of the quality levels of the samples. Moreover, our trained sensory panel results showed the same lack of difference among marbling texture groups for all measures of tenderness evaluated. However, coarse marbled steaks were identified as both juicier and more flavorful than finer marbled steaks by trained sensory panelists. These results indicate coarse marbled steaks, not fine marbled steaks as previously reported, potentially provide a palatability advantage, though these differences were not large enough for the untrained consumers to detect. In the study by Moody et al. (1970), trained sensory panelists found no differences in flavor, tenderness, juiciness, and overall satisfaction between coarse and fine marbled rib roast samples, which is in agreement with our consumer panel results. Moreover, consumers in our study indicated no visual preference or willingness to pay advantage for one marbling texture over the others, indicating that not only did marbling texture not impact their eating experience, it also has no impact on their visual valuation of steaks as would presented at retail.

Additionally, anecdotal evidence often indicates that fine marbling is more evenly dispersed, which results in a more consistent eating experience for a steak (Bass, 2016). This implies consumers receive a similar amount of marbling within each bite with fine marbling as opposed to coarse marbling, which may create pockets of marbling that result in large differences in the bite-to-bite eating experience of a steak. In an effort to measure this effect, we determined the coefficient of variation for the sensory traits evaluated for each sample and compared them across treatments. There was no marbling texture differences for any of the coefficients of variation evaluated, indicating none of the marbling texture groups evaluated provided a more (or less) consistent eating experience than the others. This finding contradicts common beliefs (Bass, 2016) related to the impact of marbling texture on eating quality.

Marbling texture did impact pH and the fat percentage of samples, with coarse marbled steaks having a higher fat percentage than medium or fine steaks, despite being from the same quality grades. This is likely due to the increased size of the individual marbling flecks within coarse marbled samples. The USDA quality grade is based upon the amount or number of pieces of marbling within the ribeye, without the size of the marbling pieces considered (USDA, 2017a). Therefore, it would be expected that beef with larger (coarser) marbling would have a higher fat percentage than steaks with a similar amount of marbling, with smaller (finer) marbling pieces, as was observed in the current study. Additionally, marbling texture had no impact on the other proximate measures, cooking loss, or instrumental color measures.

It is also important to note that in the current study there was no marbling texture × quality grade interaction for any of the traits evaluated. This pro-

vides evidence that the impact of marbling texture on beef palatability is not dependent upon quality grade, with marbling texture having the same effect, or lack thereof, in low marbled beef (Select) as it does in high marbled beef (Top Choice). Our results clearly indicate that marbling texture has only minimal impact on beef palatability traits. Coarse marbled steaks provide an equivalent eating experience to steaks with fine and medium textured marbling. Therefore, coarse marbled carcasses should not be discriminated against in the assessment of USDA quality grades or excluded from branded beef programs for palatability-based reasons.

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