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Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments

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ABSTRACT

The palatability of tender [Warner-Bratzler shear force values <33.34 N (3.4 kg)] beef strip loins of 10 different treatments [USDA Prime, High Choice (upper 1/3 Choice), Low Choice (lower 1/3 Choice), Select, Standard, Australian Wagyu, American Wagyu, Holstein Select, Holstein Top Choice (upper 2/3 Choice) and Grass-finished] was evaluated by consumers and a trained flavor panel. In general, tenderness, juiciness, flavor, and overall liking ratings as well as acceptability percentage for each trait, increased with increased fat levels. Moreover, overall liking was highly correlated ($P < 0.01$) with flavor liking ($r = 0.96$) as well as fat percentage ($r = 0.79$). Beef flavor scores were positively associated ($P < 0.01$) with fat-like ($r = 0.67$) and umami ($r = 0.59$) flavors. Fat level was the primary driver of beef flavor acceptability in all samples when no undesirable off-flavors were present.

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1. Introduction

Increased marbling level has a positive effect on beef tenderness, juiciness, flavor, and overall palatability (Emerson, Woerner, Belk, & Tatum, 2013; O'Quinn et al., 2012; Savell et al., 1987; Smith et al., 1985). However, in many studies evaluating marbling and palatability, tenderness level varied among samples. Tenderness has been cited as the most important factor affecting beef palatability (Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Miller et al., 1995; Savell et al., 1987). However, additional studies have shown that when tenderness reaches an acceptable level, flavor becomes the next most important driver of beef eating satisfaction (Behrends et al., 2005a, 2005b; Goodson et al., 2002; Killinger, Calkins, Umberger, Feuz, & Eskridge, 2004b). Moreover, several studies have shown consumer overall acceptability to be more highly correlated with flavor than tenderness or juiciness, regardless of tenderness variation (Neely et al., 1998; O'Quinn et al., 2012; Thompson, 2004). According to the most recent U.S. National Beef Tenderness Survey, over 94% of retail and foodservice steaks from the rib and loin would be considered tender or very tender (Guelker et al., 2013). With such a large percentage of the U.S. beef supply classified as tender, the importance of flavor to overall beef eating satisfaction is magnified.

Beef from cattle finished exclusively on forage-based diets has a flavor profile that differs from beef from cattle finished on grain-based diets (Killinger, Calkins, Umberger, Feuz, & Eskridge, 2004a; Sitz, Calkins, Feuz, Umberger, & Eskridge, 2005). Additionally, beef from Holstein cattle has been shown to have a more desirable flavor profile than beef from Angus cattle (O'Quinn, 2012). With the diversity of beef in the U.S. retail market, a better understanding of the role animal diet and cattle type plays on beef flavor is needed.

Consumers often generalize and misevaluate sensory traits because of a favorable evaluation of another trait; termed the halo-effect (Roeber et al., 2000). Thus, consumers are more likely to rate flavor as desirable if tenderness is desirable. To more accurately determine the role marbling plays in beef flavor perception of consumers, this halo-effect, specifically tenderness variation among samples, should be minimized. Therefore the objectives of this study were to measure the effects of varying marbling levels on consumer assessment of beef strip loin steaks that are classified as tender based on Warner-Bratzler shear force values (WBSF) and evaluate the roles fat level, animal diet, and cattle type play in flavor perception.

2. Materials and methods

2.1. Product

Beef strip loins [Institutional Meat Purchase Specifications #180; NAMP, 2010], representing 10 different treatments that are currently

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available to beef consumers in U.S. retail and food service markets were used for this study. Sixty sides of beef [12 per USDA quality grade; Prime, High Choice (upper 1/3 Choice), Low Choice (lower 1/3 Choice), Select, and Standard; (USDA, 1997)] were selected by trained Texas Tech personnel through visual appraisal of marbling and maturity of the product at the time of selection from a processing plant in Omaha, Nebraska. USDA Prime represented the highest quality grade within young "A" maturity carcasses, while USDA Standard represented the lowest. Additionally, two treatments from cattle of predominantly Wagyu breed type (one from the U.S. and the other from Australia) were selected to represent fat levels higher than the USDA Prime product. Four strip loins from Australian Wagyu (AUWA) cattle, finished on a barley-based diet, were obtained from a distributor in Australia and steaks from four strip loins from American Wagyu (AMWA) cattle, finished on a corn-based diet, were obtained from a distributor in Omaha, Nebraska. In addition to fat level treatments, 24 strip loins from Holstein cattle [12 per USDA quality grade: Top Choice (upper 2/3 Choice) and Select] were obtained from a foodservice steak purveyor in Houston, Texas. Lastly, 9 strip loins from cattle that were finished exclusively on a forage-based diet in New Zealand were obtained from a distributor in the United States to allow a grain-finished beef versus grass-finished beef comparison.

Strip loins were collected and shipped to the Gordon W. Davis Meat Science Laboratory, Lubbock, Texas and aged under vacuum packaging at 2–4 °C for 28 d postmortem, with the exception of the grass-finished products, which were aged 48 d postmortem. All exterior fat, connective tissue and the *gluteus medius* muscle were removed from each strip loin. Strip loins were fabricated into 2.5-cm thick steaks from anterior to posterior. The most anterior steak from each strip loin was used for proximate analysis. The following steak from the anterior end was used for WBSF determination. All remaining steak portions were further processed into 5-cm × 5-cm steak pieces following Meat Standards Australia (MSA) protocols (Gee, 2006a). Four 5-cm × 5-cm steaks from each strip loin were saved for use in trained flavor descriptive analysis. All steaks were vacuum-packaged and stored frozen (−20 °C) until subsequent analyses.

2.2. Proximate analysis

Proximate analysis of fat, crude protein, and moisture was conducted using an AOAC-approved (AOAC, 2005) near infrared spectrophotometer (FoodScan, FOSS NIRsystems, Inc., Laurel, MD) as described by O'Quinn et al. (2012).

2.3. Warner-Bratzler shear force analysis

Steaks were thawed overnight at 2 °C and cooked to an internal temperature of 71 °C, monitored by a thermocouple probe (Type J, Cole Parmer, Vernon Hills, IL) attached to a thermometer (Digi-Sense; Cole Parmer), on a clamshell grill (Model S-143 K; Silex Grills Australia Pty. Ltd., Marrickville, Australia) with plate temperature set at 225 °C. The grill was preheated for 45 min before cooking to equilibrate and stabilize temperatures throughout the heating elements and cooking surface. After cooking, steaks were cooled overnight at 2 °C. Six 1.3-cm cores were removed parallel to the muscle fiber from each steak and sheared once perpendicular to the muscle fiber using a WBSF analyzer (G-R Elec. Mfg., Manhattan, KS). The values from the six cores from each steak were averaged.

2.4. Sample selection

Following proximate and WBSF analyses, 4 to 8 strip loins per treatment best matching the fat percentages of the USDA quality grades presented by O'Quinn et al. (2012) were selected for the consumer sensory evaluations. Moreover, all samples selected for consumer analyses possessed a WBSF of 33.34 N (3.4 kg) or less. This value was chosen because previous research has shown that 99% of consumers were satisfied with steak tenderness at this shear force value (Miller et al., 2001). Additionally, the USDA has recently set WBSF standards for tenderness certification, certifying beef with a WBSF value of 43.25 N (4.4 kg) or lower as "Certified Tender" and of 38.25 N (3.9 kg) and lower as "Certified Very Tender" (ASTM, 2011). Thus, all of the samples used in the present study would have met the WBSF criteria for the USDA "Certified Very Tender" claim. Only tender samples were used in the current study in an attempt to minimize any halo-effect that tenderness variation might have on flavor ratings.

2.5. Consumer sensory evaluation

The Texas Tech University Institutional Review Board approved procedures for use of human subjects for sensory panel evaluations. Sample preparation for consumer panels followed a modified MSA protocol (Gee, 2006b). Samples were cooked with equipment described for WBSF. Samples were cooked 10 at a time following a strict timing schedule. Steaks were cooked for 5 min with the lid closed on the grill followed by a 3-min rest period. Following the rest period, samples were cut into two equally sized pieces and served immediately to two predetermined consumers. The grill remained empty for 75 s between cooking rounds to facilitate cleaning. Modifications to the original protocol included extending the cooking schedule to accommodate 10 rounds. Additionally, no warm-up samples were served to consumers before evaluation of test samples.

Consumer panels were conducted at the Texas Tech University Animal and Food Science Building in a large banquet room under florescent lighting. Panelists ($n = 120$) were recruited from communities in and around Lubbock, Texas and paid to participate in the study. Panel sessions were conducted with 20 consumers seated in individual sensory booths, and lasted about 1 h and 20 min. Two panels each night were conducted on three separate nights.

Panelists were provided with a ballot, plastic utensils, toothpick, napkin, expectorant cup, cup of water, and palate cleansers (unsalted crackers and apple juice) to use between samples. Each ballot packet contained an information sheet, demographic questionnaire, 10 sample ballots, and a post-panel survey concerning beef purchasing habits. Before the start of each panel, panelists were given verbal instructions about the ballot and use of the palate cleaners. Panelists were instructed to cut samples into pieces representative of the size consumed per bite in the home or restaurant.

Consumers were served 10 samples from each quality grade treatment (USDA Prime to Standard), an AMWA, AUWA, Grass-finished (GR), Holstein Top Choice (HTC), and Holstein Select (HSEL) in a predetermined, balanced order. The design provided a balance for frequency, order, and carryover effects (Watson, Gee, Polkinghorne, & Porter, 2008). Attributes for each sample were ranked on a paper ballot with 100-mm continuous-line scales for tenderness, juiciness, flavor liking and overall liking. The zero anchors were labeled as not tender, not juicy, dislike flavor extremely, and dislike overall extremely; the 100 mm anchors were labeled as very tender, very juicy, like flavor extremely, and like overall extremely. Also, each consumer rated each sample as either acceptable or unacceptable for each palatability trait. Furthermore, consumers were asked to designate each sample as unsatisfactory, good everyday quality, better than everyday quality, or premium quality.

2.6. Trained panel flavor descriptive analysis

Samples from each of the strip loins evaluated in the consumer study were evaluated by a highly trained, descriptive 5 member flavor panel from the Sensory Analysis Center at Kansas State University (Manhattan, Kansas). The panel evaluated flavor traits using the beef flavor lexicon previously developed by Kansas State University (Adhikari et al., 2011). The panel evaluated and rated 20 different flavor traits for each sample.

Samples were thawed for 24 h at 2–4 °C prior to cooking. Samples were prepared on the same model S-143K Silex clamshell grill as used in the consumer study. However, the plate temperature and timing were modified to accommodate cooking of single 5-cm × 5-cm steak samples. The plate temperature was set at 170 °C and the samples were cooked for 2 min and 45 s. This cooking temperature and time were chosen because it best represented the degree of doneness used in the consumer sensory panels.

Thirty-six 1.5-h sessions were conducted and panelists evaluated 3 to 4 samples per session. Samples were identified with random numeric codes and were served in a random order. Each panelist was provided with two 1.3 cm^3 cubes per sample. Panelists were given unsalted crackers and reverse osmosis, de-ionized, carbon-filtered water for palate cleansing. Each sample was evaluated in duplicate.

2.7. Statistical analysis

All statistical analyses were conducted using SAS (Version 9.3; SAS Inst. Inc., Cary, NC). Treatment comparisons were tested for significance using linear, mixed model procedures (PROC MIXED). Acceptability data was analyzed using PROC GLIMMIX with a binomial error distribution. For all analyses, denominator degrees of freedom were calculated using the Kenward–Roger approximation.

Proximate composition data from strip loins were analyzed using statistical methods that included the fixed effect of treatment. Consumer ratings and acceptability percentages for all palatability traits were analyzed using a model that included the fixed effect of treatment and the random effects of panel time and consumer nested within panel. The model used for trained panel evaluations included the fixed effect of treatment. Also, WBSF value was used as a covariate when analyzing consumer and trained panel data.

PROC FREQ was used to summarize the demographic data and post-trial questionnaire.

For all tests, the PDIFF option was used to compare treatment least squares means when the F-test for the effect of treatment was significant. All comparisons were tested using a pairwise significance level of $\alpha = 0.05$.

Correlation analyses (PROC CORR) were used to identify ($P < 0.05$) and quantify the relationship between consumer ratings for all palatability traits, trained panel flavor traits, fat content, and moisture content.

3. Results

3.1. Proximate analysis

Data for proximate analyses of the quality treatments are shown in Table 1. Treatment had an effect on fat, moisture, and protein percentage ($P < 0.05$). Fat content among treatments ranged widely from 1.96% (Standard) to 26.64% (AUWA). However, no differences ($P > 0.05$) in fat percentage were observed between High Choice and HTC. Additionally, both USDA Select treatments and GR samples were similar in fat level ($P > 0.05$). Prime, High Choice, HTC, Low Choice, Select, HSEL, Select, and Standard treatments had fat percentages similar to each respective USDA quality grade reported by previous authors (Dow, Wiegand, Ellersieck, & Lorenzen, 2011; Emerson et al., 2013; Savell, Cross, & Smith, 1986). The two Wagyu treatments had a higher ($P < 0.05$) fat level than all other treatments, including Prime. Moisture and protein content had an inverse relationship with fat content, increasing as fat level decreased. Moisture content ranged from 72.17% in Standard samples to 54.16% in AUWA samples and protein ranged from 24.26% (Select) to 17.37% (AUWA).

Table 1
Proximate composition of raw beef strip steaks from various fat levels and quality treatments.

	%		
Quality treatment	Fat	Moisture	Protein
Australian Wagyu	26.64^{a}	54.16^{e}	17.37^{f}
American Wagyu	18.37^{b}	60.00^{f}	18.75^{e}
Prime	14.67^{c}	62.88^{d}	20.63^{d}
High Choice	8.99^{d}	66.81^{c}	22.51^{c}
Top Choice, Holstein	8.54^{d}	67.44^{c}	22.17^{c}
Low Choice	5.56^{e}	69.34^{b}	23.21^{b}
Grass-finished	3.81^{f}	71.82^{a}	22.55^{c}
Select, Holstein	3.45^{fg}	71.73^{a}	23.20^{b}
Select	3.31^{fg}	71.36^{a}	24.26^{a}
Standard	1.96^{g}	72.17^{a}	24.10^{a}
SEM[1]	0.67	0.55	0.27
P-value	<0.0001	<0.0001	<0.0001

[abcdefg]Least squares means in the same column lacking a common superscript differ ($P < 0.05$).
[1] SE (largest) of the least squares means.

3.2. Demographic profile of consumers

The demographic profile of consumers who participated in the current study is presented in Table 2. The panel was composed of an equal number of males and females, with a majority of panelists (66.7%) from a dual income household. The primary ethnic origin of consumers was Caucasian/White, comprising 88.1% of participants. More than half (55.6%) of the participants reported an annual

Table 2
Demographic characteristics of consumers ($n = 120$) who participated in sensory panels.

Characteristic	Response	Percentage of consumers
Sex	Male	50.0
	Female	50.0
Household size	1 person	14.3
	2 people	27.6
	3 people	21.9
	4 people	22.7
	5 people	7.6
	6 people	2.5
	>6 people	3.4
Household income	Single income	33.3
	Dual income	66.7
Age group	18–25	18.5
	26–35	16.8
	36–45	12.6
	46–55	25.2
	56–65	26.9
Ethnic origin	African–American	0.9
	Caucasian/White	88.1
	Native American	0.9
	Hispanic	9.3
	Other	0.8
Annual household income, $	<20,000	7.7
	20,000 to 29,999	5.1
	30,000 to 49,999	11.1
	50,000 to 69,999	20.5
	70,000 to 100,000	23.9
	>100,000	31.7
Highest level of education completed	Non-high school graduate	0.8
	High school graduate	6.7
	Some college/technical school	29.2
	College graduate	36.7
	Post graduate	26.6
Weekly beef consumption	None	1.7
	1 to 3 times	48.7
	4 to 6 times	41.2
	7 or more times	8.4

household income of greater than $70,000. This result is likely because of the large proportion (64.7%) of participants who were over 36 y of age, as well as the large majority (63.3%) who were either college graduates or post-college graduates. Most (48.7%) consumers in the current study consumed beef 1 to 3 times a week, whereas nearly half (49.6%) of the panel participants consumed beef 4 or more times weekly. The demographics of these consumers were similar to those used in previous research in Lubbock, Texas (Brooks et al., 2010; O'Quinn et al., 2012). Lubbock beef consumers have been shown to have similar beef preferences to consumers in multiple, geographically diverse U.S. metropolitan cities (Mehaffey et al., 2009; Miller et al., 2001).

3.3. Purchasing habits of consumers

The majority (70.8%) of consumer panelists were the regular purchaser of beef in their families (Table 3). More than half (56.7%) of participants identified the quality of steaks and roasts purchased with a USDA quality grade, with 37.5% indicating that USDA Choice was regularly purchased. Only 28.3% of consumers identified a branded beef program as the quality of beef purchased and 15% did not know what quality level they regularly purchased. When consuming beef roasts, the majority (50%) of consumers indicated that tenderness was the most important palatability trait, followed by flavor (31.7%), and juiciness (18.3%). However, when consuming steaks, a higher percentage of consumers (50.8%) rated flavor as most important followed by tenderness (30.8%) and juiciness (18.4%). This difference in perceived importance of tenderness and flavor between steaks and roasts is of particular interest. This result could be caused by the high percentage of retail beef that is tender (Guelker et al., 2013) and an increasing consumer expectation for tender steak.

3.4. Consumer palatability ratings

The effects of treatment on consumer sensory ratings are presented in Table 4. Treatment had an effect ($P < 0.05$) on consumer sensory panel ratings for tenderness, juiciness, flavor and overall liking, with all ratings typically increasing with increased fat level. No difference ($P > 0.05$) in tenderness was observed among the three treatments with the highest fat levels (AUWA, AMWA, and Prime); however, all three were rated as more tender ($P < 0.05$) than all other treatments except Low Choice. All three Choice treatments were more tender ($P < 0.05$) than GR and lower grading samples. No difference ($P > 0.05$) was observed among GR, HSEL, and Select samples for tenderness. The Standard treatment was less tender ($P < 0.05$) than all except the GR and Select treatments.

Juiciness ratings were positively associated with fat content, increasing with increased fat percentages. AUWA and AMWA samples were rated higher ($P < 0.05$) for juiciness than all other treatments. Prime samples were juicier ($P < 0.05$) than all other treatments with a lower fat content. However, no differences ($P > 0.05$) in juiciness were found among treatments within the same USDA quality grade. The three Choice treatments (High Choice, HTC, and Low Choice) were juicier ($P < 0.05$) than the Select, HSEL, GR and Standard samples. Moreover, GR samples were rated similar ($P > 0.05$) for juiciness as Select and HSEL samples.

Prime, AUWA, and AMWA samples were rated higher ($P < 0.05$) for flavor liking than all other treatments except Low Choice. Similar to the tenderness ratings, Low Choice samples were rated comparable ($P > 0.05$) to Prime samples for flavor liking. High Choice, HTC, and Low Choice treatments were rated as more likable ($P < 0.05$) for flavor than Select, HSEL, Standard, and GR. Additionally, GR samples were rated lower ($P < 0.05$) than all other treatments evaluated for flavor liking. Means for flavor liking showed less variation across treatments than tenderness and juiciness means.

No difference ($P > 0.05$) was found among AMWA, AUWA, and Prime samples for overall liking, with all three rating higher ($P < 0.05$) than all other treatments. The three USDA Choice treatments (High Choice, HTC, and Low Choice) rated higher ($P < 0.05$) for overall liking than Select, HSEL, GR, and Standard samples. Also, no difference ($P > 0.05$) was found among Select, HSEL, and Standard samples for overall liking. Standard and GR treatments were similar ($P > 0.05$) for consumer overall liking ratings.

3.5. Consumer acceptability and quality level ratings

The percentage of samples rated as acceptable for each palatability trait is presented in Table 5. No difference ($P > 0.05$) was found in tenderness acceptability among the AUWA, AMWA, Prime, High Choice,

Table 3
Beef purchasing habits of consumers ($n = 120$) who participated in sensory panels.

Characteristic	Response	Percentage of consumers
Consumer is a regular purchaser of beef in family	Yes	70.8
	No	29.2
Quality of steaks or roasts normally purchased	USDA Prime	5.0
	USDA Choice	37.5
	USDA Select	14.2
	Certified Angus Beef	5.0
	Store Brand	0.8
	Sterling Silver	15.0
	Chef's Exclusive	0.8
	Foreman's Choice	4.2
	Nolan Ryan's Beef	0.8
	Steak House brand (Wal-mart)	1.7
	Do not know	15.0
Most important palatability trait when consuming beef roasts	Flavor	31.7
	Tenderness	50.0
	Juiciness	18.3
Most important palatability trait when consuming beef steaks	Flavor	50.8
	Tenderness	30.8
	Juiciness	18.4
How often the consumer has an excellent eating experience when eating steak in a restaurant	Always	4.2
	Almost always	41.2
	Some of the time	47.9
	Almost never	6.7

Table 4
Consumer ratings[1] of the palatability traits of grilled beef strip loin steaks[2] of varying fat levels and quality treatments.

Quality treatment[3]	Tenderness	Juiciness	Flavor liking	Overall liking
Australian Wagyu (26.64%)	79.34^{a}	85.00^{a}	68.20^{ab}	70.15^{a}
American Wagyu (18.37%)	74.27^{ab}	81.60^{a}	72.16^{a}	73.22^{a}
Prime (14.67%)	75.35^{ab}	74.80^{b}	69.88^{ab}	71.58^{a}
High Choice (8.99%)	64.87^{d}	60.92^{c}	60.30^{c}	61.24^{b}
Top Choice, Holstein (8.54%)	65.56^{cd}	63.25^{c}	61.54^{c}	62.67^{b}
Low Choice (5.56%)	70.89^{bc}	64.54^{c}	63.70^{bc}	62.93^{b}
Grass-finished (3.81%)	54.09^{ef}	49.12^{d}	41.65^{e}	43.31^{d}
Select, Holstein (3.45%)	56.92^{e}	50.01^{d}	51.51^{d}	50.40^{c}
Select (3.31%)	54.81^{ef}	45.96^{de}	52.22^{d}	50.95^{c}
Standard (1.96%)	49.34^{f}	41.82^{e}	48.52^{d}	45.20^{cd}
SEM[4]	2.70	3.09	3.61	3.28
P-value	<0.0001	<0.0001	<0.0001	<0.0001

^{abcdef}Least squares means in the same column without a common superscript differ ($P < 0.05$).
[1] Sensory scores: 0 = not tender/juicy, dislike flavor/overall extremely; 100 = very tender/juicy, like flavor/overall extremely.
[2] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).
[3] Chemical fat percentages for each quality treatment are listed in parenthesis.
[4] SE (largest) of the least squares means.

Table 5
Percentage of beef strip steaks[1] of varying fat levels and quality treatments considered acceptable for tenderness, juiciness, flavor, and overall liking by consumers ($n = 120$).

Quality treatment[2]	Tenderness	Juiciness	Flavor liking	Overall liking
Australian Wagyu (26.64%)	96.09^{a}	96.51^{a}	85.86^{ab}	83.92^{bc}
American Wagyu (18.37%)	94.81^{a}	97.89^{a}	93.24^{a}	91.38^{ab}
Prime (14.67%)	95.53^{a}	95.63^{a}	93.09^{a}	92.92^{a}
High Choice (8.99%)	92.11^{ab}	90.51^{b}	90.53^{ab}	92.34^{ab}
Top Choice, Holstein (8.54%)	85.68^{bc}	91.57^{b}	86.72^{ab}	88.76^{ab}
Low Choice (5.56%)	94.04^{a}	89.12^{c}	87.20^{ab}	86.61^{ab}
Grass-finished (3.81%)	79.66^{c}	70.41^{d}	63.74^{d}	67.96^{d}
Select, Holstein (3.45%)	82.10^{c}	70.98^{d}	72.04^{cd}	73.58^{cd}
Select (3.31%)	80.75^{c}	66.98^{d}	79.74^{bc}	66.48^{d}
Standard (1.96%)	76.23^{c}	60.32^{d}	68.29^{cd}	61.15^{d}
SEM[3]	5.77	7.45	7.74	7.30
P-value	<0.0001	<0.0001	<0.0001	<0.0001

^{abcd}Least squares means in the same column without a common superscript differ ($P < 0.05$).
[1] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).
[2] Chemical fat percentages for each quality treatment are listed in parenthesis.
[3] SE (largest) of the least squares means.

and Low Choice treatments. Likewise, no difference ($P > 0.05$) was found among GR, HSEL, Select, and Standard treatments for tenderness acceptability, all with a lower percentage of tenderness acceptability ($P < 0.05$) than High Choice, Low Choice, Prime, AUWA, and AMWA samples.

Juiciness acceptability followed a similar trend with fatness, with AUWA, AMWA, and Prime all similar ($P > 0.05$) and having a greater proportion of acceptable samples ($P < 0.05$) for juiciness than all other treatments. The two treatments representing upper 2/3 Choice (HTC and High Choice) were perceived to be acceptable for juiciness more often ($P < 0.05$) than Low Choice, HSEL, Select, GR, and Standard. Low Choice samples were considered acceptable for juiciness more often ($P < 0.05$) than all treatments with a lower fat percentage. The two Wagyu treatments, Prime, HTC, and High Choice samples were considered over 90% acceptable for juiciness.

No difference ($P > 0.05$) in flavor acceptability was found among AUWA, AMWA, Prime, HTC, High Choice, and Low Choice, with more than 85% of samples considered acceptable. Conversely, GR, HSEL, and Standard samples were deemed acceptable for flavor liking less often ($P < 0.05$) than all other treatments. The percentage of Select samples considered acceptable for flavor was similar ($P > 0.05$) to High Choice, HTS, Low Choice, HSEL, and Standard.

Prime samples were similar ($P > 0.05$) to AMWA, High Choice, HTC, and Low Choice samples for overall acceptability, but were rated as acceptable overall more often ($P < 0.05$) than AUWA. Additionally, all USDA Prime and Choice treatments had a greater ($P < 0.05$) percentage of samples rated as acceptable overall than Standard, GR, and both USDA Select treatments. Interestingly, AUWA samples were similar ($P > 0.05$) in overall acceptability to HSEL samples.

The perceived quality levels assigned to treatments by consumers are presented in Table 6. AMWA and AUWA samples were considered premium quality more often ($P < 0.05$) than all other treatments, with almost half (47.5%) of AUWA being rated as premium quality. Prime was rated as unsatisfactory the least often (6.67%; $P < 0.05$). More than 60% of the samples from the Prime, AUWA, and AMWA were rated as better than everyday quality or premium quality. Conversely, samples from GR, Select, and Standard treatments were rated as unsatisfactory more often ($P < 0.05$) than all other treatments. More than 31% of the samples from each of these three treatments were classified as unsatisfactory.

3.6. Flavor descriptive analysis

Results from the trained panel descriptive flavor analysis are presented in Table 7. Of the 20 flavor descriptors evaluated, no differences ($P > 0.05$) were found among treatments for brown/roasted, cardboard, green, hay-like, liver, metallic, overall sweet, sour, bitter, and salty flavors. No differences ($P > 0.05$) were found among Low Choice, HSEL, Select, and Standard samples for all flavor traits evaluated. Beef ID scores of AUWA samples were lower ($P < 0.05$) than AMWA, Prime, High Choice and HTC samples. Moreover, GR samples had the lowest ($P < 0.05$) beef ID flavor, similar ($P > 0.05$) only to AUWA, Select and Standard samples. Additionally, the initial flavor impact score was highest ($P < 0.05$) for GR samples, with GR samples rating comparable ($P > 0.05$) to only AUWA and AMWA.

Of particular interest were the ratings for the fat-like flavor note. No difference ($P > 0.05$) was observed for fat-like flavor among High Choice, HTC, Low Choice, GR, HSEL, Select, and Standard treatments, all rating lower ($P < 0.05$) than Prime, AMWA, and AUWA samples. AUWA rated the highest ($P < 0.05$) for fat-like, followed by AMWA, and Prime. GR samples rated the highest ($P < 0.05$) for fish ID and higher ($P < 0.05$) for barnyard and refrigerator/stale flavors than all treatments except AUWA. Moreover, GR steaks rated higher ($P < 0.05$) for warmed-over flavor than all treatments except Standard. AUWA and GR samples rated higher ($P < 0.05$) for oxidized than all other treatments.

3.7. Correlations

Pearson correlation coefficients for consumer palatability traits and percentage fat and moisture are presented in Table 8. All correlations among palatability traits were significant ($P < 0.01$). Overall liking was highly correlated to flavor liking ($r = 0.96$), juiciness ($r = 0.93$), and

Table 6
Percentage of beef strip steaks[1] of varying fat levels and quality categorized into eating quality levels by consumers ($n = 120$).

Quality treatment[2]	Unsatisfactory	Good everyday quality	Better than everyday quality	Premium quality
Australian Wagyu (26.64%)	15.83^{c}	11.67^{c}	25.01^{abc}	47.50^{a}
American Wagyu (18.37%)	11.11^{cd}	20.51^{c}	33.33^{a}	35.04^{a}
Prime (14.67%)	6.67^{d}	32.50^{b}	31.66^{a}	29.17^{b}
High Choice (8.99%)	10.83^{cd}	50.00^{a}	29.17^{ab}	10.00^{c}
Top Choice, Holstein (8.54%)	13.33^{cd}	42.50^{ab}	30.01^{ab}	14.17^{c}
Low Choice (5.56%)	15.83^{c}	45.00^{a}	32.49^{a}	6.68^{cde}
Grass-finished (3.81%)	31.67^{a}	49.17^{a}	11.66^{d}	7.50^{e}
Select, Holstein (3.45%)	28.81^{b}	51.70^{a}	15.26^{cd}	4.24^{de}
Select (3.31%)	34.17^{a}	41.67^{ab}	19.98^{bcd}	4.17^{de}
Standard (1.96%)	40.00^{a}	44.17^{ab}	12.51^{d}	3.33^{e}
SEM[3]	4.47	4.60	4.36	4.56
P-value	<0.0001	<0.0001	<0.0001	<0.0001

^{abcde}Least squares means in the same column without a common superscript differ ($P < 0.05$).
[1] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).
[2] Chemical fat percentages for each quality treatment are listed in parenthesis.
[3] SE (largest) of the least squares means.

Table 7
Descriptive flavor attributes of beef strip steaks[1] from varying in fat[2] levels and quality treatments.

Attribute[3]	Australian Wagyu (26.64%)	American Wagyu (18.37%)	Prime (14.67%)	High Choice (8.99%)	Top Choice, Holstein (8.54%)	Low Choice (5.56%)	Grass-fed (3.81%)	Select, Holstein (3.45%)	Select (3.31%)	Standard (1.96%)	SEM[4]	*P*-value
Initial flavor impact	4.71^{ab}	4.64^{ab}	4.45^{bc}	4.23^{bc}	4.37^{bc}	4.22^{bc}	5.02^{a}	4.08^{c}	4.31^{bc}	4.10^{bc}	0.23	0.0112
Beef ID	4.88^{bc}	5.92^{a}	5.66^{a}	5.62^{a}	5.57^{a}	5.38^{ab}	4.75^{c}	5.36^{ab}	5.31^{abc}	4.90^{bc}	0.29	0.0036
Bloody/serumy	5.17^{ab}	5.45^{a}	5.00^{ab}	4.51^{bcd}	4.42^{bcd}	4.20^{cd}	4.64^{bc}	4.31^{bcd}	4.20^{cd}	3.87^{d}	0.34	0.0379
Brown/roasted	4.92	5.24	5.27	5.32	5.51	5.10	5.08	5.02	5.24	4.86	0.25	0.2768
Refrigerator/stale	1.30^{ab}	0.74^{d}	0.83^{cd}	0.90^{bcd}	1.15^{bc}	1.06^{bcd}	1.58^{a}	0.86^{bcd}	0.95^{bcd}	0.97^{bcd}	0.18	0.0009
Barnyard	1.80^{ab}	1.35^{bc}	1.20^{c}	1.15^{c}	1.22^{c}	1.27^{bc}	2.01^{a}	1.18^{c}	1.02^{c}	1.33^{bc}	0.20	0.0005
Cardboard	1.73	1.96	2.39	2.29	2.41	2.52	2.69	2.53	2.67	2.81	0.25	0.1021
Fat-like	4.82^{a}	3.96^{b}	3.23^{c}	2.37^{d}	2.27^{d}	2.38^{d}	2.33^{d}	2.22^{d}	1.89^{d}	1.89^{d}	0.27	<0.0001
Green	0.74	0.68	0.79	0.63	0.48	0.49	0.87	0.65	0.76	0.90	0.16	0.1036
Hay-like	1.07	0.54	0.68	0.61	0.54	0.52	1.04	0.53	0.51	0.58	0.22	0.2376
Liver	1.08	0.63	1.02	0.86	0.99	1.05	1.46	1.01	0.70	1.27	0.26	0.1162
Metallic	2.94	2.91	2.78	2.75	2.80	2.83	2.91	2.51	2.75	2.73	0.15	0.2950
Overall sweet	1.19	1.38	1.39	1.23	1.32	1.28	1.10	1.28	1.21	1.19	0.10	0.1505
Oxidized	2.27^{a}	1.47^{b}	1.40^{bc}	1.30^{bc}	1.44^{b}	1.35^{bc}	2.07^{a}	1.28^{bc}	1.11^{bc}	1.00^{c}	0.18	<0.0001
Warmed-over	1.25^{bcd}	0.86^{d}	1.13^{cd}	1.46^{bc}	1.51^{bc}	1.33^{bcd}	1.96^{a}	1.46^{bc}	1.44^{bc}	1.65^{ab}	0.20	0.0013
Fish ID	0.13^{b}	0.05^{b}	0.05^{b}	0.15^{b}	0.15^{b}	0.06^{b}	1.38^{a}	0.13^{b}	0.09^{b}	0.18^{b}	0.12	<0.0001
Sour	3.28	3.22	3.24	3.24	3.00	3.12	3.34	3.02	3.20	3.16	0.14	0.3515
Bitter	4.33	4.22	4.14	4.02	4.17	4.20	4.25	4.07	4.11	4.13	0.13	0.5998
Salty	2.41	2.42	2.48	2.37	2.33	2.32	2.32	2.25	2.39	2.28	0.11	0.6674
Umami	1.70^{bc}	2.27^{a}	2.19^{a}	1.90^{ab}	1.64^{bc}	1.90^{ab}	1.25^{c}	1.72^{b}	1.81^{ab}	1.49^{bc}	0.20	0.0002

[abcd] Least squares means in the same row lacking a common superscript differ ($P < 0.05$).
[1] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).
[2] Chemical fat percentages for each quality treatment are listed in parenthesis.
[3] Traits were evaluated from 0 to 15, in half unit increments and were anchored with a single quantitative reference point as described by Adhikari et al. (2011).
[4] SE (largest) of the least squares means.

tenderness ($r = 0.92$). Moreover, fat percentage was correlated with overall liking ($r = 0.79$), tenderness ($r = 0.81$), juiciness ($r = 0.88$), and flavor liking ($r = 0.74$).

The relationships between trained panel flavor traits and consumer sensory scores, percentage fat and moisture are displayed in Table 9. Overall consumer liking was positively correlated ($P < 0.05$) with fat-like, umami, bloody/serumy, overall sweet, and beef ID flavors, as well as negatively correlated ($P < 0.05$) with warmed-over, cardboard, fish ID, refrigerator/stale, and liver flavors. Consumer flavor liking was positively correlated ($P < 0.05$) with fat-like, umami, bloody/serumy, overall sweet, beef ID, and salty flavors. Also, consumer flavor liking was negatively correlated ($P < 0.05$) with warmed-over, cardboard, fish ID, refrigerator/stale, and liver flavors. Fat percentage was positively correlated ($P < 0.05$) with fat-like, bloody/serumy, umami, metallic, oxidized, salty, and overall sweet flavors, as well as initial flavor impact.

4. Discussion

Results of the current study are consistent with numerous published reports indicating increased beef palatability and flavor scores with increased fat or marbling level (Emerson et al., 2013; Lorenzen et al., 1999, 2003; Smith et al., 1985). However, unlike previous studies, attempts were made in this study to minimize the halo-effect tenderness might have on consumer flavor ratings. Only tender beef steaks, screened by WBSF (WBSF < 33.34 N; 3.4 kg), were used in the current study. Moreover, WBSF was used as a covariate in the statistical analysis of sensory panel data to minimize the effect of tenderness variation on other sensory ratings. Despite these attempts to standardize tenderness, consumers rated samples with higher fat contents (Prime, AUWA, AMWU) as more tender than samples from treatments with lower fat contents (GR, HSEL, Select, and Standard), following a similar trend in juiciness and flavor ratings. It is unclear if consumers possess the ability to categorize very tender beef or if superior juiciness and flavor in higher fat beef influence consumer perception of tenderness following the halo-effect hypothesis. However, these results do indicate that fat percentage plays a large role in all three palatability factors and present evidence that evaluating a single palatability trait without the influence of the others is difficult because of the inherent interrelationships among tenderness, juiciness, and flavor.

Several studies have been conducted with the objective of establishing a WBSF tenderness threshold for consumers (Miller et al., 1995, 2001; Shackelford, Morgan, Cross, & Savell, 1991). Additionally, Miller et al. (2001) found that 99% of consumers were satisfied with USDA Select beef steak tenderness with a WBSF of 33.34 N (3.4 kg) when cooked to a medium degree of doneness. Miller et al. (2001) studied the relationship of WBSF and consumer tenderness thresholds by holding fat level, USDA quality grade, and degree of doneness constant. By holding these three variables constant, consumers were able to find differences in steaks of various WBSF without a significant halo-effect. In the current study, a wide range in mean tenderness acceptability (96.09–76.23%) was observed across treatments, despite all samples having a WBSF below 33.34 N (3.4 kg). Tenderness acceptability in the current study was much lower than previously reported values for beef with similarly low WBSF values. This result could be attributed to numerous reasons including changing consumer preferences due to a more tender beef supply than when the earlier studies were conducted more than 10 years ago. Moreover, previous work often included fewer (or even single) USDA quality grades. It is possible that, because of the interactions between flavor, juiciness, and tenderness, the consumer acceptability threshold for tenderness differs across USDA quality grades. Current results indicate that consumers were more accepting of the tenderness of samples with higher marbling levels than samples with

Table 8
Pearson correlation coefficients among consumer sensory scores and proximate composition of beef strip steaks[1] from varying fat levels and quality treatments.

Trait	Overall liking	Tenderness	Juiciness	Flavor	% fat	% moisture
Tenderness	0.92*					
Juiciness	0.93*	0.93*				
Flavor	0.96*	0.88*	0.87*			
% fat	0.79*	0.81*	0.88*	0.74*		
% moisture	−0.80*	−0.81*	−0.89*	−0.76*	−0.99*	
% protein	−0.72*	−0.76*	−0.85*	−0.67*	−0.95*	0.92*

* Correlation coefficient differs from 0 ($P < 0.01$).
[1] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).

Table 9
Pearson correlation coefficients among descriptive flavor attributes, consumer sensory scores, proximate composition of beef strip steaks[1] from varying fat levels and quality treatments.

	Consumer sensory evaluation scores					
Attribute	Overall liking	Flavor	Tenderness	Juiciness	% fat	% moisture
Initial flavor impact	−0.04	−0.11	0.13	0.18	0.30*	−0.19
Beef ID	0.36*	0.35*	0.22	0.21	0.11	−0.07
Bloody/serumy	0.53**	0.50**	0.51**	0.56**	0.65**	−0.65**
Brown/roasted	−0.10	−0.08	−0.22	−0.16	−0.27*	0.27
Refrigerator/stale	−0.37*	−0.37*	−0.28	−0.24	−0.15	0.22
Barnyard	−0.18	−0.22	−0.03	0.03	0.17	−0.12
Cardboard	−0.63**	−0.64**	−0.57**	−0.61**	−0.64**	0.62**
Fat−like	0.69**	0.67**	0.71**	0.76**	0.89**	−0.89**
Green	−0.25	−0.25	−0.19	−0.20	0.10	0.01
Hay-like	−0.24	−0.27	−0.17	−0.08	−0.06	0.04
Liver	−0.30*	−0.30*	−0.24	−0.17	−0.13	0.17
Metallic	0.29	0.27	0.37*	0.34*	0.45**	−0.42**
Overall sweet	0.47**	0.46**	0.45**	0.37*	0.38**	−0.34*
Oxidized	0.15	0.13	0.27	0.29	0.44**	−0.34*
Warmed-over	−0.65**	−0.67**	−0.53**	−0.53**	−0.53**	0.55**
Fish ID	−0.40**	−0.48**	−0.22	−0.22	−0.19	0.29
Sour	−0.10	−0.14	−0.07	−0.01	0.21	−0.10
Bitter	−0.20	−0.18	−0.11	−0.05	0.18	−0.13
Salty	0.28	0.34*	0.23	0.19	0.39**	−0.31*
Umami	0.59**	0.59**	0.51**	0.49**	0.51**	−0.50**

* Correlation coefficient differs from 0 ($P < 0.05$).
** Correlation coefficient differs from 0 ($P < 0.01$).
[1] All steaks were classified as tender (<33.34 N; 3.4 kg) according to Miller et al. (2001).

lower marbling levels, despite attempts to reduce WBSF variation. More research is needed investigating how marbling level affects tenderness acceptability and to determine the WBSF tenderness threshold for today's consumers.

Flavor liking was slightly more associated with overall liking scores than either tenderness or juiciness. Previous studies have reported similar findings indicating the importance of beef flavor to the overall acceptability of beef (Killinger et al., 2004b; Neely et al., 1998; O'Quinn et al., 2012). A highly-trained descriptive flavor panel was used in the current study to identify specific flavor attributes to explain observed differences in consumer flavor ratings. Many of the flavor traits evaluated, including beef ID and brown/roasted, showed little variation across U.S. sourced, grain-finished samples. The flavor trait that increased the most in the high fat treatments was the fat-like flavor. Consumer flavor liking scores followed a similar trend, increasing with increased fat percentage. Taken together, these results indicate a possible general background beef flavor that is similar across various USDA quality grades, with the fat percentage and the corresponding fat-like flavor being the primary driver of consumer flavor liking. In the current study, USDA Select and Standard samples scored lower for consumer flavor liking than higher fat samples due largely to lower desirable flavors, specifically fat-like and umami, as opposed to the presence of undesirable flavors.

The relationship between flavor scores and fat content did not hold true in GR steaks. It is well documented that beef from cattle finished exclusively on a forage based diet have a different flavor profile from that of grain-finished beef (Davis, Cole, Backus, & Melton, 1981; Killinger et al., 2004a; Sitz et al., 2005). In the current study, the GR samples were characterized by flavors including barnyard, refrigerator/stale, warmed-over, and fish ID. Additionally, GR samples had one of the highest initial flavor impact scores indicating these flavor notes were immediately and strongly perceived by trained panelists. Many of these flavors were negatively correlated with consumer flavor liking scores indicating that they were not preferred by consumer panelists as evidenced by GR samples having the lowest flavor acceptability among all treatments evaluated. Furthermore, GR samples scored similar to the two treatments with a comparable fat percentage (Select and HSEL) for tenderness and juiciness acceptability but had a lower overall acceptability, indicating the importance of flavor to overall acceptability.

Among the high-fat treatments, a similar indication of the role of flavor in driving consumer acceptance was observed. A lower percentage of AUWA steaks were rated acceptable for overall and flavor liking than Prime; however, both treatments had a similar percentage of steaks classified as acceptable for tenderness and juiciness. Additionally, AUWA steaks had a higher oxidized flavor than all treatments other than GR. This oxidized flavor could explain the lower consumer flavor and subsequent lower overall acceptability percentages. The high fat content of these samples may have resulted in a greater amount of lipid oxidation and the off-flavor.

The barley-based finishing diet of the AUWA steaks may have been responsible for the differences in flavor traits observed between the two Wagyu treatments. Barley-based diets, low in Vitamin A, such as those used in the AUWA cattle have previously been associated with improved marbling levels (Gibb, Van Herk, Mir, Loerch, & McAllister, 2011). This dietary difference could have explained the 8% fat difference between AUWA and AMWA steaks. Consumers in the U.S. have previously rated the flavor of beef from cattle finished on corn-based diets as superior to that of beef from barley-based diets (Sitz et al., 2005). In the current study, trained panelists rated AMWA steaks higher for beef ID, yet consumers scored flavor liking and overall liking similar between AMWA and AUWA samples.

In the current study, steaks from Holstein cattle performed similar to steaks from beef-type cattle from the same quality grade for all palatability and flavor traits evaluated. This is in agreement with previous reports that have compared Holstein beef with beef from other cattle breeds (Adams, Smith, & Carpenter, 1982; Jeremiah & Gibson, 1999; Ramsey, Cole, Meyer, & Temple, 1963) and offers no evidence of a palatability advantage for Holstein beef.

Results from this study further indicate the importance of flavor to beef eating satisfaction. These results also reveal that fat content has a positive effect on beef flavor perception regardless of its effect on tenderness. Consumer overall liking and flavor scores were closely related to the fat-like flavor, which increased in treatments with higher fat levels. In addition, GR and AUWA treatments possessed unique off-flavors which negatively affected their flavor and overall acceptability. These results indicate that producing beef without undesirable off-flavors is equally, and perhaps more important, to beef flavor perception than increasing positive flavor traits.

Conflict of interest

There is no conflict of interest on this paper.

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