Published January 20, 2015

Consumer assessment of beef strip loin steaks of varying fat levels

T. G. O'Quinn,* J. C. Brooks,* R. J. Polkinghorne,† A. J. Garmyn,* B. J. Johnson,* J. D. Starkey,* R. J. Rathmann,* and M. F. Miller*[1]

*Department of Animal and Food Sciences, Texas Tech University, Lubbock 79409; and †Marrinya Pty. Ltd., 70 Vigilantis Rd., Wuk Wuk, Victoria 3875, Australia

ABSTRACT: A consumer study was conducted in Lubbock, Texas, to determine the effects of fat level of beef strip steaks on the palatability traits of tenderness, juiciness, flavor liking, and overall liking, while further investigating the window of acceptability for fat content of beef. Thirty beef strip loins were selected by trained personnel to equally represent USDA Prime, High Choice (upper 1/3 Choice), Low Choice (lower 1/3 Choice), Select, and Standard. Proximate analysis was conducted on all strip loins to determine percentage fat, moisture, protein, and collagen. Three strip loins from each quality grade were selected based on fat percentages from proximate analysis to best represent each USDA quality grade for use in the consumer evaluations. Strip loins were fabricated into 2.5-cm steaks, and further processed into 5 × 5 cm pieces. In addition to the US-sourced product, beef LM pieces from 6 Australian Wagyu steers (Wagyu) and 6 Australian grain finished steers (Australian) were used in the consumer evaluations. Consumers (n = 120) were served 7 samples: a warm-up sample, 1 sample from each USDA quality grade treatment, and either a Wagyu or Australian sample, in a balanced order in accordance with a 6 × 6 Latin square. Consumers rated each steak sample for tenderness, juiciness, flavor, and overall liking and rated each palatability trait as either acceptable or unacceptable. Moreover, consumers rated each sample as unsatisfactory, good everyday quality, better than everyday quality, or premium quality. Tenderness, juiciness, flavor liking, and overall liking increased with increasing fat content ($P < 0.05$). However, Wagyu and Australian samples did not follow this trend for flavor and overall liking. A decrease in consumer acceptability of each palatability trait was observed as fat level decreased ($P < 0.05$). Consumer overall liking was correlated ($P < 0.05$) with consumer tenderness (r = 0.76) and juiciness ratings (r = 0.73), but most highly correlated with flavor liking (r = 0.88). Results of this study indicated that increased fat level in beef strip steaks positively affected tenderness, juiciness, flavor liking, and overall liking of beef strip steaks. Moreover, flavor liking was the most highly correlated palatability trait with overall liking. In US-sourced samples, fat level had a large effect on the flavor liking of beef as determined by consumers.

Key words: beef, consumer, fat, flavor, palatability, strip loin

J. Anim. Sci. 2012. 90:626–634
doi:10.2527/jas.2011-4282

INTRODUCTION

Several studies have shown tenderness is the single most important factor affecting beef palatability (Dikeman, 1987; Savell et al., 1987; Miller et al., 1995; Miller et al., 2001). However, other studies have shown flavor is equally important and, in some cases, more important than tenderness in determining overall palatability of beef steaks. A study by Killinger et al. (2004b) found flavor more highly correlated (r = 0.83) with overall acceptability scores than juiciness (r = 0.76) or tenderness (r = 0.78). Neely et al. (1998) also found consumer overall like scores most highly correlated with flavor ratings (r = 0.86) and suggested that beef flavor may be as important as tenderness in determining beef palatability. Platter et al. (2003) showed that even small changes in flavor scores resulted in large changes in consumer overall palatability acceptance. Moreover, Polkinghorne (2007) noted Australian beef consumers have changed their view on the importance of flavor and tenderness over the past 10 yr. When calculating a combined weighted score (including tenderness, juiciness, flavor liking, and overall liking) to measure consumer satisfaction, tenderness and juiciness are now weighted equally, but earlier work weighted tenderness twice as important (Polkinghorne, 2007).

[1]Corresponding author: mfmrraider@aol.com
Received May 22, 2011.
Accepted September 12, 2011.

It has been documented that increased marbling is related to increased beef tenderness, juiciness, flavor, and overall palatability rankings in both trained and consumer sensory panels (Smith et al., 1985; Savell et al., 1987; Lorenzen et al., 1999, 2003; Garmyn et al., 2011). More specifically, panel flavor scores improved as the marbling of beef increased (Lorenzen et al., 1999, 2003). In contrast, Voges et al. (2007) reported sensory panel ratings for tenderness, juiciness, flavor liking, and overall liking did not differ across quality grades from Prime to Select for top loin steaks. However, the average postfabrication aging time for these steaks was 42 d.

By identifying intramuscular fat as the major contributor to beef flavor, a better understanding of how to ensure consistently flavorful beef to the consumer could be achieved. It was therefore the objective of this study to measure the effects of fat level on the palatability traits of tenderness, juiciness, flavor, and overall liking of beef strip loin steaks as determined by consumers, and further investigate the window of acceptability for fat content of beef.

MATERIALS AND METHODS

Animal Care and Use Committee approval was not obtained for this study because the samples were obtained from federally inspected slaughter facilities.

Product

Thirty sides of beef [6 per USDA quality grade treatment; USDA Prime, USDA High Choice (upper 1/3 Choice), USDA Low Choice (lower 1/3 Choice), USDA Select, and USDA Standard; USDA, 1997] were selected from a beef processing plant in West Texas. Steer carcasses were selected by trained Texas Tech personnel to represent each USDA quality grade. The strip loin (IMPS #180; NAMP, 2010) was collected from each carcass and transported to the Gordon W. Davis Meat Science Laboratory, Lubbock, Texas, and aged at 2 to 4°C for 22 d postmortem under vacuum. All exterior fat, connective tissue, and the gluteus medius were removed from the strip loins before steak fabrication. Strip loins were fabricated into 2.5-cm steaks, starting at the anterior end of the strip loin. The most anterior steak from each strip loin was used for proximate analysis. Steaks for proximate analysis were vacuum packaged and stored 1 d at 2 to 4°C. According to Meat Standards Australia (**MSA**) protocols (Gee, 2006), all remaining steak portions were further processed into 5 cm × 5 cm steak pieces and vacuum packaged as sets of 5 in sequential order from the anterior to the posterior end. Packages were frozen (−10°C) until consumer evaluations.

Three strip loins were selected, based on proximate fat data, for each quality grade treatment for use in the consumer evaluations. Strip loins were selected to best represent the fat range presented by Savell and Cross (1988) for each quality grade. Ten to 25 steak pieces were obtained from the 3 selected strip loins, resulting in a total of 60 steak pieces for each quality grade.

In addition to the US-sourced product, 36 LM pieces measuring 2.5 cm × 5 cm × 5 cm (6 sets of 6; 1 set per animal) from 6 Australian Wagyu (aged 17 d postmortem) and 36 LM pieces measuring 2.5 cm × 5 cm × 5 cm (6 sets of 6; 1 set per animal) from 6 Australian short-term grain-finished *Bos indicus* crossbred cattle (aged 48 d postmortem) were shipped frozen, under vacuum to the Gordon W. Davis Meat Science Laboratory for use in the trial. One sample from each animal was used for proximate analysis, and the other 5 were used for consumer sensory evaluation.

The frozen steak pieces were sorted into a predetermined cook order. Thirty-six cooking group sets of 10 preselected steak pieces from across treatments were vacuum packaged and stored in the absence of light at −10°C before consumer evaluations. Steak preparation from the primal cuts, allocation to cooking order, and consumer allocation followed the MSA protocols (Gee, 2006).

Proximate Analysis

Proximate analyses were conducted to determine the chemical percentage of fat, moisture, protein, and collagen of each strip loin. A 2.5-cm-thick steak was removed from each strip loin at the time of fabrication of all US-sourced products. Samples were vacuum packaged and stored 1 d before proximate analysis. A single 2.5 cm × 5 cm × 5 cm steak piece was used for proximate analysis of Australian and Wagyu samples. Frozen Wagyu and Australian samples were thawed at 2 to 4°C for 24 h before proximate analysis.

All exterior fat and connective tissue were removed before proximate analysis, leaving only the LM. Each sample was coarse ground through a tabletop grinder to obtain an approximately 200-g sample. The ground sample was then placed in a sample tray for analysis. Proximate analysis was conducted using an AOAC-approved (official method 2007.04; Anderson, 2007) near infrared spectrophotometer (FoodScan, FOSS NIRsystems Inc., Laurel, MD). Fifteen independent readings were taken per sample and averaged for the final reported chemical value.

Preparation

Samples were thawed at 2 to 4°C for 24 h before consumer panel evaluation. All samples were prepared on a model S-143K Silex clamshell grill (Silex Grills Australia Pty. Ltd., Marrickville, Australia) with plate temperature set at 225°C. The grill was preheated 45 min before the start of panels to equilibrate and stabilize temperatures throughout the entire heating elements. At the start of each panel, a set of 10 starter sam-

ples was prepared on the grill immediately before the consumer samples. The grill was scraped to remove all baked-on grease and sprayed with a nonstick cooking spray immediately before placing each round of steaks on the grill. A strict time schedule was used to ensure all steaks were prepared identically. Additionally, using a regular time pattern to load and unload steak pieces should result in consistency of the heating elements (Gee, 2006). Ten sample steaks were prepared on the grill for each cooking round. Steaks were cooked for 5 min with the grill closed before being removed. Steaks were allowed to stand for 3 min before serving. After standing, each steak was cut in half into 2 equally sized rectangular pieces and served to 2 separate preselected consumers. The grill was allowed to stand empty for 75 s between cooking rounds for cleaning.

Panels

Consumer panels were conducted in the Texas Tech University Animal and Food Science Building. Consumer panelists (n = 120) were recruited from Lubbock and the surrounding communities, paid to participate in the study, and only allowed to participate once. Panels were conducted with 20 consumers per panel and lasted approximately 1 h. Three panels were conducted each night for 2 nights.

Each panelist was assigned to a numbered consumer booth and provided a ballot, plastic utensils, toothpicks, a napkin, an expectorant cup, a cup of water, and palate cleansers to use between samples (unsalted crackers and a 10% apple juice, 90% water solution). Before the start of each panel, panelists were given verbal instructions about the ballot and the procedure for the testing of samples, and each filled out a demographic questionnaire. Panelists were instructed to cut each sample using their utensils to a size representative of beef consumed in the home or in a restaurant. The panels were conducted in a large banquet room with tables that had been divided into individual sensory booths under fluorescent lighting. Each ballot contained a consent form, 7 sample ballots, and a postpanel survey concerning beef purchasing habits.

Consumers were served a total of 7 samples; a warm-up sample (USDA Select or Low Choice from the loins collected but not used in this experiment) followed by a sample from each USDA quality grade (USDA Prime to Standard) and either a Wagyu or Australian sample, in a predetermined balanced order in accordance with a 6 × 6 Latin square. This design provided a balance for frequency, order, and carryover effects (Watson et al., 2008). One-half of the consumers consumed a Wagyu sample, and the other one-half consumed an Australian sample. All samples were identified with an α-numeric code assigned by the MSA software (Gee, 2006). Each sample was rated on a 100-mm continuous-line scale for tenderness, juiciness, flavor liking, and overall liking. On the scale, 0 mm was verbally anchored at not tender, not juicy, dislike flavor extremely, and dislike overall extremely, and 100 mm was verbally anchored at very tender, very juicy, like flavor extremely, and like overall extremely. Each consumer was also asked to rate each sample as acceptable or unacceptable for each palatability trait. Additionally, consumers rated each sample as unsatisfactory, good everyday quality, better than everyday quality, or premium quality.

Statistical Analysis

Data were analyzed as a randomized block design using consumer as a random block. The fixed effect of quality treatment was analyzed using the MIXED procedure (SAS Inst. Inc., Cary, NC). Acceptability and steak quality data were analyzed using the GLIMMIX procedure of SAS. Significant differences were separated using the PDIFF option at $P < 0.05$. The CORR procedure of SAS was used for calculating Pearson correlations, and the FREQ procedure was used to summarize demographic and posttrial questionnaire data.

RESULTS

Demographic Profile of Consumers

To document the participants, the demographic profile of consumers is presented in Table 1. Miller et al. (2001) showed the preferences of beef consumers in Lubbock, Texas, were not different from those of beef consumers in Baltimore, Maryland/Washington, DC; Chicago, Illinois; Dallas/Fort Worth, Texas; or Los Angeles, California. Moreover, the demographics of the panelists in the current study were similar to the demographics of the United States as reported by the 2009 American Community Survey (US Census Bureau, 2009). More females participated in the study than males (53.6 vs. 46.4%), as compared with the US population which is composed of 50.7% females and 49.3% males (US Census Bureau, 2009). The median age of people living in the US was 36.8 yr (US Census Bureau, 2009), and the greatest percentage of consumers (41.9%) corresponded to the age grouping of 35 to 50 yr. The current study included slightly more Caucasians than the US population (80.5 vs. 74.8%) and fewer Asians (0.9 vs. 4.5%); however, the number of Hispanics was extremely similar to the US population (16.1 vs. 15.8%; US Census Bureau, 2009). The household income grouping that represented the median income level in the current study ($50,000 to $69,999), would also include the median household income of the US population, $50,221 (US Census Bureau, 2009). Consumers who participated in this survey had educational backgrounds similar to the US population. Slightly fewer consumers reported a high school diploma as their highest level of education completed as compared with the US population (18.5 vs. 28.5%); however, consumers in this study represented a similar number of college

Table 1. Demographic characteristics of consumers (n = 120) who participated in consumer sensory panels

Characteristic	Response	Percentage of consumers
Sex	Male	46.4
	Female	53.6
Household size	1 person	8.7
	2 people	30.4
	3 people	16.5
	4 people	27.0
	5 people	9.6
	6 people	3.5
	>6 people	4.4
Household income	Single income	32.1
	Dual income	67.9
Age, yr	Under 18	0.9
	18 to 34	28.2
	35 to 50	41.9
	Over 50	29.1
Ethnicity	Caucasian	80.5
	Native American	0.9
	Hispanic	16.1
	Asian	0.9
	Other	1.7
Average annual household income, $	<20,000	14.0
	20,000 to 29,999	5.0
	30,000 to 49,999	22.0
	50,000 to 69,999	20.0
	70,000 to 100,000	30.0
	>100,000	9.0
Highest level of education completed	No high school	3.4
	High school	18.5
	Some college	37.0
	College	25.2
	Postgraduate	16.0
Weekly beef consumption	None	0.8
	1 to 3 times	56.3
	4 to 6 times	34.5
	7 or more times	8.4

graduates (25.2 vs. 25.0%) as compared with the US population (US Census Bureau, 2009).

Purchasing Habits of Consumers

The beef purchasing habits of consumers who participated in the sensory panels are presented in Table 2. The USDA Choice steaks and roasts were the most popular grade purchased by consumers (38.3%) compared with 18.3% for USDA Select, 3.3% for USDA Prime, and 12.5% for store brand. Consumers indicated tenderness was the most important palatability trait when consuming beef steaks (58.0%) and roasts (54.7%). Flavor was listed as the most important palatability trait when consuming beef steaks by 31.9% of consumers and for 31.6% of consumers for beef roasts.

Proximate Analysis

Data from proximate analysis of steaks fed to consumers are presented in Table 3. Quality treatment affected ($P < 0.05$) fat level. The fat level in each quality treatment decreased as USDA quality grade decreased; however, no differences ($P > 0.05$) between USDA High Choice and Low Choice were found, nor between USDA Low Choice, Select, and Standard. Moisture was inversely related to fat content; however, significant differences in moisture were not always found between adjacent quality levels. Collagen content was affected ($P < 0.05$) by quality treatment. Wagyu steaks had greater collagen than all other quality treatments; however, Prime, High Choice, Low Choice, and Select did not differ ($P > 0.05$). Protein level was the least variable among the treatments; however, a decrease in protein was observed as fat content increased.

Tenderness

The effects of quality treatment on consumer sensory panel ratings are presented in Table 4. Wagyu, Prime, and High Choice samples had similar scores for tenderness and were rated more tender ($P < 0.05$) than the remaining quality treatments. Low Choice and Standard samples were rated higher ($P < 0.05$) in tender-

Table 2. Beef purchasing habits of consumers (n = 120) who participated in the consumer study

Purchasing habits	Response	Percentage of consumers
Consumer is the regular purchaser of beef in family	Yes	62.5
	No	37.5
Quality grades of beef steaks and roasts normally purchased	USDA Prime	3.3
	USDA Choice	38.3
	USDA Select	18.3
	Certified Angus beef	5.8
	Store brand	12.5
	Do not know	20.8
Most important palatability trait when consuming beef roasts	Flavor	31.9
	Tenderness	58.0
	Juiciness	10.1
Most important palatability trait when consuming beef steaks	Flavor	31.6
	Tenderness	54.7
	Juiciness	13.7
How often consumer has an excellent eating experience when eating steak in a restaurant	Always	3.3
	Almost always	37.5
	Some of the time	49.2
	Almost never	9.2
	Never	0.8

ness than Select and Australian samples. Consumers rated the Australian samples lower ($P < 0.05$) for tenderness than all other quality treatments. Consumer acceptability ratings by quality treatment are presented in Table 5. No differences ($P > 0.05$) in tenderness acceptability were detected among Wagyu, Prime, High Choice, Low Choice, and Standard samples, all rating more than 88% acceptable for tenderness. Select and Australian steak samples were the least acceptable ($P < 0.05$) for tenderness of all quality treatments studied.

Juiciness

A gradual decrease in juiciness was observed as fat content decreased (Table 4). No differences ($P > 0.05$) were found among the Low Choice, Select, and Standard samples. The Australian samples were rated the lowest ($P < 0.05$) in juiciness, despite having an intermediate fat content between the Select and Standard samples. No difference ($P > 0.05$) in juiciness acceptability was observed among the 5 quality treatments that were greatest in fat content (Table 5). The Australian samples were rated lowest ($P < 0.05$) in juiciness acceptability.

Flavor

Among US sourced beef, a decrease in flavor scores was observed as fat decreased (Table 4). Prime and High Choice samples were rated higher ($P < 0.05$) than all other US-sourced samples for flavor. Consumers rated Low Choice samples higher ($P < 0.05$) than Select and Standard samples for flavor. Consumers rated Wagyu samples similarly ($P > 0.05$) to High Choice and Low Choice samples for consumer flavor rating. Australian samples were rated lower ($P < 0.05$) for flavor than all other quality treatments. No differences ($P > 0.05$) in flavor acceptability were detected among Prime, High Choice, and Low Choice samples (Table 5). Wagyu samples were similar ($P > 0.05$) to Low

Table 3. Least squares means (±SEM) for percentage chemical fat, collagen, moisture, and protein for beef strip steaks (n = 27) used in consumer evaluations differing by quality treatment determined by proximate analysis[1]

	%			
Quality treatment	Fat	Collagen	Moisture	Protein
Wagyu	21.61^{a} (±0.91)	2.53^{a} (±0.09)	57.56^{a} (±0.71)	18.48^{a} (±0.24)
Prime	13.56^{b} (±1.28)	2.08^{b} (±0.13)	63.81^{b} (±1.01)	21.70^{b} (±0.34)
High Choice	7.21^{c} (±1.28)	1.93^{bc} (±0.13)	69.11^{c} (±1.01)	21.94^{b} (±0.34)
Low Choice	4.70^{cd} (±1.28)	1.76^{bcd} (±0.13)	70.24^{cd} (±1.01)	23.09^{c} (±0.34)
Select	3.00^{d} (±1.28)	1.71^{bcd} (±0.13)	71.31^{cde} (±1.01)	23.09^{c} (±0.34)
Standard	1.28^{d} (±1.28)	1.63^{cd} (±0.13)	73.57^{e} (±1.01)	23.40^{c} (±0.34)
Australian	2.29^{d} (±0.91)	1.56^{d} (±0.09)	71.75^{de} (±0.71)	23.10^{c} (±0.24)
P-value	<0.0001	<0.0001	<0.0001	<0.0001

$^{a-e}$Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Proximate analysis performed using a FoodScan (FOSS NIRsystems Inc., Laurel, MD).

Table 4. Least squares means (±SEM) for consumer (n = 120) sensory scores[1] for palatability traits of beef strip steaks varying by fat level

Quality treatment[2]	Tenderness	Juiciness	Flavor	Overall liking
Wagyu (21.61%)	75.99^{a} (±3.17)	80.88^{a} (±2.85)	69.27^{bc} (±2.93)	69.15^{bc} (±2.95)
Prime (13.56%)	79.57^{a} (±2.28)	78.33^{ab} (±2.03)	76.95^{a} (±2.09)	77.76^{a} (±2.13)
High Choice (7.21%)	74.16^{a} (±2.28)	73.59^{b} (±2.03)	71.93^{ab} (±2.09)	72.48^{ab} (±2.15)
Low Choice (4.70%)	63.78^{b} (±2.28)	61.60^{c} (±2.04)	66.44^{c} (±2.09)	63.27^{c} (±2.13)
Select (3.00%)	52.34^{c} (±2.28)	61.74^{c} (±2.03)	60.20^{d} (±2.09)	56.86^{d} (±2.14)
Standard (1.28%)	63.10^{b} (±2.28)	57.99^{c} (±2.03)	55.60^{d} (±2.09)	57.48^{d} (±2.14)
Australian (2.29%)	45.04^{d} (±3.17)	47.76^{d} (±2.81)	46.55^{e} (±2.88)	42.82^{e} (±2.92)
P-value	<0.0001	<0.0001	<0.0001	<0.0001

$^{a–e}$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]Fat percentage for each quality treatment listed in parentheses.

Choice, Select, Standard, and Australian samples for flavor acceptability.

Overall Liking

Overall liking scores decreased among US-sourced samples as fat level decreased from Prime to Standard; however, no difference ($P > 0.05$) was found between Select and Standard samples (Table 4). Prime and High Choice samples were rated the highest ($P < 0.05$), and Australian samples rated the lowest ($P < 0.05$) for overall liking. Consumers rated Wagyu samples similarly ($P > 0.05$) to High Choice and Low Choice samples for overall liking. No differences ($P > 0.05$) were detected among Prime, High Choice, and Low Choice samples for overall acceptability, all rating more than 91% acceptable (Table 5). Only Prime and High Choice samples were different ($P < 0.05$) from Wagyu samples for overall acceptability. Overall acceptability did not differ ($P > 0.05$) among Wagyu, Select, and Australian samples.

Consumer Perceived Quality Levels

The quality levels of samples as perceived by consumers for each treatment are presented in Table 6. Prime and High Choice samples were rated as good everyday quality, better than everyday quality, or premium quality more often ($P < 0.05$) than they were rated as unsatisfactory. Low Choice and Select samples were rated as good everyday quality more often ($P < 0.05$) than they were rated any other quality level. Australian samples were rated as unsatisfactory 33% of the time, a greater percentage ($P < 0.05$) of the time than the samples were rated as good everyday quality, better than everyday quality, or premium quality. No differences were detected among the percentage of Wagyu samples that were rated in each quality level. Overall, in US-sourced samples, a greater percentage of samples were rated as premium quality as fat level increased.

Correlations

Simple correlation coefficients for consumer sensory scores and proximate data are presented in Table 7. All correlation coefficients were significant ($P < 0.05$). Fat percentage was correlated to consumer overall liking rating (r = 0.28), consumer tenderness rating (r = 0.31), consumer flavor liking (r = 0.25), and consumer juiciness rating (r = 0.37). All consumer ratings were highly correlated with each other, with overall liking most highly correlated to flavor liking (r = 0.88).

DISCUSSION

Results of the current study are consistent with previous findings from both trained and consumer sensory panels of beef differing in marbling level. Many stud-

Table 5. Percentage (±SEM) of samples for tenderness, juiciness, flavor, and overall liking rated as acceptable by consumers (n = 120) for beef strip steaks varying by fat level

Quality treatment[1]	Tenderness	Juiciness	Flavor	Overall liking
Wagyu (21.61%)	96.67^{a} (±2.86)	98.31^{a} (±1.68)	83.05^{bc} (±4.88)	82.76^{bcd} (±4.96)
Prime (13.56%)	95.83^{a} (±1.82)	96.67^{a} (±1.64)	97.50^{a} (±1.43)	95.83^{a} (±1.82)
High Choice (7.21%)	90.83^{a} (±2.63)	96.67^{a} (±1.64)	94.17^{a} (±2.14)	94.17^{a} (±2.14)
Low Choice (4.70%)	88.24^{a} (±2.95)	92.44^{ab} (±2.42)	92.44^{ab} (±2.42)	91.60^{ab} (±2.54)
Select (3.00%)	71.67^{b} (±4.11)	89.17^{ab} (±2.84)	85.83^{bc} (±3.18)	78.99^{cd} (±3.73)
Standard (1.28%)	88.24^{a} (±2.95)	86.55^{b} (±3.13)	85.71^{bc} (±3.21)	84.75^{bc} (±3.31)
Australian (2.29%)	68.33^{b} (±6.01)	78.33^{c} (±5.32)	76.67^{c} (±5.46)	70.00^{d} (±5.92)
P-value	<0.0001	0.0004	0.0007	<0.0001

$^{a–d}$Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Fat percentage for each quality treatment listed in parentheses.

Table 6. Percentage (±SEM) of samples of beef strip steaks varying by fat level rated at different perceived quality levels by consumers (n = 120)

Quality treatment[1]	Unsatisfactory	Good everyday quality	Better than everyday quality	Premium quality	*P*-value
Wagyu (21.61%)	16.67 (±4.81)	26.67 (±5.71)	21.67 (±5.32)	35.00 (±6.16)	0.1296
Prime (13.56%)	4.17^{a} (±1.82)	25.83^{b} (±4.00)	34.17^{b} (±4.33)	35.83^{b} (±4.38)	<0.0001
High Choice (7.21%)	6.67^{a} (±2.28)	37.50^{b} (±4.42)	25.00^{c} (±3.95)	30.83^{bc} (±4.22)	<0.0001
Low Choice (4.70%)	12.50^{a} (±3.02)	52.50^{b} (±4.56)	20.83^{a} (±3.71)	14.17^{a} (±3.18)	<0.0001
Select (3.00%)	20.00^{a} (±3.65)	50.83^{b} (±4.56)	18.33^{a} (±3.53)	10.83^{a} (±2.84)	<0.0001
Standard (1.28%)	18.33^{a} (±3.53)	47.50^{b} (±4.56)	27.50^{a} (±4.08)	6.67^{c} (±2.28)	<0.0001
Australian (2.29%)	33.33^{a} (±6.09)	55.00^{b} (±6.42)	10.00^{c} (±3.87)	1.67^{c} (±1.65)	<0.0001

$^{a–c}$Least squares means in the same row without a common superscript differ ($P < 0.05$).

[1]Fat percentage of quality treatment listed in parentheses.

ies have shown increased marbling level was associated with greater tenderness, juiciness, flavor, and overall palatability scores (Smith et al., 1985; Lorenzen et al., 1999, 2003; Garmyn et al., 2011). In the current study, a decrease in juiciness was observed as fat content decreased from Wagyu to Standard. However, consumers rated Australian samples drier than all other treatments despite a numerically intermediate fat percentage to Select and Standard. In this instance, it seems plausible that differences in tenderness or flavor may have influenced the ratings of consumers for juiciness.

The greater fat content samples (Wagyu, Prime, and High Choice) all rated higher for tenderness than the lower fat samples (Low Choice, Select, Standard, and Australian). However, only limited differences were found in tenderness acceptability among all treatments. Despite the longer aging time (48 d postmortem), Australian samples were rated tougher and less acceptable for tenderness than all other quality treatments. Wagyu samples were the same for tenderness acceptability as all US-sourced product, but were aged for a shorter period of time (17 vs. 22 d postmortem). The effect of fat level on tenderness was less pronounced than the effect of fat level on the other palatability traits, most likely due to many other physiological traits known to affect tenderness that were not measured in this trial.

Fat content had a large effect on flavor and overall liking ratings. In the US-sourced samples, a clear linear decrease in flavor rating was shown as fat level decreased from Prime to Standard, though not significantly different at each successive decrease in quality grade. No differences were found between Wagyu and Prime samples for tenderness and juiciness ratings as well as their percent acceptability, yet Wagyu samples were scored substantially lower for flavor and overall liking ratings as well as for flavor acceptability and overall acceptability. These results possibly demonstrate an upper limit for fat content as in the window of acceptability by Savell and Cross (1988). The same was observed in the US-sourced samples; no differences were found between Low Choice and Standard samples for tenderness and juiciness, with Low Choice samples scoring higher in flavor and overall liking than Standard samples. The higher flavor ratings for Low Choice samples and the lower flavor ratings for Wagyu samples affected their overall liking rating more than both tenderness and juiciness ratings. Moreover, Select steaks were rated lower in tenderness and tenderness acceptability compared with Standard samples; however, overall liking did not differ between these grades. These results indicated that flavor, and potentially juiciness, were capable of compensating for inferior tenderness at lower fat levels. Savell and Cross (1988) proposed the minimum fat percentage required for acceptable palatability of beef loin cuts was 3%; however, overall liking and acceptability did not differ between Select and Standard in the current study.

Exceptions to the relationship between increased fat content and increased flavor ratings occurred in the Wagyu and Australian samples. The Wagyu had 8% more fat than the Prime samples yet scored the same as High and Low Choice for flavor. These results may

Table 7. Simple correlation coefficients for consumer sensory scores and proximate data for beef strip steaks varying in fat level[1]

Item	Overall liking	Tenderness	Juiciness	Flavor	% Fat	% Collagen	% Moisture
Tenderness	0.76						
Juiciness	0.73	0.70					
Flavor	0.88	0.63	0.60				
% Fat	0.28	0.31	0.37	0.25			
% Collagen	0.24	0.28	0.33	0.20	0.92		
% Moisture	−0.27	−0.29	−0.35	−0.24	−0.99	−0.90	
% Protein	−0.17	−0.22	−0.30	−0.14	−0.87	−0.87	0.84

[1]All correlation coefficients were significant ($P < 0.05$).

suggest the greater fat content of Wagyu has breached the window of consumer acceptability and flavor liking. Savell and Cross (1988) observed a plateau in overall palatability when fat content increased above 7%. The Australian samples had a similar fat content to the Low Choice, Select, and Standard samples and yet scored significantly lower for flavor than all treatments. These differences could be caused by differences in animal diet, breeding, postmortem aging time, off-flavor development during transportation from Australia to the United States, or another unknown factor. The exact diet composition was not known because the product was sourced from commercial abattoirs; however, beef from cattle fed different diets have different flavor profiles (Killinger et al., 2004a; Sitz et al., 2005). In support of the current results, Killinger et al. (2004a) reported consumers rated domestic steaks higher for flavor, juiciness, tenderness, and overall acceptability compared with Argentine beef although fat content and Warner-Bratzler shear force were similar. Killinger et al. (2004a) attributed these differences to feeding practices and aging time. Moreover, the Australian grain fed cattle in the current study were exposed to a much shorter finishing period (approximately 70 d) than typically observed in US feedlots. These differences could explain some of the variation in flavor ratings observed between Australian-sourced product and US product with similar fat content.

Overall liking was most highly correlated with flavor liking. These findings are similar to the findings of previous studies (Huffman et al., 1996; Neely et al., 1998; Killinger et al., 2004a,b). Consumers stated tenderness was the most important palatability trait when consuming beef steaks and roasts; however, results of the current study showed that the same consumer group appeared to place more emphasis on flavor liking when rating overall liking. These results align with Huffman et al. (1996), who found 51% of consumers stated tenderness was the most important palatability trait, but reported that flavor accounted for the most variation in overall palatability scores. This indicated that consumers may perceive tenderness as the most important palatability trait, but in practice flavor may be the major determining factor of overall palatability.

Increased fat content in beef had a positive effect on the palatability traits of tenderness, juiciness, flavor, and overall liking of beef steaks. Flavor liking was the most highly correlated palatability trait with overall liking of beef. When scoring samples for overall liking, consumers appeared to place more emphasis on flavor liking compared with tenderness or juiciness. In this study, fat content contributed the most in determining the flavor liking of beef raised in US commercial feeding systems. However, other factors affecting flavor liking may be important when animal diet, genetics, breed type, and meat handling practices are not similar. Further studies are needed to examine why Australian sourced samples were rated lower for flavor than US-sourced samples with similar fat contents.

LITERATURE CITED

Anderson, S. 2007. Determination of fat, moisture, and protein in meat and meat products using the FOSS FoodScan near-infrared spectrophotometer with FOSS Artificial Neural Network Calibration Model and Associated Database: Collaborative study. J. AOAC Int. 90:1073–1083.

Dikeman, M. E. 1987. Fat reduction in animals and the effects on palatability and consumer acceptance of meat products. Pages 93–103 in Recip. Meat Conf.

Garmyn, A. J., G. G. Hilton, R. G. Mateescu, J. B. Morgan, J. M. Reecy, R. G. Tait Jr., D. C. Beitz, Q. Duan, J. P. Schoonmaker, M. S. Mayes, M. E. Drewnoski, Q. Liu, and D. L. VanOverbeke. 2011. Estimation of relationships between mineral concentration and fatty acid composition of longissimus muscle and beef palatability traits. J. Anim. Sci. 89:2849–2858.

Gee, A. 2006. Protocol Book 4: For the thawing preparation, cooking and serving of beef for MSA [Meat Standards Australia] pathway trials. Meat and Livestock Australia, North Sydney.

Huffman, K. L., M. F. Miller, L. C. Hoover, C. K. Wu, H. C. Brittin, and C. B. Ramsey. 1996. Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. J. Anim. Sci. 74:91–97.

Killinger, K. M., C. R. Calkins, W. J. Umberger, D. M. Feuz, and K. M. Eskridge. 2004a. A comparison of consumer sensory acceptance and value of domestic beef steaks and steaks from a branded, Argentine beef program. J. Anim. Sci. 82:3302–3307.

Killinger, K. M., C. R. Calkins, W. J. Umberger, D. M. Feuz, and K. M. Eskridge. 2004b. Consumer sensory acceptance and value for beef steaks of similar tenderness, but differing in marbling level. J. Anim. Sci. 82:3294–3301.

Lorenzen, C. L., R. K. Miller, J. F. Taylor, T. R. Neely, J. D. Tatum, J. W. Wise, M. J. Buyck, J. O. Reagan, and J. W. Savell. 2003. Beef customer satisfaction: Trained sensory panel ratings and Warner-Bratzler shear force values. J. Anim. Sci. 81:143–149.

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: Cooking method and degree of doneness effects on top loin steaks. J. Anim. Sci. 77:637–644.

Miller, M. F., M. A. Carr, C. B. Ramsey, K. L. Crockett, and L. C. Hoover. 2001. Consumer thresholds for establishing the value of beef tenderness. J. Anim. Sci. 79:3062–3068.

Miller, M. F., K. L. Huffman, S. Y. Gilbert, L. L. Hamman, and C. B. Ramsey. 1995. Retail consumer acceptance of beef tenderized with calcium chloride. J. Anim. Sci. 73:2308–2314.

NAMP. 2010. The Meat Buyer's Guide. 6th ed. North American Meat Processors Association, Reston, VA.

Neely, T. R., C. L. Lorenzen, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1998. Beef customer satisfaction: Role of cut, USDA quality grade, and city on in-home consumer ratings. J. Anim. Sci. 76:1027–1033.

Platter, W. J., J. D. Tatum, K. E. Belk, P. L. Chapman, J. A. Scanga, and G. C. Smith. 2003. Relationships of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. J. Anim. Sci. 81:2741–2750.

Polkinghorne, R. J. 2007. Targeting the consumer demand for beef in Australia, Japan, Korea, Ireland, and the United States. Pages 27–33 in Proc. 60th Recip. Meat Conf., Brookings, SD. Am. Meat Sci. Assoc., Champaign, IL.

Savell, J. W., R. E. Branson, H. R. Cross, D. M. Stiffler, J. W. Wise, D. B. Griffin, and G. C. Smith. 1987. National consumer retail beef study: Palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. 52:517–519.

Savell, J. W., and H. R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. Pages 345–355 in Designing Food: Animal Product Options in the Marketplace. Natl. Acad. Press, Washington, DC.

Sitz, B. M., C. R. Calkins, D. M. Feuz, W. J. Umberger, and K. M. Eskridge. 2005. Consumer sensory acceptance and value of

domestic, Canadian, and Australian grass-fed beef steaks. J. Anim. Sci. 83:2863–2868.

Smith, G. C., Z. L. Carpenter, H. R. Cross, C. E. Murphey, H. C. Abraham, J. W. Savell, G. W. Davis, B. W. Berry, and F. C. Parrish Jr. 1985. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7:289–308.

US Census Bureau. 2009. 2009 American Community Survey. Accessed Apr. 7, 2011. http://www.census.gov/acs/www/.

USDA. 1997. United States standards for grades of carcass beef. A. M. Service, ed. USDA, Washington, DC.

Voges, K. L., C. L. Mason, J. C. Brooks, R. J. Delmore, D. B. Griffin, D. S. Hale, W. R. Henning, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, R. K. Miller, J. B. Morgan, B. E. Baird, B. L. Gwartney, and J. W. Savell. 2007. National beef tenderness survey–2006: Assessment of Warner-Bratzler shear force and sensory panel ratings for beef from US retail and foodservice establishments. Meat Sci. 77:357–364.

Watson, R., A. Gee, R. Polkinghorne, and M. Porter. 2008. Consumer assessment of eating quality—Development of protocols for Meat Standards Australia (MSA) testing. Aust. J. Exp. Agric. 48:1360–1367. Accessory publication available at http://www.publish.csiro.au/nid/72/issue/4061.htm.