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Descriptive Beef Flavor Attributes and Consumer Acceptance Relationships for Heavy Beef Eaters[†]

Rhonda K. Miller[1]*, Rachel A. Gray[2], Chris R. Kerth[1], Koushik Adhikari[3], and Jay Neal[4]

[1]Department of Animal Science, Texas A&M University, College Station, TX, USA
[2]Tyson Foods, Springdale, AR, USA
[3]Department of Food Science and Technology, University of Georgia Griffin, Griffin, GA, USA
[4]University of Houston, Houston, TX, USA
[†]Funding for this research was provided by the Beef Checkoff.
*Corresponding author. Email: rmiller@tamu.edu (Rhonda K. Miller)

Abstract: Differences in beef flavor attributes were created using beef cuts (Choice *M. gluteus medius* (GM) steaks; Choice *M. biceps femoris* (BF) roasts; Select BF roasts; Choice *M. longissimus lumborum* (LM) steaks, and high pH LM steaks), cooking method, and internal cook temperature endpoint (END). Steaks were cooked to 58°C and 80°C END utilizing either a George Foreman clamshell grill (GF) or a flat top electric food-service grill (GRILL). Roasts were cooked at low temperatures using a Crock-Pot (CP) cooking to 58°C and 80°C END. Thirty-seven flavor descriptive attributes were evaluated by an expert, trained descriptive beef flavor panel. Heavy beef eaters were recruited in Houston, TX; Olathe, KS; Philadelphia, PA; and Portland, OR. Consumers evaluated overall, flavor, beef flavor, and grill flavor liking using 9-point hedonic scales and beef flavor, grill flavor and off-flavor intensity using 9-point intensity scales. Steaks and roasts differed in descriptive and consumer attributes ($P < 0.05$). Treatments with higher levels of fat-like, salt, beef identity, and brown/roasted flavor attributes had higher consumer liking ratings (Choice LM or GM GRILL steaks cooked to 58°C or 80°C and Choice GM GRILL steaks cooked to 80°C). Select and Choice BF CP roasts cooked to 58°C or 80°C, Choice GM GF steaks cooked to 80°C, and high pH LM GF steaks cooked to 80°C had the lowest consumer liking scores and higher levels of warmed-over flavor, cardboardy, and liver-like flavor attributes. Heavy beef consumers segmented into 4 classes. Class 4 consumers liked beef regardless of treatment, whereas Class 3 consumers were discerning. Heavy beef eaters discerned differences in beef flavor attributes, and beef flavor was a driver of consumer liking.

Key words: beef, flavor, consumer, sensory
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Introduction

Understanding drivers of consumer acceptance for beef is critical to sustaining beef demand and improving consumer satisfaction. Researchers have identified that beef flavor is a critical component of consumer acceptability (Miller et al., 1995; Huffman et al., 1996; Reicks et al., 2011). Additionally, Huffman et al. (1996) found that flavor accounted for 67% of the variation in overall consumer beef palatability in an in-home consumer study. One of the challenges in understanding beef flavor is that beef flavor is not a single sensory attribute. Flavor is composed of basic tastes on the tongue, flavor aromatics detected by the olfactory bulb during chewing, and aromas identified by drawing air into the nose and then detected by the olfactory bulb. To more fully understand the complexity of beef flavor, Adhikari et al. (2011) identified trained descriptive flavor attributes for whole muscle beef cuts. Although this is a living lexicon, and other attributes may be present in some beef samples, major and minor attributes were identified. Although these attributes provide a method of identifying individual flavor attributes in beef, understanding if descriptive beef flavor attributes are related to consumer liking has not been fully examined.

Drivers of liking for heavy beef eaters, or consumers who eat beef 3 or more times per week, has not been fully elucidated. Understanding what flavor attributes are related to heavy beef eater consumer liking will provide the beef industry with information on how to target increased consumption of beef by these consumers. In our study, 16 treatments were utilized that have been shown to affect beef flavor. Differences in flavor across beef muscles have been examined (McKeith et al., 1985; Belk et al., 1993; Carmark et al., 1995; Luchak et al., 1998). Additionally, cooking method and internal cook temperature endpoint has been shown to impact beef flavor (Cross et al., 1976; Belk et al., 1993; Berry, 1993; Luchak et al., 1998; Modzelewska-Kapituła et al., 2012; Sepulveda et al., 2019). Our objective was not to fully elucidate how muscle, cooking method, or internal cook temperature affected flavor but to use these treatments to create differences in beef flavor to determine what descriptive flavor attributes were drivers of consumer overall liking and other consumer sensory attributes.

In this study, 3 beef muscles (Choice (Ch) *M. gluteus medius* (GM), Ch and Select (Se) *M. biceps femoris* (BF), Ch *M. longissimus lumborum* (LM) and high pH (>6.0 pH) LM muscles) were used and cooked to 2 internal cooked temperature endpoints (58°C and 80°C) to induce differences in beef flavor attributes. Beef BF muscles were cut into roasts and cooked using a low-temperature, slow cooking method (Crock-Pot (CP)). GM and LM muscles were cut into steaks and cooked to 1 of 2 internal cooked temperature endpoints (58°C and 80°C) using either a George Foreman clamshell grill (GF) or a flat top electric food-service grill (GRILL). The intent of these cooking methods was to create beef cuts that differed in flavor attributes and consumer acceptance. The objective was to determine descriptive flavor attributes and to evaluate consumer sensory attributes for liking and intensity of flavors of beef from these 16 treatments and then to evaluate the relationships between descriptive beef flavor attributes and consumer liking for heavy beef eaters.

Materials and Methods

This project was approved by the Texas A&M University Institutional Review Board (IRB2012-3017) and the Drexel University Institutional Review Board (IRB1301001768) for use of human subjects in research.

Sample selection and preparation

On one selection day at a commercial beef processor in Texas, 10 USDA Ch, 10 USDA Se, and 10 high pH (>6.0) beef carcasses were selected based on USDA Quality grade (USDA, 1996) assigned by USDA graders. Carcass pH was determined in duplicate (pH meter calibrated daily with 4.0 and 7.0 pH buffer solutions; Model IQ150, IQ Scientific Instrument, Inc., Carlsbad, CA) by inserting the probe in 2 random locations in the lean surface of the *M. longissimus thoracic* muscle at the 12th rib. From the Ch carcasses, the strip loin (IMPS 180), top sirloin butt (IMPS 184), and bottom round (IMPS 171B) subprimals were selected (2 per carcass). The bottom round subprimals (IMPS 171B) were obtained from Se carcasses and the strip loin subprimals (IMPS 180) were selected from the high pH carcasses (2 per carcass). Vacuum-packaged subprimals (Cryovac, Sealed Air Corporation, Charlotte, NC; oxygen transmission rate of 3 to 6 cc at 4°C (m^2, 24 h at 4°C, 0% relative humidity (RH); water vapor transmission rate of 0.5 to 0.6 g at 38°C (100% RH, 0.6 m^2, 24 h))) were shipped under refrigeration (2°C ± 1°C) to the Rosenthal Meat Science and Technology Center at Texas A&M University. Subprimals were stored for 14 d post carcass fabrication at 2°C. From the strip loins, the LM muscle was removed and the GM was fabricated from the top sirloin butts. The BF was obtained from each bottom round subprimal. These cuts were selected to differ in flavor based on previous research (Miller and Kerth, 2012). The LM and GM muscles within a carcass were cut into 20 steaks (Ch LM, Ch GM, high pH LM; 2.54 cm thick with 0.25 cm external fat), and the BF muscles were cut into 10 roasts (Se and Ch BF; 1.3 kg with no external fat). Steaks within a carcass were randomly assigned so that 10 steaks were assigned to 1 of 2 cooking methods (GF or GRILL with a 2.54-cm-thick flat top Star-Max 536TGF 91.44 cm Countertop Electric Griddle; Star International Holdings Inc., St. Louis, MO) and within the cooking method, 5 steaks were assigned to 1 of 2 internal cook temperature endpoints (58°C or 80°C). For roasts, 5 roasts per carcass were randomly assigned to 1 of 2 internal cook temperature endpoints (58°C or 80°C). This resulted in steaks and roasts segmented into 16 treatments. Of the 5 steaks or roasts per carcass and treatment, 1 steak or roast was randomly assigned to trained descriptive flavor evaluation and 4 steaks or roasts were randomly assigned to consumer evaluation in 1 of 4 cities (Philadelphia, PA; Houston, TX; Olathe, KS; or Portland, OR). These treatments were defined to create differences in beef flavor attributes and to induce differences in Maillard reaction products and heat-induced lipid oxidation. Steaks and roasts were vacuum-packaged, frozen, and stored at −40°C until evaluated (B2470, Cryovac, Sealed Air Corporation; oxygen transmission rate of 3 to 6 cc at 4°C (m^2, 24 h at 4°C, 0% RH; water vapor transmission rate of 0.5 to 0.6 g at 38°C (100% RH, 0.6 m^2, 24 h))).

Expert, trained descriptive beef flavor analysis

Steaks and roasts were evaluated by an expert trained beef flavor descriptive attribute panel that helped develop and validate the whole muscle beef flavor lexicon (Adhikari et al., 2011) and as defined by AMSA (2016). Panelists ($n = 5$) were retrained using the attributes (0 = none and 15 = extremely intense) defined by Adhikari et al. (2011) for 10 d. Flavor aromatics were beef identity, brown/roasted, bloody/serumy, fat-like, metallic, liver-like, overall sweet, cardboardy, warmed-over flavor, sour milk/sour dairy, green hay-like, barnyard, rancid, heated oil, blue cheese, chemical, cumin, refrigerator stale, butter, soapy, chocolate, spoiled, dairy, medicinal, smoky wood, petroleum, painty, and fishy and basic tastes were umami, sweet, salty, sour, and bitter. Validation was conducted using 12 beef samples from the study in which panelists received the samples at least 2 times. Data were analyzed using the general linear model (GLM) procedure of SAS (v. 9.3, SAS Institute, Cary, NC) with panelists as an experimental unit and treatment by panelist as the main effect. Across attributes, if the panelist by treatment effect was nonsignificant ($P > 0.05$), it was determined that the panel was consistent. After training, panelists were presented 12 samples per day. Prior to the start of each trained panel evaluation day, panelists were calibrated using one orientation or “warm up” sample that was evaluated and discussed orally. After evaluation of the orientation sample, panelists were served the first sample of the session and asked to individually rate the sample for each beef flavor attribute. Double distilled water, unsalted saltine crackers, and ricotta cheese were available for cleansing the palette between samples. During evaluation, panelists were seated in individual breadbox-style booths separated from the preparation area, and samples were evaluated under red lights. In order to prevent taste fatigue, each evaluation day was divided into 2 sessions, with a 10-min break between sessions, and samples were served at least 4 min apart. Panelists evaluated the 12 samples over 2 h.

Steaks and roasts were randomly assigned to sensory panel day. Steaks were cooked either on a George Foreman clamshell grill (GF; George Foreman Precision Grill-Model GRP99/Applica Consumer Products Inc., Miramar, FL) set at 190°C or flat top grill (GRILL; 2.54-cm-thick flat top Star Max 536TGF 91.44cm Countertop Electric Griddle; Star International Holdings Inc.) at 232°C. Roasts were cooked in a Crock-Pot Manual Slow Cooker (Jarden Corporation, Inc., Boca Raton, FL) oval 5.67 L on the high setting. For CP cooking, 0.5 L of distilled water was added, and the lid was placed over the CP. This was to induce a high moisture environment to limit Maillard reactions. Internal temperatures were monitored by iron-constantan thermocouples (Omega Engineering, Norwalk, CT) inserted into the steak or roast geometric center. Temperatures were displayed using an Omega HH501BT Type T thermometer (Omega Engineering).

After cooking, samples were cut into 1.27 × 1.27 × 2.54 sections. Two sections per sample randomly were selected and served in clear plastic soufflé cups tested to ensure that they did not impart flavors in the samples. Samples were identified with random 3-digit codes and served in random order. Samples were cut and served immediately to ensure samples were approximately 60°C ± 2°C upon time of serving.

Consumer evaluation

Consumers ($n = 80$ per city) were randomly selected in 4 cities (Houston, TX; Olathe, KS; Philadelphia, PA; and Portland, OR) so that geographical areas represented the south, midwest, east coast, and west coast. In each city, 4 consumer sessions with approximately 20 consumers per session were conducted. After completion of each consumer session, 5 consumers ($n = 20$ consumers per city) were asked to participate in one-on-one interviews to determine attitudes toward beef and beef flavor (data not presented).

Consumer panelists were recruited by the individual research institution, and all panelists were required to pass a consumer screener guaranteeing them to be over 18 y of age, have no food allergies, and consume beef 3 or more times per week. Consumers ($n = 22$) responded that they ate beef 3 or more times per week to the screener but indicated lower consumption on the demographic questions. These consumers were removed from analyses. On the day of evaluation, recruited consumer panelists were asked to sign an informed consent document. An instructional document, demographic ballot, and 8 individual sample ballots were provided to each consumer upon entering the testing room. Consumer demographics for age, sex, income, household income, type of employment, dietary restrictions, protein sources consumed, meat consumption levels of beef, and meat shopping habits were determined. The ballot included overall liking, overall flavor liking, beefy flavor liking and intensity, grilled flavor liking and intensity, and off-flavor intensity rankings using a 9-point end- and centered-anchored hedonic or end-anchored intensity scales. Open-ended questions to list any additional positive flavors and negative flavors were asked after evaluation of each sample. Panelists were provided 8 preidentified random samples in a predetermined random order 4 min apart. Samples were served in clear plastic weigh boat containers labeled with a random 3-digit number corresponding to their ballot. Samples were cut and prepared as defined for expert trained beef flavor descriptive analysis.

Statistical analyses

The trained panel descriptive flavor attributes were analyzed using Proc GLM of SAS (v. 9.3, SAS Institute) to understand what chemical attributes drive specific beef flavor attributes. A predetermined alpha of $P < 0.05$ was used in all analyses. For descriptive sensory data, the effect of panelist by treatment was examined using Proc GLM, and because interactions were not reported, data were averaged across panelists. Sensory day and order served were defined as random variables and treatment ($n = 16$) was defined as the fixed effect. For consumer data, normality of data was examined using the Box-Cox function of SAS (v. 9.3, SAS Institute). Overall, flavor, and beef flavor liking were not normally distributed and were transformed by 1.4, 1.3, and 1.4 logs, respectively. Level of beef flavor also was not normally distributed and was transformed 1.4 log. Treatment and the treatment by city interaction were included as fixed effects. Order served and consumer within city were defined as random variables in the analyses. Least-squares means were calculated, and the pdiff function of SAS was used to determine differences between least-squares means when significance ($P < 0.05$) was defined in analysis of variance. Least-squares means and root mean square errors for transformed data were converted back to 1 log for ease of interpretation. Consumer demographic data were analyzed using the Proc Freq function of SAS.

Principal component analysis (PCA) and agglomerative hierarchical cluster analysis (AHCA) were conducted using XLSTAT (v. 2013, Lumivero, Denver, CO). Data were averaged across treatments for PCA analyses. Pearson correlations were used to remove cross correlations within the data. Factors 1 and 2 were presented in bi-plots. For the AHCA, data were averaged across consumer and 4 classes were defined. Classes were used as fixed effects using SAS as previously defined with consumer class and treatment and their interaction as fixed effect for consumer sensory attributes. This analysis was conducted to understand how consumers varied in their evaluation of beef treatments and to further understand drivers of liking.

Results and Discussion

Descriptive flavor attributes

Beef flavor attributes as defined by Adhikari et al. (2011) were evaluated. Green hay-like, barnyard, rancid, heated oil, blue cheese, chemical, cumin, refrigerator stale, butter, soapy, chocolate, spoiled, dairy, medicinal, smoky wood, petroleum, painty, and fishy aromatics were not present at levels greater than 0.1 on a 16-point scale, and therefore, data were not presented. This was expected as most of the aforementioned attributes are associated with spoilage or preharvest nutrition or handling effects. Our intent was to provide consumers with commodity, grain-fed beef within acceptable shelf-life that would be similar to beef purchased at retail.

Treatment affected beef flavor attributes (Table 1). Beef identity, brown/roasted, bloody/serumy, fat-like, metallic, liver-like, overall sweet, cardboardy, and sour milk/sour dairy flavor aromatics; and umami, sweet, salty, sour and bitter basic tastes differed ($P < 0.05$) across treatments. For top sirloin or GM steaks, steaks that were GRILL and cooked to an internal temperature of 80°C had higher levels of beef identity and brown/roasted flavor aromatics and the highest levels of umami compared with other beef samples. Beef identity has been shown to be the predominant flavor in beef top loin and sirloin steaks (Carmack et al., 1995; Grayson et al., 2016; Miller et al., 2019). Additionally, beef identity was highly related to brown/roasted and umami flavor attributes in steaks as similarly reported in this study. Top sirloin steaks cooked to 58°C, regardless of cooking method, had higher levels of bloody/serumy flavor attributes. Top sirloin steaks cooked using a GF grill to 80°C had lower fat-like flavor

Table 1. Beef flavor attribute least-squares means[g] in which 0 = none and 15 = extremely intense from Adhikari et al. (2011) for 16 treatments that differed in beef cut, cooking method, USDA grade, pH, and internal cooked temperature endpoint

Treatment	Beef Identity	Brown/ Roasted	Bloody/ Serumy	Fat-Like	Metallic	Liver-Like	Basic Taste: Umami	Basic Taste: Sweet	Basic Taste: Sour	Basic Taste: Salty	Basic Taste: Bitter
***P* Value**[f]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.02	<0.0001	<0.0001	<0.0001	<0.0001	0.006
Choice GM Steaks											
GF, 58°C	9.4[ab]	0.9[abcd]	3.3[e]	1.4[de]	2.8[d]	0.1[a]	0.3[a]	0.2[a]	2.6[e]	1.2[bc]	1.9[b]
GF, 80°C	10.2[bcd]	1.1[bcd]	1.7[b]	0.9[ab]	2.1[bc]	0.1[ab]	0.7[b]	0.5[b]	2.1[de]	1.2[b]	1.7[b]
GRILL, 58°C	9.7[abc]	1.1[bcd]	3.0[e]	1.5[de]	2.9[d]	0.1[a]	0.2[a]	0.3[ab]	2.7[e]	1.2[bc]	1.8[b]
GRILL, 80°C	11.6[f]	2.5[e]	1.7[b]	1.0[abcd]	2.1[b]	0.0[a]	0.9[bc]	0.5[b]	2.1[d]	1.2[bc]	1.6[b]
Choice BF Roasts											
CP, 58°C	9.9[bc]	0.5[a]	2.7[de]	1.1[bcd]	2.6[d]	0.3[ab]	0.8[bc]	0.6[bc]	2.2[de]	1.3[bc]	1.7[b]
CP, 80°C	11.0[def]	1.2[cd]	1.1[ab]	1.0[abc]	1.7[a]	0.2[ab]	1.2[c]	0.7[bc]	1.4[bc]	1.4[c]	1.3[a]
Select BF Roasts											
CP, 58°C	9.2[a]	0.4[a]	2.3[ce]	1.0[abc]	2.5[c]	0.0[a]	0.7[b]	0.4[ab]	2.5[e]	1.3[bc]	1.8[b]
CP, 80°C	11.3[ef]	0.9[abcd]	0.9[a]	1.0[abc]	1.7[a]	0.4[b]	1.3[c]	0.7[bc]	1.4[bc]	1.2[b]	1.4[ab]
Choice LM Steak											
GF, 58°C	10.1[bcd]	0.8[abc]	2.5[de]	1.3[cd]	2.6[cd]	0.0[a]	0.5[ab]	0.6[bc]	2.1[de]	1.3[bc]	1.5[ab]
GF, 80°C	10.8[def]	0.9[abcd]	1.6[b]	1.2[cd]	2.0[ab]	0.4[b]	1.1[c]	0.6[bc]	2.0[cd]	1.3[bc]	1.5[ab]
GRILL, 58°C	10.4[cde]	1.4[d]	2.7[e]	1.5[de]	2.5[cd]	0.0[a]	0.6[ab]	0.5[bc]	2.2[de]	1.3[bc]	1.4[ab]
GRILL, 80°C	11.4[ef]	2.2[e]	1.8[b]	1.3[d]	2.2[b]	0.1[a]	1.1[c]	0.8[c]	1.7[c]	1.5[bc]	1.6[b]
High pH LM Steaks											
GF, 58°C	8.8[a]	0.6[ab]	2.7[e]	1.6[e]	2.2[bc]	0.0[a]	0.4[ab]	0.7[bc]	1.3[ab]	1.0[ab]	1.6[b]
GF, 80°C	9.7[abc]	1.0[abcd]	1.5[ab]	1.3[d]	1.6[a]	0.2[ab]	0.5[ab]	0.6[bc]	1.3[bc]	1.0[ab]	1.7[b]
GRILL, 58°C	8.8[a]	0.6[ab]	2.7[e]	1.6[de]	2.2[bc]	0.0[a]	0.3[ab]	0.6[bc]	1.3[b]	1.0[a]	1.7[b]
GRILL, 80°C	11.1[def]	2.1[e]	1.6[b]	1.9[e]	1.7[a]	0.0[a]	0.8[bc]	0.8[c]	0.9[a]	1.2[bc]	1.4[ab]
Root Mean Square Error	1.03	0.61	0.58	0.31	0.38	0.28	0.38	0.24	0.38	0.20	0.32

Treatment	Overall Sweet	Cardboardy	Warmed Over Flavor	Sour Milk/ SourDairy
***P* – value**[g]	<0.001	0.01	0.25	<0.001
Choice GM steaks				
GF, 58 °C	0.4[a]	0.0[a]	0.0	0.1[b]
GF, 80 °C	0.7[abc]	0.2[ab]	0.1	0.0[ab]
GRILL, 58 °C	0.4[a]	0.1[ab]	0.0	0.2[b]
GRILL, 80 °C	0.6[abc]	0.2[ab]	0.1	0.0[ab]
Choice BF roasts				
CP, 58 °C	0.5[abc]	0.3[b]	0.1	0.0[ab]
CP, 80 °C	0.9[c]	0.2[ab]	0.2	0.0[ab]
Select BF roasts				
CP, 58 °C	0.5[ab]	0.3[b]	0.0	0.2[ab]
CP, 80 °C	0.9[c]	0.3[ab]	0.2	0.0[ab]
Choice LM steak				
GF, 58 °C	0.5[abc]	0.2[ab]	0.0	0.0[ab]
GF, 80 °C	0.6[abc]	0.2[a]	0.1	0.0[ab]
GRILL, 58 °C	0.7[abc]	0.0[ab]	0.0	0.0[ab]
GRILL, 80 °C	0.9[c]	0.0[ab]	0.0	0.0[ab]
High pH LM steaks				
GF, 58 °C	0.7[bc]	0.2[ab]	0.1	0.0[ab]
GF, 80 °C	0.7[abc]	0.3[b]	0.1	0.0[a]
GRILL, 58 °C	0.8[bc]	0.1[ab]	0.1	0.0[a]
GRILL, 80 °C	1.0[c]	0.2[ab]	0.0	0.0[ab]
Root Mean Square Error	0.33	0.23	0.16	0.1

GM = *M. Gluteus medius*; LM = *M. Longissimus lumborum*; BF = *M. Biceps femoris*; GF = *George Foreman Precision Grill*; GRILL = *Flat top electric grill*; CP = *Crock-Pot Manual Slow Cooker*.

[abcdef]Mean values within a column followed by the same letter are not significantly different ($P > 0.05$).

[g]P – value from analysis of variance tables.

aromatics than top sirloin steaks cooked to 58°C. Wall et al. (2019) reported that top sirloin steaks had lower levels of beef identification, brown/roasted, and umami and more intense levels of metallic and sour flavor attributes than either ribeye or top loin steaks when steaks were cooked to 71°C. Additionally, regardless of grill temperature, top sirloin steaks differed from top loin and ribeye steaks in the aforementioned flavor attributes. Yancey et al. (2005) reported that top sirloin steaks had slightly more intense levels of metallic flavor than top blade and tenderloin steaks and that top sirloin steaks had slightly more intense sour basic tastes compared with top blade steaks. It has been long established that increasing internal cook temperature endpoint increases toughness (Cross et al., 1976) and changes beef flavor (Wulf et al., 1996; Luchak et al., 1998). Therefore, it is not surprising that differences in flavor were reported for top sirloin steaks cooked to different internal cook temperature endpoint and using different cooking methods.

Ch and Se bottom round roasts (BF) were cooked in CP to 1 of 2 internal cooked temperature endpoints. Bottom round roasts, regardless of USDA quality grade, cooked to 80°C internal temperature had higher levels of beef identity, metallic and overall sweet flavor aromatics, and umami basic tastes than bottom round roasts cooked to 58°C. Additionally, the bottom rounds across quality grades had lower levels of bloody/serumy flavor aromatics and sour basic tastes when cooked to 80°C internal cook temperature. Bottom round roasts did not differ in fat-like flavor aromatic regardless of quality grade or internal cooked temperature endpoint. Bottom round roasts have been shown to be lower in chemical lipid than cuts from the top sirloin and strip loin (McKeith et al., 1985). Differences in chemical lipid, although not measured, would be expectantly low and therefore, differences in fat-like flavor would most likely not be detected for bottom round roasts across quality grades. Jones et al. (1992) reported that Ch and Se raw bottom round roasts with no external trim contained 5.2% and 3.4% chemical lipid and after cooking contained 7.8% and 5.4% chemical lipid, respectively. Carmack et al. (1995) evaluated beef from 12 muscles and reported that BF muscles had the highest level of beef flavor intensity compared with the GM and LM muscles. It should be noted that Carmack et al. (1995) defined beef flavor intensity as the brown, roasted, aromatic flavor generally associated with beef cooked by dry heat and measured at its peak point during the initial 10 chews. Hamouz et al. (1995) showed that as oven service temperature increased during cooking of beef bottom round roasts, cook yield increased and juiciness and tenderness decreased. Although beef flavor attributes were not measured, the changes in cook yield, juiciness, and tenderness implied that beef flavor attributes most likely changed because of the cooking environment.

Ch top loin steaks of normal pH tended to have slightly higher beef identify flavor aromatic compared with high pH top loin steaks. Additionally, Ch top loin steaks cooked using the GRILL were higher in brown/roasted taste than Ch top loin steaks cooked on the GF to 58°C internal cook temperature endpoint. Top loin steaks cooked either on the GF or GRILL to 58°C were slightly higher in bloody/serumy, metallic, and umami basic tastes. GF 80°C top loin steaks were slightly higher in liver-like flavor aromatic. Yancey et al. (2005) reported that top sirloin steaks from high pH carcasses had lower intensities of beef flavor identity and brown/roasted flavor aromatics than these steaks from normal pH carcasses.

For high pH LM steaks, steaks cooked to 80°C on the GRILL were highest in beef identity and brown/roasted flavor aromatics. High pH LM steaks from the other treatments were low in beef identity and brown/roasted flavor aromatics and similar in beef identity and brown/roasted flavor aromatics as GM steaks and normal pH LM steaks cooked similarly. High pH top loin steaks cooked to 58°C, regardless of cooking method, were higher in bloody/serumy and metallic flavor aromatics and tended to be slightly higher, but barely detectable, in umami and lower in sour basic tastes than other high pH top loin steaks. Although these differences were less than 2 on a 16-point scale, the combined differences may be detectable by consumers. Wulf et al. (2002) reported that LM steaks from high pH beef carcasses were less tender and had lower flavor desirability levels compared with LM steaks from normal pH beef carcasses. Grayson et al. (2016) used the beef flavor descriptive attributes from Adhikari et al. (2011) and evaluated beef classified as severe, moderate, mild, or shady for dark cutting beef based on meat pH and color attributes. They reported that severe dark cutting beef LM steaks were slightly more intense in browned/roasted, fat-like, and overall sweet, and slightly lower in metallic, umami, sour and salty descriptive attributes compared with normal LM steaks. Lawrie and Ledward (2006) proposed that as pH increases in beef, increased water holding capacity results in protein swelling. As water retention increased, Grayson et al. (2016) hypothesized that overall flavor may be diluted.

These results showed that cooking method, muscle, and internal cook temperature endpoint impacted beef flavor attributes as defined by the beef flavor lexicon. These results were expected and compatible with the trained descriptive panel results from a recent beef flavor study conducted by Miller and Kerth (2012). It has been well established that cooking method, muscle, and internal cook temperature endpoint influenced beef sensory attributes (Gilpin et al., 1965; Parrish et al., 1973; Luckak et al., 1998; Belk et al., 1993; Berry, 1993; Modzelewska-Kapituła et al., 2012). However, Miller and Kerth (2012) did not determine if these differences could be detected by consumers, especially heavy beef consumers who ate beef 3 or more times per week. In general, flavor attributes differed across treatments. The Ch GM steaks, Ch BF roasts, Se BF roasts, Ch LM steaks, and high pH LM steaks cooked to 80°C on the GRILL had similar beef identity and brown/roasted flavor attributes. When these same cuts were cooked to 58°C, beef identity and brown/roasted decreased. Interestingly, Ch GM steaks cooked on a GRILL or GF to 58°C, Se BF roasts cooked to 58°C, and high pH LM steaks cooked to 58°C on the GRILL or GF had the lowest levels of beef identity compared with the other treatments. The aforementioned treatments also tended to be the lowest in brown/roasted. Differences from the lowest to the more intense cuts in beef identity and brown/roasted tended to differ between 2 and 3 intensity points. Although these differences would be considered detectable by trained panelists as indicated by the statistical significance in this study, the magnitude of the differences is not great.

Bloody/serumy differed across treatments with steaks and roasts cooked to 58°C having slightly higher intensities. Steaks and roasts cooked to 58°C, regardless of muscle or cooking method, had more intense bloody/serumy and metallic flavors than steaks and roasts cooked to 80°C, except metallic was lower in high pH LM steaks cooked to 58°C compared with other beef cuts cooked to 58°C. For the other flavor aromatic and basic taste attributes, although differences existed ($P < 0.05$), most of the differences were less than 1 unit on the scale, indicating that flavor differences were subtle. It is apparent that the 16 treatments differed in flavor attributes, but the question remains if these differences are enough for consumers to detect or to impact their liking of beef. Trained panelists are taught to evaluate individual flavor attributes and to scale these attributes using defined references. However, consumers perceive beef flavor differently. Consumers tend to evaluate flavor and its relationship to overall liking as a multivariate attribute, wherein they evaluate all the flavors at once and may or may not know or be able to describe individual attributes. Beef from these 16 treatments differed as discussed in flavor attributes from barely to slightly different in magnitude. The question is, if heavy beef eaters could detect differences and differences were detected, did these differences impact their overall liking?

Consumer demographics

Consumer demographics are reported in Table 2. There were 280 consumers who participated across 4 cities. Slightly more women participated than men, and age ranged from under 20 (but over 18) to over 66; however, 52 % of consumers were between ages 21 and 35. The income of consumers spanned a broad range with 21.7% of consumers earning below $25,000 per year and 19.1% of consumers earned greater than $100,000 per year. The vast majority of the selected population consumed chicken, beef, pork, fish, lamb, eggs, and soy. As expected, the majority of consumers consumed beef 3 or more times per week, and 20 consumers said that they ate beef every day. Purchasing habits were determined, and the majority of consumers did not purchase grass-fed, dry-aged, or organic beef. The primary classification of beef bought by consumers in this study was traditional in that it was defined as purchasing commodity beef at the retail store.

Consumer sensory

Consumer sensory attributes were affected by treatment (Table 3). Overall, consumers liked Ch LM steaks cooked on the GRILL to 58°C or 80°C internal cook temperature endpoints ($P < 0.05$), followed by Ch GM steaks cooked on the GRILL to 58°C. High pH LM steaks cooked on the GRILL to 80°C and Ch LM steaks cooked on the GF to 58°C had slightly lower liking ratings, but ratings were 6.6 and 6.3, respectively. For high pH LM steaks, consumers liked grilled steaks cooked to 80°C more than these steaks cooked to lower degrees of doneness or prepared on the GF ($P < 0.05$). Consumers had the lowest preference for Se and Ch BF roasts cooked in the CP to 58°C and 80°C ($P < 0.05$). These results agreed with a nationwide in-home beef palatability consumer study comparing steaks from the GM, LM, and BF. Neely et al. (1998) reported that regardless of quality grade or degree of doneness, steaks originating from the BF were the least preferred ($P < 0.05$). Differences reported in this study were in agreement; however, based on design, differences may have been due to

Table 2. Consumer demographics and estimated protein consumption

Demographic Characteristic	Number	Percentage
City		
Houston	47	19.9
Olathe	80	28.8
Philadelphia	72	25.9
Portland	79	28.4
Gender		
Male	135	48.6
Female	145	51.4
Age, Years		
<20	10	3.9
21–25	64	25.0
26–35	69	27.0
36–45	36	14.1
46–55	32	12.5
56–65	32	12.5
>66	13	5.1
Income per Year		
<$25,000	60	21.7
$25,001–$49,999	65	23.5
$50,000–$74,999	64	23.1
$75,000–$99,999	35	12.6
>$100,000	53	19.1
Food Allergies		
Yes	11	5.6
No	187	94.4
Protein Consumption		
Chicken		
Yes	195	97.5
No	5	2.5
Beef		
Yes	198	100.0
No	0	0.0
Pork		
Yes	187	94.4
No	11	5.6
Fish		
Yes	176	88.9
No	22	11.1
Lamb		
Yes	176	72.4
No	67	27.6
Eggs		
Yes	188	94.9
No	10	5.1
Soy		
Yes	106	53.8
No	91	46.2
Beef Consumption Frequency		
Daily	20	7.2
5 or more times per week	70	25.3
3 or more times per week	187	67.5
Beef Purchasing Habits		
Grass Fed		
Yes	47	16.9
No	231	83.1
Dry Aged		
Yes	12	4.3
No	266	95.7
Traditional		
Yes	237	85.2
No	41	14.8
Organic		
Yes	46	16.6
No	231	83.4

muscle or cooking method or internal cook temperature endpoint. The main objective of our study was to create differences in flavor across cuts using cooking method and internal temperature endpoint differences. It is apparent that differences were reported in descriptive sensory testing and that consumers also detected differences in sensory attributes.

Consumers tended to like the flavor of steaks cooked on the GRILL compared with similar steaks cooked on the GF. Overall liking ratings were higher for the Ch GM cooked to 58°C on the GRILL compared with the GF ($P < 0.05$). Savell et al. (1999) showed that cooking method and degree of doneness affected consumer flavor desirability ratings for top sirloin steaks. Consumers liked the flavor of top sirloin steaks cooked using the indoor grill or pan-frying. However, Legako et al. (2015) evaluated tenderloin, top loin, top sirloin, and eye of round steaks for consumer sensory attributes and found that Ch top sirloin and top loin steaks had similar consumer ratings for juiciness, flavor, and overall liking when cooked to the same internal temperature and using the same cooking method.

All steaks prepared on the GRILL, regardless of muscle, ranked higher for overall liking as compared with roasts prepared in the CP, regardless of internal temperature or quality grade. The Ch LM steaks cooked on the GRILL were preferred to steaks cooked on the GF ($P < 0.05$). High pH LM steaks cooked to a high degree of doneness on the GRILL were preferred over high pH steaks prepared on the GF ($P < 0.05$). Sepulveda et al. (2019) reported that top loin steaks cooked on a clamshell-type grill were rated lower for flavor than steaks cooked on a flat grill by consumers. Yancey et al. (2011) evaluated ribeye steaks cooked using 5 cooking methods. They evaluated Warner-Bratzler shear force values (WBSF) as an indication of tenderness. They reported that ribeye steaks cooked on a clamshell grill had higher WBSF or were tougher than similar steaks cooked using a forced air convection or air impingement systems. It is apparent that cooking method impacts beef sensory attributes and that steaks cooked using a

Table 3. Least-squares means for consumer attributes[k] for 16 treatments that differed in beef cut, cooking method, USDA grade, pH, and internal cooked temperature endpoint

Treatment	Overall Like/ Dislike	Flavor Like/ Dislike	Beef Flavor Like/ Dislike	Beef Flavor Intensity	Grill Flavor Like/ Dislike	Grill Flavor Intensity	Off-Flavor Intensity
***P* Value**[j]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Choice GM Steaks							
GF, 58°C	5.8^{d}	5.8^{def}	6.0^{cd}	5.7^{ab}	4.8^{cd}	4.3^{cd}	4.6^{cde}
GF, 80°C	5.3^{bc}	5.3^{abc}	5.6^{abc}	5.7^{ab}	4.7^{bc}	4.2^{bc}	4.4^{abcd}
GRILL, 58°C	6.8^{g}	6.9^{i}	7.0^{f}	6.8^{e}	6.5^{f}	6.2^{g}	5.5^{ghi}
GRILL, 80°C	6.1^{de}	6.2^{fgh}	6.4^{e}	6.4^{d}	6.3^{f}	6.1^{g}	5.0^{efg}
Choice BF Roasts							
CP, 58°C	5.0^{ab}	5.1^{ab}	5.3^{ab}	5.4^{a}	4.0^{a}	3.6^{a}	4.2^{ab}
CP, 80°C	4.8^{ab}	4.9^{a}	5.3^{a}	5.3^{a}	4.3^{ab}	3.8^{ab}	4.0^{a}
Select BF Roasts							
CP, 58°C	5.1^{ab}	5.2^{abc}	5.3^{ab}	5.3^{a}	4.1^{a}	3.6^{a}	4.2^{ab}
CP, 80°C	4.8^{a}	4.8^{a}	5.2^{a}	5.4^{a}	4.1^{a}	3.6^{a}	4.2^{abc}
Choice LM Steak							
GF, 58°C	6.3^{ef}	6.2^{gh}	6.3^{de}	6.3^{cd}	5.5^{e}	5.0^{ef}	5.1^{fgh}
GF, 80°C	6.0^{de}	6.0^{efg}	6.2^{de}	6.3^{cd}	5.2^{de}	4.7^{de}	4.8^{def}
GRILL, 58°C	7.4^{h}	7.3^{j}	7.3^{f}	7.2^{e}	7.3^{g}	6.8^{h}	5.7^{i}
GRILL, 80°C	7.1^{gh}	7.1^{ij}	7.0^{f}	7.0^{e}	7.0^{g}	6.8^{h}	5.9^{i}
High pH LM Steaks							
GF, 58°C	5.8^{d}	5.5^{cde}	5.7^{bc}	5.6^{ab}	5.3^{e}	4.4^{cd}	4.7^{de}
GF, 80°C	5.6^{c}	5.4^{bcd}	5.7^{bc}	5.4^{a}	4.8^{c}	4.1^{bc}	4.5^{bcd}
GRILL, 58°C	5.9^{de}	5.8^{efg}	5.9^{cd}	5.9^{bc}	5.6^{e}	5.2^{f}	4.7^{def}
GRILL, 80°C	6.6^{f}	6.4^{h}	6.5^{e}	6.3^{cd}	6.4^{f}	6.2^{g}	5.5^{hi}
Root Mean Square Error	3.15	2.84	3.12	3.14	1.80	1.85	1.83

[a–i]Mean values within a column followed by the same letter are not significantly different ($P > 0.05$).

[j]*P* value from analysis of variance tables.

[k]Consumer attributes wherein 1 = dislike extremely or extremely bland and 9 = like extremely or extremely intense, respectively.

BF = *M. biceps femoris*; CP = *Crock-Pot Manual Slow Cooker*; GF = George Foreman clamshell grill; GM = *M. gluteus medius*; GRILL = flat top electric food-service grill; LM = *M. longissimus lumborum*.

clamshell grill, like the GF, would expectantly differ in sensory attributes.

Flavor liking and beef flavor liking showed similar results to overall liking ratings across treatments. Beef flavor intensity, grill flavor liking, and grill flavor intensity were higher for Ch LM steaks cooked using the GRILL compared with steaks cooked on the GF ($P < 0.05$). High pH LM steaks grilled and cooked to 80°C were rated higher for beef flavor intensity, grill flavor liking, and grill flavor intensity ($P < 0.05$). Ch GM steaks cooked on the GRILL ranked higher for grill flavor liking and intensity as compared with Ch GM steaks prepared on the GF ($P < 0.05$). These results agreed with Savell et al. (1999), who also found higher consumer flavor intensity ratings when steaks were cooked on an outside grill. As expected, all steaks cooked on the GRILL received higher ratings for grill flavor liking and intensity as compared with Ch and Se BF roasts cooked in the CP ($P < 0.05$). This would be expected because roasts cooked in the CP had added water and were cooked at a low temperature for a longer period of time compared with either GF or GRILL treatments. This treatment was added to provide a treatment that would have reduced levels of Maillard reaction products. Although data are not presented, volatile flavor aromatic compounds were assessed, and CP cooked bottom round roasts had lower levels of Maillard reaction products (Glascock, 2014).

Off-flavor intensity was highest in grilled Ch LM steaks cooked to 80°C and lowest in Se BF roasts cooked in the CP to 80°C ($P < 0.05$). Although consumers were asked to describe what they disliked in steaks and roasts, evaluation of the open-ended questions for steaks and roasts with highest values for off-flavor intensity did not provide insight into what consumers experienced in these samples.

These results indicated that steaks and roasts from these 16 treatments differed in consumer liking for heavy beef eaters. Additionally, differences in beef flavor descriptive attributes were reported using trained panelists. To understand relationships between overall liking and other consumer sensory attributes and descriptive flavor attributes, principal component analyses were conducted.

Relationships between trained descriptive flavor panel and consumer perception of beef interaction

The relationship between trained descriptive beef flavor attributes and consumer acceptance is reported in Figure 1. Principle component Factors 1 and 2 accounted for 70% of the variation in the model. For Factor 1, consumer sensory attributes contributed the highest percentage of variation (10.6% to 9.4%), and descriptive flavor attributes of warmed-over flavor, cardboardy, liver-like, fat-like, brown/roasted and blood/serumy flavor aromatics contributed 6.8%, 4.5%, 4.1%, 3.7%, 3.2%, and 2.1% to the factor, respectively. Overall sweet, sweet, metallic, bloody/serumy, beef identity, umami, and bitter accounted for 11.6%, 11.2%, 11.2%, 10.8%, 10.3%, 9.4%, and 8.5% of Factor 2. Consumer sensory variables were very closely clustered together and were associated with fat-like, brown/roasted, and beef identity flavor aromatics and salt basic tastes. The treatment that most closely clustered with consumer sensory attributes was Ch top loin steaks grilled to an internal temperature of 58°C. Treatments of Ch top sirloin steaks cooked to 80°C, high pH top loin GF and GRILL steaks cooked to 58°C, and Ch and Se bottom round roasts cooked to 58°C in a CP were least liked and segmented in the opposite quadrant from the consumer liking attributes. Sour milk/sour dairy, bloody/serumy, and metallic flavor aromatics, and bitter and sour basic tastes were closely clustered with Ch top sirloin GF and GRILL steaks cooked to 58°C, and Ch top loin steaks cooked on the GF to 58°C internal cook temperature.

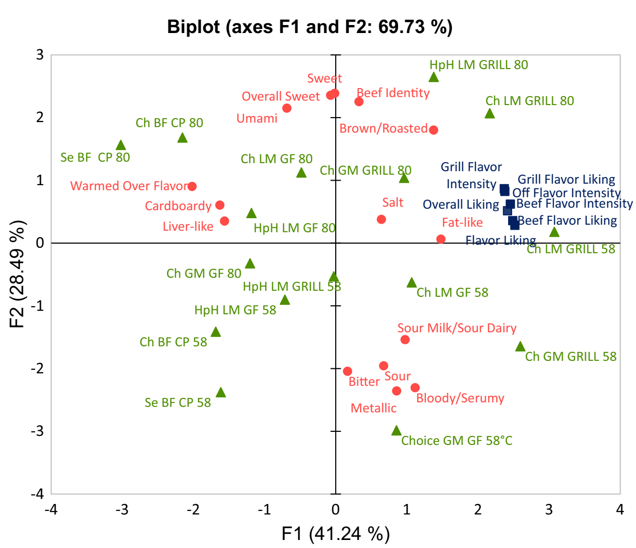

Figure 1. Principal component analysis bi-plot of Factor 1 (41.58% of variation) and Factor 2 (28.46% of variation) with treatments (green triangle), descriptive sensory attributes (red circle), and consumer sensory attributes (blue square). BF = *M. biceps femoris*; Ch = Choice; CP = Crock-Pot Manual Slow Cooker; GF = George Foreman clamshell grill; GM = *M. gluteus medius*; GRILL = flat top electric food-service grill; HpH = high pH (<6.0 pH); LM = *M. longissimus lumborum*; Se = Select.

Flavor attributes of beef identity, brown/roasted, and overall sweet flavor aromatics and umami and sweet basic tastes were closely clustered. These descriptive attributes tended to be closely related to consumer sensory attributes but not as closely clustered as fat-like flavor aromatics. Warmed-over flavor, cardboardy, and liver-like flavor aromatics were negatively related to consumer liking and closely associated with Se CP cooked bottom round roasts cooked to either 58°C or 80°C, and high pH top loin steaks and Ch top sirloin steaks cooked on the GF to 80°C. These results indicate that cooking steaks on the GF grill resulted in lower consumer sensory ratings and that this effect was intensified when steaks were cooked to higher internal cook temperatures. Metallic and bloody/serumy clustered together and were opposite of umami and beef identity. These results indicate that as umami, brown/roasted, and beef identity increased, metallic and bloody/serumy decreased.

These results showed that for heavy beef eaters, fat-like is the primary driver of consumer liking with increased levels of beef identity, brown/roasted, overall sweet, umami, salt, and sweet as secondary drivers of overall consumer liking. Warmed-over flavor, cardboardy, and liver-like are negative drivers of consumer liking. Even though levels of the majority of the aforementioned flavor attributes were at lower levels on a 16-point scale, differences at low intensities impacted consumer liking.

Understanding consumer segments

To further understand factors influencing liking of heavy beef consumers, agglomerative hierarchial cluster analysis was conducted with the consumer as the experimental unit. This analysis was used to understand if consumers segmented into different categories based on drivers of liking and if there were attributes that differed within a consumer segment. Four consumer clusters were reported (Table 4). It should be noted that consumers who did not respond to a consumer attribute were eliminated from this analysis; therefore, there were only 289 consumers included. Consumer segments differed in their consumer sensory responses. Consumers in Segment 4 liked beef evaluated to a greater extent than consumers in other segments. Consumers in Segment 3 rated beef lowest for consumer liking attributes, and consumers in Segments 1 and 2 were intermediate in

Table 4. Agglomerative hierarchical consumer clusters least-squares means for consumer sensory attributes[f]

Clusters	Flavor Like/Dislike	Beef Flavor Like/Dislike	Beef Flavor Intensity	Grill Flavor Like/Dislike	Grill Flavor Intensity	Off-Flavor Intensity	Overall Like/Dislike
Least-Squares Means							
***P* Value**[e]	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
1 (*n* = 176)	5.6[b]	5.6[b]	5.6[b]	5.2[b]	4.7[b]	4.6[b]	5.7[b]
2 (*n* = 69)	6.7[c]	6.7[c]	6.8[c]	6.2[c]	6.0[c]	5.6[c]	6.6[c]
3 (*n* = 20)	3.8[a]	4.0[a]	3.9[a]	3.6[a]	3.1[a]	3.6[a]	3.9[a]
4 (*n* = 24)	7.7[d]	7.7[d]	7.5[d]	7.5[d]	7.4[d]	7.3[d]	7.7[d]
Root Mean Square Error	0.64	0.66	0.69	0.59	0.73	0.92	0.67

[a–d]Mean values within a column followed by the same letter are not significantly different (P > 0.05).

[e]*P* value from analysis of variance tables.

[f]Consumer attributes measured wherein 1 = dislike extremely or extremely bland and 9 = like extremely or extremely intense, respectively.

assessing their consumer ratings for beef presented to them. These results indicate that consumers differed in how they rated beef. There was significant treatment by consumer segment interactions for all consumer overall liking and flavor liking (Figure 2). Consumers within segments followed the aforementioned trend with consumers in Segment 3 rating beef lowest, consumers in Segment 4 rating beef highest, and consumers in Segments 1 and 2 being intermediate in their consumer overall liking ratings across the 16 beef treatments. However, consumers in Segment 3, those that rated beef the lowest overall for liking, varied to a greater extent in their liking ratings across treatments. For GRILL Ch top loin steaks cooked to 58°C, their overall liking and flavor liking ratings were highest compared with all other treatments. This was seen for consumers in Segments 1, 2, and 4, but their overall and flavor liking ratings were slightly higher than consumers in Group 3.

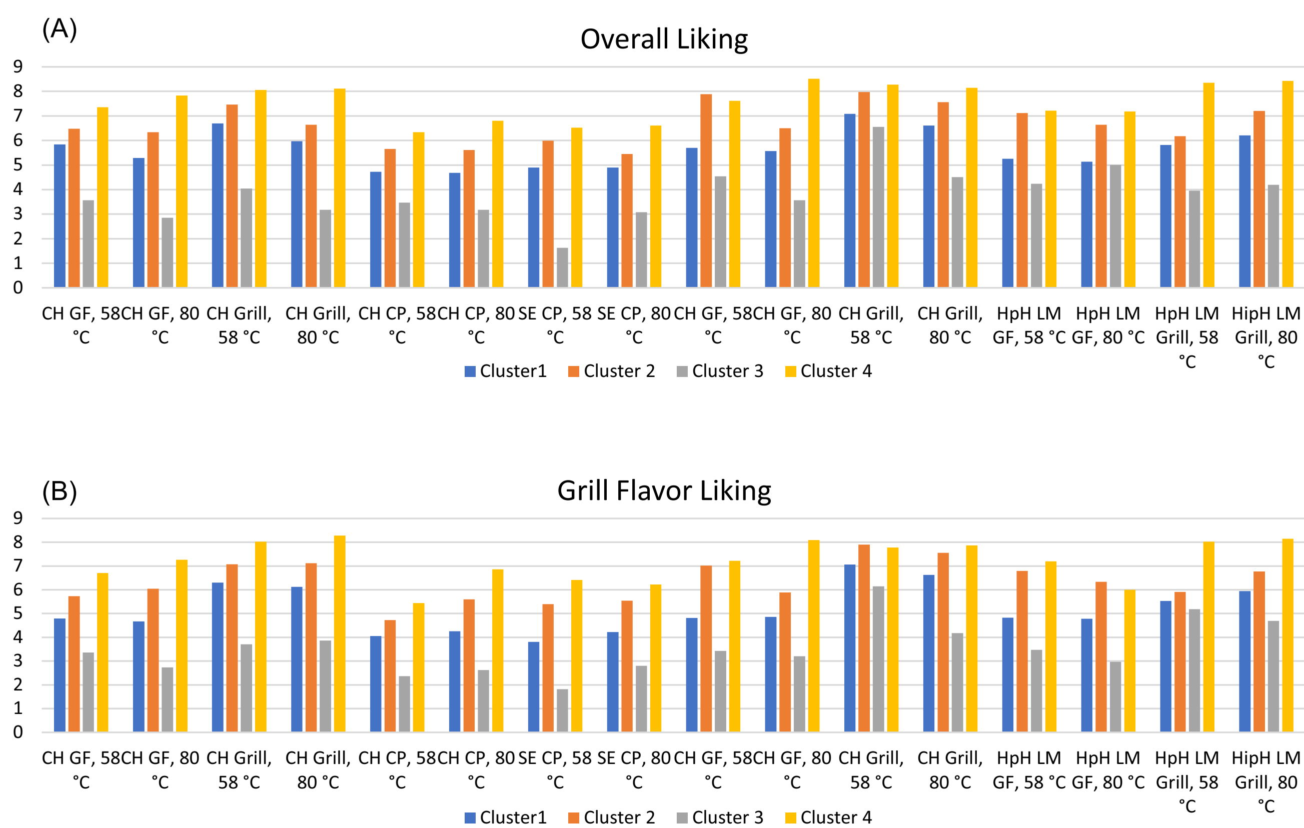

Figure 2. Least-squares means for (A) consumer overall liking and (B) grill flavor liking (1 = dislike extremely; 9 = like extremely) by treatments for 4 agglomerative hierarchical consumer clusters. CH = Choice; CP = Crock-Pot Manual Slow Cooker; GF = George Foreman clamshell grill; Grill = flat top electric food-service grill; HpH LM = high pH (<6.0 pH) *M. longissimus lumborum*; SE = Select; 58 = 58°C internal cook temperature endpoint; 80 = 80°C internal cook temperature endpoint.

When Group 3 consumers were presented with Se bottom round roasts cooked in a CP to an internal cooked temperature of 58°C, their liking ratings were less than 2, whereas Group 4 consumers rated these roasts at about 6.7. Consumers in Group 3 were more discerning and more critical of flavor attributes of beef. In other words, they overall tended to rate all beef lower in acceptability, and they had a wider range in acceptability than consumers in the other groups. Consumers in Group 3 rated samples that they did not like lower than other consumers and tended to use the disliking categories to segment their preferences. Consumers in Group 4 tended to like beef from all the treatments; on average, they rated beef from 6 to 8. Consumers in Groups 1 and 2 rated beef at slightly lower levels than consumers in Group 4. They tended to rate beef treatments intermediate to consumers in Groups 3 and 4. Groups 1 had the highest number of consumers, and they rated beef close to 5 or neither like nor dislike. Consumers in Group 2 tended to like the beef presented because they rated beef approximately 1 point higher than consumers in Group 1. These results show that consumers rated beef samples differently and used the hedonic scales differently. Font-i-Furnols and Guerrero (2014) discussed factors that influence consumer perceptions. They discuss how marketing, psychological, and sensory factors influence consumer behavior. To account for these differences, the consumer was included in the statistical model to assist in removing variation associated with differences in consumer ratings, but differences in consumer liking were still apparent. To more clearly understand consumers' perceptions, data were collected from the open-ended questions on the ballot of "Please write any words that describe the POSITIVE or GOOD FLAVORS" and "Please write any words that describe the NEGATIVE or BAD FLAVORS." Responses from consumers in Groups 3 and 4 are presented as word clouds in which larger words represent more frequent responses (Figure 3). Group 3 consumers, the more discerning group, used words of flavor, grilled, juicy, tender, and beefy when they had a positive eating experience, and consumers from Group 4 used similar words. For negative eating experiences, bland was the predominant response for consumers in Group 3, whereas Group 4 consumers used words like bland, nothing, dry, tough, and undercooked. There was an appreciable number of consumers in Group 3 who commented that there was nothing that they liked in their beef samples. These consumers were the discerning consumers, and for many of these consumers, they did not find anything in their samples to like. Nothing was the third most common response by Group 3 consumers for what they liked about the sample. Consumers in Group 4 responded an appreciable number of times that there was nothing that they disliked about the beef samples, with nothing being the most common response. This further substantiates that these consumers liked almost everything as long as it was beef, because they did not dislike the samples. It should be noted that other descriptive words were similar for both groups.

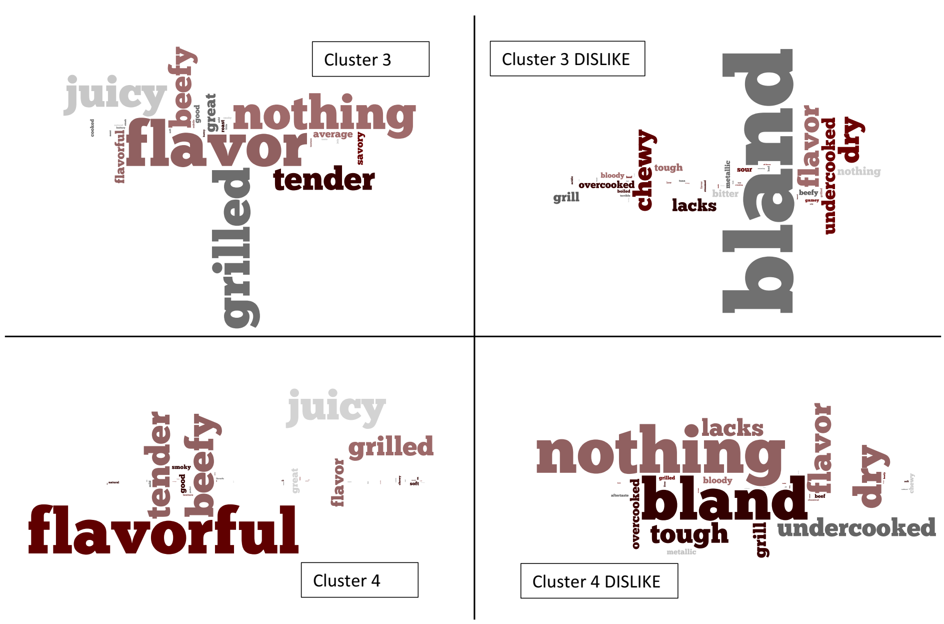

Figure 3. Word clouds wherein larger font indicates more frequent consumer response and smaller font indicates fewer consumer responses for Cluster 3 and 4 agglomerative hierarchical consumer classes based on consumer responses to open-ended questions of "Please write any words that describe the POSITIVE or GOOD FLAVORS" (LIKE) and "Please write any words that describe the NEGATIVE or BAD FLAVORS" (DISLIKE).

To further ascertain if there were demographic differences between consumer clusters, frequency distributions for consumer demographics and protein consumption between groups were examined (Table 5). Consumer Group 3, or the more discerning group, contained the lowest number of consumers, consisted of 60% women, and had a slightly lower percentage of consumers who ate beef 5 or more times per week. Group 4, the least discerning group, had a tendency to eat a slightly higher percentage of fish, lamb, eggs, and soy than consumers from Group 3 and tended to eat slightly less traditional beef. Although these differences were not substantial, there may be evidence of trends.

Table 5. Consumer demographics and estimated protein consumption for consumers from 4 agglomerative hierarchical consumer clusters

	Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Attribute	*n*	%	*n*	%	*n*	%	*n*	%
n	176		69		20		24	
City								
Houston	26	15	8	12	3	15	9	45
Olathe	48	28	19	29	11	55	2	10
Philadelphia	46	46	20	30	2	10	4	20
Portland	51	51	19	29	4	20	5	25
Gender								
Male	90	53	30	45	8	40	6	30
Female	81	47	36	55	12	60	14	70
Age								
<20	6	4	3	5	1	5	0	0
21–25	42	25	12	18	6	30	3	15
26–35	41	24	18	27	5	25	5	25
36–45	23	13	7	11	2	10	4	20
46–55	17	10	7	11	4	20	5	20
56–65	22	13	6	9	1	5	3	15
>66	18	10	12	18	0	0	1	5
Income per Year								
<$25,000	34	20	15	23	4	20	6	30
$25,001–$49,999	46	27	14	21	1	5	4	20
$50,000–$74,999	34	20	20	30	7	35	3	15
$75,000–$99,999	20	12	9	14	4	20	2	10
>$100,000	37	22	8	12	4	30	4	20
Food Allergies								
Yes	9	7	1	8	0	0	0	0
No	114	93	46	94	9	100	10	100
Protein Consumption								
Chicken								
Yes	122	99	46	98	9	100	17	94
No	3	1	1	2	0	0	1	6
Pork								
Yes	136	94	46	98	8	89	16	89
No	7	6	1	2	1	11	2	11
Fish								
Yes	112	91	41	87	8	89	14	78
No	11	9	6	13	1	11	4	22
Lamb								
Yes	85	69	30	64	6	67	10	56
No	38	31	17	36	3	33	8	44
Eggs								
Yes	116	94	46	98	7	78	16	89
No	7	6	1	2	2	22	2	11
Soy								
Yes	66	54	26	58	5	56	8	44
No	56	46	21	45	4	44	10	56

(*Continued*)

Table 5. (*Continued*)

Attribute	Cluster 1 *n*	Cluster 1 %	Cluster 2 *n*	Cluster 2 %	Cluster 3 *n*	Cluster 3 %	Cluster 4 *n*	Cluster 4 %
Beef Consumption Frequency								
Daily	11	6	4	6	3	15	2	10
5 or more times per week	47	27	16	24	2	10	5	25
3 or more times per week	113	66	46	70	15	75	13	65
Beef Purchasing Habits								
Grass Fed								
Yes	28	16	11	17	4	20	4	20
No	143	84	55	83	16	80	16	80
Dry Aged								
Yes	6	4	3	5	3	15	0	0
No	165	96	63	95	17	85	20	10
Traditional								
Yes	146	85	58	88	16	80	16	80
No	25	14	8	12	4	20	4	20
Organic								
Yes	27	16	13	20	7	15	4	20
No	144	84	53	80	18	85	16	80

Conclusions

Beef that differed in beef descriptive flavor attributes resulted in differences in consumer liking for heavy beef eaters. The biggest flavor driver for overall liking was fat-like flavor aromatic followed by brown/roasted, salt, and beef identity flavor attributes for heavy beef eaters. Flavor attributes associated with dislike were warmed-over flavor, cardboardy, and liver-like flavor aromatics. Heavy beef eater consumers segmented into 4 groups. Consumers in Groups 1 and 2 tended to rate beef treatments between 4 (dislike slightly) and 7 to differentiate their preferences between treatments. Consumers in Group 3 were discerning consumers who used from 2 to 6 on the 9-point scale to evaluate the beef treatments; whereas consumers in Group 4 liked beef and tended to not differentiate extensively between treatments (used 6 to 8 points on a 9-point scale). These results indicate that beef flavor is important to consumers classified as heavy beef eaters and that differences in beef flavor impacted consumer acceptance of beef. Further understanding of why some consumers differentiate beef flavor to a greater extent than other consumers may provide greater understanding of how flavor differences in beef affect beef demand.

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