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Cooking Method and USDA Quality Grade Affect Consumer Palatability and Flavor of beef strip Loin Steaks

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Abstract: Consumer sensory analysis ($n = 288$) was conducted, along with cooking loss, slice shear force (SSF), pressed juice percentage (PJP), and volatile compound analyses, to evaluate the effects of different dry heat cooking methods. Specifically, an electric clamshell grill (CLAM), flat top gas grill (FLAT), charbroiler gas grill (CHAR), and salamander gas broiler (SAL) were used to cook beef strip loin steaks from 4 USDA quality grades [Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select)] to determine the palatability. Cooking method and quality grade influenced ($P < 0.01$) consumer tenderness, juiciness, flavor liking, and overall liking. Steaks cooked on CHAR had greater ($P < 0.05$) flavor liking and subsequently greater overall liking than any other cooking method. Steaks cooked on FLAT were scored lower for tenderness and juiciness than any other cooking method ($P < 0.05$), whereas steaks cooked on CLAM had lower ($P < 0.05$) flavor liking scores than any other cooking method, excluding FLAT. Overall acceptance was greater ($P < 0.05$) for steaks cooked on CHAR compared to all other cooking methods, regardless of quality grade. Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking ($P < 0.05$), but Prime did not differ from Top Choice for all traits. No main effects or interactions influenced ($P > 0.05$) SSF or PJP. Both cooking method and quality grade impacted ($P < 0.05$) the headspace concentration of some volatile compounds in the alcohol, n-aldehyde, Strecker aldehyde, and furan groups. Cooking method also affected all pyrazines, and quality grade had an effect on 1 ketone ($P < 0.05$). These results indicate cooking method had a significant impact on consumer palatability ratings and objective measures of beef flavor, and those results were consistent across a range of quality grades.

Keywords: consumer, cooking methods, USDA quality grade, volatile flavor compounds
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Introduction

Cooking impacts basic traits related to consumer preferences such as flavor, tenderness, color, and appearance (Lorenzen et al., 1999; Modzelewska-Kapituła et al., 2012; Domínguez et al., 2014; Pathare and Roskilly, 2016). Biochemical and physical changes occur during the heating process and these changes affect the quality and sensory characteristics (Boles and Swan, 2002; Barbera and Tassone, 2006; Pathare and Roskilly, 2016).

Beef flavor is a combination of taste and odor. Meat aroma develops from the interactions of non-volatile precursors during cooking. These interactions include the Maillard reaction, the oxidation of lipids, the thermal degradation of thiamine, and interactions between these pathways (Mottram, 1987; Mottram, 1991). Most flavor compounds of cooked meats associated with roasted, broiled, and meaty notes are generated via the Maillard reaction (Toldrá and Flores, 2007). High temperatures and low moisture result in high numbers of Maillard reaction derived volatile compounds including Strecker aldehydes, pyrazines, sulfides, and thiols (Toldrá and Flores, 2007). The induced oxidation of unsaturated fatty acids is responsible for the cooked meat aroma and development of rancid notes during storage periods (Toldrá and Flores, 2007). Different cooking methods can allow the conditions to be more prevalent in one pathway over an-other resulting in the formation of a different flavor profile (Domínguez et al., 2014; Domínguez et al., 2015).

In recent years cooking meat using an electric clamshell grill has become common during university research because it is faster than electric broiling and oven roasting, relatively inexpensive, and the repeatability of Warner-Bratzler shear force values are acceptable (>0.60) and relatively high ($R \geq 0.86$; Kerth et al., 2003; McKenna et al., 2003). However, other cooking methods such as charbroiling and salamander grills have also become a popular method in the hotel and restaurant industry (Yancey et al., 2011). Lorenzen et al. (1999) and McKenna et al. (2004) both found that consumers cook steaks on outdoor grills (charbroiling) over 40% of the time and use broiling and indoor grills over 13% of the time. Cooking method has a documented effect on beef palatability (Lorenzen et al., 1999; McKenna et al., 2004), but cooking method often interacts with other factors such as quality grade, degree of doneness, and city when assessing palatability traits using in-home consumer tests.

Increased marbling (intramuscular fat) level and USDA quality grade have a well-documented positive relationship with beef eating quality (Smith et al., 1985; O'Quinn et al., 2012; Corbin et al., 2015). However, limited research has been conducted examining the effect of different dry heat cooking methods on beef palatability across a range of USDA quality grades. Therefore, the purpose of this study was to evaluate possible differences in consumer perception of palatability and objective measures of tenderness, juiciness, and flavor of strip loin steaks representing 4 USDA quality grades cooked using 4 different dry cooking methods.

Materials and Methods

Strip loin collection and fabrication

Beef strip loins (IMPS # 180, NAMP, 2011) were selected at a commercial abattoir in Omaha, NE, from carcasses representing 4 USDA quality grades (Prime, Top [upper 2/3] Choice, Low [lower 1/3] Choice, and Select [n = 12/quality grade]). Carcass data, including marbling, skeletal and lean maturity, 12th rib fat thickness, ribeye area, hot carcass weight (HCW), and kidney, pelvic, and heart fat (KPH), were collected and recorded during carcass selection according to USDA standards (USDA, 1997) by trained Texas Tech University (TTU) personnel. Strip loins were selected, identified, and transported to TTU, located in Lubbock, TX. Upon arrival at TTU, strip loins were aged at 0 to 4°C under vacuum until 21 d postmortem. Each strip loin was fabricated into 2.54-cm thick steaks, which were numbered from 0 to 12 from anterior to posterior. The anterior most steak (steak 0) was designated to compositional analysis. Every 3 adjacent steaks (steaks 1 to 3, 4 to 6, 7 to 9, 10 to 12) were grouped and assigned randomly to 1 of the 4 cooking methods. Within each group of 3 steaks, the first 2 anterior-most steaks were designated to consumer assessment and the remaining steak was designated to slice shear force (SSF), pressed juiciness percentage (PJP), and volatile analysis. All steaks were vacuum packaged individually, labeled, and stored frozen (–20°C) until subsequent analysis.

Compositional analysis

Proximate analysis of raw steaks was conducted by an AOAC official method (Anderson, 2007) using a near infrared spectrophotometer (FoodScan, FOSS NIRSystems, Inc., Laurel, MD). Prior to analysis, steaks were thawed for 24 h at 4°C. All accessory muscles, heavy connective tissue, and external fat were removed leaving only the *longissimus lumborum* muscle. Samples were cubed, then placed in a grinder and ground through a 4-mm plate 3 times. A Petri dish disc was filled with approximately 80 g of sample, leveled with a plastic spatula, and was placed into the FOSS FoodScan to obtain percentages of fat, moisture, and protein for each sample.

pH determination

Ten grams of ground sample, retained from the compositional analysis described above, were placed in a 150-mL beaker, and 90 mL of distilled water were added. The beaker was placed on a mixer (ThermoScientific Cimarec Stirring Hot Plate, 7×7" Ceramic; 120 VAC, Waltham, MA). The mixture was agitated with a magnetic stirrer for 30 s at a G-force of 9 g. A filter paper #140 (Qualitative P8 Fisherbrand Filter Paper, Fisher Scientific, Pittsburgh, PA) cone was placed into the homogenate. An electrode connected to an OAKTON MS-PH02 pH meter (Hills, IL) was placed in the center of the cone to measure the pH of the dilution and the value was recorded. The pH of each subprimal was determined as the average of 3 ground subsamples.

Cooking procedure for objective measures and consumer evaluation

Approximate cooking times were established for each cooking method, using steaks from strip loins unrelated to the trial, but representing the same range in quality grade (Select to Prime). A cooking schedule was constructed using the approximate cooking times required to achieve medium degree of doneness. To reach a final internal temperature of 71 to 72°C, steaks were removed from their respective cooking device at approximately 68°C (depending on the cooking method). Steaks would then rest for 1 to 2 min, allowing the temperature to stabilize and reach 71 to 72°C.

For consumer and objective evaluations, steaks were thawed at 2 to 4°C for 24 to 30 h. Steaks were then trimmed, and the initial core temperature and the raw weight were recorded. The cooking devices were powered on 30 min prior to cooking and were set to maintain a surface temperature of 200 to 220°C, which was monitored using a surface thermometer (Omega RDXL4SD). Steaks were cooked on 1 of 4 cooking methods: flat surface of an electric clamshell grill (CLAM; Cuisinart Griddler Deluxe, Model GR-150, East Windsor, NJ), flat top gas grill (FLAT; Imperial IR-6-GT36, Corona, CA), grated surface of a charbroiler gas grill (CHAR; Imperial IRB-36 Charbroiler, Corona, CA), or salamander gas broiler (SAL; Vulcan 36RB-N, Baltimore, MD). Four steaks (one from each quality grade) were cooked using 1 of 4 methods for each cooking/serving round. The steaks were flipped at 6 min 30 s and 7 min 30 s of cooking on SAL and FLAT, respectively (pre-determined time for reaching approximately 35°C), the steaks on CHAR were flipped every 3 min to prevent burning from fat dripping on the flame source, and the steaks on CLAM were not flipped because of the double heating surface. The steaks were removed from each cooking device at the internal core temperature of 66 to 68°C and were then monitored with a digital Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT) until reaching the final peak temperature. Steaks samples were served to panelists approximately every 6 min.

Consumer sensory analysis

Consumer panel procedures were approved by the Texas Tech University Institutional Review Board (IRB2018–438). Panelists ($n = 288$) were recruited from the Lubbock, TX, area. Participants were provided with an iPad (fifth generation; Model A1822 EMC 3017; Apple, Cupertino, CA 95014) preloaded with an electronic ballot developed and presented using Qualtrics (Provo, UT) online survey software, plastic fork, toothpick, napkin, expectorant cup, a cup of water, and palate cleansers (unsalted crackers and diluted apple juice) to use between samples. Each ballot contained an information sheet, demographic questionnaire, and 8 sample ballots. Before starting each panel, panelists received verbal instructions about the ballot and use of the palate cleansers. Steaks were cooked as previously described, and at least 12 cubes (1.3-cm × 1.3-cm × steak thickness) were cut from each steak so that 2 pieces were served immediately to each predetermined consumer. Consumers received and scored 8 samples representing 8 of the 16 combinations of cooking methods and quality grades in a predetermined order. Serving order was dictated by a matrix developed to ensure equal representation of every treatment combination within a session. Each consumer received 8 samples, where 2 samples represented each quality grade and 2 samples represented each cooking method. Every cooking method × quality grade combination was compared an equal number of times within each panel session. Attributes for each sample were ranked on an electronic ballot with a 100-point continuous-line scales for juiciness, tenderness, flavor liking, and overall liking. The zero-point anchors were labeled as extremely dry, extremely tough, dislike flavor extremely, and dislike overall extremely; the 100-point anchors were labeled as extremely juicy, extremely tender, like flavor extremely, and like overall extremely. Also, consumers were asked if each palatability trait was acceptable (yes/no) and if the sample was acceptable overall (yes/no).

Cooking loss and slice shear force

Objective tenderness was evaluated by SSF as described by Shackelford et al. (1999). In brief, steaks designated to SSF, PJP, and volatiles, were cooked as previously described. Steaks were trimmed of subcutaneous fat and connective tissue and were weighed on a digital scale (Model AY1501; Sartorius, Göttingen, Germany), with a 0.1 g sensitivity, prior to cooking. Upon completion of cooking, steaks were weighed to obtain a cooked weight. Cooking loss was determined as the difference between steak raw weight and cooked weight divided by the raw weight.

After final peak temperature and weight were recorded, a 1-cm slice was removed from the lateral end of each steak to provide a square surface, and a second parallel cut was made 5 cm from the initial cut. Following this step, a 1× 5 cm slice was obtained parallel to the muscle fiber orientation by slicing at a 45° angle with a double-bladed knife. Each slice was sheared perpendicular to the muscle fiber orientation using a United Force Analyzer (Model #SSTM-500 with tension attachment, United Calibration Corp., Huntington Beach, CA) with a crosshead speed of 500 mm/min.

Pressed juiciness percentage

Objective juiciness was evaluated using the methods described by Lucherk et al. (2017). Immediately following shear force testing, an additional 1-cm thick, steak-width slice was removed immediately adjacent to the SSF sample and cut into three 1-cm samples, parallel to the muscle fiber orientation. Two sheets of filter paper (VWR Filter Paper 415, 12.5 cm, VWR International, Radnor, PA) previously stored in a desiccator were weighed for each 1-cm sample. Then, each of the 3 samples was weighed with 2 sheets of filter paper and compressed (Model 5542, Instron, Canton, MA) for 30 s at 8-kg pressure. After compression, the sample was removed from the 2 filter papers and the filter papers were re-weighed. The percentage moisture lost during compression was quantified as PJP.

Volatile compound evaluation

Volatile compound collection and gas chromatography-mass spectrometry (GC–MS) analysis were conducted using the modified version of the methods described by Legako et al. (2016). After conducting SSF and PJP, the remaining parts for each steak were retained. All connective tissue, external fat and any adjacent muscles were removed leaving only the *longissimus lumborum* muscle. The muscle was submerged into liquid nitrogen for 30 s using a metallic strainer, and the frozen meat pieces were ground for 20 s using a food processor (Robot Coupe Blixer-3 31/2QT, Ridgeland, MS) until obtaining a frozen powdered sample. Each powdered sample was packed in a double plastic bag, labeled, and stored at –80°C.

Subsequently, 5 g (± 0.05) of powdered sample were placed into a 15-mL clear glass vial (Supelco, Bellefonte, PA) and placed on a multipurpose sampler (Gerstel Inc., Linthicum, MD) for 5 min at room temperature (~23°C). Samples were agitated at 65°C for a 5-min incubation period in the Gerstel agitator (500 rpm; Gerstel, Inc.) and allowed to equilibrate for 5 min. Following equilibration, an 85-µm film thickness carboxen polydimethylsiloxane (CAR/PDMS) solid phase microextraction (SPME) fiber was exposed in the headspace above the sample for 10 min. Following a 10-min extraction period, the SPME fiber apparatus was capped with a septum (LB-2, Supelco). Analysis of cooked beef volatile flavor compounds were conducted using an Agilent 7890B series gas chromatograph (Agilent Technologies, Santa Clara, CA), equipped with a 5977A mass selection detector (GC–MS; Agilent Technologies) and the data were recorded.

Statistical analysis

Carcass, compositional, and pH data were analyzed using the GLIMMIX procedure of SAS (vers. 9.4; SAS Inst. Inc., Cary, NC), with quality grade as the fixed effect. Data gathered from objective measures (cooking loss, SSF, PJP, and volatile compounds) and consumer data (tenderness, juiciness, flavor liking, and overall linking) were analyzed as split-plot design with USDA quality grade as a whole plot factor, the strip loin as the whole plot unit, and cooking method as a subplot factor. Data were analyzed using the GLIMMIX procedures of SAS, with fixed effects of cooking method, quality grade, and their interaction. Final peak temperature was included into the model as a covariate when it was significant ($P \leq 0.05$). The cooking day was included in the model as a random effect for cooking loss, SSF, and PJP. Consumer nested within cooking day was included as a random effects for sensory attributes. Acceptability data for each palatability trait were analyzed with a binomial model. Treatment least squares means were separated with the PDIFF option of SAS using a significance level of $P \leq 0.05$. Denominator degrees of freedom were calculated using the Kenward-Roger approximation. PROC FREQ of SAS was used to summarize consumer demographic information. Finally, the CORR procedure of SAS was used to determine Pearson correlation coefficients between composition, objective measures, and consumer scores.

Results and Discussion

Carcass data

Complete carcass data can be found in Table 1, but only traits pertaining to quality grading will be reported here to help characterize the carcasses utilized. As expected, marbling differed ($P < 0.01$) between quality grade, with a significant difference between each grade from Prime to Select. The average marbling scores were slightly abundant-80, modest-88, small-61, and slight-40 for Prime, Top Choice, Low Choice, and Select, respectively. Lean and skeletal maturity were similar ($P > 0.05$) between quality grades, and would suggest all carcasses were young "A" maturity.

Table 1. Least squares means for carcass data, pH, and composition data from *longissimus lumborum* muscle representing 4 different quality grades[1] (n = 12 samples per quality grade)

Trait	Prime	Top Choice	Low Choice	Select	SEM[2]	*P*-value
Marbling[3]	780[a]	588[b]	461[c]	340[d]	7.3	< 0.01
Lean maturity[4]	139	144	146	142	2.7	0.33
Skeletal maturity[4]	137	148	148	145	3.5	0.10
Rib fat, mm	21.3[a]	19.7[ab]	16.1[bc]	12.2[c]	1.5	< 0.01
Ribeye area, cm^2	96.1	94.0	97.4	99.1	2.2	0.44
HCW, kg[5]	490.4[a]	487.1[a]	461.6[ab]	440.8[b]	10.4	< 0.01
KPH, %[6]	2.3	2.3	2.3	2.2	0.1	0.56
Calculated yield grade	4.4[a]	4.3[a]	3.6[b]	3.0[c]	0.2	< 0.01
pH	5.52[b]	5.55[ab]	5.53[b]	5.58[a]	0.02	0.05
Fat, %	10.6[a]	9.0[b]	5.6[c]	3.6[d]	0.3	< 0.01
Protein, %	23.1[b]	23.4[b]	24.2[a]	24.5[a]	0.2	< 0.01
Moisture, %	65.8[d]	66.9[c]	69.4[b]	70.9[a]	0.4	< 0.01

[a–c]Within a row, means without a common superscript differ ($P < 0.05$).

[1]Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select.

[2]SE (largest) of the least squares means.

[3]Marbling: 300 = slight00, 400 = small00, 500 = modest00, 600 = moderate00, 700 = slightly abundant00 (USDA, 1997).

[4]Maturity: 100 = A00, 200 = B00 (USDA, 1997).

[5]HCW = hot carcass weight.

[6]KPH = kidney, pelvic, and heart fat.

Compositional analysis

Results for the compositional and pH analysis of the 4 quality grades are displayed in Table 1. USDA Quality grade influenced fat, moisture, and protein percentage ($P < 0.01$). Prime had the greatest fat percentage, followed by Top Choice, Low Choice, and Select, with each grade differing ($P < 0.05$). Select had greater moisture percentage than any other quality grade, again with a significant decrease in moisture from Select to Prime ($P < 0.05$). Select and Low Choice had greater ($P < 0.05$) protein percentage than Top Choice or Prime, which were similar ($P > 0.05$). These results are comparable to fat percentages reported previously for each respective USDA quality grade (O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016). Quality grade also influenced pH ($P < 0.05$). Select had a greater ($P < 0.05$) pH than Low Choice and Prime but did not differ ($P > 0.05$) from Top Choice. Although statistical differences were detected for pH, all values were within a normal pH range suggested by Jeremiah et al. (1991) between 5.4 and 5.8.

Demographic profile and beef consumption habits of consumers

Consumer participant demographic information is presented as Table 2. The majority of panelists (52.4%) were aged 20 to 39 yr old. Most participants were employed full-time (79.5%) or were students (12.2%). Household size of participants was primarily 4, 2, and 1 member. Caucasian/white was the primary ethnic group followed closely by Hispanic. Household incomes among participants were primarily in the range of $20,000 to $50,000, which was nearly twice as many participants than any other income bracket. These consumer demographics were proportionally similar to previous research conducted in Lubbock, Texas (O'Quinn et al., 2012; Corbin et al., 2015; Legako et al., 2016). Lubbock has been considered to have consumers with beef preferences similar to multiple geographic areas of the United States (Mehaffey et al., 2009). The beef consumption habits of consumer participants are presented in Table 3. Nearly 75% of the consumers eat beef weekly (1 to 6 times per week). Consumers commonly identified flavor (48%) or tenderness (41%) as the most important palatability trait, while only 11% identified juiciness as the most important palatability trait. Finally, the preferred cooking levels were Medium Rare, Medium, or Medium Well Done.

Consumer sensory

Table 4 displays the effects of cooking method and USDA quality grade on consumer scores of tenderness, juiciness, flavor liking, and overall liking. There were no interactions between the cooking method and quality grade for any of the palatability attributes ($P > 0.05$). For all traits, both cooking method and quality grade

Table 2. Demographic characteristics for all consumers[1] ($n = 288$)

Trait	Consumers, %
Age	
< 20 y	6.9
20–29 y	21.9
30–39 y	30.6
40–49 y	16.7
50–59 y	15.3
≥ 60 y	8.7
Gender	
Male	45.5
Female	54.5
Occupation	
Tradesperson	14.2
Professional	28.8
Administration	18.8
Sales and service	12.2
Laborer	5.6
Homemaker	1.7
Student	12.2
Currently not employed/retired	6.3
Household size	
1 person	17.7
2 people	20.8
3 people	14.9
4 people	23.9
5 people	15.6
> 5 people	7.0
Annual income level	
< $20,000	15.9
$20,000–50,000	33.3
$50,001–75,000	14.6
$75,001–100,000	16.3
> $100,000	19.8
Education level	
Non-high school graduate	2.4
High school graduate	26.4
Some college/technical school	27.1
College graduate	29.2
Post graduate	14.9
Cultural heritage	
African American	9.7
Asian	1.0
Caucasian/white	46.2
Hispanic	40.3
Native American	0.7
Other	2.1

[1]Location: Lubbock, TX.

influenced consumer scores ($P < 0.01$). Steaks cooked on FLAT were scored lower for tenderness and juiciness than any other cooking method ($P < 0.05$). Charbroiled steaks had greater ($P < 0.05$) flavor liking and consequently greater overall liking than any other cooking method. Steaks cooked on CLAM had lower ($P < 0.05$) flavor liking scores than any other cooking method, except FLAT. Since steaks cooked on FLAT were less tender and juicy, those steaks were ultimately scored lower for overall liking than all other cooking methods, except CLAM.

One possible reason that consumers in this experiment rated CHAR steaks with greater scores could be related to the longer cooking time. Several authors have suggested that cooking methods that use low temperatures and long cooking time may induce changes in the texture of meat, due to heat-induced structural changes combined with the enzymatic breakdown of proteins (Bejerholm et al., 2014; Pathare and Roskilly, 2016). Also, the longer cooking time can enhance the formation of flavor compounds due to the Maillard reaction, lipid degradation, and other flavor compound formation pathways (Shahidi et al., 2014; Corbin et al., 2015; Legako et al., 2015).

Lorenzen et al. (1999) reported differences in consumer perception of 5 different cooking methods in 4 cities of the United States. Those authors found a significant interaction between cooking methods and USDA quality grade and between cooking method and city. Samples were scored using a scale ranging from 1 (not at all tender) to 23 (as extremely tender). Top loin steaks cooked at medium degree of doneness were rated with 19.1, 19.0 18.8, and 18.3 for pan fry, outdoor grill, broil, and indoor grill, respectively. For juiciness, the interaction between cooking method and USDA quality grade was not found; the juicier scores were received by pan-frying and the outdoor grill. Lorenzen et al. (1999) also reported higher flavor desirability ratings for outdoor grilling and pan-frying, while indoor grilling provided the least desirable beef flavor.

In the present study, Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking ($P < 0.05$). However, Top Choice did not differ from Prime or Low Choice for tenderness, juiciness, or overall liking ($P > 0.05$). Consumers scored Prime and Top Choice similarly ($P > 0.05$) and greater ($P < 0.05$) than Low Choice and Select, which were also similar ($P > 0.05$), for flavor liking.

Increased marbling (intramuscular fat) level has a positive relationship with beef eating quality (Smith et al., 1985). Higher USDA quality grades, resulting from increased marbling in beef samples, often result in greater consumer palatability ratings (Lorenzen et al., 1999; McKenna et al., 2004; Corbin et al., 2015; Lucherk et al., 2016).

Table 5 displays the percentage of beef strip loin steaks considered acceptable for tenderness, juiciness,

Table 3. Beef consumption habits for consumers[1] (n = 288)

Trait	Consumers, %
How often do you eat beef?	
Rarely (< 1 time per week)	0.7
1–3 times a week	41.7
4–6 times a week	33.7
7–9 times a week	12.2
10 or more	11.8
Most important palatability trait when eating beef	
Flavor	47.9
Juiciness	11.5
Tenderness	40.6
Preferred cooking level	
Blue	0.4
Rare	2.1
Medium rare	29.9
Medium	31.6
Medium well done	23.6
Well done	12.5

[1]Location: Lubbock, TX.

Table 4. The effects of cooking method and quality grade on the least squares mean for consumer (n = 288) sensory scores[1] for palatability traits

Treatment	Tenderness	Juiciness	Flavor liking	Overall liking
Cooking method				
Clamshell grill	63.6^{a}	62.5^{a}	59.1^{c}	61.5^{bc}
Flat top gas grill	60.6^{b}	55.6^{b}	61.1^{bc}	60.2^{c}
Char broiler	65.7^{a}	64.8^{a}	68.0^{a}	67.9^{a}
Salamander	65.6^{a}	63.7^{a}	62.5^{b}	63.9^{b}
SEM[2]	1.8	1.5	1.3	1.2
Quality grade				
Prime	67.7^{x}	66.1^{x}	65.8^{x}	67.8^{x}
Top Choice	66.4^{xy}	63.6^{xy}	64.7^{x}	65.0^{xy}
Low Choice	62.5^{yz}	59.5^{yz}	60.3^{y}	61.2^{yz}
Select	58.7^{z}	57.4^{z}	59.9^{y}	59.6^{z}
SEM	1.5	2.6	2.0	2.3
P-value				
Cooking method	< 0.01	< 0.01	< 0.01	< 0.01
Quality grade	< 0.01	< 0.01	< 0.01	< 0.01
Method × Quality grade	0.74	0.63	0.41	0.50

[a–c]Within a column, least squares means without a common superscript differ (P < 0.05) due to cooking method effect.

[x–z]Within a column, least squares means without a common superscript differ (P < 0.05) due to quality grade effect.

[1]Sensory scores: 0 = extremely tough/dry, dislike flavor/overall extremely; 100 = extremely tender/juicy, like flavor/overall extremely.

[2]SE (largest) of the least squares means.

flavor, and overall as influenced by cooking method and USDA quality grade. There were no interactions between the cooking method and quality grade for the acceptability of any of the palatability traits (P > 0.05). Cooking method influenced (P < 0.01) juiciness, flavor, and overall acceptability, but did not influence tenderness acceptability (P > 0.05). A lower (P < 0.05) percentage of consumers indicated steaks cooked on FLAT were acceptable for juiciness compared to the other cooking methods. A greater (P < 0.05) proportion of consumers believed flavor was acceptable for steaks cooked using CHAR compared to CLAM or FLAT, but CHAR did not differ from SAL for flavor acceptability (P > 0.05). Overall acceptance was greater (P < 0.05) for steaks cooked on CHAR compared to all other cooking methods, while steaks cooked on FLAT had lower (P < 0.05) overall acceptance than CHAR or SAL. Quality grade influenced consumer acceptance of all 4 traits (P ≤ 0.04). Prime and Top Choice had similar and greater (P < 0.05) acceptability for all traits compared to Low Choice and Select, which were also similar (P > 0.05); however, a similar (P > 0.05) percentage of consumers indicated that Top Choice and Low Choice were acceptable for juiciness, flavor, and overall.

Cooking loss, pressed juiciness percentage, and slice shear force

Table 6 displays the effects of quality grade and cooking method for cooking loss, PJP, and SSF. Cooking loss was not influenced (P > 0.05) by the quality grade × cooking method interaction or quality grade. Cooking method influenced (P < 0.01) cooking loss. CLAM had lower (P < 0.05) cooking loss than FLAT, SAL, and CHAR, which did not differ from each other (P > 0.05). The lower cooking loss of CLAM could be related to the shorter cooking times compared to the other methods. Average cooking time and standard deviation were calculated for each cooking method. The fastest and least variable cooking method was CLAM (8 min 43 s ± 1 min 42 s), where the principal heat transfer method is conduction from the double heating surface. Conversely, CHAR took the longest to reach the end point temperature (72°C) and was also the most variable (18 min 50 s ± 3 min 48 s). The average cooking time for cooking steaks on SAL was 13 min 50 s ± 2 min 32 s and for FLAT was 16 min 16 s ± 3 min 39 s. It has been previously reported that cooking methods with a shorter cooking time result in a lower cooking loss (Tornberg, 2005; Barbera and Tassone, 2006). However, the correlation between cooking time and cooking loss was not linear, as the cooking loss is determined by a combination of cooking time and heating rate (Bejerholm et al., 2014). Since heating rate also influences cooking

Table 5. Least squares means for the percentage of beef strip steaks considered acceptable for tenderness, juiciness, flavor, and overall by consumers ($n = 288$)

Treatment	Tenderness	Juiciness	Flavor	Overall
Cooking method				
Clamshell grill	86.3	85.9[a]	83.8[b]	86.2[bc]
Flat top gas grill	85.9	79.2[b]	86.2[b]	83.9[c]
Char broiler	89.1	87.7[a]	90.5[a]	90.5[a]
Salamander	88.9	85.8[a]	87.6[ab]	86.9[b]
SEM[1]	0.3	0.2	0.2	0.2
Quality grade				
Prime	91.7[x]	89.3[x]	90.2[x]	91.1[x]
Top Choice	90.7[x]	85.7[xy]	88.2[xy]	88.5[xy]
Low Choice	84.2[y]	81.5[y]	85.5[y]	83.8[y]
Select	81.6[y]	82.0[y]	84.1[y]	83.3[y]
SEM	0.3	0.3	0.2	0.3
P-value				
Cooking method	0.22	< 0.01	< 0.01	0.01
Quality grade	< 0.01	0.04	0.03	0.02
Method × Quality grade	0.90	0.99	0.75	0.88

[a–c]Within a column, least squares means without a common superscript differ ($P < 0.05$) due to cooking method effect.

[x,y]Within a column, least squares means without a common superscript differ ($P < 0.05$) due to quality grade effect.

[1]SE (largest) of the least squares means.

Table 6. Cooking loss, pressed juiciness percentage (PJP), and slice shear force (SSF) from steaks representing 4 different quality grades using 4 different cooking methods ($n = 192$)

	Cooking loss, %	PJP, %	SSF, kg
Cooking method			
Clamshell grill	20.5[a]	15.9	12.90
Flat top gas grill	24.7[b]	14.5	13.06
Char broiler	26.0[b]	14.9	13.29
Salamander	25.8[b]	15.8	12.35
SEM[1]	1.0	0.7	0.57
Quality grade			
Prime	24.9	14.5	12.57
Top Choice	24.8	15.0	12.57
Low Choice	23.6	15.5	12.56
Select	23.7	16.1	13.91
SEM	1.1	0.8	0.70
P-value			
Cooking method	< 0.01	0.19	0.40
Quality grade	0.34	0.21	0.15
Method × Quality grade	0.40	0.55	0.58

[a,b]Within a column, least squares means without a common superscript differ ($P < 0.05$) due to cooking method effect.

[1]SE (largest) of the least squares means.

loss, that could explain why no differences were observed between FLAT, SAL, and CHAR in the current study. Lawrence et al. (2001) found cooking *longissimus lumborum* steaks on a belt grill with a target temperature of 163°C required significantly less cooking time than a forced-air convection oven or electric broiler, but cooking loss did not differ between those 3 methods (25.9 to 27.6%), indicating cooking loss was not a direct function of cooking time. Unlike our results, Lucherk et al. (2017) found that cooking loss decreased from 19.7 to 15.7% as quality grade increased from USDA Standard to USDA Prime. Cooking loss in the current study was somewhat higher (23.6 to 24.9%) and did not differ by quality grade. However, that trend for higher cooking loss and lack of difference between quality grade was reported by Hunt et al. (2014) when cooking steaks from 4 muscles, including the *longissimus lumborum* muscle, from USDA Select and Top Choice carcasses on a clamshell grill.

Pressed juiciness percentage was not influenced by quality grade, cooking method, or their interaction ($P > 0.05$). Likewise, McKillip et al. (2017) saw no difference in PJP due to quality grade ranging from Select to Prime. However, the current results are slightly lower than the averages presented by both McKillip et al. (2017) and Lucherk et al. (2017).

Slice shear force was also not influenced by quality grade, cooking method, or their interaction ($P > 0.05$). Researchers have previously shown similarity in shear force values between various cooking methods, when evaluating different sous-vide conditions (García-Segovia et al., 2007), different speeds on a belt grill (Shackelford et al., 1999), or different oven cooking conditions (Vittadini et al., 2005; Yusnaini et al., 2015). However, differences in shear force values have been reported when evaluating different cooking methods (Lawrence et al., 2001; Obuz et al., 2003; Modzelewska-Kapituła et al., 2012; Wyrwisz et al., 2012; Mora et al., 2011; Yancey et al., 2011; Chumngoen et al., 2018). In the current study, consumer tenderness scores were lower for steaks cooked on FLAT despite a lack of difference in SSF values between the cooking methods. The reduced juiciness scores for FLAT could have influenced the consumers' perception of tenderness, and a halo effect could be responsible for the lower tenderness scores of FLAT compared to the other cooking methods.

In partial agreement to the current results, Nyquist et al. (2018) reported that SSF was similar between Low Choice and Select *longissimus lumborum* steaks, but steaks from both grades required greater force to shear than Prime steaks. Wheeler et al. (1994) found that Warner-Bratzler shear force of *longissimus* steaks from *Bos taurus* cattle was higher in carcasses with slight marbling compared to small, modest, or moderate marbling, but did not observe any differences in shear force from small to moderate marbling (i.e., within USDA Choice carcasses). McKillip et al. (2017), however, saw no difference in SSF between Prime, Low Choice, or Select beef strip loins steaks, which supports the current findings. Yet, Derington et al. (2011) reported a significance increase in *longissimus* SSF values from USDA Select to Low Choice to Top Choice steaks, which contradicts the current results. Discrepancies exist with previous findings as to whether or not quality grade (marbling score) influences shear force and ultimately consumer perception of tenderness. These inconsistencies could be attributed to a number of factors such as postmortem aging period, sample size, cooking method, and animal background or cattle genetics. Aging period was similar to the current study (21 d postmortem) in all of the aforementioned trials except Wheeler et al. (1994), where samples were aged until 7 d postmortem. Wheeler et al. (1994) used an electric broiler, and Derington et al. (2011) cooked steaks on a belt grill, whereas McKillip et al. (2017) and Nyquist et al. (2018) both used clamshell grills to cook all steaks. Sample size was smaller for McKillip et al. (2017) and Nyquist et al. (2018), but larger in the studies conducted by Wheeler et al. (1994) and Derington et al. (2011), which could impact variance and the ability to detect differences between grades. In most instances when subprimals are selected from commercial abattoirs to represent a particular USDA quality grade, animal background information is unknown, which was the case in the current trial.

Volatile compounds

A total of 30 volatile compounds representing pathways of cooked beef flavor development (e.g., thermal oxidation of lipids, Maillard reaction) were selected and quantified (ng/g cooked sample). Table 7 shows the quantities of volatiles collected from the 4 cooking methods and 4 quality grades. Cooking method impacted ($P < 0.05$) the headspace concentration of at least 1 volatile compound in the alcohol, n-aldehyde, Strecker aldehyde, sulfide, furan, and pyrazine groups, but none in the ketone, thiol, or alkane groups ($P > 0.05$). At the same time, quality grade affected ($P < 0.05$) concentration of at least 1 volatile compound in the alcohol, n-aldehyde, Strecker aldehyde, ketone, thiol, furan, and alkane groups, but none in the sulfide or pyrazine groups ($P > 0.05$). No interactions were observed between the cooking method and quality grade for any of the volatile compounds analyzed ($P > 0.05$).

In general, lipid oxidation during long-term storage generates a rancid off flavor, but during cooking rapid thermal degradation of lipids may contribute to a desirable flavor profile (Mottram and Edwards, 1983). Alcohols are derived from unsaturated fatty acids during thermal degradation and are associated with fermented, rancid, and grassy flavors (Mottram and Edwards, 1983). Cooking method affected ($P < 0.05$) the concentration of 1-hexanol and 1-penten-3-ol, whereas quality grade affected ($P < 0.05$) the concentration of 1-hexanol, 1-octen-3-ol, and 1-octanol. 1-Hexanol is associated with fermented and rancid flavors and 1-penten-3-ol is associated with green-grass, cheesy, and toasted flavors (Flores et al., 1997). Samples cooked on CHAR had a lower ($P < 0.05$) concentration of 1-hexanol compared to FLAT, CLAM, and SAL, which did not differ ($P > 0.05$). However, CHAR had a greater ($P < 0.05$) concentration of 1-penten-3-ol compared to the other cooking methods, FLAT and SAL similarly ($P > 0.05$) had intermediate levels, and CLAM had the lowest ($P < 0.05$) concentration of 1-penten-3-ol. For 1-hexanol and 1-octanol, Prime steaks had a lower concentration ($P < 0.05$) than all other grades, which were similar ($P > 0.05$). For 1-octen-3-ol, Prime steaks had a lower concentration ($P < 0.05$) than Top Choice and Select, but did not differ ($P > 0.05$) from Low Choice. Prime steaks generally have a lower proportion of polar lipids compared to Select or Low Choice, which could reduce the susceptibility of beef with greater marbling or IMF to lipid oxidation (Mottram and Edwards, 1983).

n-Aldehydes are the most prominent class of compounds produced by lipid degradation and are reported to be associated with beef aroma (Mottram and Edwards, 1983). Unsaturated fatty acids such as oleic, linoleic, and linolenic acids are the primary source of saturated n-aldehydes (Mottram and Edwards, 1983; Elmore et al., 1999). Cooking method influenced pentanal and heptanal, where CLAM and SAL had greater concentrations than FLAT and CHAR. Samples cooked on FLAT also had a greater concentration of pentanal compared to CHAR ($P < 0.05$), but they did not differ for heptanal ($P > 0.05$). Quality grade only impacted the concentration of hexanal ($P < 0.05$). Prime steaks had a lower ($P < 0.05$) concentration of hexanal compared to Select, but Prime was not different ($P > 0.05$) from Top Choice or Low Choice. Greater quantity of n-aldehydes in lower quality grade steaks is in agreement with previous results (Legako et al., 2015; Legako et al., 2016).

The Strecker degradation is one pathway of Maillard reaction, where dicarbonyl compounds originating from early stages of the Maillard reaction, produce a deamination and decarboxylation of amino

Table 7. Least squares means for volatiles flavor compounds (ng/g of sample) for beef *longissimus lumborum* steaks from 4 different quality grades using 4 different dry cookery methods ($n = 179$)

Volatile compound,	Cooking method (M)[1]					Quality grade (Q)[2]					*P*-value		
ng/g cooked sample	CHAR	SAL	FLAT	CLAM	SE[3]	Pr	T.Ch	L.Ch	Sel	SE[3]	M	Q	M×Q
Alcohol													
1-Hexanol	1.59^{b}	2.29^{a}	2.24^{a}	2.16^{a}	0.19	1.61^{y}	2.34^{x}	2.18^{x}	2.15^{x}	0.19	0.03	0.04	0.68
1-Penten-3-ol	0.59^{a}	0.39^{b}	0.41^{b}	0.15^{c}	0.06	0.51	0.40	0.35	0.28	0.06	< 0.01	0.07	0.51
1-Octen-3-ol	4.24	4.88	5.82	5.33	0.53	3.82^{y}	5.47^{x}	4.76^{xy}	6.24^{x}	0.51	0.15	< 0.01	0.23
1-Octanol	3.66	3.90	3.50	3.34	0.29	2.73^{y}	3.66^{x}	3.94^{x}	4.08^{x}	0.31	0.52	0.02	0.78
n-Aldehyde													
Pentanal	0.80^{c}	1.32^{ab}	1.14^{b}	1.45^{a}	0.11	0.98	1.30	1.06	1.37	0.13	< 0.01	0.12	0.09
Hexanal	88.70	128.33	130.78	107.38	13.80	86.17^{y}	118.31^{xy}	112.89^{xy}	137.83^{x}	13.43	0.08	0.04	0.23
Heptanal	7.09^{b}	9.27^{a}	7.37^{b}	9.54^{a}	0.66	7.55	8.50	8.10	9.14	0.69	< 0.01	0.41	0.62
Nonanal	2.36	2.72	2.31	2.26	0.26	2.14	2.28	2.55	2.67	0.26	0.55	0.45	0.73
Strecker aldehyde													
Acetaldehyde	9.47	10.32	9.57	13.85	1.87	10.83	10.49	8.86	13.02	1.98	0.26	0.50	0.61
3-Methyl butanal	1.39	1.48	1.10	1.75	0.38	1.46	1.39	1.33	1.55	0.36	0.67	0.97	0.46
2-Methyl butanal	1.25^{a}	1.05^{ab}	1.01^{ab}	0.65^{b}	0.15	1.32^{x}	1.11^{x}	1.09^{x}	0.45^{y}	0.15	0.04	< 0.01	0.51
Benzaldehyde	8.99^{c}	10.53^{bc}	11.64^{ab}	12.11^{a}	0.57	10.06	11.53	10.66	11.02	0.56	< 0.01	0.29	0.61
Phenylacetaldehyde	3.19	4.98	3.01	2.42	1.09	3.19	2.72	5.44	2.26	1.09	0.36	0.15	0.61
Ketone													
2-Propanone	48.33	52.79	51.93	68.80	9.25	60.28	54.43	42.02	64.66	9.96	0.35	0.40	0.36
2,3-Butanedione	62.41	63.10	64.14	67.76	7.49	71.63^{x}	79.81^{x}	39.20^{y}	66.78^{xy}	9.87	0.93	0.03	0.13
2-Butanone	11.80	11.41	12.23	10.30	1.57	10.92	12.84	10.53	11.46	1.57	0.82	0.72	0.24
3-Hydroxy-2-butanone	64.23	61.86	63.54	97.65	21.53	78.76	77.85	37.07	93.59	23.76	0.52	0.36	0.25
Sulfide													
Dimethyl sulfide	2.00	1.86	1.85	1.91	0.17	1.92	1.98	1.66	2.05	0.18	0.91	0.43	0.73
Dimethyl disulfide	0.04^{a}	0.04^{a}	0.02^{b}	0.03^{ab}	0.003	0.04	0.03	0.03	0.02	0.003	0.02	0.07	0.30
Thiol													
Methanethiol	3.69	3.50	3.12	3.10	0.33	3.44	3.18	2.97	3.81	0.30	0.50	0.19	0.20
Methional	1.39	1.44	1.35	1.19	0.11	1.41^{xy}	1.25^{yz}	1.51^{x}	1.19^{z}	0.09	0.40	< 0.01	0.87
Furan													
2-Pentyl furan	0.91^{b}	1.53^{a}	1.06^{b}	1.11^{b}	0.15	0.69^{y}	1.29^{x}	1.15^{x}	1.49^{x}	0.16	0.02	< 0.01	0.19
Pyrazine													
Methyl pyrazine	2.04^{a}	0.79^{c}	1.37^{b}	0.21^{d}	0.15	1.32	1.05	1.18	0.87	0.16	< 0.01	0.25	0.61
2–5/6-Dimethyl pyrazine	4.50^{a}	1.86^{c}	2.82^{b}	0.48^{d}	0.27	2.74	2.45	2.55	1.92	0.30	< 0.01	0.25	0.72
Trimethyl pyrazine	3.18^{a}	1.30^{c}	1.81^{b}	0.38^{d}	0.18	1.83	1.68	1.68	1.49	0.19	< 0.01	0.65	0.80
2-Ethyl-3,5/6-dimethyl pyrazine	0.70^{a}	0.23^{b}	0.28^{b}	0.07^{c}	0.05	0.31	0.32	0.34	0.32	0.06	< 0.01	0.99	0.41
Alkane													
D-limonene	77.98	59.28	59.67	52.81	13.83	60.74	54.77	51.22	82.99	14.80	0.58	0.42	0.43
Octane	2.95	3.09	5.22	3.46	0.93	2.64	3.56	3.75	3.18	0.30	0.28	0.05	0.52
Nonane	0.36	0.29	0.31	0.32	0.04	0.577	0.429	0.35	0.36	0.04	0.55	0.07	0.24

[a–d]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to cooking method effect.

[x–z]Within a row, least squares means without a common superscript differ ($P < 0.05$) due to quality grade effect.

[1]CHAR = char broiler, SAL = salamander, FLAT = flat top gas grill, CLAM = clamshell grill.

[2]Pr = Prime, T.Ch = Top choice, L.Ch = Low choice, Sel = Select.

[3]SE (largest) of the least squares means.

acids. This reaction results in α-aminoketones and aldehydes with fewer carbons than the original amino acid (Hofmann and Schieberle, 2000). Of the Strecker aldehydes, 2-methyl butanal concentration was affected by cooking method and quality grade ($P < 0.05$), whereas benzaldehyde was only influenced by cooking method ($P < 0.01$). 2-methyl butanal originates from the degradation of isoleucine and is a flavor compound associated with musty and nutty flavors (Guth et al., 1994). For this compound, CHAR generated a greater concentration ($P < 0.05$) compared to CLAM, but CHAR did not differ from FLAT or SAL ($P > 0.05$. Conversely, CHAR had a lower ($P < 0.05$) concentration of benzaldehyde than FLAT or CLAM, but did not differ from SAL. Select steaks had a lower concentration ($P < 0.05$) of 2-methyl butanal than all other quality grades, which were similar ($P > 0.05$). Benzaldehyde originates from Strecker degradation of phenylalanine and is one of the components that provides sweet floral flavors. Additionally, benzaldehyde and other aminoketones are precursors for the formation of pyrazines in later stages of the Maillard reaction (Mottram and Edwards, 1983).

Only 1 ketone, 2,3-butanedione, was influenced ($P < 0.05$) by quality grade. Ketones are thought to increase with fat percentage (El-Magoli et al., 1996), but Legako et al. (2016) did not observe a linear trend in the sum of ketones of *longissimus lumborum* steaks from Prime, Low Choice, and Standard quality grades. Similar to our findings, 2,3-butanedione decreased from Prime to Low Choice, but Low Choice and Standard were similar (Legako et al., 2016); however, Select had similar 2,3-butanedione than Prime and Top Choice in the current study.

Sulfur-containing compounds contribute to meaty flavor notes. Dimethyl sulfide and dimethyl disulfide are associated with roasted characteristics (Mottram, 1991). Cooking method influenced dimethyl disulfide, where FLAT had a lower concentration ($P < 0.05$) than CHAR or SAL. No other cooking method or quality grade effects were detected for sulfides ($P > 0.05$).

Pyrazines are known to contribute to roasted, grilled, and nutty characteristics (Mottram, 1991). Cooking method affected ($P < 0.01$) the concentration of all 4 pyrazine compounds. For 3 of the 4 pyrazines (methyl pyrazine, 2–5/6-dimethyl pyrazine, trimethyl pyrazine), CHAR had the greatest concentration ($P < 0.05$) of pyrazine compounds with a significant difference in the concentration of pyrazine compounds where CHAR > FLAT > SAL > CLAM. Samples cooked on CHAR had a greater ($P < 0.05$) concentration of 2-ethyl-3,5/6-dimethyl pyrazine than samples cooked on FLAT or SAL, which were similar ($P > 0.05$). Samples cooked on CLAM had a lower ($P < 0.05$) concentration of 2-ethyl-3,5/6-dimethyl pyrazine than samples cooked using all other methods.

Even though all the cooking methods evaluated are classified as dry cooking methods, there could be differences in the cooking condition that yielded differences in the concentration of pyrazines. Wall et al. (2019) compared different electric grill surface temperatures on the formation of volatile compounds in 3 muscles including beef strip loin. In their results, they found grill temperature influenced the production of pyrazines including methyl pyrazine, 2–5/6-dimethyl pyrazine, trimethyl pyrazine, and 2-ethyl-5/6-dimethyl pyrazine. Higher concentrations were found in steaks cooked at high surface temperature (232°C) compared with those cooked at medium (205°C) and low (177°C) temperatures. The authors in this paper related the higher formation of pyrazines with high surface temperature. However, in the present study, the temperature was maintained between 200 and 220°C during the cooking. Toldrá and Flores (2007) suggested that the Maillard reaction is promoted by high temperature and low humidity. Even though the temperature was similar for all the 4 dry cooking methods in the current study, the heat source for CHAR originated from the bottom, then whatever moisture released by the steak either dropped down or it was immediately evaporated by the hot air, maintaining the dry surface at a high temperature. Additionally, CHAR required the longest cooking time of all methods in the current study, allowing for more time for the formation of these compounds. The second highest concentration of pyrazines were generated using FLAT. The cooking time was shorter for FLAT compared to CHAR, which could have limited the pyrazine formation. Steaks cooked on SAL had lower pyrazine concentration despite relatively similar cooking time compared to FLAT. However, the origin of the heat source could have influenced this variation as heat originated from below the steak surface for FLAT and above via radiant heat for SAL. Steaks cooked on CLAM generated the lowest concentration of pyrazines, most likely due to the shorter cooking time and reduced air flow for this particular cooking method.

Correlations

Pearson correlation coefficients were generated to quantify the relationships between consumer scores and objective measures of palatability (Table 8). Within the consumer eating quality traits, flavor liking was most strongly correlated to overall liking ($r = 0.91$; $P < 0.01$), followed by tenderness ($r = 0.84$, $P < 0.01$) and juiciness ($r = 0.81$, $P < 0.01$). Tenderness and juiciness scores were also strongly related ($r = 0.81$; $P < 0.01$) to each other. The similar high correlation for consumer eating quality traits was found by other authors as well (Corbin et al., 2015; Legako et al., 2015; Lucherk et al., 2016). However, correlation between consumer quality traits and objective evaluation of SSF resulted in low negative correlations ($r = –0.18$ to $–0.12$) and nonsignificant correlations with PJP. As SSF decreased, tenderness and all other palatability traits increased, as would be expected from this inverse relationship. In previous studies (Lucherk et al., 2017; McKillip et al., 2017), PJP may have had a direct relationship with consumer rat-

Table 8. Pearson correlation coefficients quantifying relationships between fat, objective evaluation and consumer palatability ratings

Trait	Fat	SSF[1]	PJP[2]	Cooking loss	Tenderness	Juiciness	Flavor liking	Overall liking
SSF[1]	–0.15*							
PJP[2]	–0.14*	–0.04						
Cooking loss	–0.06	–0.02	–0.08					
Tenderness	0.24**	–0.16**	–0.04	–0.16*				
Juiciness	0.23**	–0.18**	–0.03	–0.27**	0.81**			
Flavor liking	0.21**	–0.12*	0.01	–0.08	0.75**	0.70**		
Overall liking	0.24**	–0.17**	–0.02	–0.15*	0.84**	0.81**	0.91**	
Alcohols	–0.24**	–0.05	–0.08	–0.01	–0.13	–0.07	–0.15*	–0.16*
n-Aldehydes	–0.20**	–0.06	–0.04	0.06	–0.18*	0.16*	–0.24**	–0.27**
Strecker aldehydes	–0.10	–0.12	0.05	–0.02	0.07	0.05	0.08	0.07
Ketones	0.02	–0.10	0.07	0.01	0.10	0.07	0.08	0.09
Sulfides	0.14	–0.13	–0.12	0.19**	0.01	0.02	0.10	0.06
Pyrazines	0.08	–0.05	0.11	0.43**	0.15*	0.15*	0.30**	0.22**
1-Penten-3-ol	0.20**	–0.14	–0.01	0.33**	0.20**	0.20**	0.27**	0.22**
1-Octen-3-ol	–0.22**	–0.05	–0.08	–0.04	–0.17*	–0.12	–0.19*	–0.19*
Hexanal	–0.19**	–0.05	–0.04	0.07	–0.18*	–0.16*	–0.24**	–0.27**
2-Pentyl furan	–0.40**	0.04	0.02	0.01	–0.22**	–0.17*	–0.23**	–0.25**
2–5/6-Dimethyl pyrazine	0.10	–0.07	–0.12	0.44**	0.16*	0.17*	0.31**	0.22**
2-Ethyl-3,5/6-dimethyl pyrazine	–0.01	0.04	–0.04	0.25**	0.13	0.20**	0.26**	0.20**

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

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

[1]Slice shear force.

[2]Pressed juiciness percentage.

ings, especially juiciness, but in the current study, it was not linked with any measure of consumer eating quality.

Several volatile flavor compounds had significant correlations with consumer eating quality traits. Despite a positive correlation ($P < 0.01$) between 1-penten-3-ol with flavor liking, tenderness, and juiciness, the sum of alcohols were negatively related to flavor liking and overall liking scores, likely due to the negative correlation of 1-octen-3-ol ($P < 0.01$). Fat percentage was also negatively correlated ($P < 0.01$) with alcohols, which could be explained by the lower detection of both 1-octen-3-ol and 1-hexanol in Prime samples than other USDA quality grades. The sum of n-aldehydes, and specifically hexanal, were also negatively related ($P < 0.01$) with fat percentage, as well as flavor liking and all other consumer palatability traits. Fat percentage and flavor liking were also negatively associated ($P < 0.01$) with 2-pentyl furan, which was detected in lower concentration in Prime samples compared to all other USDA quality grades. Most of the compounds included into the groups of alcohols, n-aldehydes and the 2-pentyl furan compound, are derivated from lipid oxidation. Pyrazines, on the other hand, were positively linked ($P < 0.01$) with flavor liking scores and with the other palatability traits, as both 2–5/6-dimethyl pyrazine and 2-ethyl-3,5/6-dimethyl pyrazine had positive relationships with flavor liking ($P < 0.01$). Pyrazines are known to contribute to roasted, grilled and nutty characteristics (Mottram, 1991), and CHAR followed by FLAT, SAL, and CLAM generated the greatest concentration of pyrazines supporting the grilled flavor development. Pyrazines were not linked ($P > 0.05$) with fat percentage, which aligns with the lack of differences in concentration of various pyrazines due to quality grade in the current study. Strecker aldehydes, ketones, and sulfur-containing compounds seemed to have neutral effects on flavor liking as indicated by nonsignificant Pearson correlation coefficients for these groups of compounds ($P > 0.05$).

Conclusions

The purpose of this study was to evaluate possible differences in consumer perception of 4 different USDA quality grades cooked using 4 dry heat cooking methods. Clamshell grills are often used by universities and institutions for research, whereas CHAR, FLAT, and SAL are frequently used in the home and in restaurants. Consumers in this study were able to perceive differences in tenderness and juiciness between CLAM and FLAT; consumers also detected differences in flavor between CLAM, CHAR, and SAL. Finally, consumers detected differences in overall acceptability between

CHAR and CLAM. Samples cooked on CLAM had the lowest cooking loss but the cooking method did not affect objective measures of tenderness or juiciness. Even though differences in SSF and PJP where not observed, consumers perceived samples differently for tenderness and juiciness. Moreover, certain groups of volatile compounds were associated with flavor liking. Namely, pyrazines were positively related to flavor liking, while alcohols and n-aldehydes tended to have negative relationships with flavor liking. Cooking methods that generated more and less of these compounds, respectively, were scored accordingly for flavor and overall liking. These results indicate cooking method had a significant impact on consumer palatability ratings, and those results were consistent across a range of quality grades.

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