Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness

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Abstract

The objective of this study was to evaluate the impact of quality grade on beef eating quality of top sirloin steaks when cooked to multiple degrees of doneness (DOD). Beef top sirloin butts (N = 60; 15 / quality grade) were collected to equally represent 4 quality grades [Prime, Top Choice (modest^{00} – moderate^{100}), Low Choice, and Select]. Top butts were cut into six consecutive steaks, and then divided laterally to get a total of twelve steaks per top butt. Steaks were assigned to one of three DOD: rare (60°C), medium (71°C), and well-done (77°C). Steaks within DOD were assigned to consumer sensory analysis, trained sensory analysis, fat and moisture analysis, and Warner-Bratzler shear force (WBSF). There were no interactions (P > 0.05) for all consumer ratings of palatability traits, indicating increases in DOD had the same impact across all quality grades. There was a difference (P > 0.05) within quality grade for consumer ratings of juiciness (P > 0.05). Prime steaks had greater (P < 0.05) juiciness ratings than all other quality grades, except for Top Choice. As DOD increased, consumer ratings and the percentage of steaks rated acceptable for each palatability trait decreased (P < 0.05; rare > medium > well-done). There was a quality grade × DOD interaction (P < 0.05) for trained sensory panel juiciness scores. When cooked to medium, Prime and Top Choice steaks were rated higher (P < 0.05) for juiciness than Low Choice and Select steaks. Similar to consumer ratings, trained panel ratings of tenderness decreased (P < 0.05) as DOD increased (rare > medium > well-done). Lastly, there were no quality grade by DOD interactions (P > 0.05) for Warner-Bratzler shear force. These results indicate that regardless of the DOD steaks were cooked to, quality grade had minimal impact on the palatability of beef top sirloin steaks. Therefore, unless cooked to a medium DOD, it is unnecessary for consumers, retailers, and

foodservice to pay premium prices for higher quality top sirloin steaks, as the same eating experience will be given.

Key words: beef, consumer, degree of doneness, palatability, marbling, top sirloin steaks

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Dedication

This thesis is dedicated to my parents, Todd and Sheila Olson. Your continual love and support throughout this process will never go unappreciated.

Chapter 1 - Literature Review

Impact of marbling on beef retail and food service cuts

Emphasis on marbling has long been placed on beef through the United States beef grading system for its relationship to eating satisfaction and pricing (Blumer, 1963; Parrish et al., 1973; USDA, 2017). The grading standards were first developed in 1916 by the United States Department of Agriculture (**USDA**) as a means of reporting consistent market grades of beef (USDA, 2017). The standards were revised in 1926, leading to the publishing of the Official United States Standards for the Grades of Carcass Beef (USDA, 2017). These standards were ultimately a foundation for grading when voluntary beef grading services began one year later in 1927 (USDA, 2017). This system gives producers a chance to receive premiums for their cattle, while also giving retailers and consumers an idea of an expected level of eating satisfaction. Typically, beef is graded on whole carcasses, between the 12th and 13th rib, using a combination of subjective assessment and electronic instruments to measure quality and cutability criteria. Two different types of grading are assessed on whole carcasses: quality grading and yield grading. Quality grading refers to the evaluation of indicators of palatability traits related to eating satisfaction (tenderness, juiciness, and flavor), whereas yield grading determines the amount of lean meat yield from a carcass (USDA, 2014). There are eight quality grades based on the amount of marbling within the lean (intramuscular fat), lean color, and maturity of the carcass (USDA, 2014).

Marbling is well established within literature as a major contributor to the tenderness, juiciness, and flavor of beef (Blumer, 1963; Parrish et al., 1973; Smith et al., 1985; Smith et al., 1987). Early studies noted that steaks with higher degrees of marbling ultimately receive higher palatability ratings than steaks with lower degrees of marbling (Parrish et al., 1973; Smith and

Carpenter, 1974b; Savell and Cross, 1988). One theory known as the lubrication theory, suggests that marbling within and around muscle fibers adds an additional source of lubrication to the steak, leading to a more tender and juicier steak (Smith and Carpenter, 1974a). During cooking, intramuscular fat solubilizes and becomes a part of juices that act as lubrication during chewing, and in this way, marbling is directly associated with juiciness, and indirectly associated to tenderness (Jeremiah et al., 1970). Tenderness is closely associated with the amount of connective tissue within the muscle (Blumer, 1963). Another theory known as the strain theory proposes fat deposition helps lessen the toughness of meat through the decrease in elasticity of connective tissue (Smith and Carpenter, 1974a). When fat is deposited into the walls of the perimysium and epimysium, the overall strength is lost due to the spreading of connective tissue strands between muscle fibers (Blumer, 1963; Smith and Carpenter, 1974a).

While previous literature has reported tenderness to be the most important factor when evaluating beef eating quality, flavor has been shown to be the most important factor when tenderness is at an acceptable level (Smith et al., 1987; Miller et al., 1995; O'Quinn et al., 2018). Flavor is the combination of the factors of odor and taste (Legako et al., 2015). Odors and tastes are the result of marbling within meat and produce flavors that are associated with their respective species (i.e. pork and beef). However, consumers have varying perceptions of flavor, as some may prefer meat with a bland flavor, compared to others who prefer a more intense flavor (Smith and Carpenter, 1974a).

It has been thoroughly noted that as quality grade increases, consumer acceptability of steaks increase (Smith et al., 1985; O'Quinn et al., 2012; Hunt et al., 2014b; Lucherk et al., 2016). Hunt et al. (2014) evaluated four muscles [gluteus medius (GM), longissimus dorsi (LD), semimembranosus (SM), and serratus ventralis (SV)] from USDA Choice and Select carcasses

for consumer acceptability of tenderness, juiciness, flavor, and overall liking. As quality grade decreased from Choice to Select, there was a decrease in the proportion of samples rated acceptable by consumers for all palatability traits evaluated (Hunt et al., 2014). Lucherk et al. (2016) evaluated longissimus dorsi (**LD**) steaks from Prime, Top Choice (upper 2/3 Choice), Low Choice, Select, and Standard carcasses. There were no differences among Prime, Top Choice, and Low Choice samples for the percentage of samples rated acceptable for flavor (Lucherk et al., 2016). As expected, Standard and Select steaks had lower percentages of samples rated acceptable than Prime, Top and Low Choice for all palatability traits, but when compared to each other, were similar (Lucherk et al., 2016). O'Quinn et al. (2012) also found no differences in flavor acceptability for Prime, Top Choice, and Low Choice steaks; however, Wagyu, Prime, Top Choice, Low Choice, and Standard steaks were all similar in tenderness acceptability (O'Quinn et al., 2012). With the additional quality treatments of American Wagyu, Top Choice (Holstein), Grass-finished, and Select (Holstein), Corbin et al. (2015) found similar results to O'Quinn et al. (2012) and Lucherk et al. (2016) for flavor and tenderness acceptability. Additionally, American Wagyu, Australian Wagyu, and Prime steaks had a greater proportion of acceptable samples for juiciness than all other quality treatments (Corbin et al., 2015b). A study by O'Quinn et al. (2018) evaluated the palatability of USDA quality grades across 11 different consumer sensory studies of LD steaks. Across all quality grades, the percentage of acceptable samples increased as quality grade increased, and more notably indicating that quality grade can be an effective method of sorting steaks according to acceptability (O'Quinn et al., 2018).

Top sirloin steaks

Consumer sensory analysis

The impact of quality grade has been evaluated over a variety of muscles, including the LD, psoas major (**PM**), semimembranosus (**SM**) serratus ventralis (**SV**), and gluteus medius (**GM**; Neely et al., 1998; Hunt et al., 2014; Legako et al., 2015). However, when compared against other muscles, the GM has typically been rated lower in comparison to more tender cuts of beef. Guelker et al. (2013) sampled ten retail and three food service cuts, with top sirloin steaks (**TSS**) ranging within five quality grades; Prime, Top Choice (upper two-thirds of Choice) Low Choice, Select, and Ungraded. Ungraded TSS had the greatest ratings for overall like, like flavor, and like juiciness than all other grades (Guelker et al., 2013). These results are the opposite from Martinez et al. (2015), where no differences were observed in sensory traits among all quality grades (Prime, Top Choice, Low Choice, Select) within TSS. Additionally, retail top sirloin steaks received the lowest ratings for like flavor, flavor level, like juiciness and juiciness level when compared to cuts from the rib, loin, and chuck (Martinez et al., 2015). Savell et al. (1999) used in-home consumers to evaluate Top sirloin steaks from Top Choice, Low Choice, High Select, and Low Select carcasses for tenderness, juiciness, flavor desirability, flavor intensity, and overall like. Top Choice TSS received the highest ratings for overall like, while Low Choice steaks received the lowest ratings (Savell et al., 1999). Additionally, High Select steaks were rated less tender than Low Choice and Top Choice steaks. A study by Hunt et al. (2014) evaluated GM steaks from Top Choice and Select carcasses, finding tenderness ratings to be greater in Top Choice steaks compared to Select. Additionally, Top Choice GM steaks contained higher ratings for juiciness, flavor and overall like (Hunt et al., 2014). In comparison, Legako et al. (2015) tested GM steaks of Prime, Top Choice (upper two-thirds Choice), Low Choice, Select, and Standard carcasses. Quality grade effects on juiciness, flavor liking, and

overall liking were dependent on type of muscle. Prime TSS were similar to all other quality treatments for consumer ratings of juiciness, flavor liking, and overall liking. Additionally, there were no differences in consumer ratings of tenderness. Brooks et al. (2000) and Voges et al. (2007) both sampled retail and foodservice steaks of four quality grades (Prime, Top Choice, Low Choice, and Select), and no roll carcasses. Both retail and foodservice top sirloin steaks from Prime, Top Choice, Low Choice, and Select carcasses showed no differences for tenderness, juiciness, overall flavor, and beef flavor (Brooks et al., 2000). Voges et al. (2007) found top sirloin steaks to have lower ratings for juiciness, like juiciness, tenderness, like tenderness, and overall like when compared to ribeye and top loin steaks. Opposite from Brooks et al. (2000), Prime TSS received higher ratings than all other quality grades for tenderness and juiciness.

Trained sensory analysis

Because consumer panelists are less likely to detect differences between treatments, trained sensory panelists are used as an additional objective measurement to assess differences in sample palatability (AMSA, 2015). Lorenzen et al. (2003) conducted trained panels using TSS from Top Choice (upper two-thirds choice), Low Choice, High Select, and Low Select carcasses. A USDA quality grade by cut interaction was significant for muscle fiber tenderness, and connective tissue amount; however, no quality grade effects were observed within TSS for tenderness (Lorenzen et al., 2003). Moreover, TSS were rated higher than top round steaks for tenderness. George-Evins et al. (2004) evaluated Select, Choice, and Certified Angus Beef (**CAB**) top sirloin steaks using trained panelists for flavor, juiciness, myofibrillar tenderness, connective tissue amount, and overall tenderness. Ratings for flavor, juiciness, and myofibrillar tenderness were similar across all treatments (George-Evins, 2004). A study by Wulf et al. (1996) evaluated top sirloin steaks from Limousin steers of varying marbling scores (Modest^{00}-

Traces[40]). Marbling scores were reported to be negatively correlated with trained panel tenderness across all cuts observed (Wulf et al., 1996). Conversely, trained panel juiciness and flavor intensity showed no correlation to quality grade (Wulf et al., 1996). Harris et al. (1992) only evaluated top sirloin steaks from USDA Choice carcasses but were compared to top loin steaks. Steaks were subjected to six different aging periods postmortem (0,7,14,21,28, and 35 days) Between top sirloin and top loin steaks, no differences were found for juiciness or flavor intensity ratings; however, top loin steaks had higher overall tenderness ratings than TSS across all aging periods (Harris et al., 1992). In another study, trained panelists gave USDA Choice TSS higher ratings for overall tenderness and juiciness when compared to Select steaks (King et al., 2009). Additionally, no differences were observed between quality grades for beef flavor intensity and off flavor intensity (King et al., 2009).

Similar to consumer sensory analysis, only one study has evaluated TSS cooked to multiple DOD using trained panelists. Luchak et al. (1998) evaluated TSS cooked to final internal temperatures of 57 and 74°C. Steaks cooked to 57°C received higher scores greater ratings than steaks cooked to 74°C for juiciness, muscle fiber tenderness, overall tenderness, and flavor intensity (Luchak et al., 1998). However, no differences were observed between both DOD for connective tissue amount (Luchak et al., 1998).

Warner – Bratzler shear force

Warner- Bratzler Shear Force (**WBSF**) has been highly utilized throughout the beef industry as an objective measurement for tenderness (AMSA, 2015). Different from sensory evaluation, WBSF values have noted an inverse relationship with marbling level, where an increase in marbling level causes a decrease in shear force values (Wheeler et al., 1994; Gruber et al., 2006). A study by Hunt et al. (2014b) evaluated TSS of Top Choice (upper two-thirds Choice) and Select carcasses, finding no differences in WBSF values (3.21 vs 3.14 kg). These

findings agree with Lorenzen et al. (2003), where Top Choice (3.1 kg) sirloin steaks had the lowest WBSF value when compared to Low Choice (3.2 kg), High Select (3.2 kg) and Low Select (3.3 kg) samples. Brooks et al. (2000) evaluated retail and foodservice TSS from Prime, Top Choice, Low Choice, and Select carcasses. No WBSF differences were observed in retail steaks across all quality grades, however; both Prime and Top Choice foodservice steaks had lower WBSF values (2.76 and 2.47 kg) than Choice and no roll steaks (3.11 and 3.37 kg) (Brooks et al., 2000). Additionally, Voges et al. (2007) found no differences among quality grades (Prime, Top Choice, Low Choice, and Select) for foodservice TSS. Luchak et al. (1998) found differences in WBSF values between Choice (4.2 kg) and Select (4.5 kg) TSS. Gruber et al. (2006) collected WBSF values from USDA Select and Top Choice TSS subjected to seven aging periods postmortem (2,4,6,10, 14, 21, and 28 days). Regardless of aging period, Select steaks had higher shear values than Top Choice steaks (Gruber et al., 2006).

Fat and moisture analysis

It is well documented in top loin steaks that as quality grade increases, an increase in chemical fat percentage follows (Parrish et al., 1973; Savell et al., 1986; Savell and Cross., 1988; Luchak et al., 1998; Dow et al., 2011; O'Quinn et al., 2012; Emerson et al., 2013; Hunt et al., 2014a; Legako et al., 2015; Lucherk et al., 2016; Drey et al., 2018).Within top loin steaks, Standard contains the lowest fat percentage (1 - 2%), followed by Select (2 - 4%), Low Choice (4 - 5%), Top Choice (6 -9%) (upper two-thirds of Choice), and Prime having the highest fat percentage (10 -14%). Inversely, as quality grade increases, the percentage of moisture in steaks decreases (Savell et al., 1986; Wulf et al., 1996; O'Quinn et al., 2012; Hunt et al., 2014a; Acheson et al., 2015; Corbin et al., 2015; Lucherk et al., 2016; Drey et al., 2018). While fat and moisture percentage has been thoroughly evaluated in cuts from the strip loin, few studies have incorporated fat and moisture analysis of TSS into their data set, especially when compared

across multiple quality grades. Dransfield (1977) evaluated eighteen different muscles for fat and moisture composition but did not indicate marbling level or quality grade. It was indicated that GM samples had values for fat and moisture percentage of 3.1 and 73.5% respectively (Dransfield, 1977). Mc Keith et al. (1985) tested thirteen muscles with a marbling level range of slight^{40} to moderate^{00} and reported values as one mean value. Gluteus medius steak composition values differed slightly from Dransfield (1977) with fat and moisture percentages of 5.1 and 71.8%. In another study, fat and moisture analysis were evaluated on TSS from Limousin steers grading 3% Standard, 68% Select, and 29% Choice (Wulf et al., 1996). While data were not reported in tabular form, it was noted by the authors that as quality grade increased, fat percentage increased, and moisture decreased. Luchak et al. (1998) completed fat and moisture analysis of TSS from USDA Choice and Select carcasses. It is important to note that analysis was conducted on cooked steaks, as opposed to analysis of raw samples. Choice (7.7%) steaks had a greater percentage of fat than Select (5.9%) steaks; however, both quality grades were similar in moisture percentage (64.0 and 64.1%) (Luchak et al., 1998). Hunt et al. (2014a) also evaluated steaks from Top Choice and Select carcasses. Steaks from Top Choice carcasses had a higher fat percentage than Select steaks (6.35 and 3.82%), and lower moisture content than Select steaks (68.82 and 70.92%) (Hunt et al., 2014a). Legako et al. (2015) determined fat and moisture content in GM steaks across the largest span of quality grades (Prime, Top Choice, Low Choice, Select, and Standard). Prime (7.1%) and Top Choice (4.3%) steaks had a greater percentage of fat than Low Choice (1.6%), Select (2.9%), and Standard (2.6%) steaks which were all similar in content (Legako et al., 2015). As expected, Prime steaks had the lowest amount of moisture (69.0%); however, Top Choice, Low Choice, Select, and Standard all had similar moisture content (71.8, 72.4, 71.8, and 72.3%, respectively) (Legako et al., 2015).

Fiber type / sarcomere length

Beef tenderness has been thoroughly researched across objective and subjective measurements; however, additional measurements such as sarcomere length play a key role into the mechanical structure of meat and should not be overlooked. Muscles containing shorter sarcomeres are less tender than sarcomeres of longer length (Herring et al., 1965). Additionally, fiber type characteristics show that muscles containing larger amounts of α-white fibers have more connective tissue and are ultimately less tender than muscles with β-red fibers (Calkins et al., 1981; Kirchofer et al., 2002). While sarcomere length and fiber type have been thoroughly evaluated in larger muscles such as the LD (Hunt and Hedrick, 1977), muscles from the chuck, round, and sirloin have limited results. Stokowski et al. (2006) measured the sarcomere length of seven muscles [(SM), semitendinosus (**ST**), biceps femoris (**BF**), vastus lateralis (**VL**), GM, LD, and triceps brachii (**TB**)] from three Angus and Brahman breed crosses. Additionally, one side of each carcass was subjected to electrical stimulation or served as a non-stimulated control. In non-stimulated muscles, the ST, BF, VL, GM, and LD had the shortest sarcomeres, with the TB samples having the longest sarcomere length (Stolowski et al., 2006). Dransfield (1977) evaluated 18 beef muscles for sarcomere length of hot deboned or control treatments. The LD, SV, and GM of the control treatment had the shortest lengths (1.43 μm, 1.51 μm, and 1.73 μm respectively), whereas the PM had the longest sarcomere length (3.47 μm). Likewise, Hunt and Hedrick (1977) also evaluated the LD, GM, and PM from USDA Choice carcasses. In agreement with previous studies, the PM was again found to have a longer sarcomere length (3.06 μm) than the LD and GM (1.83 μm and 1.73 μm) however; no differences were found between the LD and GM (Hunt and Hedrick, 1977). Additionally, Mc Keith et al. (1985) found similar results, with the PM having longer sarcomeres (3.46 μm) than the LD and GM. Unlike findings from Hunt and Hedrick (1977), the LD contained longer sarcomeres than the GM (Mc Keith et al., 1985).

Chuck cuts

The beef chuck consists of cuts from the shoulder blade and upper arm. In cattle, muscles from the shoulder region are extensively used for locomotion, making common cuts from the chuck tougher compared to support muscles in the loin. Since these muscles are used for much of the animal's daily movement, there is a greater presence of connective tissue within steaks. Due to the tough nature of these steaks, cuts from this primal have been underutilized, and typically marketed as ground product (Von Seggern et al., 2005; Lepper-Blilie et al., 2014). However, due to the decline in value of the beef chuck, research was conducted with funding from the Beef Checkoff to create new ways to increase the value of steaks from this primal. From this research came several new value-added cuts, such as the Denver, Delmonico, and Flat Iron Steak. When compared to the ribeye, these steaks were found to have relative or greater tenderness (Lepper-Blilie et al., 2014). Von Seggern et al. (2005) evaluated WBSF effects of multiple muscles from the chuck, including the infraspinatus (INF), SV, TB, as well as the LD. The INF (3.4 kg), SV (3.8 kg), and TB (4.2 kg) had lower WBSF values when compared to the LD (5.2 kg).

While value-added cuts have shown to be advantageous, multiple authors have also evaluated the beef chuck across multiple quality grades for differences in palatability traits. Nyquist et al. (2018) tested the IF, SV, and TB from Prime, Choice (small^{00} – small^{100}) and Select carcasses. No quality grade by muscle interactions were found for consumer traits, indicative of a consistent impact of quality grade across muscles. However, the IF and SV had greater juiciness and flavor ratings than the TB (Nyquist et al., 2018). Additionally, the IF and SV were similar in consumer tenderness ratings, but greater than the TB (Nyquist et al., 2018).

Similar to other Beef Customer Satisfaction studies (Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999); Goodson et al. (2002) tested the customer satisfaction of clod steaks

by in-home consumers, this time using grilled, broiled, fried, and braised cooking methods. The authors found clod steaks cooked to a medium DOD or lower were given higher ratings for tenderness and juiciness than steaks cooked to medium-well or greater. However, no differences were observed across all DOD for overall like and flavor amount of clod steaks (Goodson et al., 2002).

Rib cuts

Muscles from the beef rib are situated under the front section of the backbone and are primarily used for support. Studies that have evaluated these cuts have found conflicting results. Gilpin et al., (1965) subjected ribeye steaks using trained sensory evaluation. Samples were rated on a 9- point scale; with 1 being very tough/dry, and 9 being very tender/juicy. Steaks were also designated as either high marbled or low marbled samples; however, the authors did not mention what quality grades segregated the groups, only the marbling range (abundant – slight). Steaks from high marbled carcasses were scored only slightly higher in tenderness, juiciness, and flavor than low marbled steaks (Gilpin et al., 1965). Jones et al. (1990) used ribeye steaks of modest, small, slight, and traces marbling levels to evaluate their effects on tenderness, juiciness, flavor desirability and intensity, and overall palatability. Unlike Gilpin et al. (1965), steaks of modest marbling had greater ratings for juiciness than steaks of slight and traces marbling. However, no differences were found between all marbling levels for all other palatability traits evaluated.

Loin cuts

Cuts from the loin have been evaluated extensively in literature, and more notably in the last five years, on the influence of multiple quality grades on palatability traits (Corbin et al., 2015; O'Quinn et al., 2015; McKillip et al., 2017; Drey et al., 2018; Nyquist et al., 2018). Drey et al. (2018) and Corbin et al. (2015) both tested steaks of a wide variety of quality treatments,

noting that as quality treatment decreased, there were concurrent decreases in consumer ratings of tenderness, juiciness, flavor, and overall liking. However, Drey et al., (2018) reported similar ratings of all traits between Top Choice and Low Choice steaks. In a study using only three quality treatments, Prime steaks had greater ratings than Choice and Select for all palatability traits (tenderness, juiciness, flavor liking, and overall liking), but no differences in tenderness and overall liking ratings were found between Choice and Select (Nyquist et al., 2018). McKillip et al. (2017) also evaluated steaks of three quality grades, where each quality treatment was split into non-enhanced and enhanced samples and evaluated for the same palatability traits as Nyquist et al. (2018). Prime and Low Choice non-enhanced steaks were similar for all palatability ratings, but higher than Low Select steaks for juiciness and tenderness (McKillip et al., 2017). In another study, tenderloin steaks from USDA Choice, Select, and High Select carcasses were subjected to consumer sensory evaluation of tenderness, juiciness, flavor, and overall liking (O'Quinn et al., 2015). Different from studies evaluating strip steaks, consumers gave tenderloin steaks similar palatability scores regardless of quality grade (O'Quinn et al., 2015).

Round cuts

Cuts from the round have consistently remained at the tough end of the tenderness scale and ranked the lowest in consumer ratings. Coincidently, all National Beef Tenderness Surveys have concluded that cuts from the round are less tender and rated tougher by consumers when compared to middle meats (Morgan et al., 1991; Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013; Martinez et al., 2015). Smith et al. (1987) found that quality grades (Prime – Standard) could accurately predict 30 to 38% of tenderness, flavor, and overall palatability of loin steaks, but no more than 8% in top round steaks. In a similar study, marbling group

(moderately abundant – practically devoid) explained 33% of the variation in loin steaks and 7% in top round steaks for ratings of overall palatability (Smith et al., 1985). Neely et al. (1998) noted that regardless of quality grade, top round steaks were consistently rated the lowest in consumer ratings when compared to top loin and sirloin steaks. In a study conducted by Behrends et al. (2005), top round steaks from Top Choice (upper two-thirds Choice) and High Select (upper half of slight degree of marbling) carcasses were evaluated by in-home consumers for tenderness, juiciness, flavor like, flavor intensity, and overall like. Top Choice steaks were given higher ratings for tenderness, juiciness, flavor, and overall like compared to High Select steaks (Behrends et al., 2005). When evaluating the adductor (AD), BF, and SM, Nyquist et al. (2018) found no differences among quality grades across all muscles for slice shear force (**SSF**). However, for WBSF, Prime cuts had lower values when compared to Choice and Select, where similar values were found. When compared to muscles of support, the AD, SM, and BF had higher WBSF values than muscles from the loin (Nyquist et al., 2018). These findings indicate that even with the added benefit of increasing quality grade, round steaks remain consistently at the bottom unless additional efforts are made to improve the palatability of round cuts.

Impact of degree of doneness on beef retail and foodservice cuts

Degree of doneness is undoubtedly one of the most important factors contributing to the overall palatability of beef steaks. Degree of doneness is the final internal temperature and color that a steak is cooked to. While the exact origins of the development of beef DOD recommendations is uncertain, temperatures were first decided on by a group of industry and academia members after visual appraisal of steaks cooked to various final internal temperatures (Drey, 2018; Smith, 2018). The American Meat Science Association published its first set of Guidelines for Cookery and Sensory Evaluation of Meat in 1978, and in 1995 a revised set of

guidelines were published as the Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Fresh Meat. These guidelines were developed in conjunction with the National Live Stock and Meat Board (**NLSMB**) (American Meat Science Association, 1995). These guidelines included the AMSA's own beef steak color guide, which were shortly after deemed the official guide for the National Cattlemen's Beef Association (**NCBA**) and the USDA's Agricultural Research Service (**ARS**).

Early studies have indicated that as DOD increases, palatability traits such as tenderness, juiciness, and flavor decrease, ultimately leading to a decrease in satisfaction of consumers (Parrish et al., 1973; Cross et al., 1976b; Akinwunmi et al., 1993; Luchak et al., 1998). Cross et al. (1976b) evaluated LM steaks cooked to final internal temperatures of 60, 70, 80, and 90°C. Panelist ratings of juiciness, tenderness, and flavor acceptability decreased as final internal temperature increased; however, only when steaks were cooked to a final temperature of 80°C did tenderness become unacceptable to consumers (≤ 5.0 on a 9-point rating scale) (Cross et al., 1976b). Similarly, Parrish et al. (1973) evaluated three DOD (60,70, 80°C) within the LM on an 8-point scale (8 being the most desirable) and found a linear decrease in palatability traits as internal temperature increased. Luchak et al. (1998) also evaluated top loin steaks cooked to three DOD, but with slight differences in endpoint temperature (57, 68, and 74°C). Panelists evaluated samples on an 8- point scale for juiciness, muscle fiber, and overall tenderness, as well as flavor intensity. Ratings of juiciness and tenderness decreased as endpoint temperature increased; however, panelists detected no differences in flavor intensity across all DOD (Luchak et al., 1998).

Many authors have noted that as DOD increases, cooking loss increases (Parrish et al., 1973; Wheeler et al., 1999; George-Evins, 2004; Yancey et al., 2011; Yancey et al., 2016).

Wheeler et al., (1999) cooked USDA Select LM steaks to three DOD (60, 70, and 80°C) using a belt grill, noting that as endpoint temperature increased from 60 to 80°C there was a 10% increase in cook loss. Additionally, Parrish et al. (1973) found a 9.7% increase in cook loss of LM steaks broiled from 60 to 80°C in an industrial oven. Yancey et al. (2011) cooked USDA Select LM steaks to slightly different endpoint temperatures of 65.5, 71.1, and 76.6°C using various cookery methods (forced-air convection oven, gas-fired char-grill, electric griddle, forced-air impingement oven, and clam-shell grill). There were no interactions between cooking method and endpoint temperature for cook loss, but steaks cooked to 76.6°C had the greatest cook loss (35.2%), with a 9% difference when compared to steaks cooked to 65.5°C. No differences were observed between steaks cooked to 65.5 (26.2%) and 71.1°C (29.3%), with only a 3% increase in cook loss (Yancey et al., 2011). In another study, the same three endpoint temperatures and five cookery methods were evaluated on SM and INF steaks from USDA Select carcasses (Yancey et al., 2016). Within all cookery methods, cook loss percentage increased as endpoint temperature increased for SM steaks. However, no interaction was observed for INF steaks. INF steaks showed an 8.4% increase in cook loss when cooked from 65.5 to 76.6°C. As expected, INF steaks cooked to 76.6°C had the greatest amount of cook loss, whereas SM steaks had no differences in cook loss from 65.5 (58.1%) and 71.1°C (57.8%), and 71.1 and 76.6°C (57.29%) (Yancey et al., 2016). George-Evins (2004) cooked TSS from USDA Choice, Select, and CAB carcasses to three endpoint temperatures (65.5, 71, and 76.6°C). Regardless of quality grade, cook loss was greatest at 76.6°C, with a 9.8% increase from 65.5 to 76.6°C (George-Evins, 2004).

Top sirloin steaks

Consumer sensory analysis

Although literature evaluating TSS across multiple DOD is very limited, studies comparing across multiple temperatures have shown that as DOD increases, palatability ratings decrease. Savell et al. (1999) conducted in-home evaluation of TSS with consumers living in Chicago, Philadelphia, Houston, and San Francisco. Consumers cooked steaks to their preferred DOD using various cooking methods and were also asked to evaluate steaks for overall like, tenderness, juiciness, flavor desirability, and flavor intensity. Cooking methods for consumer evaluation consisted of outdoor grill, broil, indoor grill, pan-fry, stir-fry, and simmer and stew. Consumer endpoint temperatures were combined into categories of medium rare or less, medium, medium well, and well done or more. Top sirloin steaks grilled outdoors, indoors, broiled, or pan-fried were given higher juiciness ratings at DOD of medium rare or less (Savell et al., 1999). Regardless of cooking method, tenderness ratings were higher at DOD of medium rare or less (Savell et al., 1999). Additionally, ratings for overall like decreased and DOD increased for cooking methods of outdoor grilling and pan-frying (Savell et al., 1999).

Warner – Bratzler shear force

Top sirloin steaks have been a challenge for the meat industry to understand how this cut responds differently to degrees of doneness (Morgan et al., 1991; Neely et al., 1998). Wulf et al., (1996) found TSS to have lower WBSF values than round steaks when cooked to rare, medium rare, and medium DOD. Both George-Evins (2004) and Lorenzen et al. (2003) found an increase in WBSF values as TSS were cooked to higher DOD. (Lorenzen et al., 2003) also found TSS cooked to 60°C were closer to top loin steaks in WBSF values, and to top round steaks when cooked to 75°C. Luchak et al. (1998) cooked TSS designated for WBSF to endpoint temperatures

of 57 and 74°C. Steaks cooked to 57°C had a lower shear value (3.9 kg) than steaks cooked to 74°C (4.7 kg) (Luchak et al., 1998).

Rib cuts

Gilpin et al. (1965) determined that ribeye steaks were scored lower by trained panelists as they were cooked to from 60 to 82°C, corresponding to rare, medium, and well done. Yancey et al. (2011) tested the effects of cookery method and endpoint temperature on WBSF of ribeye steaks. As previously mentioned, steaks were cooked to three endpoint temperatures (65.5, 71.1, and 76.6°C) using five different cookery methods. Shear force values increased by almost 30% as endpoint temperature increased from 65.5 to 76.6°C (Yancey et al., 2011). Wheeler et al. (1998) sorted ribeye steaks into five different tenderness categories (1 = < 3.5 kg; 2 = 3.51 - 4.5 kg; 3 = 4.51 - 5.5 kg; 4 = 5.51 - 6.5 kg; 5 = > 6.5 kg). These categories were based upon the shear value data of steaks cooked to 70°C. Afterwards, steaks produced from additional ribeye rolls were cooked to two endpoint temperatures (60 and 80°C), and an interaction between tenderness class and endpoint temperature was found. Results reported that regardless of tenderness class, shear force values increased from 60 to 80°C (Wheeler et al., 1998).

Loin cuts

Unlike TSS, cuts from the short loin have been consistently evaluated for changes in palatability ratings across multiple DOD. While an increase in marbling within top loin steaks has shown to have a positive relationship with palatability traits, the introduction of DOD can have a negative impact on palatability (Savell et al., 1987). Drey et al. (2018) and Lorenzen et al. (2005) evaluated strip steaks cooked to six DOD: very rare (55°C), rare (60°C), medium rare (63°C), medium (71°C), well done (77°C), and very well done (82°C). Both studies found consumer ratings of juiciness and tenderness both decreased as DOD increased from very rare to

very well done; however, steaks cooked to very rare, rare, and medium rare had similar ratings of juiciness and tenderness (Lorenzen et al., 2005; Drey et al., 2018). No differences were observed across all endpoint temperatures for liking of flavor and overall liking (Lorenzen et al., 2005). These results differed from Drey et al. (2018), where overall like and flavor ratings were similar from very rare to medium. While previous studies have not typically evaluated strip steaks across all possible DOD, a similar trend of decreased palatability with increasing DOD has been shown (Cross et al., 1976a; Cross et al., 1976b; Luchak et al., 1998; Gomes et al., 2014).

Round cuts

Few studies have evaluated the effect of DOD on cuts from the round (Gilpin et al., 1965; Neely et al., 1999; Yancey et al., 2016). Gilpin et al. (1965) evaluated eye of round (**EYR**) steaks broiled to three endpoint temperatures (60, 71, and 82°C), for tenderness, juiciness, and flavor. Trained panelists rated EYR steaks broiled to 60°C more tender than steaks cooked to 71 and 82°C, which were similar in ratings for tenderness (Gilpin et al., 1965). Additionally, EYR steaks were rated lower in juiciness as endpoint temperature increased from 60 to 82°C, while flavor ratings were highest in steaks cooked to 60°C (Gilpin et al., 1965). Yancey et al. (2016) cooked top round steaks to three endpoint temperatures (65.5, 71.1, and 76.6°C), using five cookery methods: forced-air convection oven (**FAC**), forced-air impingement oven (**IMP**), gas-fired, oven-hearth charbroiler (**CHAR**), electric griddle (**GRID**), and electric clamshell grill (**CLAM**). Using these cookery methods and endpoint temperatures, SM steaks were subjected to WBSF. Top round steaks cooked on the CHAR had greater WBSF values than all other cookery methods when cooked to 65.5 and 76.6°C (Yancey et al., 2016). Warner-Bratzler shear force values were also greater on the CHAR when cooked to 71.1°C, than steaks using all other cookery methods (Yancey et al., 2016). Neely et al. (1999) also cooked top round steaks using multiple cookery

methods (outdoor grill, broil, pan broil, pan-fry, stir-fry, braise, and simmer and stew); however, these steaks were prepared and evaluated by in-home consumers. Consumers from Chicago, Houston, Philadelphia, and San Francisco cooked steaks to their preferred DOD based on the NLSMB beef steak color guide, and rated steaks on a 23-point hedonic scale. Consumer ratings of juiciness and tenderness decreased as DOD increased (Neely et al., 1999). Additionally, higher ratings of overall like were given to top round steaks cooked to medium rare or less, and to very well-done DOD (Neely et al., 1999).

References

Acheson, R., D. Woerner, J. Martin, K. Belk, T. Engle, T. Brown, J. Brooks, A. Luna, L. Thompson, and H. Grimes. 2015. Nutrient database improvement project: Separable components and proximate composition of raw and cooked retail cuts from the beef loin and round. Meat Science 110:236-244.

Akinwunmi, I., L. Thompson, and C. Ramsey. 1993. Marbling, fat trim and doneness effects on sensory attributes, cooking loss and composition of cooked beef steaks. Journal of Food Science 58:242-244.

American Meat Science Association. 1995. Research guidlines for cookery, sensory evaluation, and instrumental tenderness measurements of fresh meat. National Live Stock and Meat Board, Chicago, IL.

AMSA. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

Behrends, J. M., K. J. Goodson, M. Koohmaraie, S. D. Shackelford, T. L. Wheeler, W. W. Morgan, J. O. Reagan, B. L. Gwartney, J. W. Wise, and J. W. Savell. 2005. Beef customer satisfaction: USDA quality grade and marination effects on consumer evaluations of top round steaks. Journal of Animal Science 83:662-670.

Blumer, T. N. 1963. Relationship of Marbling to the Palatability of Beef1. Journal of Animal Science 22. doi:10.2134/jas1963.223771x

Brooks, J. C., J. B. Belew, D. B. Griffin, B. L. Gwartney, D. S. Hale, W. R. Henning, D. D. Johnson, J. B. Morgan, F. C. Parrish, J. O. Reagan, and J. W. Savell. 2000. National Beef Tenderness Survey-1998. Journal of Animal Science 78:1852-1860. doi:/2000.7871852x

Calkins, C. R., T. R. Dutson, G. C. Smith, Z. L. Carpenter, and G. W. Davis. 1981. Relationship of fiber type composition to marbling and tenderness of bovine muscle. Journal of Food Science 46:708-710.

Corbin, C. H., T. G. O'Quinn, A. J. Garmyn, J. F. Legako, M. R. Hunt, T. T. N. Dinh, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Science 100:24-31. doi:10.1016/j.meatsci.2014.09.009

Cross, H. R., M. S. Stanfield, and E. J. Koch. 1976a. Beef palatability as affected by cooking rate and final internal temperature. Journal of Animal Science 43:114-121.

Cross, H. R., M. S. Stanfield, and E. J. Koch. 1976b. Beef Palatability as Affected by Cooking Rate and Final Internal Temperature1. Journal of Animal Science 43. doi:10.2134/jas1976.431114x

Dow, D. L., B. R. Wiegand, M. R. Ellersieck, and C. L. Lorenzen. 2011. Prediction of fat percentage within marbling score on beef longissimus muscle using 3 different fat determination methods. Journal of Animal Science 89:1173-1179. doi:10.2527/jas.2010-3382

Dransfield, E. 1977. Intramuscular composition and texture of beef muscles. Journal of the Science of Food and Agriculture 28:833-842.

Drey, L. N. 2018. Evaluation of the beef marbling insurance theory. Master's Thesis, Kansas State University, Manhattan, KS.

Drey, L. N., L. L. Prill, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, T. A. Houser, E. A. E. Boyle, and T. G. O'Quinn. 2018. Evaluation of marbling and enhancement's

abilities to compensate for reduced beef palatability at elevated degrees of doneness1. Journal of Animal Science:sky435-sky435. doi:10.1093/jas/sky435

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. Journal of Animal Science 91:1024-1034. doi:10.2527/jas.2012-5514

George-Evins, C. D., Unruh, J. A. , Waylan, A. T., Marsden, J. L. 2004. Influence of quality classification, aging period, blade tenderization, and endpoint cooking temperature on cooking characteristics and tenderness of beef gluteus medius steaks. Journal of Animal Science:1863-1867.

Gilpin, G. L., O. M. Batcher, and P. A. Deary. 1965. Influence of marbling and final internal temperature on quality characteristics of broiled rib and eye of round steaks. Food Technology 19:834-837.

Gomes, C. L., S. B. Pflanzer, A. G. Cruz, P. E. de Felício, and H. M. A. Bolini. 2014. Sensory descriptive profiling and consumer preferences of beef strip loin steaks. Food Research International 59:76-84. doi:10.1016/j.foodres.2014.01.061

Goodson, K. J., W. W. Morgan, J. O. Reagan, B. L. Gwartney, S. M. Courington, J. W. Wise, and J. W. Savell. 2002. Beef customer satisfaction: factors affecting consumer evaluations of clod steaks. Journal of Animal Science 80:401-408.

Gruber, S. L., J. D. Tatum, J. A. Scanga, P. L. Chapman, G. C. Smith, and K. E. Belk. 2006. Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. Journal of Animal Science 84:3387-3396. doi:10.2527/jas.2006-194

Guelker, M. R., A. N. Haneklaus, J. C. Brooks, C. C. Carr, R. J. Delmore, D. B. Griffin, D. S. Hale, K. B. Harris, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, J. N. Martin, R. K. Miller, C. R. Raines, D. L. VanOverbeke, L. L. Vedral, B. E. Wasser, and J. W. Savell. 2013. National Beef Tenderness Survey–2010: Warner-Bratzler shear force values and sensory panel ratings for beef steaks from United States retail and food service establishments. Journal of Animal Science 91:1005-1014. doi:10.2527/jas.2012-5785

Guzek, D., D. Glabska, K. Glabski, G. Pogorzelski, J. Barszczewski, and A. Wierzbicka. 2015. Relationships between sarcomere length and basic composition of infraspinatus and longissimus dorsi muscle. Turkish Journal of Veterinary and Animal Sciences 39:96-101.

Harris, J. J., R. K. Miller, J. W. Savell, H. R. Cross, and L. J. Ringer. 1992. Evaluation of the Tenderness of Beef Top Sirloin Steaks. Journal of food science 57:6-9. doi:doi:10.1111/j.1365-2621.1992.tb05412.x

Herring, H. K., R. G. Cassens, and E. J. Rriskey. 1965. Further studies on bovine muscle tenderness as influenced by carcass position, sarcomere length, and fiber diameter. Journal of Food Science 30:1049-1054.

Hunt, M., C. Corbin, A. Garmyn, J. Legako, T. O'Quinn, R. Rathmann, C. Brooks, and M. Miller. 2014a. Consumer assessment of flavor of steak of varying fat levels from four beef muscles. Meat Science 96:474-475. doi:10.1016/j.meatsci.2013.07.113

Hunt, M. C., and H. B. Hedrick. 1977. Profile of fiber types and related properties of five bovine muscles. Journal of Food Science 42:513-517. doi:10.1111/j.1365-2621.1977.tb01535.x

Hunt, M. R., A. J. Garmyn, T. G. O'Quinn, C. H. Corbin, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2014b. Consumer assessment of beef palatability from four

beef muscles from USDA Choice and Select graded carcasses. Meat Science 98:1-8. doi:10.1016/j.meatsci.2014.04.004

Jeremiah, L. E., Z. Carpenter, G. C. Smith, and O. D. Butler. 1970. Beef Quality: Marbling as an Indicator of Palatability. I. Texas Agricultural Experiment Station, Texas A & M University.

Jones, D., J. Savell, and H. Cross. 1990. The influence of sex-class, USDA yield grade and USDA quality grade on seam fat trim from the primals of beef carcasses. Journal of Animal Science 68:1987-1991.

King, D., T. Wheeler, S. Shackelford, and M. Koohmaraie. 2009. Comparison of palatability characteristics of beef gluteus medius and triceps brachii muscles. Journal of Animal Science 87:275-284.

Kirchofer, K. S. 2002. Fiber-type composition of muscles of the beef chuck and round. Journal of Animal Science 80:2872.

Legako, J. F., J. C. Brooks, T. G. O'Quinn, T. D. J. Hagan, R. Polkinghorne, L. J. Farmer, and M. F. Miller. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat Science 100:291-300. doi:10.1016/j.meatsci.2014.10.026

Lepper-Blilie, A., E. Berg, A. Germolus, D. Buchanan, and P. Berg. 2014. Consumer evaluation of palatability characteristics of a beef value-added cut compared to common retail cuts. Meat Science 96:419-422.

Lorenzen, C. L., V. K. Davuluri, K. Adhikari, and I. U. Grün. 2005. Effect of end-point temperature and degree of doneness on sensory and instrumental flavor profile of beef steaks. Journal of Food Science 70:S113-S118. doi:10.1111/j.1365-2621.2005.tb07114.x

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

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top loin steak. Journal of Animal Science 77:637-644.

Luchak, G. L., R. K. Miller, K. E. Belk, D. S. Hale, S. A. Michaelsen, D. D. Johnson, R. L. West, F. W. Leak, H. R. Cross, and J. W. Savell. 1998. Determination of sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. Meat Science 50:55-72.

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Science 122:145-154. doi:10.1016/j.meatsci.2016.08.005

Martinez, H. A., A. N. Arnold, J. C. Brooks, C. C. Carr, K. B. Gehring, D. B. Griffin, D. S. Hale, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, R. K. Miller, D. L. VanOverbeke, B. E. Wasser, and J. W. Savell. 2015. National Beef Tenderness Survey-2015: Palatability and Shear Force Assessments of Retail and Foodservice Beef. Meat and Muscle Biology 1:138-148. doi:10.22175/mmb2017.05.0028

McKeith, F., D. De Vol, R. Miles, P. Bechtel, and T. Carr. 1985. Chemical and sensory properties of thirteen major beef muscles. Journal of food science 50:869-872.

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. Boyle, and T. G. O'Quinn. 2017. Sensory evaluation of enhanced beef strip loin steaks cooked to 3 degrees of doneness. Meat and Muscle Biology 1:227-241.

Miller, M. F., L. C. Hoover, K. D. Cook, A. L. Guerra, K. L. Huffman, K. S. Tinney, C. B. Ramsey, H. C. Brittin, and L. M. Huffman. 1995. Consumer acceptability of beef steak tenderness in the home and restaurant. Journal of Food Science 60:963-965.

Morgan, J. B., J. W. Savell, D. S. Hale, R. K. Miller, D. B. Griffin, H. R. Cross, and S. D. Shackelford. 1991. National beef tenderness survey. Journal of Animal Science 69:3274-3283.

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

Neely, T. R., C. L. Lorenzen, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top round steak. Journal of Animal Science 77:653-660.

Nyquist, K. M., T. G. O'Quinn, L. N. Drey, L. W. Lucherk, J. C. Brooks, M. F. Miller, and J. F. Legako. 2018. Palatability of beef chuck, loin, and round muscles from three USDA quality grades1. Journal of Animal Science 96:4276-4292. doi:10.1093/jas/sky305

O'Quinn, T. G. 2012. Identifying preferences for specific beef flavor characteristics. Ph.D. Dissertation, Colorado State University, Fort Collins, CO.

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. Journal of Food Science 80:S444-S449. doi:10.1111/1750-3841.12775

O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. Journal of Animal Science 90:626-634. doi:10.2527/jas.2011-4282

O'Quinn, T. G., J. F. Legako, J. C. Brooks, and M. F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience1. Translational Animal Science 2:26-36. doi:10.1093/tas/txx008

Parrish, F. C., Jr., D. G. Olson, B. E. Miner, and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. Journal of Animal Science 37:430-434.

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

Savell, J. W., and H. R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. Designing Foods: Animal Product Options in the Marketplace. National Academy Press, Washington, D.C.

Savell, J. W., H. R. Cross, and G. C. Smith. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. Journal of Food Science 51:838-839. doi:10.1111/j.1365-2621.1986.tb13946.x

Savell, J. W., C. L. Lorenzen, T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, and J. O. Reagan. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top sirloin steak. Journal of Animal Science 77:645-652.

Smith, G., and Z. Carpenter. 1974a. Eating quality of animal products and their fat content. Proceedings of the symposium on changing the fat content and composition of animal products. p 1-63.

Smith, G. C. 2018. Photographs of steaks cooked to different degrees of doneness.

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

Stolowski, G., B. Baird, R. Miller, J. Savell, A. Sams, J. Taylor, J. Sanders, and S. Smith. 2006. Factors influencing the variation in tenderness of seven major beef muscles from three Angus and Brahman breed crosses. Meat Science 73:475-483.

USDA. 2014. Inspection & Grading of Meat and Poultry: What Are the Differences?, Washington DC.

USDA. 2017. United States standards for grades of carcass beef. Accessed Dec. 18, 2017.

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

Von Seggern, D., C. Calkins, D. Johnson, J. Brickler, and B. Gwartney. 2005. Muscle profiling: Characterizing the muscles of the beef chuck and round. Meat Science 71:39-51.

Wheeler, T. L., L. V. Cundiff, and R. M. Koch. 1994. Effect of marbling degree on beef palatability in Bos taurus and Bos indicus cattle. Journal of Animal Science 72:3145-3151.

Wheeler, T. L., S. D. Shackelford, and M. Koohmaraie. 1999. Tenderness classification of beef: III. Effect of the interaction between end point temperature and tenderness on Warner-Bratzler shear force of beef longissimus. Journal of Animal Science 77:400-407.

Wulf, D., J. Morgan, J. Tatum, and G. Smith. 1996. Effects of animal age, marbling score, calpastatin activity, subprimal cut, calcium injection, and degree of doneness on the palatability of steaks from limousin steers. Journal of Animal Science 74:569-576.

Yancey, J., J. Apple, and M. Wharton. 2016. Cookery method and endpoint temperature can affect the Warner–Bratzler shear force, cooking loss, and internal cooked color of beef semimembranosus and infraspinatus steaks. Journal of Animal Science 94:4434-4446.

Yancey, J., M. Wharton, and J. Apple. 2011. Cookery method and end-point temperature can affect the Warner–Bratzler shear force, cooking loss, and internal cooked color of beef longissimus steaks. Meat Science 88:1-7.

Chapter 2 - Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness

Introduction

Top sirloin steaks (**TSS**) are one of the most common steaks ordered in restaurants (Schmidt et al., 2002). Restaurants offer these steaks as a less expensive alternative to more expensive cuts, such as ribeyes or tenderloins (USDA, 2018a); however, they are a cut with inconsistent palatability traits (Morgan et al., 1991; Neely et al., 1998).

Previous research demonstrated degree of doneness (**DOD)** and marbling play a key role in steak palatability (Parrish et al., 1973; Smith et al., 1984), while others concluded sensory traits decreased as endpoint temperature increased (Cross et al., 1976; Smith et al., 1985; Luchak et al., 1998). One strategy to compensate for decreased palatability at increased endpoint temperatures is the use of cuts with higher degrees of marbling. O'Quinn et al. (2018) showed when cooked to a medium DOD, Prime longissimus lumborum (**LL**) steaks had a 91% likelihood of being rated as acceptable by consumers, whereas there was a 25% likelihood Select LL steaks failed to meet consumer eating expectations. Multiple studies demonstrated that as DOD increased, elevated marbling compensated for the decreased palatability associated with elevated DOD (Lucherk et al., 2016; Drey et al., 2018). This compensation for decreased palatability at elevated DOD is termed the "insurance theory", as marbling acts as "insurance" for steaks to maintain an acceptable eating experience for consumers as DOD increases (Smith and Carpenter, 1974; Savell and Cross, 1988).

Multiple studies have evaluated the palatability characteristics of TSS (Harris et al., 1992; Brooks et al., 2000; Lorenzen et al., 2003; Legako et al., 2015) but to date, studies have only evaluated TSS of differing marbling levels at a single DOD, rather than across multiple DOD. It

is unclear if marbling can provide the same protection to the palatability of TSS cooked to higher DOD as has been documented in more tender cuts such as the LL. Therefore, the objective of this study was to evaluate the impact of marbling level on the beef eating quality of TSS when cooked to multiple DOD.

Materials and Methods

The Kansas State University (**KSU**) Institutional Review Board approved all procedures for use of human subjects in sensory panel evaluations (IRB #7440.5, September 2018)

Sample collection and steak fabrication

Beef top sirloin butts (*N* = 60; 15 / quality grade; Institutional Meat Purchasing Specifications #184; North American Meat Processors, 2014) were collected to equally represent four quality grades [Prime (slightly abundant^{00} – abundant^{100} marbling), Top Choice (modest^{00} – moderate^{100} marbling), Low Choice (small^{00} – small^{100} marbling), and Select (slight^{00} – slight^{100} marbling)] from a commercial Midwestern beef processor. Kansas State University (**KSU**) research members selected carcasses prior to fabrication and collected carcass yield and quality grade information (data not reported). Following subprimal fabrication, top sirloin butts were vacuum packaged and transported under refrigeration (2-4°C) to the KSU Meat Laboratory (Manhattan, KS) for fabrication. At approximately 4 d postmortem, the *biceps femoris, gluteus accessorius, and gluteus profundus* were removed and top sirloin butts were fabricated into 2.54-cm thick steaks from anterior to posterior using a horizontal slicer (Model Puma 700F, Treif, Oberlahr, Germany). From each top sirloin butt, six consecutive steaks were cut and randomly assigned to testing. Steaks designated for sensory evaluation were randomly assigned to one of three DOD; rare (60°C), medium (71°C), and well-done (77°C). Sensory steaks were then divided in half laterally with one half of each steak being assigned to either consumer sensory

testing or trained sensory testing. The remaining three steaks were divided in half laterally and each of the six pieces were randomly assigned to either Warner-Bratzler Shear Force (**WBSF**) testing at one of the three DOD, fat and moisture analyses, or were designated as extra. Finally, steaks were given a randomized four-digit number for identification, vacuum-packaged, and aged for 28 d postmortem at 2 - 4°C. Following aging, steaks were frozen (-40°C) until further analysis.

Consumer sensory panel evaluation

Panelists (N = 236) were recruited from Manhattan, KS and the surrounding areas, and monetarily compensated for their time at the end of each panel. Panels were conducted at the KSU Meat Science Sensory Laboratory, with 8 panelists fed per session. Each panelist was placed in an individual sensory booth and 6 samples were served under low intensity (< 107.64 lumens) red incandescent lighting to remove DOD bias among samples. Panelists were provided with napkins, toothpicks, an expectorant cup, plastic fork, and apple juice, unsalted crackers, and water to use as palate cleansers between samples. Before evaluation, panelists were given verbal directions to explain the use of palate cleansers, evaluation procedures, and the digital survey.

Steaks evaluated were thawed for 24 h prior to panels at 2 to 4°C. Prior to cooking, a raw weight was taken for each steak. Steaks were cooked on a clamshell grill (Cuisinart Griddler Deluxe, East Windsor, NJ) to one of the three preassigned DOD [rare (60°C), medium (71°C), or well-done (77°C)]. Internal temperatures were monitored using a probe thermometer (Thermapen Mk4, ThermoWorks, American Fork, UT). Steaks were removed from the grill below their assigned DOD temperature to allow for the steaks to rise to their assigned DOD. Peak temperatures were recorded, and steaks were weighed for cooked weight to be used in

cooking loss calculations. Steaks were then cut into 2.5-cm thick × 1-cm × 1-cm cuboids, and 2 pieces were served immediately to consumers.

Panelists were given an electronic tablet (Model 5709 HP Steam 7; Hewlett-Packard, Palo Alto, CA) with a digital survey generated using Qualtrics Survey Software (Version 2417833; Provo, UT). Each survey contained a demographic questionnaire, a purchasing motivators page, and six sample ballots. Consumers were asked to evaluate each sample for tenderness, juiciness, flavor, and overall like on 0 to 100 continuous line scales. Anchors were set at 0 and 100, with 0 anchored as extremely tough, extremely dry, and dislike extremely. At 100, anchors were extremely tender, extremely juicy, and like extremely. An additional neutral anchor was labeled at the 50-midpoint of the lines as neither tough nor tender, neither dry nor juicy, and neither dislike or like. Lastly, panelists were asked to rate each trait evaluated as either unacceptable or acceptable, as well as to classify each sample to one of four levels of quality: unsatisfactory, everyday quality, better than everyday quality, or premium quality. Consumers evaluated 6 randomized samples that represented differences in quality grade and DOD. Sensory panels were designed as an unbalanced and incomplete block design so every quality treatment × DOD combination were compared in the same panel session as close to an equal number of times as possible across all consumer panels.

Trained sensory panel evaluation

Sensory panelists were trained according to the American Meat Science Association (**AMSA**) sensory guidelines (AMSA, 2015). Panelists were trained at 6 training sessions in the week prior to the start of panels and anchors and training methods used were similar to those described by Lucherk et al. (2016) and Vierck et al. (2018). A total of 30 panels were conducted with 6 samples fed in each panel, with 8 panelists served during each panel session. Like

consumer panels, trained panelists were fed samples representing differences in quality grade and DOD. All scales were anchored at both ends and midpoints with descriptive terms. Panelists evaluated samples on 0 to 100 continuous line scales for initial and sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off flavor intensity. Anchors set at 0 were labeled as extremely dry, extremely tough, none, and extremely bland. Midpoint anchors were labeled as neutral points of neither juicy nor dry, and neither tough nor tender. At 100, anchors were labeled as extremely juicy, extremely tender, abundant, and extremely intense. Additionally, a "not applicable" box was available for samples where no off-flavor was detected. Steaks were cooked using the procedures previously described for consumer sensory evaluation to one of the three pre-assigned DOD. Panelists were served in individual sensory booths under low-intensity (< 107.64 lumens), red incandescent lights. During each session, panelists were given an electronic tablet (Model 5709 HP Steam 7) with the survey ballot, deionized water, apple slices, and unsalted crackers for palate cleansers, as well as an expectorant cup and napkins.

Warner – Bratzler shear force

Warner – Bratzler shear force analysis was completed using the protocol described by AMSA Meat Cookery and Sensory Guidelines (AMSA, 2015). In brief, 6 cores (1.27 cm diameter) from each cooked steak were taken parallel to the muscle fiber orientation and sheared perpendicular to the muscle fiber orientation using an Instron testing machine (model 5569, Instron Corp., Canton, MA) with a cross-head speed of 250 mm/min and a load cell of 100 kg. Measurements were averaged across all 6 cores per steak and recorded as the average peak force (kg).

Moisture and fat analysis

Steaks designated for moisture and fat analyses were thawed 24 h prior to homogenization, trimmed of external fat, diced, and frozen in liquid nitrogen. Samples were homogenized using a Waring Blender (Waring Products Division; Hartford, CT), and stored at -80°C until further analysis. The percentage of intramuscular fat was determined through a modified chloroform: methanol extraction method described by Folch et al. (1957). The percentage of moisture was determined through the AOAC approved oven-drying method (950.46 and 934.01; AOAC, 1995). Both fat and moisture analysis samples were ran in duplicates.

Statistical analysis

Statistical analysis was completed using SAS (Version 9.4 SAS Inst., Inc., Cary, NC) PROC GLIMMIX, with treatment comparisons considered significant with an α of 0.05. Statistical analyses were performed using top sirloin butt as the experimental unit, with fat and moisture data analyzed as a completely randomized design using a model with the fixed effect of quality grade. For sensory panel, cooking loss, and WBSF data, data were analyzed as a split-plot, with a whole-plot factor of quality grade, and sub-plot factor of DOD. For sensory data, panel was included in the model as a random effect. Additionally, PROC FREQ was used for summarizing demographic data. All consumer panel acceptability data were analyzed with a model that included a binomial error distribution. The Kenward-Roger adjustment was used in all analyses to estimate denominator degrees of freedom.

Results

Consumer panel demographics and purchasing motivators

Table 2-1 presents the demographic profile of the 236 consumers who participated in the consumer sensory panels. Participants were primarily Caucasian/White (84.8%) and consisted of an almost equal number similar number of males (49.6%) and females (50.4%). Over half of the participants were married (56.4%), with 23.7% of consumers having a household size of 2 people. Additionally, most (31.8%) of the panelists who participated had completed some college/technical school or were college graduates (32.2%). When asked what palatability trait was most important when eating beef, consumers rated flavor most important (51.7%), followed by tenderness (32.6%), and juiciness (15.7%). Medium-rare was the most preferred degree of doneness (42.4%), and almost half (47.5%) of consumers ate beef 1 to 3 times a week.

When asked to rate the importance of a series of 15 purchasing motivators for fresh beef steaks, consumers rated "price", "size, weight, and thickness", "marbling level", "steak color", and "USDA grade" similar ($P > 0.05$) in importance, but these factors were more important ($P < 0.05$) than all other traits except "familiarity with cut" (Table 2-2). "Antibiotic use in the animal" was similar in importance to "hormone use in the animal", but more important ($P < 0.05$) to consumers than "animal fed a grass-based diet", "animal fed a corn-based diet", "natural/organic claims", "brand of product", and "packaging type." Additionally, "hormone use in the animal" was more important ($P < 0.05$) to consumers than "natural or organic claims", "brand of product", and "packaging type."

Consumer sensory evaluation

There were no ($P > 0.05$) quality grade × DOD interactions for all palatability traits (Table 2.3). Within quality grade, no differences ($P > 0.05$) were found for consumer ratings of

tenderness, flavor, and overall like, with all treatments varying by no more than 10%. However, there was a significant effect ($P < 0.05$) for juiciness. Prime steaks were juicier ($P < 0.05$) than all other quality treatments, except for Top Choice. Top Choice, Low Choice, and Select steaks were all similar ($P > 0.05$) for consumer ratings of juiciness. As DOD increased, there was a concurrent decrease in sensory ratings ($P < 0.05$; rare > medium > well-done) for all traits, with steaks becoming dryer, tougher, and liked less overall with increased DOD.

No interactions ($P > 0.05$) were found for the percentage of steaks rated acceptable for juiciness, tenderness, flavor, and overall liking (Table 2.4). No differences were observed ($P > 0.05$) among quality grades for the percentage of samples rated acceptable for all palatability traits evaluated, with all quality grades having more than 75% of samples rated acceptable for all traits and no two treatments differing by more than 10.1%. Consistent with consumer rating data, the percentage of steaks rated acceptable decreased as DOD increased ($P < 0.05$; rare > medium > well-done) for all palatability traits. The percentage of steaks rated acceptable for tenderness, juiciness, and flavor decreased by 28, 17.8, and 17.8% respectively, as DOD increased from rare to well-done.

A significant interaction was present for the percentage of steaks rated as everyday quality (Table 2.5). Steaks cooked to rare and well-done presented no differences ($P > 0.05$) among quality grades for the percentage of samples rated as everyday quality. However, when cooked to medium, Top Choice steaks were perceived as everyday quality less often ($P < 0.05$) than both Low Choice and Select steaks. No interactions or quality grade effects ($P > 0.05$) were observed for the percentage of steaks perceived as unsatisfactory, better than everyday quality, and premium quality (Table 2.6). Within DOD, steaks cooked to rare had a lower ($P < 0.05$) percentage of samples rated as unsatisfactory than medium (14.8%) and well-done (22.3%), with

a lower ($P < 0.05$) percentage of medium samples rated in this category than well-done. As DOD increased, the percentage of samples identified as better than everyday quality and premium quality decreased ($P < 0.05$; rare > medium > well-done).

Trained sensory evaluation

There was a quality grade × DOD interaction ($P < 0.05$; Table 2.7) for myofibrillar tenderness, initial juiciness, and sustained juiciness. When steaks were cooked to medium, Prime and Top Choice steaks had higher ($P < 0.05$) panelist ratings for initial and sustained juiciness than Low Choice and Select steaks. Low Choice and Select steaks were similar ($P > 0.05$) in juiciness, both initially and sustained, when cooked to a medium DOD. Similar to trained panelist ratings of juiciness, Prime and Top Choice steaks had higher ($P < 0.05$) ratings of myofibrillar tenderness than Select steaks. Prime and Top Choice steaks had similar ($P > 0.05$) ratings of myofibrillar tenderness when compared to Low Choice steaks. Moreover, Low Choice and Select steaks were similar ($P > 0.05$) in ratings of myofibrillar tenderness. For DOD, each successive increase in DOD resulted in a concurrent decrease ($P < 0.05$; rare > medium > well) in trained panelist ratings of myofibrillar tenderness, initial juiciness, and sustained juiciness. As DOD increased from rare to well-done, there was a 23.9, 45.7, and 51.7% decrease in ratings of myofibrillar tenderness, initial juiciness, and sustained juiciness, respectively.

Trained sensory panel ratings for all other sensory traits are shown in Table 2.8. There were no quality grade × DOD interactions ($P < 0.05$) for all other traits. The effect of quality grade was significant ($P < 0.05$) for beef flavor intensity. Prime and Top Choice steaks had greater ($P < 0.05$) ratings of beef flavor intensity than Select steaks but were similar ($P > 0.05$) to Low Choice. There were no differences ($P > 0.05$) among quality grades for connective tissue amount, overall tenderness, and off flavor intensity with means varying by only 1, 4, and 0.7%,

respectively, among all grades. Similar to consumer sensory ratings, as DOD increased, ratings of overall tenderness decreased ($P < 0.05$; rare > medium > well-done) with a 26.8% decrease in tenderness as steaks were cooked from rare to well done. No differences ($P > 0.05$) were observed across DOD for connective tissue amount, beef flavor intensity, and off flavor intensity, with all DOD means differing by less than 2%.

Warner – Bratzler shear force, cook loss, and moisture and fat analyses

There were no quality grade × DOD interactions ($P > 0.05$) for WBSF (Table 2-9). Prime steaks were more ($P < 0.05$) tender than Low Choice and Select steaks, but were similar ($P > 0.05$) to Top Choice. Additionally, Top Choice, Low Choice, and Select steaks all had similar ($P > 0.05$) WBSF values. Moreover, as DOD increased, WBSF concurrently increased ($P < 0.05$; well-done > medium > rare), with well-done steaks having WBSF values 0.8 kg tougher than rare steaks. For cooking loss, no differences ($P > 0.05$) were found among quality grades, with all treatments differing by less than 1%. However, as DOD increased, the percentage of cooking loss also increased ($P < 0.05$; well-done > medium > rare). There were no differences ($P > 0.05$) in fat percentage among Prime (9.0%), Top Choice (8.8%), and Low Choice (7.8%) steaks; however, Select (5.2%) steaks contained a lower ($P < 0.05$) fat percentage than all other quality grades. Additionally, no differences ($P > 0.05$) in moisture were found between Prime and Top Choice steaks (71.5% vs 71.4%), nor between Low Choice and Select steaks (74.1% vs 73.3%); however, Low Choice steaks had a greater ($P < 0.05$) amount of moisture than Prime and Top Choice steaks.

Discussion

The impact marbling level has on beef palatability has been thoroughly evaluated in previous literature (Parrish et al., 1973; Smith et al., 1985; Akinwunmi et al., 1993; O'Quinn et al., 2012a; Emerson et al., 2013; Corbin et al., 2015; Lucherk et al., 2016; McKillip et al., 2017). Studies have noted a linear increase in tenderness, juiciness, flavor, and overall acceptability of beef steaks as marbling level increases (O'Quinn et al., 2012b; Emerson et al., 2013; Drey et al., 2018); however, many of these studies have only evaluated marbling level within the LD. Cuts from the strip loin have shown to be moderate in connective tissue, and greater amounts of connective tissue are typically found within muscles of locomotion, such as the chuck and round (McKeith et al., 1985). A greater amount of connective tissue within these muscles has the possibility of masking the effects of quality grade otherwise found in the strip loin. Nyquist et al. (2018) found no differences within consumer ratings of tenderness and overall like, as well as consumer acceptability of tenderness and flavor in Choice and Select muscles from the round and chuck. Likewise, authors have found that the psoas major (**PM**), a muscle low in connective tissue, is also minimally impacted by marbling (Shackelford et al., 1995; O'Quinn et al., 2015). The TSS has been found to be more variable in tenderness and lower in consumer ratings when compared to cuts in the rib and loin (Luchak et al., 1998; Voges et al., 2007; Martinez et al., 2015).

Studies involving the TSS have evaluated palatability traits across multiple quality grades; however, no authors have examined the interaction of quality grades cooked to multiple DOD. Previous literature has established that as DOD increases; tenderness, juiciness, flavor, and overall acceptability of steaks decrease linearly (Parrish et al., 1973; Akinwunmi et al., 1993;

Luchak et al., 1998). More notably, recent studies have demonstrated enhancement and higher degrees of marbling can compensate for detrimental effects on palatability that are associated with increasing DOD in the LD (Lucherk et al., 2016; Drey et al., 2018). This compensation for decreased palatability that marbling provides is commonly known as the insurance theory (Smith and Carpenter, 1974; Savell and Cross, 1988). To date, only one study has evaluated the interaction between marbling and DOD in depth through sensory evaluation (Drey et al., 2018). In our study, no quality grade × DOD interactions were present in all consumer sensory rating data. Studies by Lucherk et al. (2016), McKillip et al. (2017), and Drey et al. (2018) have also noted the lack of this interaction in consumer ratings; however, these authors have strictly evaluated the LD. Consumer sensory and acceptability ratings in our study are both inconsistent with this theory, as the impact of increased DOD on juiciness, tenderness, flavor, and overall like ratings were independent of quality grade.

Our study found that quality grade had no effect on the consumer palatability ratings of tenderness, flavor, and overall like in TSS, with juiciness being the only trait impacted by quality grade. In the current study, Prime steaks had 11% higher juiciness ratings than Select steaks, whereas Legako et al. (2015) reported Prime steaks rated 21% higher for juiciness than Select steaks. Similarly, Voges et al. (2007) had Prime steaks rated 20% higher for juiciness than Select TSS. Moreover, Hunt et al. (2014) evaluated Top Choice and Select TSS only, and reported Top Choice steaks had 15% higher ratings of juiciness than Low Choice steaks. Guelker et al. (2013) noted no differences in consumer ratings of juiciness, with ratings across all treatments differing by less than 4%. Consumers from Legako et al. (2015) and Hunt et al. (2014) evaluated multiple muscles (PM, LL, GM, and SM). Additionally, consumers from Legako et al. (2015) did not evaluate all muscles, and these muscles were not compared among each other. More importantly,

both studies only cooked steaks to a medium DOD. Neely et al. (1998) and Savell et al. (1999) found no differences between Top Choice and Low Choice TSS, with consumer juiciness ratings differing by less than 2%.

While only a handful of these studies have incorporated consumer sensory evaluation, the method in which these steaks were tested were very different. In these studies, authors had consumers evaluate samples through either in-home evaluation, or central testing at a university. Consumers participating through in-home evaluation were asked to cook steaks to their preferred DOD, whereas steaks evaluated through central testing were cooked to a preassigned DOD instead. Samples evaluated through central testing are prepared in a more controlled setting, making for a more equal representation of DOD and alleviating effects from overcooking or undercooking that would otherwise be seen through in-home evaluation. Consumer ratings within DOD in the current study presented a consistent decline as DOD increased from rare to well-done. Savell et al. (1999) is one of the only other studies to have evaluated the effect of DOD though consumers; however, it is important to note that while a range of DOD were reported by consumers, these DOD were ultimately grouped together for analysis. As DOD increased from “medium-rare or less” to “well-done or more” juiciness ratings decreased by just under 9%, while ratings of overall like, tenderness, and flavor decreased by less than 3%. These results are drastically lower when compared to the current study however, as consumer ratings of juiciness decreased by 30.3% as DOD increased from rare to well-done.

Only one other study involving the TSS has evaluated palatability traits on an acceptability (yes/no) basis; however, Hunt et al. (2014) compared across multiple muscles (LD, SM, and SV), with only two quality grades (Top Choice and Select). Compared to consumer acceptability ratings in the current study, Hunt et al. (2014) had acceptability ratings of Top

Choice TSS 8 and 10% higher for juiciness and tenderness, and 17.8 and 14.7% higher for flavor and overall like. Additionally, acceptability ratings for Select TSS were 11.1 and 4.6% higher, while both flavor and overall like had 14.8 and 6.3% higher acceptability ratings than the current study.

An interaction was observed within trained sensory panels for initial and sustained juiciness. Previous studies involving the TSS have not evaluated samples for initial and sustained juiciness, rather, trained panelists evaluated one combined trait of juiciness. Additionally, interactions found within the current study were only seen within a medium DOD. When steaks were cooked to medium, Prime steaks were rated 24% higher than Select steaks for initial juiciness, and 30% higher for sustained juiciness. However, the magnitude of these interactions were much smaller in comparison to studies evaluating the LD, a muscle with lower amounts of connective tissue than the TSS. Lucherk et al. (2016) had almost double the values compared to the current study for initial and sustained juiciness ratings, with Prime steaks receiving 51 and 68% higher juiciness ratings than Select steaks. Drey et al. (2018) found Prime steaks cooked to medium rated 66, and 38% higher than Select steaks for initial and sustained juiciness, respectively. McKillip et al. (2017) found only a significant interaction for initial juiciness, but Prime steaks were given 34% higher ratings than Select when cooked to medium. The present study also found an interaction for myofibrillar tenderness at a medium DOD, where Prime steaks received 15.5% higher ratings than Select. No other studies involving the TSS have found this direct interaction. Consistent with previous literature, no interactions were observed in our study for trained sensory panel ratings of connective tissue, overall tenderness, beef flavor intensity, or off flavor intensity. Luchak et al. (1998), Pringle et al. (1998), and Wulf et al. (1996)

all incorporated a medium DOD into their evaluation of TSS through trained panelists; however, authors indicated no impact of quality grade on increased endpoint temperature.

Significant effects of both quality grade and DOD for all other trained panelist ratings within the current study were very limited. Trained panelists found no differences in connective tissue amount for both effects of quality grade and DOD, with values across all quality grades and DOD just over 1%. Our results within quality grade agree with both Lorenzen et al. (2003) and Luchak et al. (1998), who both reported Choice and Select steaks differing by less than 0.1% in connective tissue. King et al. (2009) found a minimal increase (1.2%) in ratings of overall tenderness as quality grade increased from Select to Choice. A larger difference was seen from Luchak et al. (1998), with Choice steaks rated 10% higher for overall tenderness ratings than Select steaks. In comparison, our study found no differences among quality grades for overall tenderness with Choice and Select TSS differing by less than 3%. Our study only found differences within quality grade for beef flavor intensity, with Prime and Top Choice steaks having greater ratings than Select steaks. Nonetheless, these differences were less than 2% across all quality grades. Trained panelists from Lorenzen et al. (2003) gave Top Choice steaks higher ratings than Low Choice; however, less than a 1% difference separated ratings between the two. Inconsistent with our study and others, Luchak et al. (1998) found an interaction for flavor intensity. Select TSS cooked to 74°C had lower flavor intensity ratings than those cooked to 54°C, as well as Choice steaks cooked to 54 and 74°C. Similar to our study, King et al. (2009) also found no differences across quality grades for off flavor, with differences between both quality grades less than 2%.

Moreover, no interactions were observed for WBSF in our study. The effect of quality grade in the current study showed Prime steaks had a lower WBSF value than Low Choice and

Select steaks, but were similar to Top Choice steaks. Additionally, Top Choice, Low Choice, and Select steaks were all similar in WBSF value. These results are contradicting when compared to Luchak et al. (1998) and Gruber et al. (2006), who both found a decrease in WBSF values when quality grade increased from Select to Choice. However, Gruber et al. (2006) subjected TSS to one of seven different aging periods beforehand (2, 4, 6, 10, 14, 21, or 28 d). Similarly, our study subjected steaks to a 28 d aging period; however, the magnitude of difference between Top Choice and Select steaks within this aging period was greater in Gruber et al. (2006) than the current study. Our study found no differences between Top Choice and Select WBSF values, whereas Gruber et al. (2006) was able to find a 0.4 kg difference in values. It is important to note that while there were no differences found in our study, we had a much smaller sample size (180 steaks) than Gruber et al. (2006) (560 steaks). Because Gruber et al. (2006) had more power within their study, significant, but smaller differences between the two quality grades were able to be found. George-Evins (2004) found an interaction between top sirloin steaks of three quality classifications [Certified Angus Beef (**CAB**), Choice, and Select] cooked to three DOD (65.5, 71, or 76.6°C). Steaks cooked to 65°C had similar WBSF values, regardless of quality classification; however, when cooked to 71 and 76.6°C, CAB and Choice steaks had lower WBSF values than Select steaks. While no interaction was present in our study, there was a steady increase in WBSF as DOD increased from rare to well-done. The significant effect of DOD in our study does agree with findings from Lorenzen et al. (2003) however, who noted an increase in WBSF of TSS as endpoint temperature increased from 65.5 to 76.6°C. Previous literature involving TSS have focused majority of its evaluation of multiple DOD through WBSF, concluding that higher quality TSS should be selected to decrease toughness from cooking to higher endpoint temperatures (George-Evins, 2004); however, results from the

current study would contradict this statement. Our study shows that objectively and subjectively, higher quality TSS do not necessarily decrease toughness caused by increasing DOD. This conclusion by George-Evins (2004) is only made in comparison with USDA Choice and Select grades, whereas adding Prime TSS into this study could ultimately change this conclusion.

Very few studies have also evaluated TSS for chemical fat percentage across multiple quality grades. In the current study, Prime (9.0%), Top Choice (8.8%), and Low Choice (7.8%) TSS were all similar in fat percentage, whereas Select steaks contained the lowest fat percentage (5.2%). Hunt et al. (2014) only evaluated Top Choice and Select TSS for fat percentage, with both values differing by 2.5 and 1.4%, respectively, when compared to Top Choice and Select TSS in the current study. Legako et al. (2015) found Prime and Top Choice steaks to have a greater fat percentage than Low Choice steaks, which had a similar value to Select steaks. Legako et al. (2015) also reported an overall range in fat percentage of 5.5% from Prime to Select, whereas our study found a lower range of 3.8%. These differences in numerical values could be explained by differences in methodology, where the current study used a modified chloroform/methanol method (Folch et al., 1957), while Hunt et al. (2014) and Legako et al. (2015) both used near infrared spectrophotometry.

Majority of previous literature involving the palatability of TSS have consistently cooked samples only to a medium DOD (Harris et al., 1992; Lorenzen et al., 2003; George-Evins, 2004; Hunt et al., 2014; Legako et al., 2015; Martinez et al., 2015). Within these studies, little, if any differences in palatability were observed from consumer panelists among multiple quality grades. However, within the current study, significant interactions for trained sensory ratings of juiciness and myofibrillar tenderness were only observed at a medium DOD, indicating that increased marbling was able to compensate for those steaks cooked to 70°C. However, this same

principle does not apply for steaks in the current study that were cooked to rare or well-done, as differences among quality grades were not found.

Currently, USDA Prime, Choice (upper 2/3 and lower 1/3), and Select prices for the top sirloin butt (IMPS # 184) are $3.85, $3.61, and $3.40 per kg, respectively (USDA, 2018b, 2018a). Although these are current prices for the wholesale cut itself and not individual steaks, these values still present retailers and foodservice establishments with an opportunity to save money that would be spent otherwise on product premiums. Results from this study do not support studies previously concluding that quality grade has a strong influence on beef palatability. However, palatability traits of juiciness and tenderness were improved by increased marbling when TSS are cooked to a medium DOD. Additionally, quality grade had a minimal effect on the palatability of TSS, as compared to muscles more intermediate in tenderness. Consumers, as well as retail and foodservice establishments, could ultimately find themselves paying a premium price for TSS that would get the same eating satisfaction as TSS of lower quality.

References

Akinwunmi, I., L. Thompson, and C. Ramsey. 1993. Marbling, fat trim and doneness effects on sensory attributes, cooking loss and composition of cooked beef steaks. Journal of Food Science 58:242-244.

Corbin, C., T. O'Quinn, A. Garmyn, J. Legako, M. Hunt, T. Dinh, R. Rathmann, J. Brooks, and M. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Science 100:24-31.

Drey, L. N., L. L. Prill, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, T. A. Houser, E. A. E. Boyle, and T. G. O'Quinn. 2018. Evaluation of marbling and enhancement's abilities to compensate for reduced beef palatability at elevated degrees of doneness1. Journal of Animal Science:sky435-sky435. doi:10.1093/jas/sky435

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. Journal of Animal Science 91:1024-1034. doi:10.2527/jas.2012-5514

George-Evins, C. D., Unruh, J. A. , Waylan, A. T., Marsden, J. L. 2004. Influence of quality classification, aging period, blade tenderization, and endpoint cooking temperature on cooking characteristics and tenderness of beef gluteus medius steaks. Journal of Animal Science:1863-1867.

Gruber, S. L., J. D. Tatum, J. A. Scanga, P. L. Chapman, G. C. Smith, and K. E. Belk. 2006. Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force

values of seventeen individual beef muscles. Journal of Animal Science 84:3387-3396. doi:10.2527/jas.2006-194

Guelker, M. R., A. N. Haneklaus, J. C. Brooks, C. C. Carr, R. J. Delmore, D. B. Griffin, D. S. Hale, K. B. Harris, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, J. N. Martin, R. K. Miller, C. R. Raines, D. L. VanOverbeke, L. L. Vedral, B. E. Wasser, and J. W. Savell. 2013. National Beef Tenderness Survey–2010: Warner-Bratzler shear force values and sensory panel ratings for beef steaks from United States retail and food service establishments. Journal of Animal Science 91:1005-1014. doi:10.2527/jas.2012-5785

Harris, J. J., R. K. Miller, J. W. Savell, H. R. Cross, and L. J. Ringer. 1992. Evaluation of the Tenderness of Beef Top Sirloin Steaks. Journal of food science 57:6-9. doi:doi:10.1111/j.1365-2621.1992.tb05412.x

Hunt, M. R., A. J. Garmyn, T. G. O'Quinn, C. H. Corbin, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2014. Consumer assessment of beef palatability from four beef muscles from USDA Choice and Select graded carcasses. Meat Science 98:1-8. doi:10.1016/j.meatsci.2014.04.004

King, D., T. Wheeler, S. Shackelford, and M. Koohmaraie. 2009. Comparison of palatability characteristics of beef gluteus medius and triceps brachii muscles. Journal of Animal Science 87:275-284.

Legako, J. F., J. C. Brooks, T. G. O'Quinn, T. D. J. Hagan, R. Polkinghorne, L. J. Farmer, and M. F. Miller. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat Science 100:291-300. doi:10.1016/j.meatsci.2014.10.026

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

Luchak, G. L., R. K. Miller, K. E. Belk, D. S. Hale, S. A. Michaelsen, D. D. Johnson, R. L. West, F. W. Leak, H. R. Cross, and J. W. Savell. 1998. Determination of sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. Meat Science 50:55-72.

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Science 122:145-154. doi:10.1016/j.meatsci.2016.08.005

Martinez, H. A., A. N. Arnold, J. C. Brooks, C. C. Carr, K. B. Gehring, D. B. Griffin, D. S. Hale, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, R. K. Miller, D. L. VanOverbeke, B. E. Wasser, and J. W. Savell. 2015. National Beef Tenderness Survey-2015: Palatability and Shear Force Assessments of Retail and Foodservice Beef. Meat and Muscle Biology 1:138-148. doi:10.22175/mmb2017.05.0028

McKeith, F., D. De Vol, R. Miles, P. Bechtel, and T. Carr. 1985. Chemical and sensory properties of thirteen major beef muscles. Journal of food science 50:869-872.

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. Boyle, and T. G. O'Quinn. 2017. Sensory evaluation of enhanced beef strip loin steaks cooked to 3 degrees of doneness. Meat and Muscle Biology 1:227-241.

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

Nyquist, K. M., T. G. O'Quinn, L. N. Drey, L. W. Lucherk, J. C. Brooks, M. F. Miller, and J. F. Legako. 2018. Palatability of beef chuck, loin, and round muscles from three USDA quality grades1. Journal of Animal Science 96:4276-4292. doi:10.1093/jas/sky305

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. Journal of Food Science 80:S444-S449. doi:10.1111/1750-3841.12775

O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012a. Consumer assessment of beef strip loin steaks of varying fat levels. Journal of Animal Science 90:626-634. doi:10.2527

O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012b. Consumer assessment of beef strip loin steaks of varying fat levels. Journal of Animal Science 90:626-634. doi:10.2527/jas.2011-4282

Parrish, F. C., Jr., D. G. Olson, B. E. Miner, and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. Journal of Animal Science 37:430-434.

Pringle, T., S. Williams, and L. Johnson. 1998. Quality grade, portion size, needle tenderization and cookery method effects on cooking characteristics and palatability traits of portioned strip loin and top sirloin steaks. Foodservice Research International 10:73-88.

Savell, J. W., C. L. Lorenzen, T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, and J. O. Reagan. 1999. Beef customer satisfaction: cooking method and

degree of doneness effects on the top sirloin steak. Journal of Animal Science 77:645-652.

Shackelford, S. D., T. L. Wheeler, and M. Koohmaraie. 1995. Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from Bos indicus and Bos taurus cattle. Journal of Animal Science 73:3333-3340.

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

USDA. 2018a. National weekly boxed beef cutout and boxed beef cuts. USDA Market News, Des Moines, IA.

USDA. 2018b. National weekly boxed beef cutout for prime product. USDA Market News, Des Moines, IA.

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

Wulf, D., J. Morgan, J. Tatum, and G. Smith. 1996. Effects of animal age, marbling score, calpastatin activity, subprimal cut, calcium injection, and degree of doneness on the palatability of steaks from limousin steers. Journal of Animal Science 74:569-576.

Table 2-1. Demographic characteristics of consumers (*N* = 236) who participated in consumer sensory panels

Characteristic	Response	Percentage of consumers
Gender	Male	49.6
	Female	50.4
Household size	1 person	8.9
	2 people	23.7
	3 people	20.3
	4 people	21.2
	5 people	14.8
	6 people	6.4
	> 6 people	4.7
Marital status	Married	56.4
	Single	43.6
Age	Under 20	8.5
	20-29	27.7
	30-39	25.9
	40-49	15.7
	50-59	10.2
	Over 60	12.3
Ethnic origin	African-American	3.4
	Asian	3.4
	Caucasian/White	84.8
	Hispanic	2.1
	Mixed Race	3.8
	Native American	0.4
	Other	2.1
Income	Under $25,000	12.7
	$25,000-$34,999	4.2
	$35,000-$49,999	7.6
	$50,000-$74,999	21.6
	$75,000-$99,999	16.9
	$100,000-$149,999	23.7
	$150,000-$199,999	7.6
	> $199,999	5.5
Education level	Non-high school graduate	2.1
	High school graduate	7.2
	Some college/technical school	31.8
	College graduate	32.2
	Post college graduate	26.7
Most important palatability trait	Tenderness	32.6
	Juiciness	15.7
	Flavor	51.7
Preferred degree of doneness	Rare	9.3
	Medium rare	42.4
	Medium	31.4
	Medium well	12.3
	Well done	3.4
	Very well done	1.3
Weekly beef consumption	1 to 3 times	47.5
	4 to 6 times	32.6
	7 or more times	19.9

Table 2-2. Fresh beef steak purchasing motivators[1] of consumers (*N* = 236) who participated in consumer sensory panels

Trait	Importance
Price	67.0[a]
Size, weight, and thickness	65.3[a]
Marbling level	63.7[ab]
Steak color	63.2[ab]
USDA grade	62.8[ab]
Familiarity with cut	59.6[b]
Nutrient content	54.5[c]
Animal welfare	54.4[c]
Eating satisfaction claims	52.2[c]
Antibiotic use in the animal	46.7[d]
Hormone use in the animal	43.5[de]
Animal fed a grass-based diet	40.2[ef]
Animal fed a corn-based diet	39.9[ef]
Natural or organic claims	37.7[f]
Brand of product	36.2[f]
Packaging type	35.7[f]
SEM[2]	1.8
P-value	< 0.01

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

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

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

Table 2-3. Least squares means for consumer (*N* = 236) ratings[1] of palatability traits of top sirloin steaks from four quality grades and cooked to three degrees of doneness

Treatment	Juiciness	Tenderness	Flavor	Overall Like
Quality grade				
Prime	63.6[a]	60.4	59.7	60.2
Top Choice[2]	61.6[ab]	60.5	55.7	58.2
Low Choice	57.6[b]	59.7	55.1	56.4
Select	56.7[b]	56.5	54.1	54.3
SEM[3]	2.0	2.0	1.9	2.2
P – value	0.02	0.42	0.10	0.16
Degree of doneness				
Rare (60°C)	75.9[a]	71.5[a]	63.8[a]	67.2[a]
Medium (71°C)	58.1[b]	57.6[b]	56.1[b]	56.1[b]
Well Done (77°C)	45.6[c]	48.6[c]	48.5[c]	48.5[c]
SEM[3]	1.7	1.5	1.7	1.7
P – value	< 0.01	< 0.01	< 0.01	< 0.01
QG × DOD				
P – value	0.80	0.99	0.96	0.93

[abc]Least squares means within the same main effect (quality grade or degree of doneness) without a common superscript differ ($P < 0.05$).

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

[2] USDA marbling score of modest[00]- moderate[100].

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

Table 2-4. Percentage of top sirloin steaks of four quality grades cooked to three degrees of doneness rated as acceptable for tenderness, juiciness, flavor, and overall liking by consumers (*N* = 236)

Treatment	Juiciness	Tenderness	Flavor	Overall Like
Quality grade				
Prime	90.6	88.3	83.2	87.3
Top Choice[1]	87.0	86.0	77.5	80.0
Low Choice	87.4	88.0	80.4	83.9
Select	80.5	85.9	75.9	78.8
SEM[2]	3.5	2.7	3.4	3.2
P – value	0.10	0.86	0.35	0.13
Degree of doneness				
Rare (60°C)	96.1[a]	94.5[a]	86.7[a]	91.1[a]
Medium (71°C)	83.7[b]	83.7[b]	78.1[b]	80.3[b]
Well Done (77°C)	69.1[c]	77.7[c]	71.2[c]	72.6[c]
SEM[2]	2.8	2.3	2.5	2.5
P – value	< 0.01	< 0.01	< 0.01	< 0.01
QG × DOD				
P – value	0.54	0.52	0.06	0.80

[abc]Least squares means within the same main effect (quality grade or degree of doneness) without a common superscript differ ($P < 0.05$).

[1] USDA marbling score of modest[00]- moderate[100].

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

Table 2-5. Interaction (*P* = 0.01) between quality grade and degree of doneness for the percentage of beef top sirloin steaks classified as everyday quality

Treatment	Everyday Quality
Rare (60°C)	
Prime	30.8
Top Choice[1]	40.9
Low Choice	40.0
Select	39.3
SEM[2]	5.0
P – value	0.47
Medium (71°C)	
Prime	45.9[ab]
Top Choice	33.9[b]
Low Choice	56.3[a]
Select	56.5[a]
SEM[2]	5.1
P – value	0.01
Well Done (77°C)	
Prime	57.8
Top Choice[1]	57.4
Low Choice	63.7
Select	46.4
SEM[2]	5.1
P – value	0.12

[ab]Least squares means within a degree of doneness without a common superscript differ ($P < 0.05$).

[1] USDA marbling score of modest[00] - moderate[100].

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

Table 2-6. Percentage of beef top sirloin steaks of varying quality grades and degrees of doneness identified as different perceived quality levels by consumer panelists (*N* = 236)

Treatment	Unsatisfactory	Better than everyday quality	Premium quality
Quality grade			
Prime	8.2	30.7	8.8
Top Choice[1]	13.9	25.1	8.9
Low Choice	10.6	24.6	6.2
Select	15.5	24.2	4.1
SEM[2]	3.1	2.9	2.0
P – value	0.21	0.33	0.15
Degree of doneness			
Rare (60°C)	4.4[c]	41.7[a]	13.8[a]
Medium (71°C)	14.8[b]	25.6[b]	7.0[b]
Well Done (77°C)	22.3[a]	15.1[c]	3.0[c]
SEM[2]	2.5	2.5	1.9
P – value	< 0.01	< 0.01	< 0.01
QG × DOD			
P – value	0.25	0.83	0.52

[abc]Least squares means within the same main effect (quality grade or degree of doneness) without a common superscript differ ($P < 0.05$).

[1] USDA marbling score of modest[00]- moderate[100].

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

Table 2-7. Least squares means for the interaction ($P < 0.05$) between quality grade and degree of doneness for trained sensory panel ratings[1] of initial juiciness, sustained juiciness, and myofibrillar tenderness

Treatment	Myofibrillar Tenderness	Initial Juiciness	Sustained Juiciness
Rare (60°C)			
Prime	76.0	75.1	70.9
Top Choice[2]	72.7	71.2	67.1
Low Choice	72.5	73.0	69.4
Select	74.7	74.7	69.8
SEM[3]	2.2	2.2	2.3
P – value	0.63	0.53	0.66
Medium (71°C)			
Prime	65.8[a]	52.5[a]	47.1[a]
Top Choice	65.1[a]	55.3[a]	49.3[a]
Low Choice	60.6[ab]	44.4[b]	38.5[b]
Select	56.3[b]	42.3[b]	36.1[b]
SEM[3]	2.2	2.2	2.3
P – value	< 0.01	< 0.01	< 0.01
Well Done (77°C)			
Prime	58.4	42.6	36.7
Top Choice[1]	53.4	37.6	31.0
Low Choice	56.6	40.3	34.3
Select	56.7	38.9	31.9
SEM[3]	2.2	2.2	2.3
P – value	0.44	0.37	0.26

[abc]Least squares means within the same section of the same column differ ($P < 0.05$).

[1] USDA marbling score of modest[00]- moderate[100].

[2] Sensory scores: 0 = extremely tough/dry; 50 = neither tough nor tender, neither dry nor juicy; 100 = extremely tender/juicy.

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

Table 2-8. Least squares means for trained sensory panel ratings[1] of top sirloin steaks of four quality grades cooked to three degrees of doneness

Treatment	Connective Tissue Amount	Overall Tenderness	Beef Flavor Intensity	Off Flavor Intensity
Quality grade				
Prime	14.0	61.2	39.0[a]	0.9
Top Choice[2]	13.0	58.8	39.9[a]	0.5
Low Choice	14.0	57.9	38.9[ab]	0.5
Select	14.1	57.3	37.6[b]	0.7
SEM[3]	1.3	2.0	0.5	0.2
P – value	0.92	0.46	0.02	0.59
Degree of doneness				
Rare (60°C)	13.3	69.3[a]	39.0	0.5
Medium (71°C)	13.6	56.5[b]	39.3	0.7
Well-done (77°C)	14.5	50.7[c]	38.2	0.8
SEM[3]	1.1	1.5	0.5	0.2
P – value	0.62	< 0.01	0.10	0.55
QG × DOD				
P – value	0.46	0.06	0.13	0.96

[abc]Least squares means within the same main effect (quality grade or degree of doneness) without a common superscript differ ($P < 0.05$).

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

[2] USDA marbling score of modest[00]- moderate[100].

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

Table 2-9. Least squares means for proximate and objective analyses of beef top sirloin steaks cooked to 3 degrees of doneness

Treatment	Fat, %	Moisture, %	Warner-Bratzler shear force, kg	Cook loss[1], %
Quality grade				
Prime	9.0[a]	71.5[b]	3.13[b]	20.13
Top Choice[2]	8.8[a]	71.4[b]	3.33[ab]	20.98
Low Choice	7.8[a]	74.1[a]	3.44[a]	20.32
Select	5.2[b]	73.3[ab]	3.37[a]	20.99
SEM[3]	0.01	0.01	0.08	0.5
P – value	< 0.01	< 0.01	0.05	0.42
Degree of doneness				
Rare (60°C)			2.89[c]	15.75[c]
Medium (71°C)			3.38[b]	20.07[b]
Well Done (77°C)			3.69[a]	25.99[a]
SEM[3]			0.07	0.4
P – value			< 0.01	< 0.01
QG × DOD				
P – value			0.59	0.59

[abc]Least squares means within the same main effect (quality grade or degree of doneness) without a common superscript differ ($P < 0.05$).

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

[2] USDA marbling score of modest[00]- moderate[100].

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

Appendix A – Consumer and Trained Evaluation Forms

INFORMED CONSENT STATEMENT

1. I volunteer to participate in research involving Sensory Evaluation of Meat. This research will be conducted by personnel in the Department of Animal Sciences and Industry at Kansas State University.

2. I fully understand the purpose of the research is for the evaluation of beef steaks, pork chops, lamb chops, goat meat, poultry meat, ground meat, and processed meat products from the previously mentioned species for the sensory traits of tenderness, juiciness, flavor intensity, connective tissue amount, off flavor presence, odor, and color and sensory evaluation will last approximately one hour.

3. I understand that there are minimal risks associated with participating and that those risks are related to possible food allergies. All meat products will be USDA inspected and all ingredients are GRAS (generally accepted as safe) by FDA.

4. I understand that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring confidentiality of my performance and responses.

5. My participation in this study is purely voluntary; I understand that my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

6. If I have any questions concerning my rights as a research subject, injuries or emergencies resulting from my participation, I understand that I can contact the Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3224.

7. If I have questions about the rationale or method of the study, I understand that I may contact, Dr. Travis O'Quinn, 247 Weber Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3469 or Sally Stroda, 107 Weber Hall, at 785-532-1273.

I have read the Subject Orientation and Test Procedure statement and signed this informed consent statement, this _____ day of _____, _____.

_____ _____

Printed name Signature

Demographics Questionnaire

Big Panel #

Please tell us a little about yourself:

Panelist Number

Gender

- Male
- Female

Household Size

- 1 Person
- 2 People
- 3 People
- 4 People
- 5 People
- 6 People
- > 6 People

Marital Status

- Single
- Married

Age

- Under 20
- 20 to 29 years old
- 30 to 39 years old
- 40 to 49 years old
- 50 to 59 years old
- Over 60

Ethnic Origin

- African-American
- Asian
- Caucasian/White
- Hispanic
- Native American
- Other
- Mixed Race

Annual Household Income

- < $25,000
- $25,000 - $34,999
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - 149,999
- $150,000 - $199,999
- > $199,999

Highest Level of Education Completed

- Non-High School Graduate
- High School Graduate
- Some College / Technical School
- College Graduate
- Post-College Graduate

When eating beef, what palatability trait is the most important to you?

- Flavor
- Juiciness
- Tenderness

When eating beef steaks, what degree of doneness do you prefer?

- Very Rare
- Rare
- Medium-Rare
- Medium
- Medium-Well
- Well-Done
- Very Well-Done

How many times a week do you consume beef?

0 3 6 9 12 15 18 21

None

Purchasing Motivators

Please indicate the importance of each trait when purchasing fresh beef steaks:

Animal Welfare

Extremely Unimportant
0

Extremely Important
100

Antibiotic use in the animal

Extremely Unimportant
0

Extremely Important
100

Brand of Product

Extremely Unimportant
0

Extremely Important
100

Color

Extremely Unimportant
0

Extremely Important
100

Animal fed a corn-based diet

Extremely Unimportant
0

Extremely Important
100

Animal fed a forage-based (grass) diet

Extremely Unimportant
0

Extremely Important
100

Eating Satisfaction Claims (ex: Guaranteed Tender)

Extremely Unimportant
0

Extremely Important
100

Familiarity with cut

Extremely Unimportant
0

Extremely Important
100

Growth hormone use in the animal

Extremely Unimportant
0

Extremely Important
100

Natural or Organic Claims

Extremely Unimportant
0

Extremely Important
100

Nutrient content

Extremely Unimportant
0

Extremely Important
100

Packaging Type

Extremely Unimportant
0

Extremely Important
100

Price

Extremely Unimportant
0

Extremely Important
100

Size, weight and thickness

Extremely Unimportant
0

Extremely Important
100

USDA Grade

Extremely Unimportant
0

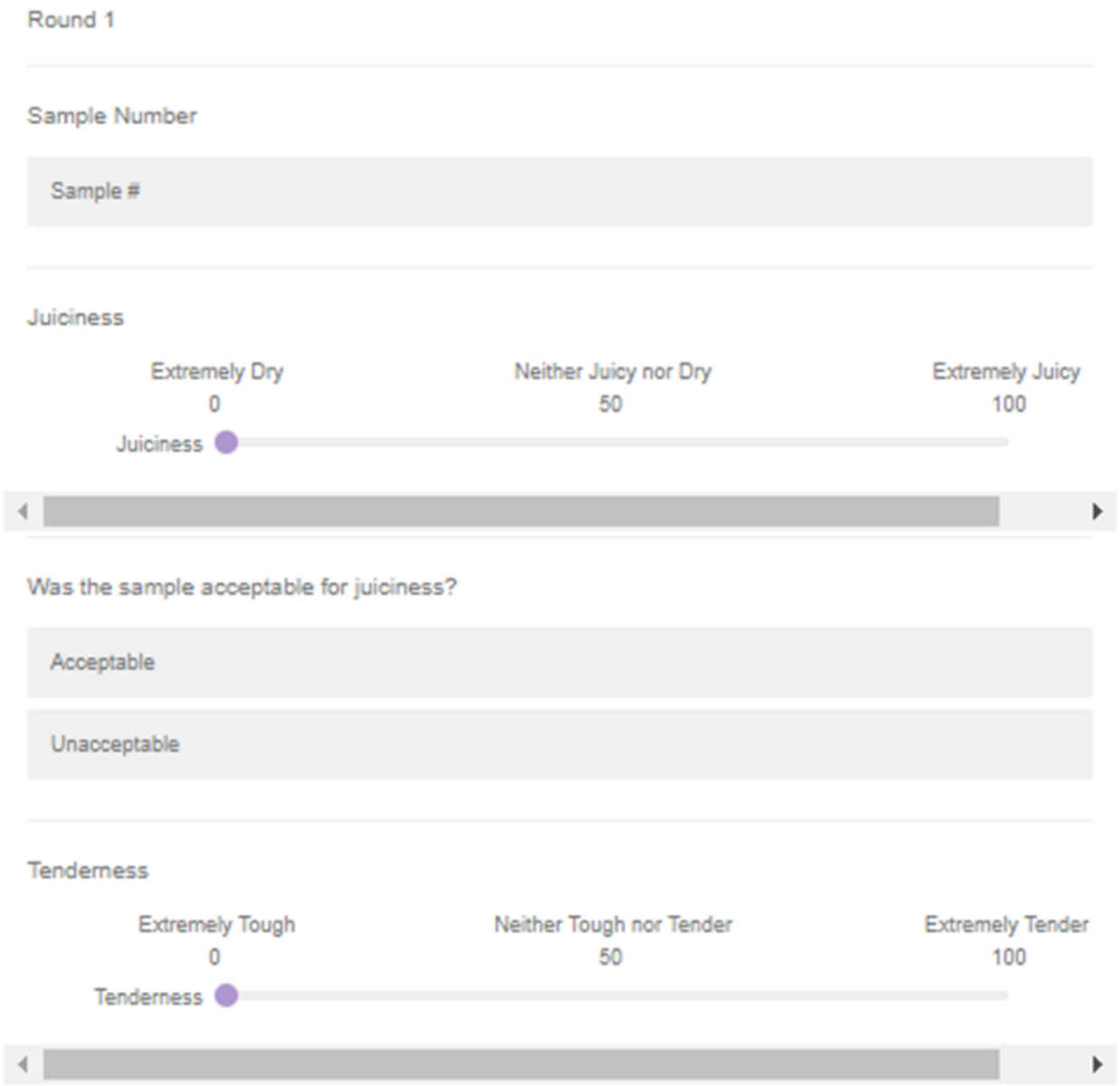
Extremely Important
100

Marbling

Extremely Unimportant
0

Extremely Important
100

Consumer Sample Evaluation Survey



Flavor

Dislike Extremely	Neither Like nor Dislike	Like Extremely
0	50	100

Flavor

Was the sample acceptable for flavor?

- Acceptable
- Unacceptable

Overall Liking

Dislike Extremely	Neither Like nor Dislike	Like Extremely
0	50	100

Overall

Was the sample acceptable overall?

- Acceptable
- Unacceptable

Please choose one of the following to rate the quality of the beef sample you have just eaten.

- Unsatisfactory
- Everyday Quality
- Better than everyday quality
- Premium Quality

Trained Sample Evaluation Survey

Panelist

Sample Number

Initial Juiciness

Extremely Dry
0

Neither Juicy nor Dry
50

Extremely Juicy
100

Initial Juiciness

Sustained Juiciness

Extremely Dry
0

Neither Juicy nor Dry
50

Extremely Juicy
100

Sustained Juiciness

Myofibrillar Tenderness

Extremely Tough
0

Neither Tough nor Tender
50

Extremely Tender
100

Myofibrillar Tenderness

Amount of Connective Tissue

None
0

Abundant
100

Amount of Connective Tissue

Overall Tenderness

Extremely Tough
0

Neither Tough nor Tender
50

Extremely Tender
100

Overall Tenderness

Beef Flavor Intensity

Extremely Bland
0

Extremely Intense
100

Beef Flavor Intensity

Off Flavor Intensity

Extremely Bland
0

Extremely Intense
100

Off Flavor Intensity

☐ Not Applicable

Off Flavor Description

Appendix B – Data Sheets

Percent Moisture Data Sheet

Sample ID	Weight of Pan	Wet Sample	Dried Sample + Pan

Percent Fat Data Sheet

Sample ID	Weight of Tube	Wet Sample	Dried Sample + Tube

Cook Loss/Peak Temperature Data Sheet

Steak ID	Raw Weight	Cooked Weight	Peak Temperature