Evaluation of the impact of bone-in versus boneless cuts on beef palatability

by

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Abstract

The objective of this study was to determine the palatability traits of beef cuts of differing bone state and quality grade. Paired (*n* = 12) beef short loins, export ribs, and boneless ribeye rolls of USDA 2/3 Choice and Select were collected from a commercial abattoir. Short loins were fabricated into boneless strip loins with corresponding bone-in tenderloins or bone-in strip loins with boneless tenderloins at Kansas State University (KSU). No further fabrication was necessary for ribeye rolls, thus they remained in native packaging from the processing facility. Product was aged for 28 days and fabricated into 2.5-cm thick steaks.

A total of 18 trained sensory panels were conducted. Steaks were cooked on clamshell style grills to a peak temperature of 71°C. Trained panelists were asked to rate samples for initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, beef flavor intensity, and off-flavor intensity on 100-point continuous line scales.

Consumer sensory panelists evaluated samples for juiciness, tenderness, flavor liking, beef-like flavor intensity, beef-fat like flavor intensity, and overall liking on a 100-point continuous line scales anchored on both ends with descriptive terms. Additionally, panelists were asked to classify each sample as acceptable or unacceptable for each of the sensory traits previously listed and to assess the quality of the sample by identifying if the sample was unsatisfactory, everyday quality, better than everyday quality, or premium quality.

Furthermore, the following assays were also conducted: fat percentage, moisture percentage, cook time, cook yield, cook loss, and Warner-Bratzler Shear Force.

Overall, bone state had a minimal impact on palatability traits evaluated through trained sensory evaluation. Choice steaks were rated higher ($P < 0.05$) than Select steaks for all

palatability traits evaluated. Bone state had no impact ($P > 0.05$) on initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, or off-flavor intensity in strip loin, tenderloin, and ribeye steaks. Other than strip loins, bone-in samples had a more ($P < 0.05$) intense beef flavor.

Similarly, consumer sensory analysis revealed Choice steaks were rated higher ($P < 0.05$) than Select steaks for juiciness, tenderness, flavor, and overall liking. Bone state had no impact ($P > 0.05$) on consumer juiciness and overall liking for tenderloins and ribeyes, but in the strip loin, bone-in steaks were rated juicier ($P < 0.05$) and higher for overall liking ($P < 0.05$) when compared to boneless steaks. Moreover, bone state had no impact ($P > 0.05$) on consumer tenderness and flavor ratings for any of the three cuts. Regardless of bone state, tenderloin steaks were juicier, more tender, more flavorful, and rated higher overall ($P < 0.05$) than ribeyes and boneless strip loin steaks.

Choice steaks had a higher ($P < 0.05$) percentage of consumers that rated juiciness as acceptable when compared to Select steaks. Furthermore, bone state had no impact ($P > 0.05$) on the percent of consumer's rating juiciness as acceptable for tenderloins and ribeyes, but in strip loins, bone-in steaks had a higher ($P < 0.05$) percent of acceptable consumers responses than boneless cuts. Tenderloins had a higher ($P < 0.05$) percentage of acceptable ratings for tenderness than strip loins and ribeyes.

When evaluating WBSF, Choice steaks were more ($P < 0.05$) tender than Select samples. Bone state did not ($P > 0.05$) have an impact on shear force values within any of the cuts. However, tenderloin steaks had lower ($P < 0.05$) shear force values than strip loin and ribeye samples.

Select steaks were higher ($P < 0.05$) yielding and had a greater ($P < 0.05$) cook loss than Choice samples. Bone state also had a significant ($P < 0.05$) impact on cooking time, yield, and cook loss of strip loin, tenderloin, and ribeye samples.

All Choice samples from each cut / bone state had a greater ($P < 0.05$) fat percentage than Select samples of the same cut / bone state. Bone state only impacted fat percentage in Select tenderloin steaks. Boneless Select tenderloins were higher ($P < 0.05$) in fat than bone-in Select tenderloins. Furthermore, all USDA Select cut / bone state combinations were higher ($P < 0.05$) in moisture than all Choice cut / bone state combinations, except for Choice boneless tenderloins, which are similar ($P > 0.05$) to Select boneless tenderloin samples.

Results indicated that the same eating experience can be derived from a boneless steak as a bone-in steak of the same quality grade.

Table of Contents

List of Tables

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Dedication

This thesis is dedicated to my Grandpa Bernard. Thank you for establishing my passion for agriculture and encouraging me to never give up. I would not be where I am today without your influence on my life.

Chapter 1 - Review of literature

Palatability

Palatability refers to the overall eating experience that can be derived by a consumer. It is primarily comprised of three traits - tenderness, juiciness, and flavor (Bratzler, 1971; Smith et al., 1984; Miller et al., 1995a; Emerson et al., 2013; Hocquette et al., 2020). Over time, society has seen a shift from meat being consumed simply for its nutritional benefits to being consumed in increasing quantities as it appeals more to the palate of consumers (Bratzler, 1971). Due to this change, the concern surrounding beef quality has increased giving rise to more palatability research and comprehensive industry surveys such as the National Beef Quality Audit (**NBQA**) around the 1990's (Hocquette et al., 2020). Consequently, today we have a great number of studies evaluating beef palatability giving us a greater understanding of the components that comprise it.

Historically, beef tenderness has been the most important palatability trait to consumers, retailers, and restaurants alike (Dikeman, 1987; Savell et al., 1987; Smith et al., 1992; Miller et al., 1995a). In the early 2000's, studies revealed that consumers determined 71.0% (Egan et al., 2001) and 51.6% (Platter et al., 2003) of beef eating quality was comprised of tenderness. More recently, 50-54% of consumers declare flavor as the most important palatability trait when eating beef (Vierck et al., 2018; Drey et al., 2019; Olson et al., 2019; Prill et al., 2019). Likewise, O'Quinn et al. (2018) developed a model for overall beef eating satisfaction that indicates flavor contributes the most (49.4%) to beef eating satisfaction, followed by tenderness (43.4%), and juiciness (7.4%). When evaluating juiciness, the percentage of consumers deeming it the most important has remained around 10-12% over time (Miller et al., 1995b; Huffman et al., 1996;

Vierck et al., 2018; Prill et al., 2019).These results can largely be contributed to the extensive improvement in tenderness over the years and the large portion of beef at retail that is deemed tender (Guelker et al., 2013).

Despite a higher percentage of consumers considering flavor and tenderness most important to beef eating quality, there still needs to be a synergy between the three traits to be considered satisfactory (Savell and Cross, 1988; Aberle et al., 2001). If a sample excels at one trait but is unsatisfactory in another, the sample can still fail to meet consumer eating expectations (O'Quinn et al., 2018). With reference to relative risk, a sample is 12.3 times more likely to be unacceptable overall if flavor fails. The incidence of unacceptable overall palatability is 7.2 times greater if tenderness fails and 6.5 times more likely if juiciness fails (O'Quinn et al., 2018). Moreover, if flavor, tenderness, and juiciness all three fail, tendency of overall failure is 89.5 times higher (O'Quinn et al., 2018).

In addition to the three primary traits that make up palatability, factors such as aroma, color, appearance, and mouthfeel have been said to affect eating quality (Bratzler, 1971; Smith and Carpenter, 1974). In a study by Miller et al. (1995a) that evaluated consumer acceptability of beef steak tenderness in home and at restaurant, results suggest that when determining overall acceptability of steaks, consumers can even be influenced by the atmosphere, serving, and convivence. Samples were evaluated on an 8-point hedonic scale with 1 corresponding to very tough and 8 corresponding to very tender. Steaks at each tenderness level were then compared for tenderness acceptability by consumers. Consumers were willing to tolerate tougher steaks in the restaurant setting versus at home as evidenced by their higher tenderness acceptability ratings (Miller et al., 1995a). At a tenderness rating of 5, 94% of steaks were acceptable for tenderness by home consumers and 98% were acceptable for tenderness by restaurant consumers (Miller et al., 1995a). In the home, when tenderness ratings dropped to a 3, 60% fewer consumers rated steaks as having acceptable tenderness: however, in the restaurant setting, only 35% fewer consumers rated the steaks acceptable for tenderness (Miller et al., 1995a).

In more recent years, it has been debated that even the bone state of steaks can impact beef palatability (Chicago Steak Company, 2016; Lopez, 2018; Goldwyn, 2021). Bone-in steaks are said to have more flavor and typically sold at a higher price point at restaurants (Bass, 2018). Whether it is the actual bone or the marrow inside that improves palatability has also been debated (Chicago Steak Company, 2016). Furthermore, some even believe that it's the fact the bone provides more insulation while cooking that results in the "improved" eating experience (Lopez, 2018).

The effect of bone state on beef palatability

Limited research exists as to how bone state of steaks effects beef palatability. In a study conducted by McCullough (2013) the effect of bone-in versus boneless wet aged steaks on beef palatability was evaluated. USDA Choice ribeye, strip, and tenderloin steaks were aged for 7, 14, 21, or 28 days. Trained sensory panelists were asked to evaluate initial juiciness, sustained juiciness, first impression tenderness, overall tenderness impression, connective tissue amount, beef flavor, buttery/beef fat flavor, metallic/bloody flavor, and livery/organ flavor on 8-point hedonic scales. Results reveal minimal differences between bone-in and boneless ribeye, strip loin, and tenderloin steaks for buttery/beef fat and metallic/bloody flavors as well as tenderness (McCullough, 2013). Overall McCullough (2013) concluded that bone-in versus boneless steaks had negligible, if any impact on beef quality characteristics or sensory attributes (McCullough, 2013).

Of the remaining published literature, none of the studies have had the objective of evaluating bone-in versus boneless cuts, therefore the following findings are indirect results of the studies. Jeremiah and Gibson (2003) evaluated the effects of bone state, packaging, and retail cut preparation on palatability attributes of beef during aging. They utilized bone-in and boneless steaks from the rib and loin. Trained sensory panelists evaluated samples on a 9-point descriptive scale. Results showed that vacuum packaged bone-in steaks were more flavorful than boneless steaks and had higher ratings for juiciness and overall palatability (Jeremiah and Gibson, 2003). Alternatively, Igo et al. (2015) conducted a consumer evaluation of tenderness of beef loin steaks from retail markets in four U.S. cities. On 10-point hedonic scales, consumers rated boneless steaks higher for tenderness, juiciness, flavor, and overall liking (Igo et al., 2015). Furthermore, boneless samples were also rated higher for tenderness, juiciness, and flavor level (Igo et al., 2015). Other studies, such as those conducted by DeGeer et al. (2009) and Lepper-Blilie et al. (2016), have found no effect of bone state on palatability through their research. Though unrelated, both studies evaluated effects of aging time, aging method, and loin cut style on beef palatability. Trained sensory panelists in both studies rated bone-in and boneless steaks the same for all palatability attributes evaluated (DeGeer et al., 2009; Lepper-Blilie et al., 2016).

The three most recent National Beef Tenderness Surveys (**NBTS**) have produced mixed results regarding the palatability traits of bone-in and boneless cuts. For all three tenderness surveys, consumers utilized 10-point descriptive scales to characterize samples for overall liking, flavor liking, juiciness liking, tenderness liking, beef flavor, juiciness, and tenderness. Multiple beef cuts were evaluated as part of the surveys. Those of specific interest to the current research were bone-in and boneless ribeye and strip loin steaks. The 2006 NBTS reported that bone-in strip loin steaks were rated higher for juiciness and juiciness liking (Voges et al., 2007). However, in the same study, no differences were found between bone-in and boneless ribeye and strip loin steaks for the remaining palatability traits (Voges et al., 2007). Guelker et al. (2013) reported in the 2010 NBTS that there were no differences between bone-in and boneless ribeye and strip loin steaks for tenderness and juiciness levels and liking. However, boneless ribeyes were rated higher for flavor, flavor liking, and overall liking than bone-in ribeyes but were similar to both variations of strip steaks (Guelker et al., 2013). The 2015 NBTS reported higher ratings for tenderness liking for boneless ribeyes and boneless strip steaks than bone-in ribeyes (Martinez et al., 2017). Consumers found no differences between samples for the remaining palatability attributes (Martinez et al., 2017).

The effect of muscle on beef palatability

Muscles within a beef carcass vary in characteristics that can impact palatability. Intrinsic factors such as composition, collagen content, sarcomere length, and metabolism vary across muscles based on anatomical location and muscle function (Calkins and Hodgen, 2007). Likewise, palatability of beef muscles can also depend on extrinsic factors such as the pre-harvest environment, diet, post-harvest handling, and consumer preferences. Previous research has even reported variation between one portion of a muscle and a different portion of the same muscle (Rhee et al., 2004).

The beef industry mostly focuses on marketing steaks from the middle meats due to an increase in tenderness and perceived eating quality (Belew et al., 2003; Calkins and Sullivan, 2007; Jung et al., 2016). Historically, cuts from the chuck and round have been marketed at a lower price point and have primarily been sold as roasts (Jung et al., 2016). Presently, there are more novelty cuts such as the Delmonico, Denver, and Flat Iron steak being marketed as steaks from the chuck due to an eating experience that is similar to that of a steak from the rib or loin (Lepper-Blilie et al., 2014; Nyquist et al., 2018).

To better understand the palatability differences between muscles, Ramsbottom et al. (1945) first evaluated 25 muscles from "U.S. Good" carcasses. They utilized Warner-Bratzler shear force (**WBSF**), organoleptic, and histological ratings to conclude that there were indeed significant differences in tenderness between beef muscles. In 1985, McKeith et al. (1985) asked consumers to rate 13 different beef muscles (*semimembranosus, semitendinosus, adductor, biceps femoris, rectus femoris, gluteus medius, psoas major, longissimus lumborum, longissimus thoracis, triceps brachii, infraspinatus,* pectoral*, and supraspinatus*) from Angus steers for tenderness, juiciness, and flavor. Data showed that several muscles evaluated were consistently more palatable. Muscles from the loin (*psoas major and longissimus lumborum*), rib (*longissimus thoracis*), and the *infraspinatus* were rated higher for tenderness and flavor (McKeith et al., 1985). The pectoral muscle was consistently rated the least palatable by consumers (McKeith et al., 1985). Similar results were also found by Shackelford et al. (1995b), Jeremiah et al. (2003), and Nyquist et al. (2018).

While evaluating the relationship between shear force and overall tenderness of 10 major beef muscles, Shackelford et al. (1995b) found that once again, the *psoas major* and the *infraspinatus* were rated the highest for overall tenderness by trained sensory panelists (Shackelford et al., 1995b). Different than the McKeith et al. (1985) study, flavor ratings for the *psoas major* and *infraspinatus* were the lowest (Shackelford et al., 1995b). In terms of juiciness, the *infraspinatus* was rated the highest for juiciness while the *psoas major* was below average (Shackelford et al., 1995b). It was concluded that sans the *psoas major* and the *infraspinatus*, tenderness was the most variable palatability component among muscles. Moreover, the magnitude of difference between flavor and juiciness in muscles was smaller than that of tenderness (Shackelford et al., 1995b). Specifically in the *longissimus dorsi,* a large proportion of variation in tenderness has been attributed to the myofibrillar component (Ramsbottom et al., 1945; Shackelford et al., 1995b; Calkins and Hodgen, 2007).

Jeremiah et al. (2003) evaluated palatability on one-kilogram roasts from 33 different muscles or muscle groups. Trained sensory panelists used a 9-point hedonic scale to rate each sample. Initial tenderness (tenderness on the first bite) was similar among the *psoas major, ilio-psoas, longissimus thoracis, spinalis dorsi, and infraspinatus* (Jeremiah et al., 2003). Additionally, the *psoas major, ilio-psoas,* and the *longissimus thoracis* had the lowest detectable amount of connective tissue. Consequently, the *psoas major* and *ilio-psoas* were rated the most tender overall. Jeremiah et al. (2003) also reported flavor intensity as the highest for diaphragm, *infraspinatus, vastus lateralis*. Yet, flavor liking was still the most desirable for the *psoas major* (Jeremiah et al., 2003). Overall palatability scores indicate that the *superficial pectoral* and shank muscles were consistently rated the least palatable (Jeremiah et al., 2003). In line with other literature, overall palatability was highest for the *psoas major, ilio-psoas,* and the *longissimus thoracis* (Jeremiah et al., 2003).

Palatability of various beef cuts of three quality grades from the chuck, loin, and round were evaluated in a study by Nyquist et al. (2018). Both consumers and trained sensory panelists evaluated samples for palatability attributes on 100-point continuous line scales. It was largely determined that muscles from the round are less palatable than those from the middle meats and the chuck, while some muscles from the chuck are highly palatable (Nyquist et al., 2018).

Overall, previous literature shows that flat iron, tenderloin, ribeye, and strip steaks offer the best eating experience to consumers. There is greater variation in the tenderness of the *longissimus dorsi* depending on anatomical location and other biochemical factors. Cuts from the round are repeatedly rated higher in detectable connective tissue by trained sensory panelists and less tender overall.

The effect of quality grade on beef palatability

The United States Department of Agriculture (**USDA**) quality grading system categorizes beef carcasses based on their expected eating experience. This is determined by evaluating physiological maturity and the marbling (intramuscular fat) within the lean of the *longissimus dorsi* between the 12th and 13th rib (USDA, 2017). The development of the United States Standards for Grades of Beef Carcasses originated in 1917 (USDA, 2017). Standards were initially developed for meat reporting purposes. They were quickly adapted to be used as a method to select beef for soldiers during World War I and later were incorporated into the purchasing specifications of food service establishments (USDA, 2017). In 1926, the standards were formally put into effect by official proclamation as the “Official United States Standards for the Grades of Carcass Beef” (USDA, 2017). Shortly after, in May 1927, the standards were utilized to develop the voluntary beef grading service (USDA, 2017). As experience and knowledge was gained over the years, subsequent revisions of the standards were made to fit the industry’s needs at the time. In the early 1960’s, there was a need for separate identification standards for beef quality and cutability. Thus, cutability/yield grade standards were established (USDA, 2017). Today, steer and heifer carcasses are eligible for the USDA Quality Grades of Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner (USDA, 2017).

Marbling greatly impacts the overall eating experience, thus it has been researched extensively. Smith and Carpenter (1974) discuss multiple theories as to how marbling effects tenderness, juiciness, and flavor. The lubrication effect involves the amount and distribution of intramuscular fat within the lean. They suggest that fat between the myofibrils solubilizes during cooking and provides lubrication when eating resulting in the perception of increased tenderness and juiciness (Smith and Carpenter, 1974). Furthermore, Smith and Carpenter (1974) state that fat deposition within cells and between connective tissue thins the connective tissue enough to reduce the force needed to bite or cut through a piece of meat. Intramuscular fat acts as a depot and solvent for volatile compounds that can contribute to beef flavor (Chevance et al., 2000). Smith et al. (1983) suggested that USDA beef quality grades are interrelated to beef flavor because quality grade incidentally determines the degree to which flavor and aroma compounds are likely to be present in the meat.

Previous literature has repeatedly shown that as quality grade or degree of marbling increases, so do sensory ratings of beef palatability (Tatum et al., 1980; Smith et al., 1984; Smith et al., 1987; O'Quinn, 2012; Emerson et al., 2013; Lucherk et al., 2016; O'Quinn et al., 2018). Emerson et al. (2013) illustrates this in a study evaluating the relationship between USDA instrument-based marbling measurements and *longissimus* muscle sensory attributes. Marbling scores from the beef instrumental grading camera were able to explain 71% of variation in trained sensory panel ratings for buttery/beef fat flavor intensity (Emerson et al., 2013).

Furthermore, 98-99% of moderately abundant or slightly abundant (Prime) steaks, 80-90% of moderate and modest (Top Choice) steaks, 62% of small (Low Choice) steaks, 29% of slight (Select) steaks, and 15% of traces (Standard) steaks received positive ratings for overall sensory experience by sensory panelists (Emerson et al., 2013).

In an early study conducted by Smith et al. (1984), they evaluated palatability of top loin, top round, bottom round, and eye of round steaks from a variety of maturities (A-E) and degrees of marbling (practically devoid – moderately abundant). In top loin steaks from A maturity carcasses, as marbling score increased from practically devoid to moderately abundant, so did flavor juiciness, tenderness, and overall palatability (Smith et al., 1984). However, differences were not significant between each consecutive marbling score. Top round steaks from A maturity carcasses with moderately abundant and slightly abundant marbling were similar in flavor and juiciness ratings, but higher than all remaining marbling scores suggesting effects of marbling also differ among muscles (Smith et al., 1984). Similar to the previous study in methodology, Smith et al. (1987) found when evaluating relationships of USDA quality grades to palatability, Prime carcasses produced loin and round steaks that were more palatable than the remaining seven quality grades.

Consumer sensory analysis of beef *longissimus lumborum, gluteus medius, serratus ventralis, and semimembranosus* muscles of Choice and Select quality grades was conducted by Hunt et al. (2014b). Regardless of muscle, when comparing Top Choice to Select, data revealed more desirable liking scores for tenderness, flavor, and overall (Hunt et al., 2014b). A similar trend was observed in a study conducting a sensory analysis of beef strip loins of varying marbling levels and quality grades (Corbin et al., 2015). A positive linear relationship was observed between degree of marbling and consumer acceptability ratings for tenderness, juiciness, flavor and overall (Corbin et al., 2015). Moreover, Corbin et al. (2015) concluded from trained sensory panel results that intramuscular fat amount was the primary contributor to beef flavor when no off-flavors were present. Similar results were found in a study evaluating top sirloin steaks from Prime, Top Choice, Low Choice, and Select quality grades. Prime and Top Choice steaks had greater beef flavor than Select steaks but were similar to Low Choice (Olson et al., 2019). Prime and Top Choice steaks cooked to a medium degree of doneness had higher ratings for myofibrillar tenderness and initial and sustained juiciness (Olson et al., 2019). Correspondingly, consumer sensory analysis results showed Prime steaks had greater juiciness than lower quality grades except for Top Choice (Olson et al., 2019).

Olson et al. (2019) also concluded that the effect of quality grade on palatability is not as great for top sirloin steaks. Lorenzen et al. (2003) had similar findings in a study evaluating palatability of top sirloin, top loin, and top round steaks. They concluded that quality grade influenced palatability ratings of top loin steaks more than top sirloin and top round steaks (Lorenzen et al., 2003). In a study evaluating palatability of Choice and Select top loin, top sirloin, eye of round steaks, and loin end rib, blade end rib, and eye of round roasts, the effect of quality grade also varied among muscles. Top loin steaks, top sirloin steaks, and loin end rib roasts of the Choice quality grade had higher palatability ratings than Select variations (Luchak et al., 1998). Quality grade did not affect eating quality of blade end rib roasts, eye of round steaks, or eye of round roasts (Luchak et al., 1998). Differences in the effect of quality grade among muscles can be attributed to differences in connective tissue according to McKeith et al. (1985) and Beyer et al. (2021). Muscles such as the *longissimus dorsi* contain a more moderate amount of connective tissue when compared to some muscles from the chuck and round. These muscles of locomotion are typically higher in connective tissue. McKeith et al. (1985) suggests that the increased presence of connective tissue "masks" the effect of quality grade. Moreover, Beyer et al. (2021) provides evidence that there is a "Goldilocks Window" for marbling to have a significant impact on palatability in relation to connective tissue. Within the "Goldilocks Window", there is a range of connective tissue of a given muscle in which marbling has a significant effect on eating quality, once beyond that range, connective tissue diminishes the impact of marbling (Beyer et al., 2021). The tenderloin is extremely low in connective tissue and already tender, thus it is also less impacted by quality grade (Shackelford et al., 1995a). O'Quinn et al. (2015) used consumer assessment of tenderloin steaks agrees with Shackelford et al. (1995a)'s findings. Tenderloin steaks of USDA Choice, High Select, and Low Select quality grades were evaluated by consumers. Results indicate no detectable differences in tenderness, juiciness, flavor, or overall liking among differing quality grades (O'Quinn et al., 2015).

Literature has shown that the effect of quality grade differs based on muscle. Furthermore, successive increases in marbling score or quality grade are not always consistent or statistically significant (Tatum et al., 1980; Smith et al., 1984; Akinwunmi et al., 1993; O'Quinn, 2012). Yet, an increase in marbling has repeatedly shown to improve tenderness, juiciness, and flavor of beef.

Warner-Bratzler shear force

Warner-Bratzler shear force (**WBSF**) provides an objective measurement of tenderness (Shackelford et al., 1991; American Meat Science Association, 2016). As previously mentioned, tenderness can be impacted by a variety of factors. In a study conducted by McCullough (2013), the only differences in WBSF were found between bone-in and boneless *longissimus thoracis* steaks aged for 14 days. Boneless steaks were found to be more tender (2.85 kg) than bone-in alternatives (3.29 kg) (McCullough, 2013).

Belew et al. (2003) performed WBS evaluations on 40 different beef muscles. They developed four tenderness categories based on shear values: "very tender" (WBS < 3.9 kg), "tender" (3.2 kg < WBS < 3.9kg), "intermediate" (3.9 kg < WBS < 4.6 kg), and "tough" (WBS > 4.6 kg) (Belew et al., 2003). Among the muscles evaluated, the *psoas major* was allocated to the "very tender" group and *longissimus lumborum* and *longissimus thoracis* muscles were classified as "tender" (Belew et al., 2003). In a different study, *semimembranosus* steaks were found to have greater WBSF values than *longissimus lumborum* and *serratus ventralis* steaks and were similar in tenderness to *gluteus medius* samples (Hunt et al., 2014b). Similar results were found for *longissimus lumborum* (3.46 kg), *gluteus medias* (3.48 kg), and *semimembranosus* (3.94 kg) by McKeith et al. (1985). When comparing food service steaks for tenderness, top loin (25.8 N) and ribeye (27.3 N) steaks had the lowest WBSF compared to top sirloin steaks (30.2 N) (Guelker et al., 2013).

When evaluating the effect of quality grade, Guelker et al. (2013) also found that ungraded (31.9 N) and Select (30.6 N) food service steaks had higher WBSF values than Prime (25.1 N), Top Choice (27.4 N), and Low Choice (26.6 N) steaks (Guelker et al., 2013). Gruber et al. (2006) evaluated 17 beef muscles of upper 2/3 Choice and Select quality grades to determine the effect of aging on tenderness. WBS analysis from the study showed that shear values decreased for both quality grades among nearly all muscles when aging time increased (Gruber et al., 2006). In the Emerson et al. (2013) study, shear values decreased from steaks with traces marbling (4.12 kg) to steaks with moderately abundant marbling (2.68 kg) (Emerson et al., 2013). Likewise, data from Nyquist et al. (2018) is in agreeance and show as quality grade increases, WBSF values decrease indicating more tender meat (Nyquist et al., 2018).

Fat and moisture analysis

An abundance of literature has measured fat and moisture percentages within beef samples. It is widely known that as marbling increases in a muscle chemical fat percentage will increase while percent moisture decreases (Savell and Cross, 1988; O'Quinn et al., 2012; Emerson et al., 2013; Hunt et al., 2014b; Corbin et al., 2015; Legako et al., 2015; Lucherk et al., 2016; Nyquist et al., 2018; Drey et al., 2019). Fat percentages in the *longissimus lumborum* range from 13-14% in Prime steaks; 8-9% in Top Choice; 4-6% in Low Choice; 2-3% in Select; and 1% in Standard steaks (O'Quinn et al., 2012; Hunt et al., 2014a; Legako et al., 2015; Nyquist et al., 2018; Drey et al., 2019). The same studies also outline moisture percentages. Prime strip loin steaks range from 57-64%; Top Choice 63-67%; Low Choice 70%; Select 71-72%; and Standard 71-73% (O'Quinn et al., 2012; Hunt et al., 2014a; Legako et al., 2015; Nyquist et al., 2018; Drey et al., 2019). Nyquist et al. (2018) showed the within the *longissimus thoracis*, chemical fat percentages were 12.07% for Prime steaks, 6.13% for Choice Steaks, and 3.18% for Select steaks (Nyquist et al., 2018). Moisture percentages were 66.90% for Prime steaks, 70.46% for Choice steaks, and 73.30% for Select steaks (Nyquist et al., 2018). Furthermore, Legako et al. (2015) discussed biochemical characteristics of *psoas major* steaks their study. Prime steaks had a fat percentage of 8.1% and a moisture percentage of 69.5%; Upper 2/3 Choice has 6.9% fat and 70.3% moisture; Low choice tenderloin steaks had 3.8% fat and 73.1% moisture; Select had 3.5% fat and 72.5% moisture; and Standard steaks had 2.9% fat and 73.1% moisture (Legako et al., 2015).

Conclusion

A multitude of factors can impact beef palatability, specifically USDA quality grade and muscle. However, through the evolution of consumer demands and processing practices over the past several decades in the beef industry, have resulted in a shift to the marketing of primarily boneless subprimals. Consequently, consumers now have an increased interest in bone-in cuts of meat. Though there has been speculation that bone-in steaks offer a better eating experience, there is little to no literature to support this claim. It is therefore the intention of the current work to evaluate the palatability traits of beef cuts (ribeye, strip, tenderloin) in a bone-in versus boneless scenario in the following study.

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Chapter 2 - Evaluation of the impact of bone-in versus boneless cuts on beef palatability

Introduction

The evolution of consumer demands and processing practices over the past several decades in the beef industry has caused a shift away from traditional bone-in primals and subprimals to the marketing of primarily boneless subprimals. However, there is still an increased interest and novelty surrounding bone-in cuts in high-end steakhouses and retail markets (Bass, 2018). Millennials have coined the term "foodie" to describe those who have a passion for eating and learning about the overall eating experience (Ulver, 2019). As a result, these consumers prefer the aesthetic and visual stimulation that bone-in beef cuts offer in comparison to boneless alternatives (Bass, 2018). Boneless subprimals are marketed at a higher price per pound than bone-in cuts – yet most restaurants sell bone-in steaks at a greater premium than boneless steaks of the same cut (USDA-AMS, 2022). This discrepancy in price illustrates that consumers are willing to pay a higher price for bone-in steaks and allows restaurants to capture a greater value with these cuts (Bass, 2018).

Moreover, bone-in cuts are believed to have a more flavorful eating experience for consumers (Chicago Steak Company, 2016; Lopez, 2018; Goldwyn, 2021). This added flavor has been proposed to come from the bone itself and the marrow inside (Goldwyn, 2021). It is possible that the yellow marrow found inside the bone gets transferred to the steak itself resulting in a more buttery flavor (Chicago Steak Company, 2016). However, Jansen et al. (2015) described yellow bone marrow as a viscous substance found in the medullary cavity of bone making it unlikely to seep through the bone and into the muscle during cooking. It has also been speculated that the bone provides more insulation to the muscle, resulting in a slower cooking time and less surface area to lose moisture through and thus produces an improved eating experience (Lopez, 2018).

Previous research evaluating bone-in vs. boneless cuts is limited and has produced mixed results related to eating quality. McCullough (2013) found only minimal differences between bone-in and boneless steaks, however only one USDA quality grade was compared in that study. Thus, it is unclear whether the impact of bone is dependent on marbling level, as many of the bone-in cuts marketed in restaurants are often from only the premium quality grades of USDA Prime and upper 2/3 Choice. Jeremiah and Gibson (2003) reported that when compared to boneless cuts, bone-in steaks cut from beef ribs and short loins had improved tenderness and flavor attributes. Data from the National Beef Tenderness Surveys have also produced mixed results over recent years (DeGeer et al., 2009; Igo et al., 2013). These studies have shown that there are no palatability differences between bone-in and boneless cuts of the same quality grade while others have even reported improved palatability within boneless cuts (DeGeer et al., 2009; Igo et al., 2015). With the exception of the McCullough (2013) study, none of the cited studies had the objective to evaluate the impact of bone-in versus boneless cuts and thus, in many cases, lack the appropriate experimental control or replication to draw meaningful conclusions regarding the impact of bone state on beef palatability.

Therefore, the objective of the current study was to evaluate palatability traits of beef cuts (ribeye, strip loin, tenderloin) in a bone-in versus boneless scenario and compare the palatability characteristics of these cuts in a high quality (upper 2/3 Choice) and a lower quality (USDA Select) product to evaluate the interactions of marbling level and bone state.

Materials and Methods

The Kansas State University (**KSU**) Institutional Review Board approved all procedures for use of human subjects in sensory panel evaluation (IRB #7440.7, February 2, 2021).

Sample preparation

Left and right sides of 12 beef carcasses representing USDA Choice (upper 2/3) and USDA Select quality grades were selected by trained KSU personnel at a commercial abattoir in the Midwest. Kansas State University research personnel collected quality and yield grade data prior to fabrication (data not presented). Cuts from both sides of carcasses (n = 12) were fabricated into beef short loins (IMPS #174) and the rib from one side fabricated into a bone-in ribeye roll (IMPS #109E) and the other into a boneless ribeye roll (IMPS #112A). All cuts were vacuum-packaged and transported under refrigeration to the KSU Meat Laboratory (Manhattan, KS).

After arriving at KSU, short loins from each animal were fabricated into either a boneless strip loin (IMPS #180) with a corresponding bone-in tenderloin (IMPS #188) or a bone-in strip loin (IMPS #175) with a paired boneless tenderloin (IMPS #190B) at 3 d postmortem. Following the initial fabrication, product was vacuum-packaged. No further fabrication was necessary for ribeye rolls, thus they remained in native packaging from the processing facility. All product was then aged in dark storage for a total 28-d postmortem at 0 – 4°C.

At the completion of the aging period, frozen subprimals were fabricated into 2.5 cm thick steaks using a band saw (Model #3344, Biro, Marblehead, Ohio). Strip loin steaks for use in the study were selected anterior to the *gluteus medius* and tenderloin steaks were selected from the posterior end of the cuts where the steaks were largest in size. For ribeye rolls, steaks were taken from the approximate center of the cut. Following cutting, steaks were randomly assigned to one of four assays: 1) consumer sensory analysis; 2) trained sensory analysis; 3) Warner-Bratzler shear force evaluation; or 4) chemical fat and moisture analysis. Steaks were then individually vacuum-packaged and frozen (-20°C) until further analysis.

Trained sensory panel evaluation

Steaks designated for trained sensory analysis were thawed at 2 to 4°C for 24-h prior to cooking. Testing procedures followed those previously described by Drey et al. (2019); Olson (2019); Prill et al. (2019). Steaks were cooked to a peak temperature of 71°C (medium) following the post-cooking temperature rise on clamshell style grills (Cuisinart Griddler Deluxe, East Windsor, NJ) and temperatures were monitored using a probe thermometer (Thermapen Mk4, ThermoWorks, American Fork, UT). For ribeye samples, only the *longissimus thoracis* muscle was evaluated by panelists. Following cooking, samples were cut into 2.5-cm thick × 1-cm × 1-cm cuboids, and 2 pieces were served to the trained sensory panelists.

Trained sensory panelists were trained according to the American Meat Science Association (**AMSA**) sensory guidelines (AMSA, 2016). Panelists were trained over four sessions leading up to the panels with anchors and methods similar to those described by Lucherk et al. (2016) and Vierck et al. (2018). A total of 18 panels were conducted at the KSU Meat Science Sensory Lab (Manhattan, KS). For each session, 8 panelists were seated at individual booths under low-intensity red incandescent lights and fed 8 samples representing each treatment in a randomized order. A warm-up sample was fed to panelists and discussed to calibrate participants and prevent panel drift before the beginning of each panel session. Panelists evaluated the samples for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off-flavor intensity. Samples were rated on 100-point continuous line scales with descriptive anchors at 0, 50, and 100. The scales anchor of 0 corresponded to extremely dry/tough/none/extremely bland/no off-flavor; 50 neither dry nor juicy/neither tough nor tender; and 100 extremely juicy/tender/abundant/extremely intense.

Trained sensory panelists recorded their responses using a digital survey (Qualtircs Software, Provo, UT) on an electronic tablet (Lenovo TB-8505F). Additionally, final peak temperature and steak weights (raw and cooked) were collected for the calculation of cook loss ([raw weight – cooked weight) / raw weight] x 100). All external fat, connective tissue, and bone was separated from the lean of the steaks and weighed. The weight of the inedible portion of the steak was used to calculate cook yield ([cooked weight – inedible weight) / raw weight] x 100).

Consumer sensory panel evaluation

Consumer sensory panelists (*N* = 144) were recruited from Manhattan, KS and the surrounding area and monetarily compensated for their participation in the study. Panels were conducted in a lecture-style classroom at KSU. Steaks designated for consumer sensory analysis were thawed at 2 – 4°C for 24-h prior to testing and all exterior fat was removed prior to analysis. Testing followed procedures previously described McKillip et al,. 2017, Nyquist et al., 2018, Vierck et al., 2018, Rice et al. (2019), and Davis (2021). Steaks were cooked and prepared for the consumer panelists using the procedures previously described for trained sensory panel evaluation.

Each consumer evaluated samples for juiciness, tenderness, flavor liking, beef-like flavor intensity, beef-fat like flavor intensity, and overall liking on a 100-point continuous line scales anchored on both ends with descriptive terms. Additionally, panelists were asked to classify each sample as acceptable or unacceptable for each of the sensory traits previously listed and to assess the quality of the sample by identifying if the sample was unsatisfactory, everyday quality, better than everyday quality, or premium quality.

Consumers were provided apple juice, water, and unsalted saltine crackers to use as palate cleansers in addition to a napkin, plastic fork, and an expectorant cup. Consumer sensory panelists recorded their responses using a digital survey (Qualtircs Software, Provo, UT) on an electronic tablet (Lenovo TB-8505F). Additionally, final peak temperatures of all samples were recorded.

Warner-Bratzler shear force analysis

Warner-Bratzler shear force analysis was performed using the protocol described by the AMSA Meat Cookery and Sensory Guidelines (AMSA, 2016). A total of 6 cores (1.27-cm diameter) were cut from each cooked steak parallel to the muscle fiber orientation. The cores were then sheared perpendicular to the muscle fiber orientation using an Instron testing machine (model 5569, Instron Corp., Canton, MA) with a crosshead speed of 250 mm/min and a load cell of 100 kg. Measurements of the 6 cores per steak were averaged and results were recorded as average peak force (kg).

Fat and moisture analysis

Steaks designated for fat and moisture analysis were thawed at 2 – 4°C for 24-h prior to homogenization. All exterior fat and bone were trimmed from samples and only the muscle of interest was cut into small cubes and submerged in liquid nitrogen. Samples were then ground to a fine powder using a blender (Waring Products, New Hartford, CT). Once powdered, the samples were stored at -80°C until further analysis. A modified Folch method described by Martin et al. (2013) was utilized to analyze intramuscular fat percentage. Moisture content of samples was determined by an oven drying method described by the AOAC (2016). Both analyses were performed in duplicate.

Statistical analysis

Statistical analysis was completed using the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC) with α set at 0.05. Carcass served as the experimental unit for statistical analyses and data were analyzed as a split-plot with the whole plot factor of quality grade and a subplot factor of bone state / muscle. Peak temperature was used as a covariant and a model with a binomial error distribution was utilized for acceptability data. Additionally, the Kenward-Roger approximation was used for all analyses.

Results

Consumer panel demographics and purchasing motivators

Table 2.2 presents the demographic profile of the 144 consumers who participated in the consumer sensory panels. Participants were primarily Caucasian/White (93.8%) and consisted of predominately males (66.7%) versus females (33.3%). Of the consumers, 36.1% were between the age of 20-29 years old, and more than 50% were over 40 years of age. Over half of the participants were married (52.8%), with 76.4% of consumers having a household size of 2 or more people. Most (86.2%) consumers had completed some college/technical school or more. The majority (53.2%) of consumers had an annual household income level of $75,000 or greater. When asked what beef palatability trait was most important, 45.1% of consumers rated flavor the highest, followed by tenderness (25.2%), and juiciness (16.1%). Medium rare was the most preferred degree of doneness (45.1%), and over half (52.8%) of participants consumed beef 1 to 3 times a week.

Participants were asked to rate the importance of 16 different beef purchasing motivators when purchasing fresh steaks at retail (Table 2.3). “Price” and “color” were more ($P < 0.05$) important than all other purchasing motivators other than “size, weight, and thickness”. “Marbling”, “USDA grade”, and “familiarity with cut” were rated similar ($P > 0.05$), but more important ($P < 0.05$) to consumers than “nutrient content”, “animal welfare”, “eating satisfaction claims”, “antibiotic use in animal”, and “packaging”. Additionally, traits identified as “animal fed grain-based diet”, “natural or organic claims”, “animal fed a grass-based diet”, and “brand of product” were among the least important ($P < 0.05$) purchasing motivators to participants of this study.

Consumer sensory evaluation

There were no ($P > 0.05$) interactions found between quality grade and cut / bone state for any of the traits evaluated by consumers. The means for the main effects of quality grade and cut / bone state are reported in Table 2.4 When evaluating the main effect of quality grade, all Choice steaks were rated higher ($P < 0.05$) than Select steaks for juiciness, tenderness, flavor, and overall liking. Bone state had no impact ($P > 0.05$) on consumer juiciness and overall liking for tenderloins and ribeyes, but in the strip loin, bone-in steaks were rated juicier ($P < 0.05$) and higher for overall liking ($P < 0.05$) when compared to boneless steaks. Moreover, bone state had no impact ($P > 0.05$) on consumer tenderness and flavor ratings for any of the three cuts. Regardless of bone state, tenderloin steaks were juicier, more tender, more flavorful, and rated higher overall ($P < 0.05$) than ribeyes and boneless strip loin steaks. However, bone-in strip loin steaks were similar ($P > 0.05$) in juiciness to bone-in tenderloins. There were no differences ($P > 0.05$) between strip loins and ribeyes for flavor liking. But, ribeye steaks were similar ($P < 0.05$) to bone-in and boneless strip loin samples for tenderness and overall liking ratings.

Consumers were also asked to rate palatability traits as either acceptable or unacceptable as they were evaluating each sample (Table 2.4). No ($P > 0.05$) interactions were found between quality grade and cut / bone state. Choice steaks had a higher ($P < 0.05$) percentage of consumers that rated juiciness as acceptable when compared to Select steaks. But, quality grade did not impact ($P > 0.05$) the percentage of acceptable consumers ratings for tenderness, flavor, and overall acceptability. Furthermore, bone state had no impact ($P > 0.05$) on the percent of consumer’s rating juiciness as acceptable for tenderloins and ribeyes, but in strip loins, bone-in steaks had a higher ($P < 0.05$) percent of acceptable consumers responses than boneless cuts. The percent of acceptable consumer ratings for tenderness and overall acceptability were not ($P > 0.05$) impacted by bone state in tenderloins and strip loins; however, in ribeyes, the percentage of acceptable consumer ratings was higher ($P < 0.05$) for bone-in cuts for both traits. Tenderloins had a higher ($P < 0.05$) percentage of acceptable ratings for tenderness than strip loins and ribeyes. Likewise, tenderloins also had a higher ($P < 0.05$) percentage of acceptable ratings for juiciness and overall acceptability when compared to boneless strip loins and boneless ribeyes.

Strip loin and ribeye steaks had similar ($P > 0.05$) percentages of acceptable juiciness ratings, except for boneless strip loins which were also similar ($P > 0.05$) to boneless ribeyes.

Additionally, consumer panelists were asked to identify the quality level at which they perceived each sample. Once again, there were no ($P > 0.05$) interactions observed between quality grade and cut / bone state. Likewise, no ($P > 0.05$) quality grade effects were observed for the percentage of steaks rates as unsatisfactory, every day, and premium quality. However, a greater ($P < 0.05$) percentage of Choice samples were rated as better than everyday quality than Select. Moreover, bone state did not ($P > 0.05$) impact quality perception on strip loin and tenderloin samples. Bone state also did not ($P > 0.05$) impact premium, better than every day, and every day quality perceptions among ribeyes; but the percentage of consumers rating ribeye samples unsatisfactory was higher ($P < 0.05$) for boneless ribeye steaks. Fewer ($P < 0.05$) samples from tenderloins were perceived as unsatisfactory and every day quality when compared to strip loin and ribeye steaks. Likewise, a greater ($P < 0.05$) percentage of consumer ratings for tenderloin samples were perceived as premium quality.

Trained sensory evaluation

Overall, bone state had a minimal impact on palatability traits evaluated through trained sensory evaluation. There was a significant ($P < 0.05$) interaction between quality grade and cut / bone state (Table 2.5). Select bone-in strip loin steaks had the most ($P < 0.05$) detectable connective tissue amount. Conversely, Choice and Select tenderloins of both bone states had the least ($P < 0.05$) amount of detectable connective tissue. Choice bone-in and boneless strip loin samples were lower ($P < 0.05$) in connective tissue than Select bone-in and boneless strip loins. Similar results were observed for Choice boneless ribeye steaks which were also lower ($P <$

0.05) in detectable connective tissue than Select boneless ribeye samples. For the main effect of quality grade, Choice steaks were rated higher ($P < 0.05$) than Select steaks for all palatability traits evaluated. Bone state had no impact ($P > 0.05$) on initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, or off-flavor intensity in strip loin, tenderloin, and ribeye steaks. Other than strip loins, bone-in samples had a more ($P < 0.05$) intense beef flavor. Furthermore, tenderloin samples were rated higher ($P < 0.05$) for myofibrillar and overall tenderness than strip loin and ribeye steaks which were which were rated similar ($P > 0.05$) by trained sensory panelists.

Warner-Bratzler shear force, cooking characteristics, and moisture and fat analyses

The main effects of quality grade and cut / bone are reported in Table 2.6. When evaluating WBSF, Choice steaks were more ($P < 0.05$) tender than Select samples. Bone state did not ($P > 0.05$) have an impact on shear force values within any of the cuts. However, tenderloin steaks had lower ($P < 0.05$) shear force values than strip loin and ribeye samples. Strip loin and ribeye steaks had similar ($P > 0.05$) WBSF values.

When evaluating cooking characteristics between quality grades, cook time did not have a significant ($P > 0.05$) effect. However, Select steaks were higher ($P < 0.05$) yielding and had a greater ($P < 0.05$) cook loss than Choice samples. Bone state also had a significant ($P < 0.05$) impact on cooking time, yield, and cook loss of strip loin, tenderloin, and ribeye samples. Bone-in strip loin, tenderloin, and ribeye steaks had a longer ($P < 0.05$) cooking time than boneless strip loin, tenderloin, and ribeye steaks. Data show that bone-in strip loin and bone-in ribeye steaks had similar ($P > 0.05$) cooking times. Similarly, boneless strip loin and boneless ribeye steaks also had statistically similar ($P > 0.05$) cooking times. Boneless tenderloins took the least

($P < 0.05$) amount of time to reach the final degree of doneness and bone-in tenderloins had the longest ($P > 0.05$) cooking time. Furthermore, when evaluating cooking yield, in strip loin, tenderloin, and ribeye steaks, boneless samples had the more ($P < 0.05$) edible lean when compared to bone-in steaks. Moreover, boneless strip loin, tenderloin, and ribeye steaks also had the greatest ($P < 0.05$) cooking loss. Boneless tenderloins yielded the most ($P < 0.05$) edible lean and had the greatest ($P < 0.05$) cook loss when compared to strip loin and ribeye steaks of both bone states. Boneless ribeyes were higher ($P < 0.05$) yielding that strip loin samples and similar ($P > 0.05$) in terms of cook loss. Alternatively, bone-in tenderloin and strip loin steaks were the lowest ($P < 0.05$) yielding cuts.

There was a significant ($P < 0.05$) interaction between quality grade and cut / bone state (Table 2.6) for moisture and fat percentages. As expected, all Choice samples from each cut / bone state had a greater ($P < 0.05$) fat percentage than Select samples of the same cut / bone state. Bone state only impacted fat percentage in Select tenderloin steaks. Boneless Select tenderloins were higher ($P < 0.05$) in fat than bone-in Select tenderloins. Furthermore, all USDA Select cut / bone state combinations were higher ($P < 0.05$) in moisture than all Choice cut / bone state combinations, except for Choice boneless tenderloins, which are similar ($P > 0.05$) to Select boneless tenderloin samples.

Discussion

Consumer demographics and purchasing motivators

About two-thirds of consumers in our study were male, whereas the ratio of male to female consumers in studies conducted by Drey et al. (2019), Olson et al. (2019), Prill et al. (2019), and Davis et al. (2021) were split closer to half and half. Most consumers consumed beef

1 to 3 times a week, similar to findings also found by Drey et al. (2019), Olson et al. (2019), and Prill et al. (2019). The preferred degree of doneness by most consumers was medium rare, which is slightly rarer than the degree of doneness steaks were cooked to in this study. These findings are consistent with results reported by Nyquist et al. (2018); Drey et al. (2019); Olson et al. (2019); Beyer et al. (2021), which also found that a majority of consumers preferred medium rare beef steaks (Nyquist et al., 2018; Drey et al., 2019; Olson et al., 2019; Beyer et al., 2021).

Purchasing motivator data provides insight into how consumers prioritize beef steak characteristics when selecting meat at retail. Previous beef palatability studies have determined that color, price, and size are the most important purchasing motivators for consumers (Lucherk et al., 2016; Vierck et al., 2018; Olson et al., 2019). Consumers in our study also found steak color to be of equal importance to price. Size, degree of marbling, quality grade, and familiarity with cut also highly motivate consumers in this study when selecting fresh beef steak to purchase at retail.

Effect of bone state on palatability

Previous research evaluating the impact of bone state on beef eating quality is limited and has produced inconsistent results. Our study found that bone state had no impact on consumer ratings for tenderness, flavor, juiciness, and overall liking in tenderloin and ribeye steaks. However, in the strip loin, bone-in steaks were rated 7.4% higher for juiciness and 6.8% higher for overall liking. Similarly, DeGeer et al. (2009); McCullough (2013); Lepper-Blilie et al. (2015) have noted that there are no detectable palatability differences among bone-in and boneless steaks of the same quality grade. Some studies have found that bone-in samples are juicier and more flavorful than boneless steaks (Jeremiah and Gibson, 2003; Voges et al., 2007)

Conversely, Igo et al. (2015) found that boneless strip loin steaks were rated 1% higher for juiciness and 0.9% higher for overall liking. Boneless strip loin steaks were also rated higher for tenderness and flavor. The smaller magnitude of difference observed between bone-in and boneless results found by Igo et al. (2015) is likely due to their much larger sample size. It is also important to note that an unbalanced number of samples from USDA Prime, Choice, Select, and ungraded quality grades were utilized for the previous study. The other previously mentioned studies typically only evaluate one quality grade, do not have the main objective of evaluating differences between bone-in and boneless cuts, or they lack the experimental replication to draw meaningful conclusions.

No other studies have collected acceptability data for bone-in versus boneless steaks. Bone state had no impact on the percent of acceptable ratings by consumers for tenderloins. Results did indicate that bone-in strip loin and ribeye steaks provided consumers in our study with a more acceptable eating experience despite palatability ratings showing minimal differences between the bone states. Despite bone-in samples having close to 10% more consumers deeming them acceptable, boneless steaks still had well over 50% of consumers rating them as acceptable indicating that bone-in and boneless strip loin and ribeye steaks are still both extremely well accepted by consumers.

Studies comparing bone-in and boneless cuts via trained sensory analysis have produced mixed results. Studies conducted by DeGeer et al. (2009) and Lepper-Blilie et al. (2016) found no palatability differences between bone-in and boneless strip loins. McCullough (2013) utilized trained sensory analysis to evaluate specific palatability attributes in strip loin, ribeye, and tenderloin steaks of varying aging periods. Their study revealed no differences in beef flavor among differing bone-states and cuts (McCullough, 2013). However, they did find that bone-in tenderloin and ribeye steaks aged for 21d were rated higher for initial juiciness, first impression tenderness, and overall tenderness than boneless alternatives (McCullough, 2013). This result was not mirrored in tenderloin or ribeye steaks aged for 28d. In this case, bone-in tenderloin steaks were actually rated lower for initial and sustained juiciness, while bone-in ribeyes were rated lower for just initial juiciness (McCullough, 2013). The margins of difference between each of these traits is less than 1% indicating that inherent variability between the samples contributed to the observed differences. McCullough (2013) concluded that overall palatability differences between bone-in and boneless samples were minimal which is consistent with our study. We found that bone state had no impact on initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, or off-flavor intensity. However, when evaluating beef flavor, bone-in tenderloins and ribeyes were more flavorful, whereas Guelker et al. (2013) found boneless ribeye steaks to be more flavorful than bone-in ribeyes. Other than the McCullough (2013) study, none of the other research mentioned has had the objective to evaluate the impact of bone-in versus boneless cuts and thus, in many cases, lack the appropriate experimental control or replication to draw meaningful conclusions regarding the impact of bone state on beef palatability.

Effect of muscle on palatability

Muscles within a beef carcass vary in palatability based on muscle function and anatomical location. Typically steaks from the middle meats are more tender and desirable in terms of eating quality which is why we chose to evaluate strip loin, tenderloin, and ribeye steaks (Belew et al., 2003; Calkins and Sullivan, 2007; Jung et al., 2016). Our study found that untrained and trained sensory panelists rated tenderloin steaks higher for sensory attributes than strip loin and ribeye steaks, whereas strip loin and ribeyes were also consistently rated similar. McKeith et al. (1985) discovered similar results. In their study, tenderloin samples were also rated highest for tenderness and flavor while strip loin and ribeye steaks were rated similar (McKeith et al., 1985). However, different from our findings, tenderloin samples were similar in juiciness to strip loin and ribeye steaks (McKeith et al., 1985). Similarly, Shackelford et al. (1995) found that tenderloin samples evaluated by trained panelists were rated higher for overall tenderness when compared to steaks from the *longissimus*. In another study by Shackelford et al. (1995) it was found that flavor ratings for tenderloin samples were the lowest when compared to other muscles from the chuck, loin, and round. However, neither of these studies compared all of the same three beefs cuts that we utilized in the present study. Overall, tenderloin steaks are proven to offer one of the most tender and palatable eating experiences.

Effect of quality grade on palatability

It has been well documented that quality grade or degree of marbling has a large impact on the palatability of beef (Tatum et al., 1980; Smith et al., 1984; Smith et al., 1987; O'Quinn, 2012; Emerson et al., 2013; Lucherk et al., 2016; Nyquist et al., 2018; O'Quinn et al., 2018). There is a positive linear relationship between quality grade and sensory analysis ratings (Tatum et al., 1980; Smith et al., 1984; Smith et al., 1987; O'Quinn, 2012; Emerson et al., 2013; Corbin et al., 2015; Lucherk et al., 2016; Nyquist et al., 2018; O'Quinn et al., 2018). Our results were consistent with this trend. Consumers rated USDA Choice samples higher for juiciness, tenderness, and flavor. Choice steaks also had 11% more consumers that rated juiciness as acceptable when compared to Select steaks. Quality grade didn't impact consumer acceptability ratings for tenderness, flavor, and overall acceptability. Smith et al. (1984) had similar findings in a study evaluating palatability of top loin steaks. It was concluded that differences were not always significant within consecutive marbling scores (Smith et al., 1984). Our results from trained sensory analysis were also in-line with former findings. Choice steaks were once again rated higher for all palatability traits when compared to Select steaks.

Warner-Bratzler shear force

Warner-Bratzler shear force, an objective measurement of tenderness, can be influenced by a variety of factors. In our case, we found that bone state did not impact shear force values for strip loin, tenderloin, or ribeye steaks. McCullough (2013) found shear force values of strip loin and ribeye steaks aged 28d to be about 1% lower than our findings. This nuance can be explained by the fact McCullough (2013) only evaluated steaks of the USDA Choice quality grade, whereas, we evaluated Choice and Select. The only difference in WBSF McCullough (2013) observed was between bone-in and boneless ribeye steaks aged for 14 days. In this case, boneless steaks had lower shear force values than bone-in alternatives.

Consistent with our sensory findings, tenderloin steaks had lower shear force values than strip loin and ribeye steaks. Belew et al. (2003) found very similar WBSF values for strip loin, tenderloin, and ribeye steaks as what we reported in our study. However, they found all three cuts to be statistically similar in shear force values. This is most likely due to the fact they evaluated 40 different beef muscles from all regions of the carcass.

Multiple previous studies have shown that lower shear force values are associated with higher quality grades or degrees of marbling (Gruber et al., 2006; Emerson et al., 2013; Guelker et al., 2013; Nyquist et al., 2018). Our results also showed that Choice steaks had lower shear force values than Select samples providing further evidence that Choice steaks from the middle meats are more tender than Select.

Cooking characteristics

When evaluating cook time of steaks within our study, quality grade logically did not have a significant effect. Bone-in steaks, however, were found to have a longer cooking time due to the presence of bone. Interestingly, bone-in tenderloins took the longest to cook. Alternatively, boneless tenderloin steaks cooked the fastest because they were the smallest in size.

As previously mentioned, all exterior fat and bone was removed from samples and cook yield (edible lean) was measured. Our results showed that Select steaks were higher yielding than Choice steaks. This can be explained by differences in carcass characteristics (Table 2.1). Select steaks used in this study had a larger ribeye area than Choice steaks, thus were higher yielding. Bone-in steaks were lower yielding than boneless due to the weight of the bone and external fat that was trimmed off. Boneless tenderloin steaks had the least trim and were consequently the highest yielding cut. This indicates when buying these cuts at retail or at a restaurant, consumers are essentially paying for extra plate waste with bone-in cuts. Boneless ribeyes were found to be higher yielding than strip loin steaks due to having a greater amount of lean.

Results from cook loss calculations largely mirrored findings of cook yield. Select steaks had a higher cook loss than Choice. This difference is attributed to Select steaks losing more moisture throughout the cooking process. Moreover, boneless steaks had a higher cooking loss than bone-in. It is speculated this difference is due to the bone decreasing the surface area to lose moisture through. In our study, tenderloin steaks also had the greatest cook loss. The percentage of weight lost through cooking in tenderloins in our study was similar to findings by O'Quinn et al. (2015) and cook loss of strip loin and ribeye steaks was similar to values reported by DeGeer et al. (2009). Alternatively, Yancey et al. (2011) reported cook loss values for the *longissimus dorsi* that were close to 10% higher than steaks in our study. This difference could be attributed to different cooking methodology and the fact only USDA Select steaks were used by Yancey et al. (2011).

Conclusion

Overall, bone state also has a minimal impact on beef palatability factors in this study. USDA Choice and tenderloin steaks continue to be more palatable than lower quality grades and other cuts of beef. We currently see restaurants selling bone-in steaks at a higher price point than the same boneless alternatives when bone-in subprimals are actually marketed at a lower price point than boneless cuts (USDA-AMS, 2022). The results of this study indicate that the same eating experience can be derived from a less expensive boneless steak as with a higher priced “premium” bone-in steak.

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Table 2.1. Sample of A-maturity beef carcasses ($N = 144$) selected for this study

Trait[1]	Choice	Select	SEM[2]	*P* - Value
HCW	959.5	940.9	14.4	> 0.05
PYG	3.5[a]	2.8[b]	0.04	< 0.01
APYG	3.7[a]	2.9[b]	0.04	< 0.01
KPH	3.5	3.5	N/A[3]	N/A[3]
REA	14.3[b]	16.9[a]	0.3	< 0.01

[ab]Least square means lacking a common superscript differ ($P < 0.05$).
[1]HCW = hot carcass weight, PYG = preliminary yield grade, APYG = adjusted preliminary yield grade, KPH = kidney pelvic, and heart fat, REA = ribeye area
[2]SEM (largest) of the least squares means.
[3]KPH measurements were the same for all carcasses.

Table 2.2. Demographic characteristics of consumers (N = 144) who participated in consumer sensory panels

Characteristic	Response	Percentage of consumers
Gender	Male	66.7
	Female	33.3
Household size	1 person	23.6
	2 people	38.2
	3 people	6.9
	4 people	13.9
	5 people	7.6
	6 people	6.9
	Greater than 6 people	2.8
Marital Status	Married	52.8
	Single	47.2
Age	Under 20	5.6
	20-29	36.1
	30-39	5.6
	40-49	15.3
	50-59	20.1
	Over 60	17.4
Ethnic Origin	African American	0.7
	Asian	1.4
	Caucasian/White	93.8
	Hispanic	2.1
	Mixed Race	1.4
	Native-American	0.7
	Other	0.7
Household Income Level	Under $25,000	26.6
	$25,000-$34,999	2.8
	$35,000-$49,999	7.7
	$50,000-$74,999	9.8
	$75,000-$99,999	19.6
	$100,000-$149,999	16.1
	$150,000-$199,999	8.4
	Greater than $199,999	9.1
Education Level	Non-high school graduate	0.7
	High school graduate	16.7
	Some college/technical school	36.1
	College graduate	29.2
	Post-college graduate	17.4
Most important palatability trait when consuming beef	Tenderness	25.2
	Juiciness	16.1
	Flavor	58.7
Preferred degree of doneness when consuming beef	Very rare	1.4
	Rare	6.9
	Medium rare	45.1
	Medium	29.2
	Medium well	12.5
	Well done	4.2
	Very well done	0.7
Weekly beef consumption	1 to 3 times	52.8
	4 to 6 times	36.8
	7 to 9 times	6.3
	10 or more times	4.2

Table 2.3. Fresh beef steak purchasing motivators of consumers (N = 144) who participated in consumer sensory panels

Characteristic	Importance of each trait[1]
Price	75.1[a]
Color	74.3[a]
Size, weight, and thickness	71.1[ab]
Marbling	67.3[bc]
USDA Grade	65.5[bc]
Familiarity with cut	61.3[c]
Nutrient Content	53.8[d]
Animal welfare	52.1[d]
Eating satisfaction claims	50.4[de]
Antibiotic use in animal	44.8[ef]
Packaging	44.5[efg]
Growth hormone used in animal	41.7[fgh]
Animal fed a grain-based diet	41.4[fgh]
Natural or organic claims	38.4[gh]
Animal fed a grass-based diet	37.3[h]
Brand of product	37.0[h]
SEM[2]	2.3
P-value	< 0.01

[abcdefgh] Least square means lacking a common superscript differ ($P < 0.05$).

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

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

Table 2.4. LS means for consumer sensory panel ratings[1], acceptability ratings, and perceived level of quality for strip loin, tenderloin, and ribeye steaks of varying bone states and USDA quality grade[2]

Trait	Strip		Tenderloin		Ribeye							
	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	SEM[3]	*P*-value	Choice	Select	SEM[3]	*P*-value
Juiciness rating	58.5^{bc}	51.1^{d}	63.7^{ab}	66.6^{a}	57.2^{cd}	52.7^{cd}	2.5	< 0.01	66.7^{a}	54.0^{b}	1.8	< 0.01
Tenderness rating	53.1^{bc}	49.7^{c}	73.5^{a}	78.4^{a}	56.5^{b}	51.2^{bc}	2.6	< 0.01	64.9^{a}	55.9^{b}	1.9	< 0.01
Flavor rating	59.7^{b}	55.6^{b}	66.2^{a}	64.7^{a}	58.3^{b}	56.0^{b}	2.2	< 0.01	63.0^{a}	57.1^{b}	1.7	< 0.01
Overall like rating	60.0^{b}	53.2^{c}	69.0^{a}	72.2^{a}	58.2^{bc}	54.5^{c}	2.4	< 0.01	65.2^{a}	57.2^{b}	1.9	< 0.01
Juiciness Acceptability	83.7^{ab}	72.1^{c}	87.5^{a}	89.0^{a}	81.7^{ab}	76.1^{bc}	0.04	< 0.01	87.3^{a}	76.3^{b}	0.03	< 0.01
Tenderness Acceptability	77.3^{bc}	74.2^{c}	95.0^{a}	96.9^{a}	83.8^{b}	70.1^{c}	0.04	< 0.01	89.7	82.8	0.03	0.08
Flavor Acceptability	86.1	79.2	87.2	85.6	82.9	79.1	0.03	0.2	85.4	81.7	0.02	0.20
Overall Acceptability	84.6^{abc}	78.1^{cd}	91.2^{a}	89.1^{ab}	82.2^{bc}	73.4^{d}	0.04	< 0.01	86.7	80.7	0.03	0.08
Unsatisfactory	13.6^{bc}	15.5^{ab}	7.2^{cd}	6.8^{d}	15.0^{b}	23.4^{a}	0.04	< 0.01	9.9	16.0	0.03	0.07
Every day	50.9^{a}	55.8^{a}	37.0^{b}	34.2^{b}	57.2^{a}	47.4^{a}	0.04	< 0.01	43.0	51.0	0.03	0.09
Better than every day	28.2^{abc}	20.9^{c}	31.6^{ab}	33.8^{a}	19.4^{c}	23.6^{bc}	0.04	0.02	31.0^{a}	21.3^{b}	0.03	0.02
Premium	4.5^{b}	2.0^{b}	21.4^{a}	23.0^{a}	6.4^{b}	3.8^{b}	0.04	< 0.01	9.5	5.3	0.02	0.1

[abc]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).
[1]Sensory scores: 0 = extremely dry/tough/extremely bland; 50 neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/extremely intense.
[2]Quality grade: Choice = USDA Choice (upper 2/3) with marbling scores ranging from modest^{00} to moderate^{100}; Select = USDA Select with marbling scores ranging from slight^{00} to slight^{100}.
[3]SEM (largest) of the least square means in the same section of the same row.

Table 2.5. LS means for trained sensory panel ratings[1] for strip loin, tenderloin, and ribeye steaks of varying bone states and USDA quality grades[2]

Trait	Strip Loin		Tenderloin		Ribeye							
	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	SEM[3]	*P*-value	Choice	Select	SEM[3]	*P*-value
Initial Juiciness	60.6	59.0	56.2	55.7	58.0	56.4	1.4	0.06	60.5[a]	54.8[b]	0.8	< 0.01
Sustained Juiciness	55.0	53.8	51.3	50.9	52.4	51.2	1.6	0.24	55.6[a]	49.2[b]	0.9	< 0.01
Myofibrillar Tenderness	63.2[b]	63.7[b]	85.9[a]	85.1[a]	63.1[b]	61.9[b]	1.6	< 0.01	73.3[a]	67.7[b]	1.1	< 0.01
Overall Tenderness	59.7[b]	61.2[b]	85.2[a]	83.9[a]	60.5[b]	59.0[b]	1.8	< 0.01	71.4[a]	65.1[b]	1.6	< 0.01
Beef Flavor Intensity	37.3[ab]	37.5[a]	37.1[ab]	34.6[c]	37.8[a]	35.8[bc]	0.9	< 0.01	38.1[a]	35.2[b]	0.6	< 0.01
Off-Flavor Intensity	0.0	0.1	0.0	0.0	0.2	0.0	1.0	0.55	0.04	0.05	0.1	0.85

[abc]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).
[1]Sensory scores: 0 = extremely dry/tough/non/extremely bland/no off-flavor; 50 neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/extremely intense.
[2]Quality grade: Choice = USDA Choice (upper 2/3) with marbling scores ranging from modest^{00} to moderate^{100}; Select = USDA Select with marbling scores ranging from slight^{00} to slight^{100}
[3]SEM (largest) of the least square means in the same section of the same row.

Table 2.6. LS means for Warner-Bratzler Shear Force (**WBSF**) and cooking characteristics of strip loin, tenderloin, and ribeye steaks of varying bone states and USDA quality grades[1]

Trait	Strip		Tenderloin		Ribeye							
	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	SEM[3]	*P*-value	Choice	Select	SEM[3]	*P*-value
Cook Time (seconds)	663.1^{a}	502.6^{b}	679.0^{a}	334.6^{c}	684.1^{a}	532.2^{b}	21.7	< 0.01	567.3	564.6	13.0	0.87
Yield (%)[3]	41.2^{e}	54.5^{c}	42.0^{e}	67.6^{a}	47.1^{d}	60.3^{b}	1.4	< 0.01	50.8^{b}	50.7^{a}	0.8	0.02
Cook Loss (%)[4]	14.9^{d}	16.8^{bc}	14.5^{d}	20.0^{a}	15.6^{cd}	17.4^{b}	0.5	< 0.01	16.0^{b}	17.2^{a}	0.4	0.02
Shear Force (kgf)	3.7^{a}	3.6^{a}	2.7^{b}	2.7^{b}	3.8^{a}	3.8^{a}	0.1	< 0.01	3.1^{b}	3.7^{a}	0.1	< 0.01

[abcd]Least squares means in the same section of the same row without a common superscript differ ($P < 0.05$).
[1]Quality grade: Choice = USDA Choice (upper 2/3) with marbling scores ranging from modest^{00} to moderate^{100}; Select = USDA Select with marbling scores ranging from slight^{00} to slight^{100}.
[2]SEM (largest) of the least square means in the same section of the same row.
[3]Cook yield percentage = [(cooked weight – inedible weight) / raw weight] x 100
[4]Cook loss percentage = [(raw weight – cooked weight) / raw weight] x 100

Table 2.7. LS means for the interaction of bone state within each cut and USDA quality grade[1] for fat and moisture percentages of beef strip loin, tenderloin, and ribeye steaks

Trait	Choice						Select							
	Strip Loin		Tenderloin		Ribeye		Strip Loin		Tenderloin		Ribeye			
	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	Bone-In	Boneless	SEM[2]	*P*- Value
Fat Percentage (%)	10.7^{ab}	9.3^{bc}	10.6^{ab}	9.9^{ab}	10.3^{ab}	11.3^{a}	4.4^{e}	5.1^{de}	6.3^{d}	8.4^{c}	4.8^{de}	5.1^{de}	0.7	< 0.01
Moisture Percentage (%)	66.4^{f}	67.9^{def}	68.1^{de}	68.9^{cd}	68.1^{de}	66.8^{ef}	72.1^{a}	71.7^{ab}	71.1^{ab}	70.2^{bc}	71.9^{a}	71.5^{ab}	0.4	< 0.01
Connective Tissue Amount	6.0^{bc}	4.7^{c}	1.1^{d}	1.3^{d}	5.8^{bc}	5.6^{c}	10.9^{a}	6.7^{bc}	1.3^{d}	1.3^{d}	7.4^{bc}	8.6^{ab}	1.5	0.04

[abcde]Least squares means within the same row without a common superscript differ ($P < 0.05$).
[1]Quality grade: Choice = USDA Choice (upper 2/3) with marbling scores ranging from modest^{00} to moderate^{100}; Select = USDA Select with marbling scores ranging from slight^{00} to slight^{100}.
[2]SEM (largest) of the least square means within the same row.

Appendix A - Consumer Panel 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

Please sign and return one copy. The second copy is for your records.

Trained Sensory Panel Ballot

KANSAS STATE
UNIVERSITY

Panelist

Sample Number

Initial Juiciness

Extremely Dry	Neither Dry nor Juicy	Extremely Juicy
0	50	100

Sustained Juiciness

Extremely Dry	Neither Dry nor Juicy	Extremely Juicy
0	50	100

Myofibrillar Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Connective Tissue Amount

None	Extremely Abundant
0	100

Overall Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

.

Beef Flavor Intensity

Extremely Bland	Extremely Intense
0	100

Off Flavor Intensity

Extremely Bland	Extremely Intense
0	100

☐ Not Applicable

Off-Flavor Description

→

Sample Number

Initial Juiciness

Extremely Dry	Neither Dry nor Juicy	Extremely Juicy
0	50	100

Sustained Juiciness

Extremely Dry	Neither Dry nor Juicy	Extremely Juicy
0	50	100

Myofibrillar Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Connective Tissue Amount

None	Extremely Abundant
0	100

Overall Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Beef Flavor Intensity

Extremely Bland
0

Extremely Intense
100

Off Flavor Intensity

Extremely Bland
0

Extremely Intense
100

☐ Not Applicable

Off-Flavor Description

→

Consumer Sensory Analysis Ballot

KANSAS STATE UNIVERSITY

Big Panel 1 - Red

Please tell us a little about yourself.

Panelist Number

Gender

- Male
- Female

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
- Latino
- Native American
- Other
- Mixed Race

Marital Status

- Single
- Married

Household Size

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

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 consuming beef, which palatability trait do you experience the greatest amount of **variation** with?

- 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

→

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

Eating Satisfaction Claims (ex: Guaranteed Tender)

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

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

Familiarity with cut

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

Color

Extremely Unimportant 0 — Extremely Important 100

USDA Grade

Extremely Unimportant 0 — Extremely Important 100

Marbling

Extremely Unimportant 0 — Extremely Important 100

→

Sample Number

A - 1807

Juiciness

Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
0	50	100

Juiciness

Was the sample acceptable for juiciness?

Acceptable

Unacceptable

Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Tenderness

Was the sample acceptable for tenderness?

Acceptable

Unacceptable

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 eaten.

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