DO CARCASS WEIGHT AND RIBEYE SIZE IMPACT BEEF PALATABILITY?

A Thesis

by

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ABSTRACT

Many challenges are associated with merchandising steaks from heavier carcasses and larger ribeye sizes. This study had three primary objectives: (1) to determine if carcass weights and ribeye sizes influence tenderness and consumer acceptance of beef steaks, (2) to evaluate objective tenderness of steaks from carcasses varying in carcass weight and ribeye size, and (3) to determine differences in palatability among steaks portion cut by thickness from those cut by weight. Steaks from certain combinations of ribeye sizes and carcass weights had superior tenderness and consumer acceptance when compared to other combinations, even at the same marbling score (USDA Choice, Ch^-). Though steaks from all combinations were adequate from a palatability standpoint, consumer panelists' scores for overall and tenderness liking were highest ($P < 0.05$) for steaks in the smallest ribeye area category (83.9 to 89.8 cm^2). Additionally, steaks in the smallest ribeye area category of 83.9 to 89.8 cm^2 represented the lowest WBS force values when portioned both by thickness (3.18 cm) and by weight (340 g). This study examined the next step in addressing carcass consistency and product uniformity issues in the beef industry that could potentially place consumer palatability and customer satisfaction at risk.

DEDICATION

This work is dedicated to my parents. You set the standard and have inspired me to work hard and remain grounded in all that I do. Your unwavering support throughout this process means the world to me.

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NOMENCLATURE

HCW	Hot Carcass Weight
IMPS	Institutional Meat Purchase Specifications
LL	*M. longissimus lumborum*
NAMI	North American Meat Institute
NBQA	National Beef Quality Audit
NCBA	National Beef Cattlemen's Association
REA	Ribeye Area
USDA	United States Department of Agriculture
WBS	Warner-Bratzler Shear

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CHAPTER I

INTRODUCTION

The foodservice sector of the meat industry comprises a considerable percentage of beef consumption across the United States, with beef representing approximately 40% of the share of all foodservice menu items (Dunn, Williams, Tatum, Bertrand, & Pringle, 2000). Therefore, maintaining uniformity among beef cuts while meeting consumer expectations is of upmost importance within an industry that is ever-changing. According to the National Beef Quality Audits (Boleman et al., 1998; Boykin et al., 2017a, 2017b; Garcia et al., 2008; Gray et al., 2012; McKenna et al., 2002; Moore et al., 2012), average hot carcass weights and ribeye areas have steadily increased over the past decades. Moreover, challenges associated with merchandising steaks from heavier carcasses and larger ribeye sizes have been identified for both retail and foodservice (Dunn et al., 2000). Genetic selection and enhanced management practices by producers across the United States have allowed for heavier carcasses and larger subprimals (West et al., 2011). Dunn et al. (2000) emphasized the impact increasing hot carcass weights and ribeye sizes has across the industry, stating that variability within the foodservice sector creates inconsistencies in portioned steaks resulting in discrepancies in consumer acceptability and the overall eating experience. Therefore, understanding how carcass weights and ribeye sizes influence portion cutting of certain subprimals is of great importance.

CHAPTER II

REVIEW OF LITERATURE

2.1. Challenges identified from the National Beef Quality Audits

The National Beef Quality Audits (NBQA) have evaluated the quality and consistency of the beef industry via in-plant assessments by researchers over five-year increments from 1991 to 2016 (Boleman et al., 1998; Boykin et al., 2017; Garcia et al., 2008; Gray et al., 2012; Lorenzen et al., 1993; McKenna et al., 2002). One frequent finding over the course of the NBQA era is a steady increase in hot carcass weights and ribeye sizes among U.S. fed steers and heifers. Between the 1995 and 2016 audits, hot carcass weights increased by an average of 50.80 kg with a mean carcass weight of 339.2 kg in 1995, and 390.3 kg in 2016. This trend also is true for average ribeye area (*M. longissimus thoracis et lumborum*; in^2) measured at the interface between the 12^{th} and 13^{th} ribs. Average ribeye areas (REA) increased by approximately 6.5 cm^2 between the 1995 and 2016 audits, changing from 82.6 cm^2 to 89.5 cm^2, respectively.

Gonzalez and Phelps (2018) reported that a larger percentage of carcasses have become heavier as time has progressed, a conclusion consistent with NBQA results. A shift to heavier hot carcass weights and larger ribeye areas in more recent years could be explained by the use of growth promoting technologies, as evidenced by the 2011 NBQA (Gonzalez & Phelps, 2018; Moore et al., 2012). In addition, Moore et al. (2012) noted the shift could also be due to changes in production practices that utilize more large-framed, heavy-muscle breeds. The increase in popularity of branded beef programs in the industry is noteworthy, as the programs have potentially influenced the heavy carcass, large ribeye area trend. (Garcia et al., 2008) and Moore et al. (2012) hypothesized that the shift to heavier hot carcass weights and larger ribeye areas could be due to beef producers' efforts to meet the specifications of these programs and in some cases, gain a premium for each carcass that qualifies for a branded beef program. Consequently, as hot carcass weights and ribeye areas increase, the size of steaks from the *M. longissimus dorsi* inevitably increases, posing new difficulties for the industry (Rutherford, 2013).

Carcass weight and ribeye size were listed as industry challenges based on findings from the 2011 and 2016 NBQAs. The 2011 National Beef Quality Audit listed carcass inconsistencies resulting from increased carcass weights and ribeye sizes as a primary area of concern that needs improvement within the beef industry (National Beef Cattlemen's Association, 2017). Specifically, the 2011 audit found that more than 25% of the studied population were outside of the 12- to 16-square inch range, creating challenges "down the chain" that presumably include the beef foodservice sector. In 2016, consistency seemed to be addressed by most branded beef items but was still cited as a challenge due to carcasses that were ineligible for branded beef programs. Consistency issues arise when the range in hot carcass weights and ribeye size is too large (National Beef Cattlemen's Association, 2017). In particular, the foodservice industry is at the mercy of this broad weight and size spectrum. Further processors are challenged by inconsistencies when portion cutting by constant thickness and/or constant weight to accommodate consumer demand and specifications. In fact, when Smith, Savell, Morgan, and Lawrence (2005) interviewed representatives of six government agencies (Food Safety and Inspection Service, Agricultural Marketing Service, Grain Inspection, Packers, and Stockyards Administration, Foreign Agricultural Service, Animal and Plant Health Inspection Service, Food and Drug Administration/Center for Veterinary Medicine) and eight trade organizations (American Meat Institute, United States Meat Export Federation, Food Marketing Institute, North American Meat Processors Association, National Restaurant Association, Southwest Meat

Association, National Meat Association, National Beef Cattlemen's Association) product inconsistency tied for second place among major quality defects/challenges from results of the NBQA dating back to 2005. According to the Executive Summary of the 2016 National Beef Quality Audit, 66 percent of further processors would be willing to pay a premium for a guaranteed weight and size to overcome this challenge. In the same summary (National Beef Cattlemen's Association, 2017), the losses associated with carcass weights were the highest the industry has seen since the quality audits first began. The total lost opportunity cost due to carcass weight in 2016 was valued at US $10.88 per head. This is an over 50% increase from the first audit in 1991 that valued lost opportunities due to carcass weight at US $4.52 per head (National Beef Cattlemen's Association, 2017).

2.2. Foodservice distribution of beef

The demand for beef in foodservice establishments has increased 15 percent since 2012, with 97 percent of restaurants offering dishes that include beef on their menus (The Beef Board, 2019). Farkhas (1993) and Huffman, Miller, Hoover, Wu, Brittin, and Ramsey (1996) reported that Americans have shifted their focus from preparing and consuming steaks at home to consuming steaks in restaurants. The National Cattlemen's Beef Association (2017) reported 45 percent of operators purchase and utilize pre-cut steaks as their center-of-the-plate protein of choice. Variation in steak sizes create several repercussions for the foodservice sector of the beef industry. Steaks generated from rib and loin primals are more heavily impacted by a large range in ribeye area. In addition, these steaks also are typically of highest value, placing profit at risk if consumer perception becomes weakened by inconsistencies seen from plate-to-plate. According to National Cattlemen's Beef Association (2017), approximately 481 million pounds per year

(2017) are utilized from these primals with an estimated 5.533 billion dollars per year spent by the foodservice sector to generate pre-cut steaks from the rib and loin.

Leick, Behrends, Schmidt, and Schilling (2011) explained that variability in steak sizes can result in differences in appearance, cooking times and plate coverage. Often, product size and thickness dictates portion cutting for retail, while portion cutting for foodservice use is dictated by product weight (Leick et al., 2011). The escalation in both hot carcass weights and ribeye sizes within the beef industry means that variation in subprimal weights could lead to discrepancies in portion cutting from steak-to-steak. For example, because the weight of each steak is a fixed measure to meet foodservice requirements, one consumer may receive a thick steak from a lighter subprimal while another consumer receives a thinner steak from a heavier subprimal (Leick et al., 2011). This consistency challenge has been ongoing for at least a decade as evidenced by the NBQA dating back to 2005. In 2005, "Cut Weights Too Heavy" was selected in 2nd place for the "Top Ten Greatest Quality Challenges" by beef purveyors, restauranteurs, and supermarket operator sectors when surveyed by Smith et al. (2005). In the same survey, "Lack of Uniformity In Cuts" placed 3rd, and "Too Large Ribeyes" also was listed as a quality challenge in 10th place, further emphasizing the repercussions heavy carcass weights and large ribeye sizes pose to further processors in the beef industry.

In a study by Maples, Lusk, and Peel (2018), consumers' willingness to pay for thick versus thin steaks was assessed. When evaluating a 1.3 cm. steak against a steak with a thickness of 2.5 cm. (control), consumers' willingness to pay for the thinner steak was significantly lower, and participants were willing to pay $18.68 less per package. On the other hand, respondents were willing to pay $4.67 more for a thicker steak of 3.8 cm. when compared to the 2.54 cm. thick steak. As noted previously, steak thickness and portion-cutting can be largely influenced by the size and dimension of REA. In the same study, steaks with differing REA also were assessed by consumers' willingness to pay. With a 90 cm^2 REA steak set as the control, consumers evaluated steaks that had a 65 cm^2 area and steaks with an 116 cm^2 area. It was determined that consumers were willing to pay significantly more ($3.51/package) for steaks possessing a larger ribeye area versus a smaller ribeye area. In fact, consumers' willingness to pay for a 65 cm^2 versus a 90 cm^2 was $7.07/package less than their larger ribeye area counterparts. Maples et al. (2018) concluded that consumers prefer thick-cut steaks and are more willing to pay for thicker steaks. Variations in *M. longissimus thoracis et lumborum* areas pose risk to the uniformity of steak sizes and therefore hinder consumers' willingness to pay for these items.

Maples et al. (2018) found inconsistent portioning problematic from a marketing perspective as well. Many purveyors have resorted to cutting thinner steaks from larger subprimals to keep prices consistent for consumers. The problem, as explained by Maples et al. (2018), is that consumers do not want thinly cut steaks, but also do not want to pay a higher price associated with an increased steak weight. To combat this issue, the retail and foodservice sectors have had to become innovative and create new marketing strategies for beef products. Many purveyors are separating muscles associated with the *M. longissimus thoracis et lumborum* and selling them as separate entities such as the *M. spinalis dorsi*, commonly referred to as the "ribeye cap" (Cross, 2018). Some foodservice establishments and restaurants have attempted cutting subprimals in half and serving the resulting steaks in a form that resembles a tenderloin steak. However, as evidenced in findings from Sweeter, Wulf, and Maddock (2005), consumers discounted steaks that had been cut in half, deeming this method a possible economic disadvantage and an unsuccessful attempt in making larger subprimals more profitable. The retail sector also has attempted "family-pack" style steak merchandising in which thinner steaks are packaged together and sold on a per-pound basis. This too, becomes problematic with larger ribeye areas because the larger dimensions of each steak in a multipack create an increase in total package price (Maples et al., 2018).

2.3. Uniformity challenges in the beef industry

Differentiations in ribeye sizes supports the thought that some carcasses may be nonconforming to industry standards due to inconsistencies that will become particularly evident in portioning later down the chain (Bass, Scanga, Chapman, Smith, & Belk, 2009). Savell (2007) suggested possible nonconformity in carcasses possessing ribeye areas of less than 71.0 cm^2 or greater than 103.2 cm^2. Uniform steak sizes are essential in providing consumers with a consistent eating experience (Dunn, Williams, Tatum, Bertrand, & Pringle, 2000). Dunn et al. (2000) stated that palatability is likely compromised when steaks differing in thickness are produced by foodservice partners. Cooking times and Warner-Bratzler shear (WBS) force values were variable across steaks differing by ribeye area size in the study conducted by Dunn et al. (2000). In terms of cook time, it was found that cut type, portion size, or end point temperature did not affect steaks portioned from subprimals with a ribeye area greater than 96.7 cm^2. Steaks from this ribeye area range (greater than 96.7 cm^2) cooked the fastest among all others including steaks with ribeye areas ranging from 83.9 to 90.2 cm^2 and 90.3 to 96.6 cm^2 (Dunn et al., 2000). In contrast, steaks with ribeye areas less than 77.3 cm^2 generated the longest cooking time compared to all other ribeye areas with the exception of steaks in the 83.5 to 90.2 cm^2 range (Dunn et al., 2000). Because steaks fabricated from subprimals with larger ribeye areas tend to be thinner than those fabricated from subprimals with smaller ribeye areas, this could explain the inverse relationship discovered between the two scenarios. Woerner (2014) suggested different cookery methods may need to be implemented to keep consumers' eating experiences consistent when steak thickness and cook times become too variable.

In the same study, Dunn et al. (2000) discovered significant differences within WBS force values across ribeye size ranges as well. WBS force offers an objective assessment of meat tenderness critical to understanding the palatability of meat products to consumers (Shackelford, Morgan, Cross, & Savell, 1991). Steaks with a ribeye area greater than 103.2 cm^2 produced the highest WBS force values, while ribeye areas between 71.0 cm^2 to 83.8 cm^2 and 90.3 cm^2 to 96.6 cm^2 generated the lowest values in this research. WBS force values for REA between 96.7 to 103.1 cm^2 were considered "intermediate" when compared among others in the study by Dunn et al. (2000). This evidence by Dunn et al. (2000) demonstrates that statistically, a significant decrease in tenderness is observed in the larger ribeye sizes ($\geq$ 103.2 cm^2; $\geq$ 15.9 in^2) and the greatest tenderness is found in middle range of ribeye areas. Dunn et al. (2000) proposed these results could be explained by breed influence on ribeye size and tenderness (Wheeler, Cundiff, Koch, & Crouse, 1996), as some breeds of cattle produce large ribeye sizes, but at the cost of decreased tenderness and palatability.

It is well documented that tenderness is the most important factor influencing consumers' eating experience for beef palatability (Guillemin, Bonnet, Jurie, & Picard, 2011; Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Savell et al., 1987; Savell et al., 1989; Smith et al., 1987). Researchers have spent decades trying to scientifically justify the impact tenderness has on customer satisfaction and its importance to consumer palatability (Brooks et al., 2000; Guelker et al., 2013; Huffman et al., 1996; Martinez et al., 2017; Voges et al., 2007). Tenderness plays a paramount role in the palatability of meat and can even influence consumers' perception of taste (Brooks et al., 2000; Lorenzen et al., 1999; Neely et al., 1998). Boleman et al. (1997) suggested that consumers were willing to pay more for beef products that guarantee tenderness, emphasizing the impact of tenderness on a satisfying eating experience for consumers.

2.4. Factors influencing meat tenderness

Meat tenderness can be influenced by a multitude of factors. Aberle, Forrest, Gerrard, and Mills (2012) credit tenderness to the youthfulness a carcass may possess, or in other terms, an animal's physiological age at slaughter. In general, the younger an animal is at slaughter, the more tender muscle will become when converted to meat. Physiological age also dictates the extent to which connective tissue will form heat-stable cross-linkages predominantly found in collagen as animals age. Collagen's ability to breakdown and gelatinize is directly related to the tenderness of meat. This concept has been known for years as supported by Shimokomaki, Elsden, and Bailey (1972). Shimokomaki et al. (1972) described that with increasing age, structural changes in collagen will occur and the number of covalent crosslinks collagen acquires will increase as well. Cross, Carpenter, and Smith (1973) research demonstrates the collagen effect very well by comparing differing chronological age groups by soluble collagen content and subsequent WBS force values. They found that the oldest chronological age group contained the least amount of soluble collagen and therefore, obtained a higher WBS force measurement. On the other hand, the youngest chronological age group contained the most amount of soluble collagen and obtained a significantly lower WBS force value, supporting the concept that younger animals produce more tender meat (Cross et al., 1973). The connective tissue effect on tenderness is often referred to as the "background effect" or "background toughness" as connective tissue proteins are not direct muscle (myofibrillar) proteins, but rather stromal, supportive proteins (Aberle et al., 2012).

Another factor that contributes to meat tenderness is muscle ultrastructure. Muscle is composed of individual sarcomeres within each muscle fiber. It is at the sarcomere where muscle contraction is initiated (Aberle et al., 2012). Often, the degree of overlap of the sarcomeres at the time of rigor mortis (stiffness of death) can dictate tough from tender meat. In general, a higher degree of overlap will result in tougher meat. This concept is also referred to as a muscle's "contractile state" after slaughter. Cold shortening is a consequence of rapid chilling and is a perfect example of an undesirable contractile state in postmortem muscle. Chilling carcasses too quickly before the onset phase of rigor mortis causes a high degree of overlap between sarcomeres and thus, muscle fibers (Savell, Mueller, & Baird, 2005). However, the length of each sarcomere at the time of rigor mortis also can determine muscle tenderness. In a study comparing "more tender" from "less tender" steaks, Davis, Smith, Carpenter, Dutson, and Cross (1979) found those defined as "more tender" had longer sarcomere lengths than their "less tender" counterparts (Savell et al., 2005). In addition, it is thought that the *M. longissimus thoracis et lumborum* is inherently more tender due to the degree muscle fibers are stretched during carcass suspension. Suspension of a beef carcass by the Achilles tendon allows fibers from this muscle to be stretched close to its full potential by way of gravity (Ahnström, Hunt, & Lundström, 2012).

Postmortem proteolysis, otherwise known as postmortem aging, has a profound effect on meat tenderness (Gann & Merkel, 1978). Postmortem aging allows for the disruption of muscle structure by weakening the integrity of structural proteins found at the sarcomere level. Structural changes initially occur at the Z-disks, which are proteins responsible for holding myofibrillar proteins in place (Aberle et al., 2012). These changes allow for greater extensibility of muscle over time. Electron micrographs shown by Gann and Merkel (1978) support this idea, showing evidence of strong myofibrillar fragmentation at the site of z-disks after 48 hours postmortem. This myofibrillar fragmentation can also be observed by way of electrically stimulating beef carcasses as evidenced by Savell, Dutson, Smith, and Carpenter (1978). Myofibrillar fragmentation is highly correlated to meat tenderness and for that reason, is used as an index to differentiate tough from tender meat (Aberle et al., 2012).

Perhaps the most influential driver of meat tenderness is proteolysis by complex enzymatic systems that degrade myofibrillar proteins during postmortem storage of meat. The calpain system is given the most credit for postmortem proteolysis of muscle tissue. Two calcium-depended proteases, μ-calpain and m-calpain, comprise this system and only differ by concentration of calcium required to activate each protease. Micromolar concentrations of calcium are required for activation of μ-calpain while millimolar concentrations of calcium are required for activation of m-calpain (Aberle et al., 2012). Calpastatin is the third component of this enzyme system and serves as the primary inhibitor to calpain activity in postmortem muscle. It is well documented that the content of calpastatin activity in postmortem muscle has a direct effect on resulting meat quality and tenderness in the final product (Koohmaraie & Shackelford, 1991; Morgan, Wheeler, Koohmaraie, Savell, & Crouse, 1993; Shackelford, Koohmaraie, Cundiff, Gregory, Rohrer, & Savell, 1994; Whipple, Koohmaraie, Dikeman, Crouse, Hunt, & Klemm, 1990). *Bos indicus* cattle breeds, in particular, possess a greater amount of calpastatin within their muscles, resulting in meat that is recognized as significantly tougher than cattle of *Bos taurus* decent (Aberle et al., 2012; Whipple et al., 1990). In a study conducted by Whipple et al. (1990), differences in tenderness between *Bos indicus* and *Bos taurus* cattle were evaluated. It was discovered that steaks produced from cattle of a *Bos taurus* crossbreed generated significantly lower WBS force values than steaks from crossbred cattle with a *Bos indicus* influence. In fact, shear force values for *Bos taurus* crossbred cattle remained significantly lower than *Bos indicus* influenced alternatives even after fourteen days of aging. Consumer panel evaluations demonstrated consumers also were able to detect differences in overall tenderness – tenderness scores were significantly higher in *Bos taurus* influenced cattle versus those with *Bos indicus* influence. These results also were valid after aging for fourteen days (Whipple et al., 1990).

2.5. Analyses of meat tenderness

WBS force is nationally recognized as an objective approach for the analysis of meat tenderness (American Meat Science Association, 2015). WBS force gives researchers a technical method of evaluating the amount of force required to shear or "chew" through a particular cut of meat. The use of WBS force has provided insight to the meat industry on how meat tenderness can vary across species, breeds, muscle cuts, and much more. Until 1991, the threshold that dictates tough from tender meat by WBS force analysis was not determined. Shackelford et al. (1991) have been credited for the identification of threshold WBS force values in beef top loin steaks. Research by Shackelford et al. (1991) concluded that the threshold WBS force value for foodservice beef was 3.9 kg (38.2 N). That is, WBS force values "less than 3.9 kg [(38.2 N)] should have a 68% chance of being rated slightly tender or higher," (Shackelford et al., 1991). In addition, Shackelford et al. (1991) determined specific categories from this research that would eventually assist in the classification of beef muscles and subsequent cuts as very tender, tender, intermediate and tough (Belew, Brooks, McKenna, & Savell, 2003). However, the American Meat Science Association (2015) also has emphasized the importance of using a comparative approach between WBS force and data from consumer tenderness surveys to effectively quantify tenderness, especially when comparing data across institutions.

Consumer panels are frequently used to gain insight to consumer preferences on beef palatability, including flavor, juiciness and tenderness. The use of consumer panels is crucial, as consumers ultimately dictate the fate and value of food products (American Meat Science Association, 2015). Consumer panels for beef research are typically designed using a 9-point hedonic scale (American Meat Science Association, 2015) with recruited participants that consume beef at least once on a weekly basis. Destefanis, Brugiapaglia, Barge, and Dal Molin (2008) highlighted that objective methods of measuring tenderness (WBS force) often produce vague data when it comes to product acceptability or personal preferences among consumers. In this study by Destefanis et al. (2008), WBS force values and consumer panel tenderness scores on beef top loin steaks were compared. Results were variable as the majority of panelists failed to distinguish proper WBS force value category for each sample. In fact, participants struggled to differentiate among "very tough," "tough," and "intermediate" tenderness classes. Miller et al. (1995) found that consumers are able to detect differences in WBS force values of about 1 kg (9.81 N), if in a restaurant setting versus 0.5 kg (4.9 N) if tasting occurs at home. Results from Destefanis et al. (2008) showed that steaks with WBS force values greater than 52.68 N (5.37 kg) are perceived by most consumers as "tough," while steaks with WBS force values less than 42.87 N (4.37 kg) is perceived as "tender."

CHAPTER III

MATERIALS AND METHODS

3.1. Product collection

Beef carcasses (n = 90) were selected at a commercial beef harvest and processing facility that used instrument-assisted grading technology. Key quality and yield factors for individual carcasses were displayed on monitors, which allowed for on-line selection at the grading/sorting station in the sales cooler. Selected carcasses were USDA (2017) Choice (Ch^-) quality score (Small marbling only) and met a 3 × 3 treatment scheme of varying ribeye size (REA) and hot carcass weight (HCW) categories (Table 1). After selection, carcasses were fabricated and one strip loin, similar to the North American Meat Institute (NAMI, 2014) Institutional Meat Purchase Specifications (IMPS) 180, was obtained from each carcass (*n* = 90). Strip loins were individually vacuum-packaged using a Cryovac-Sealed Air Corp. 8600 Series chamber machine (Charlotte, NC), with labels visible, and packed six to a box. Boxes were shipped using a refrigerated truck to a collaborating beef purveyor.

All strip loins were aged under refrigeration (0 to 2 °C) for 14 days ("Day 0" was defined as the day of fabrication and vacuum packaging), then removed from their packaging and trimmed of any visible discoloration or remaining excess surface fat. After trimming, strip loins were blade tenderized with one pass through a Ross™ Tenderizer (Series No. 1060; Ross Industries Inc, Midland, Virginia). Portion thickness and weight targets were determined based on the recommendation of the purveyor that met the most requested option for their primary customer. Portioning methods for cutting were defined as: (1) consistent thickness at 3.18 cm (1.25 inches; *n* = 270 steaks), and (2) consistent portion weight at 340 g (12 ounces; *n* = 270 steaks). A Marel® intelligent portion cutter (M Series 3000, Marel®, Lenexa, KS) was used to create a cut pattern that generated three steaks per portioning method from each strip loin for a total of 6 steaks per strip loin (n = 540 total steaks). Individual steaks then were weighed on a digital scale (Model No. 9201-5A; Rice Lake® Weighing Systems, Rice Lake, WI) and evaluated using a TSI™ J-Scan™ Inspection System (Model No. SZ2288899 SPX33012; JBT FoodTech, Sandusky, OH) to obtain the dimensions of each steak (n = 540 total steaks). Steaks were labeled for consumer sensory panel (n = 360) or Warner Bratzler Shear (WBS) force (n = 180) using waterproof paper, vacuum-packaged (Multivac Model R225, Kansas City, MO), boxed, and transported to the Rosenthal Meat Science and Technology Center (College Station, Texas). Upon arrival, steaks were first flash frozen for 24 h at -40 °C, sorted based on consumer sensory panel or WBS force assignments and stored frozen (-20 °C) until analyses were performed.

3.2. Dry-heat cookery

Before cooking, steaks were thawed under refrigerated conditions (2 to 4 °C) for approximately 28 h. All steaks were cooked on grated, non-stick electric grills (Model 31065A Series; Hamilton Beach/Proctor Silex, Inc., Southern Pines, NC) preheated to an approximate surface temperature of 177 ± 2 °C. Internal steak temperatures were monitored using a thermocouple reader (Model HH506A; Omega Engineering, Stanford, CT) and a 0.02-cm diameter, copper-constantan Type-T thermocouple wire (Omega Engineering, Stanford, CT), inserted into the geometric center of each steak. Steaks were flipped at an internal temperature of 35 °C and removed from the grill when the final internal temperature reached 70 °C. Raw out-of-package weight, initial internal steak temperature, grill temperature, time on, final internal steak temperature, time off, and final cook weight were collected, and cook yields and cook times were calculated from these components (Table 2). Cooked steaks intended for WBS force evaluation were placed on metal trays in a single layer, covered with plastic wrap, and stored at refrigerated conditions (2 to 4 °C) for approximately 12 to 16 h. Steaks assigned to consumer panels were held in an Alto-Shaam oven set at 60 °C for no more than 20 min before serving to consumer panelists.

3.3. Warner-Bratzler shear force

After refrigerated storage for at least 12 h, WBS force steaks (n = 180) were allowed to equilibrate to room temperature (approximately 2 hr) before being trimmed of visible connective tissue to expose muscle fiber orientation. Six 1.3-cm cores were removed from the *M. longissimus lumborum* parallel to the muscle fibers, using a hand-held coring device. Care was taken to avoid cores containing excess fat or connective tissue. Cores were sheared once, perpendicular to the muscle fibers, using a United Testing machine (United SSTM-500, Huntington Beach, CA) at a cross head speed of 200 mm/min using a 10-kg load cell, and a 1.02-cm thick V-shape blade with a 60° angle and a half-round peak. The equipment was calibrated to 0.04 kg before the start of data collection, and calibration was repeated after every 60 cores. The peak force (kg) needed to shear each core was recorded, converted to Newtons (N), and the mean peak shear force of the cores was used for statistical analysis.

3.4. Consumer sensory panel

Consumer sensory panel procedures were approved by the Texas A&M Institutional Review Board for Use of Humans in Research (Protocol number: IRB2019-0820M). Panelists (n = 220; demographics in Tables 3 and 4) were recruited from the Bryan/College Station area using an existing consumer database.

Sensory panel steaks (n = 360) were cooked as described previously. Each cooked steak was identified with a random three-digit code. Steaks were cut into cuboidal portions (approximately 1.27 cm × 1.27 cm × steak thickness) and served warm to panelists through a breadbox-style sensory booth with red theater gel lighting to prevent panelist bias for degree of doneness. Each panelist received three matched pairs for sampling, served in a previously determined blind and random order. Each matched pair was derived from a single strip loin and represented both portioning methods (one steak cut to portion weight and one steak cut to portion thickness within a strip loin). Consumer sensory panels were designed to be completed in 15 sessions, with each session comprised of four groups of four panelists each. Twenty-four steaks were assigned to each session group in a manner to achieve uniform representation of treatments (Table 1) across panel days. Therefore, each panelist assessed six samples, and each sample was evaluated by four panelists. Double-distilled, deionized water and Nabisco Premium unsalted tops saltine crackers were provided for palate cleansing between samples. Panelists were asked to evaluate samples using 9-point scales (1 = dislike extremely; 9 = like extremely) for overall liking, flavor liking, tenderness liking, and juiciness liking. After participation, each panelist was financially compensated for their time and contribution to this research.

3.5. Statistical analyses

All data analyses were performed using JMP® Pro, Version 14.0.0 (SAS Institute Inc., Cary, NC). Consumer demographic frequencies were determined using the Distribution function of JMP. J-Scan™ dimensional analysis, cooking data, consumer panelist scores, and WBS force values were analyzed using the Fit Model function to perform analysis of variance (ANOVA). For cooking data, main effects included REA, HCW, and portioning method (weight versus thickness) as well as the REA × HCW interaction. All other data were blocked by portioning method with other previously described main effects and their interaction included in the model as previously described. Least squares means comparisons were conducted when appropriate using Student's t-test with an alpha-level 0.05.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Cook data

Cook yield (%) and cook time (s) data across ribeye area categories, carcass weight categories, and portioning methods are shown in Table 2. There were no significant differences discovered among ribeye categories (83.9 to 89.8 cm^2; 90.3 to 96.1 cm^2; 96.7 to 102.6 cm^2) or carcass weight categories (340.6 to 385.6 kg.; 386.0 to 430.9 kg.; 431.4 to 476.3 kg) for cook yield and cook time. Though not significant ($P > 0.05$), a trend in carcass weight category was apparent for cook yield (%) and cook time (s): cook yield (%) and time decreased with increasing hot carcass weights. Lorenzen, Calkins, Green, Miller, Morgan, and Wasser (2010) produced cook yield results of top loin steaks of 78.8%, consistent with data reported in Table 2. Data presented in Table 2 demonstrate higher cook yields than those presented by Saha, Jaroni, Nelson, Willoughby, McDaniel, and Jadeja (2019), in which top loin steaks of 340 g (12 oz) produced mean cook yields of 69.82 ± 5.65%.

Cook time (s) between portioning methods was most notable as significant differences ($P < 0.0001$) were seen. Steaks portioned by a constant thickness of 3.18 cm required a longer cook time by over 232 s (3 min), than steaks portioned by weight (Table 2). This could be due to the concept presented by Leick et al. (2011), in that steaks portioned by constant-weight have a greater likelihood of possessing thickness variations from steak to steak. This statement lends itself to the thought that steaks cut by constant-weight in our research could have been much thinner compared to their constant-thickness counterparts, thus requiring less time to reach the desired internal temperature of 70 °C. J-Scan™ dimensional analysis (data not presented in tabular form) validated this concept. Steaks portioned by constant-weight possessed significantly different widths regardless of differing carcass weight ($P < 0.05$) and ribeye size ($P < 0.05$) categories. In contrast, data from J-Scan™ dimensional analyses demonstrated steaks portioned by constant-thickness resulted in significantly different steak weights ($P < 0.05$). Disparities in cook times across steaks of variable thickness could place consumer preference at risk, especially for the foodservice industry. Steak thickness and cookery method in foodservice go hand-in-hand (Woerner, 2014), and if there are inconsistencies in thickness of the raw steak, cookery methods may need to be modified in order to keep consumers' overall eating experience satisfactory and consistent.

4.2. Warner-Bratzler shear force

Mean Warner-Bratzler Shear force values (N) for strip loin steaks ($n = 180$) portioned by thickness (3.18 cm) and by weight (340 g) are shown in Tables 5 and 6, respectively. A significant interaction was observed ($P = 0.031$) for WBS force values for strip loin steaks portioned by thickness (3.18 cm). Notably, steaks from the lightest HCW category (340.6 to 385.6 kg) returned the two highest mean WBS force values within ribeye ranges of 90.3 to 96.1 cm^2 and 96.7 to 102.6 cm^2. Though clear linear trends were not apparent, steaks within the 83.9 to 89.8 cm^2 REA range and 340.6 to 385.6 kg weight category produced WBS force values significantly lower than any other REA range within this weight class. This observation also presented the lowest ($P = 0.031$) mean WBS force value among other ribeye area × carcass weight combinations. A difference was also seen for WBS force values from steaks of the same HCW category (340.6 to 385.6 kg), but different REA range (96.7 to 102.6 cm^2). This ribeye area × carcass weight combination resulted in the highest WBS force value when compared to all other treatment combinations. These data suggest that steaks portioned by thickness from lighter carcasses are highly variable in terms of objective tenderness, but REA played a crucial role in dictating WBS force values for this weight category (340.6 to 385.6 kg). Among the lowest WBS force values were strip steaks representing the smallest ribeye size category (83.9 to 89.8 cm^2), with no differences observed across carcass weight categories for steaks within the 83.9 to 89.8 cm^2 REA range. WBS force values for strip loin steaks from carcasses with ribeye sizes between 83.9 to 89.8 and 96.7 to 102.6 cm^2 varied significantly within their respective REA categories. As a whole, WBS values presented in Table 5 are lower than top loin steaks evaluated in the 2010 and 2015 National Beef Tenderness Surveys (Guelker et al., 2013; Martinez et al., 2017). In 2015, Martinez et al. (2017) found the mean WBS force value for top loin foodservice steaks to be 24.6 N. It should be noted that blade tenderization could have played a role in the tenderness results of this research. However, it is a common practice of U.S. foodservice establishments to subject beef to blade or needle tenderization with the goal of creating more palatable beef cuts (McMichael, 2005).

Least squares means of WBS force values for strip loin steaks portioned by weight (340 g) are reported in Table 6. Significant differences were seen ($P = 0.014$) in WBS force values for strip loin steaks portioned by weight (340 g) with larger ribeye sizes and heavier hot carcass weights generally possessing higher mean WBS force values, mirroring results from Dunn et al. (2000). Dunn et al. (2000) reported steaks with larger ribeye sizes produced higher WBS force values ($P = 0.08$). A difference in objective tenderness was discovered within the 340.6 to 385.6 kg category – steaks having a REA of 83.9 to 89.8 cm^2 resulted in significantly lower WBS force values than steaks with a larger REA. Steaks from 386.0 to 430.9-kg carcasses with either 83.9 to 89.8 or 90.3 to 96.1 cm^2 REA and steaks from the heaviest HCW category of the 90.3 to 96.1 cm^2 REA group did not differ ($P > 0.05$) from steaks of the smallest REA and lightest HCW categories. In addition, steaks within the 386.0 to 430.9 kg carcass weight range and REA of 96.7 to 102.6 cm^2 returned significantly higher WBS force values than their smaller REA counterparts. Additionally, no differences ($P > 0.05$) in mean WBS force values were seen across HCW categories within the ribeye size of 96.7 to 102.6 cm^2, with all values being among the highest. Interestingly, mean WBS force values for the lightest HCW category of the 90.3 to 96.1 cm^2. REA group also were found to be among the highest values in the current study. Although not an objective of this study, others have found these variable results could be partially justified by the influence of genetics and breed on carcass attributes as explained by Wheeler et al. (1996); Whipple et al. (1990). Data from tables 5 and 6 demonstrate that although differences were detected within varying REA and HCW groupings, overall objective tenderness between portion styles produced a similar outcome, with smaller ribeye sizes from lighter carcasses possessing the lowest numerical WBS force values. Though the interaction between HCW and REA was significant, it is important to note that all WBS force values listed in Tables 5 and 6 qualify for "very tender" tenderness category based on categorical WBS force values (< 31.4 N) set by Belew et al. (2003), regardless of portion method. These data indicate promising progress by the beef industry in its ongoing quest to produce palatable and tender beef for consumers, regardless of increasing carcass weight and size.

4.3. Consumer sensory panel

Consumer panelists' scores for attributes of strip loin steaks portioned by thickness (3.18 cm; $n = 180$) are reported in Tables 7 and 8. An interaction for ribeye size × carcass weight categories was present with differences identified for both overall liking and flavor liking attributes ($P = 0.042$ and 0.006, respectively). No linear trends were seen across in the ribeye size × carcass weight combinations for overall like. However, within the 96.7 to 102.6 cm^2 REA range, a relationship with the light and middle range hot carcass weights was discovered. Within this range (96.7 to 102.6 cm^2), consumers were able to detect differences in overall like between steaks from carcasses possessing a HCW of 340.6 to 385.6 kg and 386.0 to 430.9 kg. Consumers ranked steaks from carcasses weighing 386.0 to 430.9 kg higher, while steaks from the lightest carcass weight category were scored significantly lower ($P < 0.0042$). In terms of flavor liking, results across all treatment groupings mirror those of overall like, as clear linear trends were not apparent. However, a significant difference in flavor liking scores ($P < 0.006$) was found within the largest REA category and middle to heavy range carcass weights. Panelists' scores were higher ($P < 0.006$) for this ribeye area × carcass weight combination when compared to others within the 386.0 to 430.9 kg carcass weight category. In contrast, consumers scored steaks from the 431.4 to 476.3 kg range the lowest out when assessing steaks from the same REA category, and among all other HCW and REA combinations. These results indicate that consumer preference for overall like and flavor liking is mostly consistent among all HCW and REA combinations evaluated in this research. Our findings are similar to those of Cassens et al. (2018), in which mean flavor liking scores tended to trend more similarly to overall liking than tenderness or juiciness liking scores. In terms of tenderness, results across all treatments were similar ($P > 0.05$). One explanation for consumers' inability to detect a difference in tenderness could be due to findings reported by Miller et al. (2001). Miller et al. (2001) found that a WBS threshold of < 3.0 kg (< 29.4 N) would result in 100% consumer acceptability of beef steak tenderness. Our data suggest all steaks analyzed in this study were below the threshold of 3.0 kg (29.4 N) regardless of portion-style as shown in Tables 7 and 8. Differences in juiciness were identified among HCW categories. Consumers scored steaks of the 386.0 to 430.9 kg category higher than those of the 340.6 to 385.6 kg category. Still, consumers were unable to differentiate juiciness either of these two categories from their heavy-weight counterpart (431.4 to 476.3 kg).

Least squares means of consumer panelists' scores for sensory attributes of strip loin steaks portioned by weight (340 g; n = 180) are provided in Table 9. Unlike steaks portioned by thickness, no significant ribeye size × carcass weight category interactions were found for any attributes associated with steaks portioned by weight, therefore only main effects were presented. No statistical differences were detected ($P > 0.05$) across any of the HCW categories, indicating consumer ratings were consistent for all sensory attributes evaluated. Mean consumer panelists' ratings for overall and tenderness liking were highest (P = 0.0418 and 0.0087, respectively) for steaks from the smallest REA category. Tenderness scores from panelists' are consistent with the WBS force previously mentioned. These data also reflect results similar to those found in Destefanis et al. (2008), in which consumers perceived steaks as "tender" when WBS force values were less than 42.87 N (4.37 kg). Panelists ranked steaks with a ribeye area ranging from 83.9 to 89.8 cm^2 significantly higher in tenderness ($P < 0.0418$). These results differ from those reported by Dunn et al. (2000), in which participants ranked steaks with the ribeye range of 90.3 to 96.1 cm^2 significantly higher than those of 83.9 to 89.8 cm^2 in both initial tenderness and sustained tenderness. Although, Dunn et al. (2000) do state that the reason behind these findings are unclear. While no other significant differences were identified, similar numerical trends can be seen for flavor and juiciness liking scores.

CHAPTER V

CONCLUSION

Every day foodservice operators are tasked to meet demands from consumers that want consistency in steak size from plate-to-plate. At this time, the beef industry is facing variations in ribeye sizes and hot carcass weights, making this expectation hard to realistically achieve. Findings from our research indicate steaks sourced from carcasses representing some combinations of ribeye sizes and hot carcass weights will result in WBS force values and sensory attributes that surpass other combinations at the same marbling score, regardless of portion-style. It did appear that cutting steaks using constant-thickness resulted in more variable results when compared to their constant-weight counterparts. Nevertheless, it was determined that steaks obtained from carcasses possessing smaller ribeye areas will have a greater likelihood of achieving low WBS force values when combined with light hot carcass weights. These data demonstrate potential challenges in larger ribeye areas, as steaks possessing this attribute showed the greatest range of inconsistency in both WBS force and consumer palatability scores. Though some significant differences were detected, the industry should find comfort in that all WBS force and palatability ratings were generally well within what would be considered highly acceptable by most comparisons to benchmark information. These results demonstrate strong efforts made by the beef industry to produce highly-palatable beef products that will ultimately result in strong customer satisfaction. However, outcomes of this research indicate the industry should consider proceeding forward with a degree of caution as ribeye sizes increase in size. Sourcing steaks from carcasses possessing larger ribeye areas could come with challenges that may place palatability in jeopardy, particularly in the foodservice sector of the beef industry.

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APPENDIX A

TABLES

Table 1. Treatment design

Carcass weight category	Ribeye size category		
	83.9 to 89.8 cm^2	90.3 to 96.1 cm^2	96.7 to 102.6 cm^2
340.6 to 385.6 kg	10 carcasses	10 carcasses	10 carcasses
386.0 to 430.9 kg	10 carcasses	10 carcasses	10 carcasses
431.4 to 476.3 kg	10 carcasses	10 carcasses	10 carcasses

Table 2. Least squares means for cook yields and times by main effects for sensory panel and WBS force steaks

Main effect	*n*[1]	Cook yield (%)	Cook times (s)
Ribeye area category			
83.9 to 89.8 cm^2	180	79.0	1178.0
90.3 to 96.1 cm^2	180	81.4	1223.7
96.7 to 102.6 cm^2	180	78.4	1161.7
SEM		2.2	30.8
P-value		0.578	0.336
Carcass weight category			
340.6 to 385.6 kg	180	82.0	1232.7
386.0 to 430.9 kg	180	78.8	1192.3
431.4 to 476.3 kg	180	78.0	1138.3
SEM		2.2	30.8
P-value		0.379	0.095
Portioning method			
Thickness (3.18 cm)	270	77.6	1304.2 a
Weight (340 g)	270	81.6	1071.3 b
SEM		1.8	25.1
P-value		0.1139	< 0.0001

[1]Number of steaks
[a-b]Least squares means within a column lacking common superscript letters differ ($P < 0.05$).

Table 3. Demographic attributes of consumer panelists

	Retail	
Item	n^1	%
Gender		
Male	88	40.0
Female	132	60.0
Age, yr		
< 20	11	5.0
21 to 25	58	26.4
26 to 35	54	24.6
36 to 45	24	10.9
46 to 55	29	13.2
56 to 65	25	11.4
≥ 66	19	8.6
Working status		
Not employed	27	12.3
Full-time	112	50.9
Part-time	23	10.5
Student	78	35.5
Income, US$		
< 25,000	55	25.1
25,000 to 49,999	47	21.5
50,000 to 74,999	26	11.9
75,000 to 99,000	37	16.9
≥ 100,000	54	24.7
Food allergy		
No	210	95.5
Yes	10	4.6
Food manufacturer		
No	215	97.7
Yes	5	2.3
Ethnicity		
Caucasian	167	75.9
Hispanic	34	15.5
Asian or Pacific Islander	11	5.0
Black	6	2.7
American Indian	4	1.8
Other	6	2.7
Consume meat		
No	0	0
Yes	220	100

[1]Number of responses

Table 4. Consumer panelists' consumption patterns

Item	n^1	%
Meat types consumed		
Chicken	220	100.0
Pork	208	94.6
Beef	220	100.0
Fish	205	93.2
Overall beef consumption		
Daily	15	6.8
5 or more times per wk	30	13.6
3 or more times per wk	116	52.7
1 time per wk	48	21.8
1 time every 2wks	11	5.0
Less than once every 2 wks	0	0
At home beef consumption		
0 times per wk	5	2.3
1 time per wk	52	24.1
2 times per wk	70	32.4
3 times per wk	57	26.4
4 times per wk	20	9.3
5 or more times per wk	12	5.6
In restaurant beef consumption		
0 times per wk	11	5.1
1 time per wk	94	43.5
2 times per wk	65	30.1
3 times per wk	30	13.9
4 times per wk	7	3.2
5 or more times per wk	9	4.2
Degree of doneness		
Rare	18	8.2
Medium rare	80	36.4
Medium	75	34.1
Medium well	41	18.6
Well done	12	5.5
Purchase tendencies		
Grass-fed	32	14.6
Traditional	188	85.5
Aged	11	5.0
Organic	12	5.5

[1]Number of responses.

Table 5. Least squares means of Warner-Bratzler Shear force values (N) for strip loin steaks portioned by thickness (3.18 cm) and stratified by ribeye size × carcass weight categories

	Ribeye size category		
Carcass weight category	83.9 to 89.8 cm^2	90.3 to 96.1 cm^2	96.7 to 102.6 cm^2
340.6 to 385.6 kg	14.3 d	20.8 ab	21.7 a
386.0 to 430.9 kg	15.9 cd	15.5 cd	18.5 abc
431.4 to 476.3 kg	15.5 cd	17.5 bcd	16.8 cd
P-value: 0.031			
SEM: 1.24			

[a-d]Least squares means lacking common superscript letters differ ($P < 0.05$).

Table 6. Least squares means of Warner-Bratzler Shear force values (N) for strip loin steaks portioned by weight (340 g) and stratified by ribeye size × carcass weight categories

	Ribeye size category		
Carcass weight category	83.9 to 89.8 cm^2	90.3 to 96.1 cm^2	96.7 to 102.6 cm^2
340.6 to 385.6 kg	13.8 e	20.7 ab	20.0 ab
386.0 to 430.9 kg	15.5 cde	14.2 de	21.3 a
431.4 to 476.3 kg	18.3 abcd	17.0 bcde	19.1 abc
P-value: 0.014			
SEM: 1.54			

[a-e]Least squares means lacking common superscript letters differ ($P < 0.05$).

Table 7. Least squares means of consumer panelists' scores for overall and flavor liking attributes of strip loin steaks portioned by thickness (3.18 cm) and stratified by ribeye size × carcass weight categories

	Overall liking			Flavor liking		
	Ribeye size category			Ribeye size category		
Carcass weight category	83.9 to 89.8 cm^2	90.3 to 96.1 cm^2	96.7 to 102.6 cm^2	83.9 to 89.8 cm^2	90.3 to 96.1 cm^2	96.7 to 102.6 cm^2
340.6 to 385.6 kg	6.7 ab	6.6 abc	6.0 c	6.8 ab	6.5 bcd	6.1 cd
386.0 to 430.9 kg	6.3 bc	6.7 ab	6.9 a	6.5 bcd	6.7 ab	7.1 a
431.4 to 476.3 kg	6.7 ab	6.7 ab	6.4 abc	6.7 ab	6.6 abc	6.0 d
P-value: 0.042 OLIKE; 0.006 FLIKE						
SEM: 0.23 OLIKE; 0.21 FLIKE						

[a-d]Least squares means within an attribute lacking common superscript letters differ ($P < 0.05$).

Table 8. Least squares means of consumer panelists' scores for tenderness and juiciness liking attributes of strip loin steaks portioned by thickness (3.18 cm) and stratified by main effects

Ribeye size category	Tenderness liking	Juiciness liking
83.9 to 89.8 cm^2	6.8	6.0
90.3 to 96.1 cm^2	6.6	5.9
96.7 to 102.6 cm^2	6.5	5.8
SEM	0.16	0.18
P-value	0.531	0.879
Carcass weight category		
340.6 to 385.6 kg	6.5	5.6 b
386.0 to 430.9 kg	6.7	6.2 a
431.4 to 476.3 kg	6.7	6.0 ab
SEM	0.16	0.18
P-value	0.658	0.046

[a-b]Least squares means within an attribute and main effect lacking common superscript letters differ ($P < 0.05$).

Table 9. Least squares means of consumer panelists' scores for attributes of strip loin steaks portioned by weight (340 g) and stratified by main effects

Ribeye size category	Overall liking	Flavor liking	Tenderness liking	Juiciness liking
83.9 to 89.8 cm^2	6.8 a	6.6	7.1 a	6.4
90.3 to 96.1 cm^2	6.4 b	6.3	6.5 b	5.9
96.7 to 102.6 cm^2	6.4 b	6.4	6.6 b	6.1
SEM	0.13	0.14	0.15	0.17
P-value	0.042	0.362	0.009	0.117
Carcass weight category				
340.6 to 385.6 kg	6.6	6.5	6.6	6.2
386.0 to 430.9 kg	6.6	6.4	6.8	6.2
431.4 to 476.3 kg	6.4	6.3	6.6	5.9
SEM	0.13	0.14	0.15	0.17
P-value	0.401	0.392	0.689	0.467

[a-b]Least squares means within an attribute and main effect lacking common superscript letters differ ($P < 0.05$).

APPENDIX B

FIGURES

Figure 1. Demographics questionnaire

Date:
Session Time:

INSTRUCTIONS

Thank you for your participation in this study. Your assistance is very much appreciated. The objective of this study is to carefully evaluate beef samples. Please take your time and evaluate the samples served to you carefully.

This sampling will take about an hour. Please answer the following questions as completely as possible. If you have any questions, please ask the monitor for assistance.

Begin by filling out the basic demographic questions on the first page. This information is confidential and will not be used in publication, or have your name associated with it in any way.

After completing the demographic information, you are ready to begin the sample evaluation. Instructions at the top of each questionnaire will provide guidance on how to complete the evaluation.

Thank you very much for your help with this study.

DEMOGRAPHICS BALLOT

Please circle each appropriate response:

1. Please indicate your gender:

   Male Female

2. Which of the following best describes your age?

   20 years or younger 46-55 years
   21-25 years 56-65 years
   26-35 years 66 years and older
   36-45 years

3. Please indicate your current working status:

   Not employed Part-time
   Full-time Student

4. Which of the following best describes your household income?

   Below $25,000 $75,000 – 99,999
   $25,001 - 49,999 $100,000 or more
   $50,000 - 74,999

5. Do you have any known food allergies or dietary restrictions?

   No Yes

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Date:
Session Time:

6. Do you or any of your immediate family work for a market research firm, advertising firm, or food manufacturing company?

No	Yes

7. Please indicate your ethnic background:

White	Black
Hispanic	American Indian
Asian or Pacific Islander	Other

8. Do you eat meat?

No	Yes

9. Which of the following meats do you eat?

Chicken	Beef
Pork	Fish

10. You said that you eat beef. Approximately how often do you eat beef?

Daily	Once per week/weekly
5 or more times per week	Once every 2 weeks
3 or more times per week	Less than once every 2 weeks

11. Please mark the number of times a week you consume beef (including ground beef):

At Home:	0	1	2	3	4	5 or more
Restaurant or Fast-food Establishment:	0	1	2	3	4	5 or more

12. Please indicate your preferred degree of doneness for beef:

Rare (cool red center)	Medium Rare (warm red center)
Medium (hot pink center)	Medium Well (slightly pink center)
Well Done (no pink)	

13. When purchasing beef, what do you typically buy?

Grass-fed	Aged
Traditional	Organic

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Figure 2. Consumer panelist form of consent

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM

INFORMATION SHEET

Project Title: Do carcass weight and ribeye area impact beef palatability and composition?

You are invited to take part in a research study being conducted by Dr. Jeffrey Savell, a researcher from Texas A&M University and funded by the National Cattlemen's Beef Association. **The information in this form is provided to help you decide whether or not to take part. If you decide you do not want to participate, there will be no penalty to you, and you will not lose any benefits you normally would have.**

Why Is This Study Being Done?
To determine differences in consumer acceptance of differing strip loin steaks.

Why Am I Being Asked To Be In This Study?
You are being asked to be in this study because you have enrolled yourself in the individual research institution's consumer panel bank and because you eat beef.

How Many People Will Be Asked To Be In This Study?
Approximately 100 people (participants) will be invited to participate in this study.

What Are the Alternatives to being in this study?
The alternative to being in the study is not to participate.

What Will I Be Asked To Do In This Study?
You will be asked to sample a variety of beef steak samples and complete a questionnaire related to each sample. Your participation in this study will last approximately 60 minutes. Upon completion of the survey, you will be compensated with a $25.00 gift card.

If you leave the study early, you may not receive compensation for your time.

Are There Any Risks To Me?
The only risks or discomforts would be from tasting various samples of beef.

Will There Be Any Costs To Me?
Aside from your time, there are no costs for taking part in the study.

Will I Be Paid To Be In This Study?
Upon completion of your participation in this study, a $25.00 gift card will be given to you as compensation for your time.

Will Information From This Study Be Kept Private?
The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only the researchers conducting this study will have access to the records.

Information about you will be stored in a limited access, coded entry lab on a computer's password protected hard drive. This consent form will be filed securely in an official area.

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People who have access to your information include the Principal Investigator and research study personnel. Representatives of regulatory agencies such as the Office of Human Research Protections (OHRP) and entities such as the Texas A&M University Human Subjects Protection Program may access your records to make sure the study is being run correctly and that information is collected properly.

Information about you and related to this study will be kept confidential to the extent permitted or required by law.

Who may I Contact for More Information?
You may contact the Principal Investigator, Dr. Jeffrey W. Savell, to tell him about a concern or complaint about this research at 979-845-3935 or j-savell@tamu.edu. You may also contact Dr. Rhonda Miller at 979-845-3901 or rmiller@tamu.edu.

For questions about your rights as a research participant, to provide input regarding research, or if you have questions, complaints, or concerns about the research, you may call the Texas A&M University Human Subjects Protection Program office by phone at 1-979-458-4067, toll free at 1-855-795-8636, or by email at irb@tamu.edu.

What if I Change My Mind About Participating?
This research is voluntary, and you have the choice whether or not to be in this research study. You may decide to not begin or to stop participating at any time. If you choose not to be in this study or stop being in the study, you may not receive compensation for your time.

By completing the survey(s), you are giving permission for the investigator to use your information for research purposes.

Thank you,

Dr. Jeffrey W. Savell

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Figure 3. Consumer panelist ballot

Date ____________________ **Participant No.**

Session Time ______________ **Sample No.**

INTRUCTIONS

Prior to tasting each sample, please take a bite of a cracker followed by a sip of water. After tasting each sample, place a mark in the box that best represents your answer for each of the following questions. The final two questions will be open ended, please answer them as completely as possible.

1. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely | No Preference | Like Extremely

2. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **FLAVOR** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely | No Preference | Like Extremely

3. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **TENDERNESS** of the meat product.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely | No Preference | Like Extremely

4. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **JUICINESS** of the meat product.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely | No Preference | Like Extremely

5. Please describe what you **LIKED MOST** about this meat sample.

____

6. Please describe what you **LIKED LEAST** about this meat sample.

____

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