NATIONAL BEEF TENDERNESS SURVEY–2015: ASSESSMENT OF WARNER-BRATZLER SHEAR FORCE AND PALATABILTY RATINGS FROM RETAIL AND FOODSERVICE ESTABLISHMENTS IN THE UNITED STATES

A Thesis

by

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ABSTRACT

Beef retail steaks from establishments across eleven US cities and beef foodservice steaks from establishments in six US cities were evaluated using Warner-Bratzler shear force (WBSF) and consumer sensory panels. The average postfabrication aging time of steaks at retail establishments was 25.9 d with a range of 6 to 102 d, and those from foodservice establishments averaged 31.5 d with a range of 3 to 91 d. The retail steak with the lowest WBSF value ($P < 0.05$) was the boneless top loin, compared to the top round which had the numerical highest ($P < 0.05$) WBSF value. Top loin and ribeye steaks had the lowest ($P < 0.05$) WBSF values, whereas the top sirloin represented the highest ($P < 0.05$) WBSF for the foodservice sector. The top blade retail steak received among the highest consumer ratings ($P < 0.05$), whereas the top round and bottom round steak received among the lowest ($P < 0.05$) consumer ratings for overall liking, tenderness liking, tenderness level, flavor liking, and juiciness liking. For the foodservice sector, the ribeye and top loin steaks were rated higher ($P < 0.05$) than top sirloin steaks across all consumer rating categories. Additional improvements in decreasing the variability of tenderness across retail and foodservice steaks, and an additional emphasis in improving the tenderness of top round and bottom round steaks are necessary to increase consumer acceptability.

DEDICATION

I dedicate this work to my family and friends. Without their support and encouragement, I would not be the person that I am today.

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CHAPTER I

INTRODUCTION

Maintaining consumer satisfaction towards beef products serves as an imperative objective of the beef industry. Many factors contribute to the overall palatability of beef steaks. Demands across all consumers are dependent on their personal needs and perceptions. This creates a variation of attributes that differ in importance conditional to the specific needs of each consumer. Regardless of the variation in consumers, the most important attributes have been shown to include tenderness, flavor, and juiciness.

The National Beef Tenderness Surveys (NBTS) serve as a beneficial resource to the beef industry by providing consistent data on tenderness across the United States for the retail and foodservice sectors. Additionally, the ability to compare the most recent survey to historical data allows insight into the improvements the industry has made, as well as identify additional variables that once improved will continue to increase consumer satisfaction for beef. On behalf of the Cattlemen's Beef Board, Texas A&M University lead a collaborative effort with North Dakota State University, Oklahoma State University, Texas Tech University, the University of Florida, and the University of Missouri. The objectives of this study were to determine the tenderness of US foodservice and retail steaks through the evaluation of Warner-Bratzler Shear Force (WBSF) and consumer sensory panels, and to collect aging, branding, grade, tenderization, and enhancement information from store visits and product packaging.

Data collected from all collaborating universities are combined in the results and discussion of this thesis.

CHAPTER II

REVIEW OF LITERATURE

In 1990, the first NBTS was conducted, and it established a baseline of the average tenderness and sensory ratings from various beef subprimal retail cuts from across the United States using WBSF force and trained sensory panels (Morgan et al., 1991). Steaks and roasts from the major subprimals were collected and different cooking methods, including braising, broiling, or roasting were used. Retail cuts were evaluated by a trained, eight-member Descriptive Attribute Panel (Cross et al., 1978) for juiciness, tenderness, flavor intensity, and connective tissue amount. Brooks et al. (2000) conducted the 1998 NBTS with adjustments from the 1990 survey. Monitoring changes in tenderness from the retail case through WBSF remained an objective, but the trained sensory panel was replaced with a consumer sensory panel. In addition, the tenderness evaluation of beef from the foodservice industry through WBSF and consumer evaluation panels was added to the 1998 survey. The 2006 survey conducted by Voges et al. (2007) maintained similar structure to the 1998 NBTS, but also began observing the percentage of branded programs. The 2010 NBTS by Guelker et al. (2013) built upon the previous benchmark studies and gave an update on beef tenderness and palatability. However, it included an additional objective to evaluate the use of moist-heat cookery for a subset of the collected round steaks since this cookery method was more ideal to this type of retail cut.

The first tenderness survey by Morgan et al. (1991) revealed that the average postfabrication time (PFT) for all cuts was approximately 17 d with a minimum of 3 d and a maximum of 90 d. Cuts from the chuck region represented the shortest aging time of 15 d. Postfabrication aging times for retail steaks increased from the 1990 survey to an average of 19 d with a smaller range of 2 to 61 d in the following survey (Brooks et al., 2000). According to research from Weatherly et al. (1998), a 14 d aging time is appropriate to optimize tenderness of all steaks. Based on the 1998 survey, approximately one-third of retail subprimals did not reach an optimal postfabrication age time (Brooks et al., 2000). Improvement was seen with the 2005 tenderness survey, as the mean percentage of subprimals aged under 14 d decreased to 19.6%. Retail subprimal PFT averaged 22.6 d with a range of 3 to 83 d, similar to the results found by Morgan et al. (1991), but greater than those reported by Brooks et al. (2000). Top rounds had the largest percentage (46.4) of subprimals aged for less than 14 d, whereas bone in ribeye steaks (3.0%) represented the lowest percentage (Voges et al., 2007). In the 2010 survey, subprimal overall average PFT decreased to 20.5 d and the range widened to 1 to 358 d, the largest range compared to all previous tenderness surveys (Guelker et al., 2013).

The first evaluation of average PFT for foodservice steaks showed an average of 32 d with a range of 5 to 67 d, meaning one-fifth of the foodservice subprimals sampled did not meet the 14 d-aging minimum (Brooks et al., 2000). The following tenderness survey, by Voges et al. (2007), reported subprimal PFT for foodservice cuts as 30.1 d, similar to results reported from Brooks et al. (2000), and a range of 7 to 136 d, wider

than what was seen with the 1998 survey. In the 2010 National Beef Tenderness Survey by Guelker et al. (2013), the foodservice PFT average decreased to 28.1 d and decreased in range to 9 to 67 d, compared to data reported by Voges et al. (2007).

Observation of the portion of retail cuts branded with a packer program or store brand began with the 2006 survey (Voges et al., 2007). Almost half of the retail cuts were found to be branded with a packer program and 43% of retail cuts displayed a label with a store brand. This portion of retail products increased, drastically, in the 2010 survey as approximately 64% of retail steaks were labeled with a packer or store brand (Guelker et al., 2013). This trend was further evidenced by Igo et al. (2015), as 61% of observed top loin retail steaks surveyed displayed packer or store brands, similar to data from Guelker et al. (2013), thus, providing evidence of a growing marketing trend. Increasing the amount of packer/processor programs will increase the amount of product required to meet stricter criteria in order to qualify for these programs. Some criteria from current programs include specific breed characteristics, minimum days of aging, electrical stimulation application, and/or other factors that may impact tenderness.

A decrease in mean external fat thickness has been seen throughout the span of the National Beef Tenderness Surveys. Although these data were not reported by Morgan et al. (1991), the National Beef Market Basket Survey, conducted during a similar time frame, reported an average external fat thickness of .38 cm (Savell et al., 1991). A trend of more closely trimmed retail cuts was shown in the 1998 and 2007 surveys as the average decreased to .28 and .27 cm, respectively (Brooks et al., 2000; Voges et al., 2007). Brooks et al. (2000), Voges et al. (2007), and Guelker et al. (2013)

reported that steaks from the rib and loin were cut the thickest ($P < 0.05$), whereas steaks from the chuck and round were cut the thinnest ($P < 0.05$). Specifically, the bottom round steak was found to be the thinnest retail cut ($P < 0.05$) (Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013). Voges et al. (2007) reported the top loin as the thickest cut steak at 2.60 cm, while Guelker et al. (2013) stated the top sirloin steak as the thickest at 2.89 cm.

For the foodservice sector, Brooks et al. (2000), Voges et al. (2007), and Guelker et al. (2013) reported the external fat thickness of the top sirloin steaks to be less than that of the ribeye and top loin steaks ($P < 0.05$). Voges et al. (2007) described the ribeye steaks as the thinnest (2.66 cm) and lightest ($P < 0.05$), and the top sirloin steaks as the thickest (3.17 cm) and the heaviest ($P < 0.05$). These results differed from findings of Guelker et al. (2013), as the lightest foodservice steak was represent by the top loin, and the heaviest by the top sirloin ($P < 0.05$).

When WBSF was analyzed for each of the National Beef Tenderness Surveys, data were categorized by different tenderness thresholds developed by Shackelford et al. (1991) in order to relate the objective measurement of WBSF to consumer acceptance. As a result, two values, 38.3 and 45.1 N, were used to distinguish tender from tough meat by using 50 and 68% confidence intervals (Shackelford et al., 1991). A new category for "very tender" (< 31.4 N) was developed by Belew et al. (2003) and was added to the tenderness surveys that followed. Therefore, the most recently used categories to relate WBSF to consumer acceptance include "very tender" (WBS < 31.4

N), “tender” (31.4 N < WBS < 38.3 N), “intermediate” (38.3 N < WBS < 45.1 N), and “tough” (WBS > 45.1 N).

Morgan et al. (1991) reported retail cuts from the chuck region had an overall WBSF of 36.5 N. Roasts from the chuck tended to have lower shear force values and higher, more desirable sensory ratings compared to their steak counterparts. Top blade steaks had an overall shear force mean of 29.9 N and were more tender ($P < 0.05$) than the other chuck retail cuts and had sensory panel attributes that were comparable to those of most of the chuck roast cuts (Morgan et al., 1991). The top sirloin steak was the toughest ($P < 0.05$) loin cut (34.9 N). The average shear force for loin and rib cuts were 31.1 and 33.0 N, respectively. Morgan et al. (1991) found that tenderloin steaks were more tender ($P < 0.05$) than other cuts from the loin and rib region, with a shear force value of 25.6 N. The overall WBSF mean for retail cuts from the round was 42.3 N. Round tip roasts were more tender ($P < 0.05$) than other round cuts. Top round steaks were the toughest round cut ($P < 0.05$) with a shear force value of 51.3 N (Morgan et al., 1991). Shackelford et al. (1991) reported that WBSF values should not exceed 38.2 N for a 68% confidence level to assure overall tenderness ratings of “slightly tender” or better from a trained sensory panel. According to this standard, approximately 23.0 and 17.5% of the retail cuts from the rib and loin, respectively, had shear force values greater than 38.2 N (Morgan et al., 1991). For the NBTS conducted by Brooks et al. (2000), retail ribeye, porterhouse, T-bone, and top loin steaks had lower ($P < 0.05$) WBSF values than other retail steaks collected in the study. The bottom round steak had the highest ($P < 0.05$) WBSF value of all steaks evaluated. Fewer than 2.0 % of the ribeye,

porterhouse, T-bone, and top sirloin steaks had WBSF values greater than the "tough" category of 45.1 N. The percentages of steaks with a WBSF value greater than 45.1 N for top round, eye of round, and bottom round steaks were 15.4, 26.6, and 52.6 %, respectively. Compared to the data reported by an Morgan et al. (1991), these percentages decreased with exception of the bottom round steak. Voges et al. (2007) stated bottom round, eye of round, shoulder, and top round steaks had higher ($P < 0.05$) WBSF values than the remaining retail cuts, with bottom round steaks representing the highest ($P < 0.05$) WBSF value at 36.0 N. Top loin, bone in strip, bone in ribeye, T-bone, and porterhouse steaks had the lowest WBSF values of 20.8, 21.0, 21.2, 22.3, and 22.8 N, respectively. Brooks et al. (2000) reported the T-bone and porterhouse steaks to have the lowest WBSF value. For the retail steaks, 100.0 % of both, the bone in ribeye and bone in top loin steaks were categorized as "very tender." Boneless ribeye, top loin, T-bone, and porterhouse steaks had over 90 % in the "very tender" category. Top round, bottom round, and eye of round were the only steaks that had presence in the "tough" category. The most recent tenderness survey by Guelker et al. (2013) reported top blade as having the lowest WBSF value, while bottom round and top round steaks had the greatest ($P < 0.05$). Based on the tenderness categories developed by Shackelford et al. (1991) and Belew et al. (2003), top round, bottom round, bone in top loin, and boneless top loin steaks were found to have approximately 2 to 5 % with WBSF values within the "tough" category. Guelker et al. (2013) reported an increased in the number of different types of retail cuts that fell into the "tough" category, compared to prior findings by Voges et al. (2007), which reported only top round and bottom round steaks. The total

percentage of top round and bottom round steaks in this category decreased compared to the findings by Voges et al. (2007). There was a wider range of tenderness within each steak, but overall, a greater percentage of steaks were found to have lower WBSF values compared to data from Voges et al. (2007). Guelker et al. (2013) reported top loin steaks as having the greatest percentage of steaks in the "very tender" category. Top sirloin steaks had the greatest percentage of steaks in the tender, intermediate, and tough categories. An additional objective added to the 2010 NBTS was to use moist-heat cookery for round steaks in addition to grated, nonstick electric grills. Therefore, a subset of top round and bottom round steaks were allocated to moist-heat cookery. There were no statistical differences reported in WBSF values between the moist-heat and dry-heat cookery methods for the top and bottom round steaks.

The first survey that included the foodservice channel, by Brooks et al. (2000), found that top loin steaks had the lowest ($P < 0.05$) WBSF value compared to the ribeye and top sirloin steaks. Voges et al. (2007) found that the top loin steaks had the highest numerical percentage represented in the "very tender" category, at 96.6. Top sirloin represented the lowest percentage in the "very tender" category (73.7) and the highest percentage in the "tough" and "tender" categories with 2.0 and 22.2, respectively. In the 2010 survey, similar results were seen as top loin and ribeye steaks had lower ($p < 0.05$) WBSF values compared to top sirloin steaks.

In regards to sensory panel ratings, Morgan et al. (1991) found the tenderloin steak to be rated higher ($P < 0.05$) in myofibrillar tenderness, connective tissue amount, overall tenderness, and flavor intensity, compared to the other cuts from the loin and rib.

Mean palatability ratings and shear force values of top loin steaks indicated palatability characteristics similar ($P > 0.05$) to those of rib cuts. Round roasts tended to be more tender and juicier and have less detectable connective tissue than their steak counterparts. Round steaks were tougher and received lower sensory scores than round roasts. Round tip roasts were more tender ($P < 0.05$) than other round cuts. For the middles meats, 22.2 and 24.7% of the rib and loin cuts received an overall sensory rating lower than "moderately tender." In conclusion, Morgan et al. (1991) reported a high percentage of cuts from the chuck and round received overall tenderness rating scores less than "slightly tender." In the 2006 NBTS, the bone in top loin, boneless top loin, ribeye, T-bone, and porterhouse received the highest ($P < 0.05$) ratings by consumers for overall like and like tenderness. Round cuts, including top round, bottom round, and eye of round steaks, received the lowest ($P < 0.05$) sensory ratings for overall like and like tenderness. In regards to tenderness evaluation, the cuts from the round received the lowest ($P < 0.05$) scores from consumers while the bone in top loin and porterhouse steaks received among the highest ($P < 0.05$) scores. For "like flavor" and "beef flavor," the ribeye, bone in ribeye, top loin, bone in top loin, T-bone, and porterhouse steaks received the highest ratings. The steaks from the round were given the lowest scores for "like flavor" and "beef flavor" by consumers. The bone in top loin steak received the highest ($P < 0.05$) "juiciness" and "juiciness desirability" ratings, whereas steaks from the round received the lowest. Overall, the bone in top loin steak received the highest ratings across all sensory attributes. Guelker et al. (2013) determined the top blade steak received among the greatest ratings for "overall like," "like tenderness," "tenderness

level," "like juiciness," and "juiciness level." The top blade and boneless ribeye received among the greatest ($P < 0.05$) ratings for "like flavor." Top round and bottom round received the lowest ($P < 0.05$) ratings by consumers for "overall like," "like tenderness," "tenderness level," "like flavor," "flavor level," and "like juiciness."

For foodservice consumer sensory evaluation, Brooks et al. (2000) revealed that overall like and sensory panel ratings for tenderness, juiciness, flavor, and beef flavor scores for the top loin, top sirloin, and ribeye steaks were not significant across different quality groups. Quality group had little influence in WBSF and consumer evaluation scores. For the 2006 NBTS, the foodservice consumer sensory evaluation for ribeye and top loin steaks received higher ($P < 0.05$) ratings for overall like, like tenderness, tenderness, like juiciness, and juiciness when compared to top sirloin steaks (Voges et al., 2007). Guelker et al. (2013) discovered for the foodservice steaks, top loin steaks received the greatest ($P < 0.05$) ratings for like tenderness, tenderness level, flavor level, like juiciness, and juiciness level.

In the first NBTS, quality grade failed to control variation in WBSF values and trained sensory panel ratings (Morgan et al., 1991). Brooks et al. (2000) found for the retail cuts from the rib and loin, quality group impacted ($P < 0.05$) WBSF values for the T-bone and porterhouse steaks, but had no effect ($P > 0.05$) on ribeye, top loin, or top sirloin steaks. For the cuts from the chuck and round, the quality grade group had no effect on WBSF values of the clod, chuck roll, top round, bottom round, or eye of round steaks. In addition, quality group had no effect on WBSF values of top loin steaks. Ribeye steaks from the Prime group had significantly lower WBS values while Select

ribeye steaks had the highest ($P < 0.05$) WBSF values than steaks from the Prime, Top Choice, or Choice groups. Consumer sensory evaluations for Prime retail ribeye steaks received higher ($P < 0.05$) ratings for "overall like" than other groups evaluated. Sensory ratings for top sirloin steaks, clod steaks, and top round steaks did not differ across quality groups for any of the sensory panel traits evaluated. The 2006 and 2010 survey did not evaluate the interaction of quality grade group or retail cuts with WBSF values or consumer panels.

For foodservice consumer sensory evaluation**,** the 1998 NBTS revealed overall like and sensory panel ratings for tenderness, juiciness, flavor, and beef flavor scores for the top loin, top sirloin, and ribeye steaks were not significant across different quality groups. Top Choice sirloin steaks had lower ($P < 0.05$) WBSF values than top sirloin steaks from the Choice and No Roll groups, but Top Choice did not differ ($P > 0.05$) from Prime top sirloin steaks. Quality group had little influence in WBSF and consumer evaluation scores (Brooks et al., 2000). Voges et al. (2007) revealed Select ribeye steaks received higher ($P < 0.05$) scores for flavor compared to other grades. Prime top sirloin steaks received higher ($P < 0.05$) ratings than other grades for tenderness and juiciness. For all other attributes, no differences were found across quality grade groups. For the 2010 NBTS, when analyzing foodservice steaks for WBSF and quality grade interactions, Prime had the lowest ($P < 0.05$) mean WBSF value, and Select and ungraded had the greatest ($P < 0.05$) mean WBSF value. Choice and ungraded ribeye steaks received the least ($P < 0.05$) ratings for overall like. Prime ribeye steaks received the greatest ($P < 0.05$) ratings for "overall like," "like tenderness," "tenderness level,"

“like juiciness,” and “juiciness level”. Ungraded top sirloin steaks received the greatest ($P < 0.05$) ratings for “overall like,” “like flavor,” and “like juiciness” than other grades. This may be attributed to tenderness and enhancement practices (Guelker et al., 2013).

Multiple factors can impact the outcome of large tenderness surveys, as the difficulty in purchasing and shipping steaks over a long period of time and widespread locations challenge the speed at which sensory panels and shear force analyses may take place. When comparing differing tenderness surveys to one another, thought for how the samples were collected, shipped, and handled must be considered. Differences in protocol between surveys influence results and may alter conclusions that were made from the comparisons of surveys conducted that vary, even minimally, in research methodology (Juárez et al., 2013). As an example, the protocol for cooking steaks intended for WBSF analysis for the current National Beef Tenderness Survey calls for steaks to be cooked to an internal degree of 70˚C, immediately weighed in order to later measure cook loss and yield, and placed on tray in a manner to avoid any overlapping. The cooked steaks were covered with plastic wrap and placed in a cooler for approximately 12 h at 2 to 4˚C before WBSF analysis. If results from the current NBTS were compared to the Canadian Beef Tenderness Survey: 2001-2011, it would be crucial to consider the differences in protocol. In the Canadian Beef Tenderness Survey, steaks were cooked to an internal temperature of 71˚C, immediately placed in polyethylene bags, sealed and immersed in an ice/water bath in order to prevent further cooking, then transferred to a 1˚C cooler for a 24 h period. Steaks then were weighed in order to calculate cook loss (Juárez et al., 2013). Neither of the protocols are incorrect, although

some may deliberate as to why one method may yield more accurate results. The goal is to conduct the NBTS in the most consistent manner to control variation within the study parameters to allow data comparison across all surveys.

Another factor impacting tenderness surveys includes the freezing of meat before consumer sensory studies and WBSF measurement, as it has been investigated thoroughly with inconsistent results and recommendations (Shanks et al., 2002; Howard et al., 2013; Juárez et al., 2013; Grayson et al., 2014). Shanks et al. (2002) showed improved tenderness in steaks that were frozen/thawed before cooking possibly due to a consequence of intracellular ice formation. Based on results, the researchers concluded aging steaks for 6 to 7 d before freezing resulted in approximately equal mean WBSF values of 14 to 21 d aged fresh steaks. Following this procedure for a nationwide collection of retail and foodservice steaks would pose many issues as knowing the precise aging time of all collected steaks is not possible. Howard et al. (2013) justified the difficulty of applying the recommendation of Shanks et al. (2002) to large scale surveys as the average aging time of retail steaks is much more variable. Researchers question the accuracy of large tenderness surveys due to the variation in shipping procedures (Howard et al., 2013). Two shipping protocols: (1) shipping fresh meat and freezing upon arrival and, (2) freezing steaks after purchase and shipping frozen, were compared. Steaks exposed to shipping conditions in a fresh state tended to have lower WBSF values than steaks immediately frozen and shipped ($P < 0.05$). Howard et al. (2013) reported temperatures varying by 6.6˚C between coolers during the phase of the project that tested the frozen before shipping procedure. The shipment process in the

collection of product for tenderness studies represents a crucial point where data may be compromised due to uncontrollable, adverse conditions that may influence WBSF value and consumer evaluation. Howard et al. (2013) recommended shipping meat in the frozen state because the steaks were expected to fluctuate less in temperature during shipping. Grayson et al. (2014) discovered similar results in that freezing and thawing, regardless of whether applied to steaks at 2 or 14 d postmortem, resulted in an increase in tenderness through SSF evaluation when compared to fresh steaks from both the *Longissimus lumborum* and *Semitendinosus* muscles. Grayson et al. (2014) recommend this process as a viable option for beef processers and sellers to implement in order to improve the consistency of meat tenderness in products. The National Beef Tenderness Surveys have followed the same protocol, with minor changes, throughout each of the surveys. This is necessary in order to be able to have comparable data between each survey. Implementing a large revision to the shipping procedures would be difficult due to time constraints and may render previous survey results incomparable to newer survey results.

All past National Beef Tenderness Surveys identified steaks from the round region as needing the most improvement in tenderness ratings (Morgan et al., 1991; Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013). Enhancement and blade tenderization are common practices the beef industry uses to improve the palatability of round subprimals. Enhancement has been shown to have greater palatability improvement for round subprimals than blade tenderization in terms of WBSF, and consumer sensory ratings (Kolle et al., 2004; Baublits et al., 2006; Mueller et al., 2006).

Although the objective of the study was not to compare blade tenderization to enhancement, Savell et al. (1977) showed ($P < 0.05$) decreases in WBSF for individual round muscles blade tenderized once, and further improvement with additional blade tenderization treatments. Igo et al. (2015) confirmed increased palatability in retail cuts through enhancement/blade tenderization practices. In the assessment of top loin steaks through WBSF, sliced shear force (SSF), and consumer panels, enhanced/blade tenderized top loin steaks had the lowest ($P < 0.05$) WBSF and SSF values, and the highest ($P < 0.05$) ratings by consumers for palatability scores compared to nonenhanced, top loin bone in steaks.

Although enhancing and blade tenderization of beef products proves beneficial in increasing palatability attributes, food safety concerns have developed when these technologies are used. The Food Safety and Inspection Service issued a final rule regulating the labeling of raw, or partially cooked needle or bladed tenderized beef products (9 CFR 317.2(e)(3)(iii)). These "non-intact" products must clearly state the procedure (i.e., blade tenderized) that had been applied to the product along with validated cooking instructions. Research supports the phenomenon of bacterial translocation to the interior muscle of steaks due to the tenderization methods (Luchansky et al., 2008). Additionally, non-intact products are often cooked to lower levels of degree of doneness not sufficient for lethality of bacteria (Luchansky et al., 2008). Multiple foodborne illness outbreaks have been associated with nonintact beef products, indicating a need of increased awareness of the health risk of undercooking enhanced and blade tenderized beef products (Laine et al., 2005).

As the beef industry moves towards marketing individual muscles from the round to increase profitability, it is important to identify what factors, such as degree of doneness and cookery method, are most beneficial to each muscle in order to reach maximum profits. Although Mueller et al. (2006) noted that overall, cooking method and degree of doneness had little impact on overall consumer ratings, the individual muscles differed in consumer preference based on these conditions. The S*emimembranosus*, *Rectus femoris*, and the *Vastus lateralis* muscles received higher consumer ratings ($P < 0.05$) in the consumer evaluation of "tenderness," "juiciness," "flavor intensity," "flavor desirability," and "overall like" when injected. When cooked with moist cookery methods, the *Vastus lateralis* muscle was more tender and higher in "overall like" ($P < 0.05$). Lower degrees of doneness for the S*emimembranosus* and *Rectus femoris* muscles cooked on a grill yielded higher acceptable consumer ratings (Mueller et al., 2006). Degree of doneness did not significantly impact any of the muscles cooked with moist-heat cookery methods, while lower a lower degree of doneness was most beneficial for the. *Vastus lateralis* when cooked in an oven.

The segregation of carcasses through USDA quality grades does not sufficiently categorize beef products in terms of palatability differences, therefore, a direct measurement of tenderness is necessary to supplement quality grades (Wheeler et al., 1994). When the financial value of carcasses is developed through the evaluation of the degree of marbling present, some carcasses will be undervalued compared to their actual palatability. This occurs most often with Select. It has been proposed to develop a Select Tender product that markets both positive attributes of leanness and tenderness

(Shackelford et al., 2001). Programs developed from carcass tenderness traits are marketable in the beef industry, as numerous studies have revealed consumers are able to differentiate beef that varies in tenderness and are willing to pay a premium for product that is guaranteed tender (Boleman et al., 1997; Lusk et al., 2001; Shackelford et al., 2001; Wheeler et al., 2002).

Boleman et al. (1997) discussed the need for research to justify tenderness as an attribute that is detectable by consumers and the profitability of the attribute's management and marketing ability in order to meet consumer satisfaction. Ultimately, this may lead to the creation of a system where consumers are willing to pay a premium for beef products that are certified tender, thus creating an additional revenue channel for the beef industry. The objective of the study conducted by Boleman et al. (1997) was to compare consumer perception of top loin steaks of known WBSF values to evaluate the purchasing trends of steaks in relation to their known variation in tenderness. Mean scores of the consumer's evaluations of the steaks revealed consumers were able to differentiate certain variables across tender, intermediate and tough threshold categories (Boleman et al., 1997). In additional phases of the study, consumers selected steaks from the three differing threshold categories. In Phase II, consumers visually selected their steaks, resulting in 33.5% of the purchases from the tender category. Phase III was conducted via telephone communication and the shear force values were disclosed to the consumers. Boleman et al. (1997) reported an increase to 92.6% of the purchases were from the tender threshold category, despite an added premium of $1.10/kg.

Lusk et al. (2001) examined consumer willingness-to-pay for higher levels of steak tenderness in a grocery retailer setting. Shoppers were asked to participate in a study where they sampled two different categories of steaks labeled “Red” and “Blue.” In experimental treatment 1, the “Red” labeled steak represented a “Guaranteed Tender” sample while the “Blue” label represented a “Probably Tough” sample. If the participant preferred the “Blue” labeled, “Probably Tough” steak, they were given a free “Probably Tough” 12 oz. ribeye and the experiment stopped. If the participant chose the “Red” labeled “Guaranteed Tender” sample, they were asked what their willingness was to pay to upgrade their free 12 oz. “Probably Tough” steak to a “Red” labeled steak that they had favored more. The second experimental treatment was designed similar to the first with the exception that the “Red” and “Blue” labels were replaced with the terminology “Guaranteed Tender” and “Probably Tough.” Therefore, the participants were able to see the category each sample represented. The average willingness-to-pay for “Guaranteed Tender” product was $1.23/lb. for treatment one and $1.84/lb. for treatment two. When treatment 2 participants were given the identification of the tenderness of the steaks, they were 18% more likely to prefer the tender steak than the participants in treatment one, who only saw the steaks labeled as either “Red” or “Blue.”

Although numerous studies have emphasized the importance beef tenderness has in consumer satisfaction of beef products, many variables have limited producers from participating in tender labeling programs. Questions of how to develop a system of incentives for premium carcasses and an economical method of verifying labeling of these carcasses have intimidated the participation in the program. Tenderness-marketing

claims are certified based on the tenderness standards set forth by the American Society for Testing and Materials (ASTM) International. Third parties approved by the Agricultural Marketing Service may conduct the required SSF or WBSF analyses necessary to verify met standards of the ASTM International Committee F10.60 on Livestock, Meat, and Poultry marketing claims (ASTM Standard F2925 11, 2011). Product that meets all requirements may carry the claim "Certified Tender" or "Certified Very Tender" depending on the minimum tenderness threshold value category that is met. This marketing claim may be used as advertising or promoting a company's product as superior in tenderness ratings and may, in turn, increase consumer satisfaction and profitability. As noted in the specifications, "If the carcass *Longissimus dorsi* is directly measured or predicted by a recognized methodology or technology or both and the *Longissimus dorsi* meets the minimum tenderness threshold value, then the *Tensor fascia late*, *Rectus femoris*, V*astus medialis*, *Psoas major*, *Infraspinatus*, *Spinalis dorsi*, *Teres major*, and *Serratus ventralis* muscles will also qualify as being tender without having to be measured." Meat products that have been further processed to improve tenderness through means such as, but not limited to, marination, mechanical tenderization, and electrical stimulation may qualify has "Inherently Tender product."

Consumers face many factors, starting with the moment a product is selected to its consumption, that will determine whether they will be satisfied with its palatability. Because research methods attempt to control variation that may alter results of a study, a large portion of research methodology of consumer studies controls the factors in which a consumer would naturally make themselves. This may alter consumer perception as it

is evaluated based on what researchers serve them, and thus, is not necessarily representative of how they personally would select, cook, or consumer the product. Home use tests are beneficial as product is able to be tested in normal conditions. Multiple consumer perceptions are captured as family members may influence one another in their overall perception of the product. Also, more information is captured as consumers benefit from more time to reveal their attitudes towards the product. Although in-home consumer tests are beneficial to capture data that may not otherwise be collected, more variation may be added as researchers are not able to control preparation methods used by consumers and must rely on consumers following issued instructions (Meilgaard et al., 1999). In-home consumer panels conducted for the Beef Customer Satisfaction surveys revealed the need for increased consumer education for the most beneficial cookery method and degree of doneness for the specific cut customers prefer to cook (Neely et al., 1998; Lorenzen et al., 1999; Neely et al., 1999; Savell et al., 1999; Behrends et al., 2005). This must be considered as consumers will evaluate the success of product that is labeled as tender based on how they perceive its attributes after preparation and consumption, not on what the label tells them about the product.

Behrends et al. (2005) conducted an in-home study evaluating consumer ratings of top round steaks. Grilling was the predominant cookery method and the preferred degree of doneness was “medium well or more” ($P < 0.05$). Similar results were found by Lorenzen et al. (1999), in an in-home study with top loin steaks revealed grilling as the most popular method of cooking. The preferred degree of doneness was dependent

by region, as consumers in San Francisco and Philadelphia preferred lower degrees of doneness while Chicago and Houston residents preferred medium to "well done or more" degrees of doneness. Neely et al. (1999) reported regional differences in preferred cooking methods for top round steaks as residents of Philadelphia most often cooked with outdoor grills, Chicago chose to simmer and stew their cuts, and San Francisco and Houston residents most often used pan-frying. Across all cities, the most frequent reported degree of doneness was well done. All forms other than dry heat methods resulted in higher ratings for all consumer attributes. Similar to results from Behrends et al. (2005), consumers need further help understanding the most beneficial form of cookery for top round steaks, as they often have shown to have issues with tenderness and acceptability. A better understanding of cookery methods and degree of doneness is not isolated to the top round steak, as emphasized by Savell et al. (1999). Consumers issued the lowest satisfaction results to top sirloin steaks cooked to more advanced levels of doneness while the most frequent level of doneness the consumers cooked to was well done or greater.

Consumers rely heavily on observing a product for quality ques before they commit to purchasing. Consumers evaluate these quality cues in order to determine if their potential purchase contains the quality attributes they are willing to pay for. It is not possible to determine the quality attributes of fresh beef until the product is cooked and consumed, therefore consumers rely heavily on visual cues that they believe will help predict the outcome they desire (Steenkamp, 1990). The variables consumers evaluate can be further categorized as intrinsic and extrinsic factors (Grunert et al., 2004). The

intrinsic cues represent the physical appearance of the product. For beef cuts, this includes the color, amount of fat, thickness of the cut, and other visual factors. The extrinsic cues are represented by the product's brand name, price, packaging, marketing claims, and other additional information regarding the product. The environment that the consumer faces during their shopping may also influence the perception of products, such as whether the grocery store visit was planned or spontaneous, or if a consumer must shop within a time restraint.

The level of experience and familiarity consumers have with different brands varies. Bredahl (2004) conducted a study to answer how consumers would react to branded fresh meat product and if the brand would serve as an extrinsic cue in developing their quality expectation. A specialty selection of steaks was distinguished by branding under the loosely translated term "Country Beef" with no price discounts, packaging in cardboard trays, extended information included on the product label, promotional information, and an optional electronic scanner that would allow consumers to scan the product to obtain additional information such as how the animal was fed. A portion of consumers who purchased this product were interviewed in the store and were asked to fill out a second interview after the preparation and consumption of the steak at home. Data showed that consumers relied heavily on extrinsic factors to determine the health quality of the product, whereas their expected eating quality relied on a combination of both, intrinsic and extrinsic cues. Consumers were divided into either high or low familiarity respondents based on how frequently they consumed beef steak. Low familiarity respondents claimed to use beef steaks sometimes, but not more than

once a month, whereas high familiarity respondents reported their consumption as at least once every two weeks. Low familiarity respondents were found to rely on perceived meat juice and past purchases as a quality cue, but predominately focused on brand. Brand also impacted high familiarity respondents in their decision-making, but was as effective as perceived fat and meat color in their assessment of beef steaks. In addition, branding for both categories of respondents was the factor that influenced the expectations about health quality.

The question of how consumers perceive national beef brands compared to store brands was further investigated by Banović et al. (2010). One well known national brand of beef was compared two unfamiliar store brands in a grocery retail setting. Consumers relied heavier on intrinsic quality cues for the store brands and heavier on extrinsic cues for the national brand. Consumers preferred the national brand based on all quality cues and quality aspects. Their preference for the national brand remained consistent after blind taste testing. Previous exposure to the national brand and past consumption that resulted in a positive eating experience may have increased consumer's acceptance and expectations of the familiar product. Consumers also viewed the higher price of the national brand as a quality indicator of the product as they associated the higher price to a greater satisfaction of the expected palatability characteristics of the product. Consideration for the demographics of the average income for the consumers should be taken into consideration, as this may vary by location and region. A benefit of a national brand is that consumers are more likely to recognize and recall the title and image of the product, but this may inflate the consumer's expectations of the brand (Bredahl, 2004). It

is important for national brands to recognize this because if consumers have a negative eating experience with the product, trust and willingness to pay for the national brand may decline.

Work by Mennecke et al. (2007) used an analysis technique, the conjoint analysis method, commonly used in marketing research to evaluate a variety of consumer goods, to identify what features of beef products are desired most by differing demographics of the U.S. consumer population. The questionnaire described common terminology found on beef products in the grocery store including animal breed (Angus versus not breed specific), animal feed (grain versus grass), farm ownership (family versus corporate), region of origin, traceability, growth promoters, cost of cut, Guaranteed Tender, and Certified Organic. Data were compared in three different phases including business and animal science students, differences in sex of respondents, and for a national, overall sample. Small notable differences were visible between the business and animal science student samples as factors such as beef quality, animal breed, and cost of cut were ranked lower for the business students as compared to animal science students, who were expected to have had more exposure to the industry compared to the average consumer represented by the business students. Male and female respondent views were similar with the exception that males tended to view the cut of steak and cost of cut as more important factors than females. Overall, the ranking of importance of factors for the national sample were region of origin, growth promoters, cost of cut, guaranteed tender, traceability, organic certification, animal breed, steak cut, and animal feed, respectively. Regardless of how data were segmented, region of origin was viewed as the

most important attribute of purchasing beef. In all, this research indicates that as the U.S. increases in the traceability of its beef production system, factors like region of origin, growth promoters, guaranteed tender, and organic certification all may provide avenues of marketing and increased profitability for companies. Supporting this idea, additional research has indicated that consumers are willing to spend more, even higher than commercial prices, for organic beef as they associated their willingness to pay with the marketing information provided regarding the differences in the lifestyle of beef animals raised for organic labeling (Napolitano et al., 2010). Therefore, the manner in which beef attributes are marketed and perceived by consumers play a large role in the consumer's willingness to pay more for the product.

CHAPTER III

MATERIALS AND METHODS

3.1 Product selection

Retail cities were chosen to represent a broad geographical range and to maintain some historical linkage with cities that have been used in previous surveys. Cities included New York, NY; Philadelphia, PA; Los Angeles, CA; Denver, CO; Las Vegas, NV; Tampa, FL; Atlanta, GA; Kansas City, MO; Houston, TX; Chicago, IL; and Seattle, WA. Representatives of the National Cattlemen's Beef Association's retail marketing team assisted with identifying and obtaining permission from the retail chains surveyed.

Each city was sampled over a 12-month time period. In each city, two to three retail chains, representing at least one-third of the total area market share were selected, with four stores per chain being sampled. Thus, product was obtained from a total of 8 to 12 supermarket stores per metropolitan area. In addition, if a membership club retail stores existed in a city and was not included in the one-third market share, one store of each club chain present was sampled. In an effort to accurately represent consumer demographics in a given region, corporate retail contacts were asked to identify individual retail stores of their respective chain. Store managers were notified of the impending sampling visit dates, to allow coordination between each individual store and the university responsible for sampling. In some circumstances, it was necessary to purchase products from stores that had not been contacted or who did not wish to participate in the full scope of the survey (e.g., access to back room, separate analyses of their information, etc.).

Within each store, brand names and grades of product available were recorded. Postfabrication dates were recorded from locations who granted permission to access the back room. Retail cuts were shipped to Texas A&M University in insulated containers with refrigerant materials and were stored under refrigerated conditions (2 to 4°C) upon arrival. Within 2 d after arrival, steaks were removed from store packaging and all information available including brand designation, marketing claims, enhancement with percentage pumped, and any other important features was recorded. External fat trim was determined by calculating the average of three different fat thickness locations in order to represent the entire steak. Steak thickness was measured in the same manner at three different thickness locations and an average was calculated. All steaks were identified individually, vacuum-packaged, and stored frozen (-40°C).

The following retail cuts were sampled and corresponding Universal Product Codes (UPC) (Industry-Wide Cooperative Meat Identification Standards Committee, 2003): Top Blade Steak (UPC 1144); Ribeye steak, lip on, boneless (UPC 1203); Ribeye steak, lip on, bone in (UPC 1197); Top loin steak, boneless (UPC 1404); Top loin steak, bone in (UPC 1398); T-bone steak (UPC 1369); Porterhouse steak (UPC 1330); Top sirloin steak, boneless, cap off (UPC 1426); Top round steak (UPC 1553); and Bottom round steak (UPC 1466).

Steaks were assigned randomly for either for WBSF evaluation or consumer sensory panels. After freezing, steaks assigned to consumer sensory panels were assigned to one of five collaborating universities. An effort was made to equally distribute the same number of each retail cut to each university. Within each cut, steaks

were assigned using the random number generator of Microsoft Excel (Microsoft, Redmond, Washington). Steaks then were shipped overnight in insulated containers with refrigerant material to each designated university.

In six cities (Houston, TX, Dallas, TX, Tampa, FL; Denver, CO; Las Vegas, NV; Philadelphia, PA), collaborators also sampled one foodservice establishment. Due to lack of available product in Houston, Dallas was identified as a city within the same region and similar demographics to supplement the remaining needed steaks. Prime, Top Choice, Choice, and Select USDA quality grades were collected, and Institutional Meat Purchase Specifications (IMPS) (USDA, 2014) descriptions were used for naming the following cuts: Ribeye roll steak, boneless (IMPS 1112); Top loin steak, boneless (IMPS 1180); and Top sirloin butt steaks, center-cut, boneless (IMPS 1184B). Postfabrication times were recorded, along with brand designation, marketing claims, enhancement with percentage pumped, and any other important features. Steaks were shipped to Texas A&M University and handled in the same manner as provided above for the retail cuts.

Foodservice steaks were vacuumed packaged and frozen. Texas A&M University randomly assigned the steaks for either WBSF evaluation or consumer sensory panels using a random number generator of Microsoft Excel. Foodservice steaks were shipped to the University of Missouri in the same manner as the retail cuts for all WBSF and consumer sensory panel evaluations.

3.2 Dry-heat cookery

Steaks were thawed in a 4 ˚C cooler for 48 h before cooking. All retail steaks were cooked on a grated, non-stick electric grill (Hamilton Beach™ Indoor/Outdoor

Grill, Southern Pines, NC). The grills were preheated for 15 min to an approximate temperature of 177 °C. Foodservice steaks were cooked on a Garland™ gas grill pre-heated before cooking to a surface temperature of approximately 232 ˚C. Cooking yields were determined from the weights of the steaks recorded prior to and after cooking. Internal temperature was monitored with a thermocouple reader (Omega™ HH506A, Stanford, CT) using a 0.02 cm diameter, copper constantan Type-T thermocouple wire. All steaks were flipped once the internal temperature reached 35 ˚C and were removed once the internal temperature of the steaks reached 70 ˚C. The total cook time was recorded for each individual steak in addition to the weight of each steak prior to and after cooking. Cooking yields were determined using the before and after cooking weights. After the steaks were weighed, they were placed on tray in a manner to avoid any overlapping. The cooked steaks were covered with plastic wrap and placed in a cooler for approximately 12 to 18 h at 2 to 4 ˚C.

3.3 Warner-Bratzler shear force

Steaks for WBSF were cooked in the same manner as consumer sensory panel steaks. In order to expose muscle fiber orientation steaks were trimmed of visible connective tissue. Cores were removed parallel to the muscle fibers. Six 1.3 cm cores were removed from each major muscle in the steak. Six cores from the *M. longissimus lumborum* and four cores from the *M. psoas major* were used to uniformly sample T-bone and Porterhouse steaks. Cores were sheared once, perpendicular to the muscle fibers on a United Testing machine (United SSTM-500, Huntington Beach, CA) at a cross-head speed of 200 mm/min using a 10.0 kg load cell, and a 1.02 cm thick V-

shaped blade with a 60˚ angle and a half-round peak. The peak force (kg) needed to shear each core was recorded, converted to Newtons (N), and the average peak shear force of the cores was used for statistical analysis. Warner Bratzler shear values were converted using the following equation:

$$WBSF\ (N) = WBSF\ (kg) \times 9.80665002864$$

3.4 Consumer panel

Procedures were approved by the Texas A&M Institutional Review Board for Use of Humans in Research (IRB2015-0393M). Consumer sensory panels were conducted at Texas A&M University, Oklahoma State University, Texas Tech University, University of Florida, University of Missouri, and North Dakota State University. Panelists were recruited from surrounding communities by randomly calling possible participants and through email list servers. Each panel participant completed a consent form and demographic questionnaire. Steaks were randomly assigned to serving days using a random number generator in Microsoft Excel. Each panelist was given unsalted saltine crackers and double distilled deionized water between each sample. Each panelist evaluated 8 samples by receiving two cuboidal (1.27 cm X 1.27 cm X cooked steak thickness) portions of each. A four-minute time delay occurred between each sample, except between the 4th and 5th sample, in which a ten-minute break occurred in order to reduce sensory fatigue. Samples were characterized using a 10-point scale for overall like (10 = like extremely; 1 = dislike extremely), overall like of

tenderness (10 = like extremely; 1 = dislike extremely), intensity of the tenderness (10 = extremely tender; 1 = extremely tough), overall like of the flavor (10 = like extremely; 1 = dislike extremely), level of beef flavor (10 = extreme intense; 1 = extremely bland/no flavor), overall like of juiciness (10 = like extremely; 1 = dislike extremely), and level of juiciness (10 = extremely juicy; 1 = extremely dry).

3.5 Statistical analysis

Data were analyzed using SAS (SAS Institute Inc., Cary, NC), where main effects and significant two-way interactions were included in the model. Least squares means were calculated and where appropriate, means were separated using the PDIFF procedure and an $\alpha < 0.05$.

CHAPTER IV

RESULTS AND DISSCUSSION

4.1 Postfabrication aging times

Subprimal post-fabrication aging times at retail and foodservice establishments are displayed in Table 1.

Table 1. Postfabrication storage or aging times for subprimals audited in the cold storage facilities of retail stores and foodservice operations

Item	No. of cases	Days				Age < 14d, %
		Mean	SD	Minimum	Maximum	
Retail						
Shoulder clod	57	19.6	8.0	6	50	24.6
Top blade	9	26.4	6.4	13	34	11.1
Ribeye boneless	225	29.2	13.5	6	101	8.4
Bone-in ribeye	171	28.1	9.8	16	91	0.0
Strip loin	296	27.2	14.3	6	101	11.8
Bone-in strip loin	83	26.0	16.2	11	102	2.4
Short loin	92	24.0	10.7	7	55	19.6
Top sirloin	265	26.6	12.1	6	75	9.1
Top round	186	23.2	11.0	8	100	5.9
Bottom round	140	21.5	11.8	8	74	40.7
Overall	1524	25.9	12.7	6	102	11.9
Foodservice						
Ribeye	21	32.2	18.1	3	84	14.3
Top loin	17	34.6	17.1	16	91	0.0
Top sirloin	17	27.6	11.4	4	46	11.8
Overall	55	31.5	16.0	3	91	9.1

For the retail sector, the average postfabrication aging time was 25.9 d with a range of 6-102 d. Compared to the results of Guelker et al. (2013), Voges et al. (2007), and Brooks et al. (2000), the current survey resulted in the highest postfabrication average aging time, as the previous three surveys noted the averages as 20.5, 22.6, and 19.0 d, respectively. Compared to work by Guelker et al. (2013) the range has decreased, as the

previous survey resulted in 1-358 d. Bottom rounds represented the retail cut with the highest frequency of product cases aged less than 14 d, at 40.7%. Bone in ribeye exhibited 0.0% of cases aged less than 14 d. The mean percentage of subprimal cases aged less than 14 d was 9.1. This is the lowest average percentage compared to previous surveys by Guelker et al. (2013), Voges et al. (2007), and Brooks et al. (2000) who reported 35.7, 19.6 and 34.1, respectively.

The average postfabrication aging time for foodservice cuts was 31.5 d with a range of 3-91 d. Guelker et al. (2013) reported a lower average of 28.1 d and a more narrow range of 9-67 d. Top loin steaks represented the cut with the least percentage of cases aged less than 14 d at 0.0. Top sirloin and ribeye steaks resulted in 11.8 and 14.3%, respectively, of cases aged less than 14 d. This differs from all previous surveys as the top sirloin cut represented the smallest percentage of cases aged less than 14 d (Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013). In addition, the present survey indicates a decrease in the overall percentage of cases aged less than 14 d, as all previous surveys exhibited numerically higher overall average percentages (Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013).

4.2 Product information

Approximately 34.5% of retail steaks were labeled with a store brand or form of claim. This is less than the percentage reported by Voges et al. (2007), which reported 43% of retail steaks labeled with a store brand, and Guelker et al. (2013), which reported 64% of retail steaks labeled with a packer/processor or store brand. Table 2 reports the average steak thickness, external fat thickness, and steak weights for the retail and

foodservice operations. Previous NBTS reported that retail cuts from the rib and loin were the thickest, whereas cuts from the chuck and round were the thinnest. In the current survey, the top blade steaks, representing a portion of the chuck primal, were similar to the thickness of the porterhouse and top round steaks ($P < 0.05$), which represented the loin and round, respectively. The thickest cut was represented by the top loin steak, at 2.97 cm, whereas the thinnest retail cut was from the bottom round at 1.92 cm. T-bone retail steaks had the highest average external fat thickness of 0.58 cm while top round steaks had the least at 0.07 cm.

In regards to foodservice operations, ribeye, top loin, and top sirloin steaks differed from each other in terms of steak thickness as data revealed average steak thicknesses of 2.91, 2.80, and 2.47 cm, respectively ($P < 0.05$). This differs from findings by Guelker et al. (2013), as steak thickness across these cuts were similar ($P > 0.05$). Top sirloin steaks had less external fat compared to ribeye and top loin steaks ($P < 0.05$), which agreed with data from Guelker et al. (2013). Steak weights also differed across all three cuts, as the ribeye steak was the heaviest at 0.43 kg, and top sirloin steak was the lightest at 0.31 kg ($P < 0.05$).

Table 2. Least squares means ± SE for steak thickness, external fat thickness, and steak weights for steaks from retail stores and foodservice operations

Source/steak	*n*	Steak thickness, cm	External fat thickness, cm	Steak weight, kg
Retail				
Top blade	102	2.30[d] (±0.06)	0.21[e] (±0.02)	0.18[f] (±0.01)
Ribeye, lip on, boneless	311	2.87[b] (±0.03)	0.45[c] (±0.01)	0.40[c] (±0.01)
Ribeye, lip on, bone in	100	2.60[c] (±0.06)	0.46[bc] (±0.03)	0.51[b] (±0.01)
Top loin	321	2.97[a] (±0.03)	0.55[a] (±0.01)	0.36[d] (±0.01)
Top loin, bone in	71	2.48[c] (±0.07)	0.56[a] (±0.03)	0.37[cd] (±0.02)
T-bone	119	2.51[c] (±0.05)	0.58[a] (±0.02)	0.50[b] (±0.01)
Porterhouse	79	2.43[cd] (±0.07)	0.52[ab] (±0.03)	0.55[a] (±0.01)
Top sirloin, boneless, cap off	307	2.79[b] (±0.03)	0.25[e] (±0.01)	0.39[c] (±0.01)
Top round	105	2.28[d] (±0.06)	0.07[f] (±0.02)	0.55[a] (±0.01)
Bottom round	86	1.92[e] (±0.06)	0.37[d] (±0.03)	0.29[e] (±0.01)
P-value		<0.0001	<0.0001	<0.0001
Foodservice				
Ribeye	160	2.91[a] (±0.03)	0.50[a] (±0.01)	0.43[a] (±0.01)
Top loin	136	2.80[b] (±0.03)	0.47[a] (±0.02)	0.35[b] (±0.01)
Top sirloin	136	2.47[c] (±0.03)	0.04[b] (±0.02)	0.31[c] (±0.01)
P-value		<0.0001	<0.0001	<0.0001

[a-f]Least squares means in the same column and within the same steak source without common superscript letters differ ($P < 0.05$).

4.3 Warner-Bratzler shear force

Warner-Bratzler shear force values for retail and foodservice steaks are reported in Table 3.

Table 3. Least squares means and SE for Warner–Bratzler shear force values (N) of retail and foodservice steaks

Source/steak	*n*	Mean	SE
Retail			
Top blade	32	20.8[cd]	4.5
Ribeye, lip on, boneless	122	20.5[d]	2.3
Ribeye, lip on, bone in	42	23.1[cd]	3.9
Top loin	123	19.9[d]	2.3
Top loin, bone in	26	22.9[cd]	4.9
T-bone	49	29.1[bc]	3.6
Porterhouse	32	23.3[cd]	4.5
Top sirloin, boneless, cap off	129	22.8[cd]	2.2
Top round	51	40.2[a]	3.5
Bottom round	35	36.4[ab]	4.3
P-value		<0.0001	
Foodservice			
Ribeye	80	29.6[a]	0.7
Top loin	68	24.6[b]	0.8
Top sirloin	68	29.4[a]	0.8
P-value		<0.0001	

[a-d] Least squares means in the same column and within the same steak source without common superscript letters differ ($P < 0.05$).

The top round steak received among the highest average WBSF value ($P < 0.05$) compared to all other retail cuts. The boneless top loin steak had among the lowest reported average WBSF value ($P < 0.05$) at 19.9 N, compared to all other retail cuts. This differs from data reported in the previous tenderness survey. Guelker et al. (2013) reported the bottom round steak as having among the highest WBSF (31.2 N), and the top blade steak with among the lowest WBSF value (21.5 N) compared to all other retail steaks. Igo et al. (2015) evaluated bone in and boneless top loin steaks and reported average WBSF values of 24.5 and 27.2 N, respectively. When comparing these results to

the current NBTS, numerically lower WBSF values were reported for the bone in and boneless top loin steaks.

In regards to foodservice WBSF values, the top loin steak had the lowest value ($P < 0.05$) at 24.6 N, compared to ribeye and top sirloin steaks, which reported 29.6 and 29.4 N, respectively. These results are similar to Guelker et al. (2013), which reported the top loin steak with the lowest numerical WBSF value (25.8 N) followed by the ribeye and top sirloin with 27.3 and 30.2 N, respectively. Voges et al. (2007) reported lower WBSF values for top loin (21.9 N), ribeye (27.0 N) and top sirloin steak (27.4 N), compared to both the 1998 and 2010 NBTS.

Tenderness categories developed by Shackelford et al. (1991) and Belew et al. (2003) are used to display threshold difference between retail steaks and foodservice steaks in Table 4. The bottom round had the lowest percentage of steaks (37.14) in the very tender category and the highest percentage of steaks in the tender (31.43), intermediate (17.14), and tough (14.29) categories. Guelker et al. (2013) reported similar findings as the bottom round also represented the steak with the lowest percentage in the very tender category and the highest in the tender, intermediate, and tough categories. Multiple retail cuts increased the percentage represented by the very tender category compared to previous findings by Guelker et al. (2013). These cuts include top blade, boneless top loin, bone in top loin, T-bone, and porterhouse steaks. Contrarily, multiple cuts decreased in the percentage present in the very tender category, and became more distributed into the tender, intermediate, and tough categories. More steaks were categorized into the tough category, compared to Guelker et al. (2013).

Table 4. Percentage distribution of retail and foodservice steaks stratified into tenderness categories based on Belew et al. (2003)

Source/steak	Very Tender, WBSF[1] < 31.4 N	Tender, 31.4 N < WBSF < 38.3 N	Intermediate, 38.3 N < WBSF < 45.1 N	Tough, WBSF > 45.1 N
Retail				
Top blade	96.88	3.13		
Ribeye, lip on, boneless	91.80	5.74	1.64	0.82
Ribeye, lip on, bone in	85.71	9.52	4.76	
Top loin	95.93	3.25		0.81
Top loin, bone in	88.46	11.54		
T-bone	95.92	2.04		2.04
Porterhouse	96.88	3.13		
Top sirloin, boneless, cap off	86.05	10.85	3.10	
Top round	64.71	17.65	7.84	9.80
Bottom round	37.14	31.43	17.14	14.29
Foodservice				
Ribeye	68.75	22.50	5.00	3.75
Top loin	89.71	8.82	1.47	
Top sirloin	69.12	23.53	5.88	1.47

[1]WBSF = Warner-Bratzler shear force values.

It should also be noted that the boneless ribeye, bone in ribeye, T-bone, top round, and bottom round steaks all had portions of the samples in the tough category at 0.82, 0.81, 2.04, 9.80, and 14.29%, respectively.

Also displayed in Table 4 are the foodservice percentage distributions stratified into tenderness categories. The top loin steak reported the highest percentage, at 89.71 in the very tender category, while ribeye and top sirloin steaks revealed 68.75 and 69.12, respectively. Guelker et al. (2013) reported a lower percentage of top loin and top sirloin steaks in the very tender category, but a higher percentage of ribeye steaks. The ribeye steaks in the present survey became more widespread within all four tenderness threshold categories, with 3.75% reported in the tough threshold. Voges et al. (2007) reported the highest numerical percentage of each foodservice cut in the very tender category, compared to Guelker et al. (2013) and the present study as ribeye steaks represented 81.4 %, top loin steaks at 96.6 %, and top sirloin steaks at 73.7%.

Table 5 reports least squares means for WBSF values for foodservice steaks stratified by USDA quality grade.

Table 5. Least squares means and SE for Warner–Bratzler shear force values (N) for foodservice steaks stratified by USDA quality grade group

USDA grade group	*n*[1]	Mean, N	SE
Prime	56	24.6[b]	0.8
Top Choice	64	28.5[a]	0.7
Low Choice	48	30.3[a]	0.8
Select	48	30.3[a]	0.9
P-value		<0.0001	

[a-b]Least squares means without common superscript letters differ ($P < 0.05$).
[1]Number of steaks.

Steaks graded Prime had lower ($P < 0.05$) average WBSF values compared to Top Choice, Low Choice, and Select grades. Guelker et al. (2013) also reported Prime as having lower ($P < 0.05$) WBSF values and a difference was also seen among the remaining grades, unlike the current survey.

4.4 Retail consumer sensory evaluations

Consumer demographic information is reported in Table 6 for both retail and foodservice consumer sensory panelists. Table 7 displays the least squares means for sensory panel ratings of retail steaks. All sensory ratings were significant across all cuts. Top blade steak was given among the highest ($P < 0.05$) panelist ratings, whereas top round and bottom round received among the lowest ($P < 0.05$) panelist ratings across all attributes including overall liking, tenderness liking, tenderness level, flavor liking, and juiciness liking. Guelker et al. (2013) and Voges et al. (2007) reported similar results as top and bottom round steaks were among the lowest consumer ratings in each sensory attribute as well ($P < 0.05$). Boneless ribeye, boneless top loin, bone in top loin, and porterhouse steaks also received among the highest ($P < 0.05$) consumer ratings for overall liking. Guelker et al. (2013) reported top blade steaks highest ($P < 0.05$) in overall liking and Voges et al. (2007) reported bone in top loin and T-bones steaks as highest ($P < 0.05$). The present NBTS reported no significant difference between bone in and boneless top loin steaks. This differs from Igo et al. (2015), which reported bone in top loins received lower ($P < 0.05$) consumer ratings compared to boneless top loins.

Table 6. Demographic attributes of consumers that participated in the retail (universities combined) and foodservice sensory panels

	Retail		Foodservice	
Item	*n*[1]	%	*n*	%
Gender				
Male	219	48.45	70	51.85
Female	233	51.55	65	48.15
Age, yr				
< 20	59	13.11	13	9.63
21 to 25	82	18.22	28	20.74
26 to 35	94	20.89	22	16.30
36 to 45	69	15.33	18	13.33
46 to 55	66	14.67	32	23.70
56 to 65	58	12.89	10	7.41
≥ 66	22	4.89	12	8.89
Working status				
Not employed	31	6.46	15	10.64
Full-time	246	51.25	70	49.65
Part-time	59	12.29	11	7.80
Student	144	30.00	45	31.91
Income, US$				
< 25,000	110	24.55	22	16.30
25,000 to 49,999	89	19.87	32	23.70
50,000 to 74,999	67	14.96	30	22.22
75,000 to 99,000	61	13.62	20	14.81
≥ 100,000	121	27.01	31	22.96
Food allergy				
No	428	94.69	126	93.33
Yes	24	5.31	9	6.67
Food manufacturer				
No	438	97.33	132	97.78
Yes	12	2.67	3	2.22
Ethnicity				
Caucasian	371	79.96	124	91.18
Hispanic	58	12.50	1	0.74
Asian or Pacific	9	1.94	6	4.41
Black	17	3.66	4	2.94
American Indian	6	1.29		
Other	3	0.65	1	0.74
Consume meat				
No	2	0.44	2	1.49
Yes	450	99.56	132	98.51

Table 6. Continued

Item	Retail		Foodservice	
	n	%	*n*	%
Meat types consumed				
Chicken	441	25.62	133	25.38
Pork	432	25.10	132	25.19
Beef	447	25.97	135	25.76
Fish	401	23.30	124	23.66
Overall beef consumption				
Daily	51	11.33	3	2.21
5 or more times per wk	89	19.78	31	22.79
3 or more times per wk	201	44.67	53	38.97
1 time per wk	93	20.67	42	30.88
1 time every 2wks	11	2.44	5	3.68
Less than once every 2 wks	5	1.11	2	1.47
At home beef consumption				
0 times per wk	15	3.38	6	4.38
1 time per wk	106	23.87	43	31.39
2 times per wk	108	24.32	28	20.44
3 times per wk	122	27.48	34	24.82
4 times per wk	43	9.68	14	10.22
5 or more times per wk	50	11.26	12	8.76
In restaurant beef consumption				
0 times per wk	17	3.84	11	8.46
1 time per wk	179	40.41	51	39.23
2 times per wk	126	28.44	45	34.62
3 times per wk	77	17.38	17	13.08
4 times per wk	17	3.84	3	2.31
5 or more times per wk	27	6.09	3	2.31
Degree of doneness				
Rare	20	4.42	13	9.29
Medium rare	180	39.74	54	38.57
Medium	130	28.70	39	27.86
Medium well	93	20.53	29	20.71
Well done	30	6.62	5	3.57
Purchase tendencies				
Grass-fed	59	11.55	33	20.63
Traditional	397	77.69	104	65.00
Aged	32	6.26	14	8.75
Organic	23	4.50	9	5.63

[1]Number of responses.

Table 7. Least squares means ± SE for sensory panel ratings[1] for retail steaks

Steak	n[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Top blade	67	6.9^{a} (±0.2)	7.5^{a} (±0.2)	7.7^{a} (±0.2)	6.5^{ab} (±0.2)	7.1^{a} (±0.2)
Ribeye, lip on, boneless	167	6.8^{a} (±0.1)	7.0^{b} (±0.1)	6.9^{bc} (±0.1)	6.5^{ab} (±0.1)	6.4^{b} (±0.2)
Ribeye, lip on, bone in	55	6.6^{ab} (±0.2)	6.6^{cd} (±0.2)	6.6^{cd} (±0.2)	6.6^{ab} (±0.2)	6.1^{bc} (±0.2)
Top loin, boneless	188	6.9^{a} (±0.1)	7.0^{bc} (±0.1)	7.0^{bc} (±0.1)	6.7^{a} (±0.1)	6.5^{b} (±0.1)
Top loin, bone in	38	6.8^{a} (±0.2)	6.8^{bcd} (±0.2)	6.8^{bcd} (±0.2)	6.8^{a} (±0.2)	6.4^{bc} (±0.3)
T-bone	67	6.6^{ab} (±0.2)	6.8^{bcd} (±0.2)	6.7^{cd} (±0.2)	6.5^{ab} (±0.2)	6.2^{bc} (±0.2)
Porterhouse	43	6.9^{a} (±0.2)	7.3^{ab} (±0.2)	7.3^{ab} (±0.2)	6.6^{ab} (±0.2)	6.5^{ab} (±0.2)
Top sirloin, boneless	168	6.4^{b} (±0.1)	6.6^{d} (±0.1)	6.5^{d} (±0.1)	6.2^{b} (±0.1)	6.0^{bc} (±0.1)
Top round	53	5.5^{c} (±0.2)	5.1^{e} (±0.2)	4.9^{e} (±0.2)	5.8^{c} (±0.2)	5.2^{d} (±0.2)
Bottom round	49	5.4^{c} (±0.2)	5.1^{e} (±0.2)	4.9^{e} (±0.2)	5.6^{c} (±0.2)	5.8^{cd} (±0.2)
P-value		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a-e]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number of steaks.

4.5 Foodservice consumer sensory evaluations

Table 8 reports least squares means for sensory panel ratings of foodservice steaks. Top loin and ribeye steaks generated higher ($P < 0.05$) consumer sensory panel ratings compared to top sirloin steaks in all categories. In addition, all sensory rating categories, including overall liking, tenderness liking, tenderness level, flavor liking, and juiciness liking were significant across the three cuts. This differs from the 2010 survey by Guelker et al. (2013), which did not report a statistical significance between cut and overall liking and flavor liking sensory panel ratings. Table 9 reported the average consumer sensory panel ratings of foodservice steak USDA grade groups. Tenderness level and tenderness like were significant while overall liking (P =0.0940), flavor liking (P =0.4934), and juiciness liking (P =0.1326) were not.

Table 8. Least squares means ± SE for sensory panel ratings[1] for foodservice steaks by cut

Steak	*n*[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Ribeye	79	7.0[a] (±0.1)	6.9[a] (±0.1)	6.8[a] (±0.2)	7.0[a] (±0.1)	6.4[a] (±0.2)
Top loin	65	7.1[a] (±0.2)	7.1[a] (±0.2)	7.0[a] (±0.2)	7.0[a] (±0.1)	6.5[a] (±0.2)
Top sirloin	67	6.5[b] (±0.2)	6.3[b] (±0.2)	6.2[b] (±0.2)	6.5[b] (±0.1)	5.5[b] (±0.2)
P-value		0.0100	0.0040	0.0063	0.0107	<0.0001

[a-b]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number of steaks.

Table 9. Least square means ± SE for sensory panel ratings[1] for foodservice steaks by USDA grade group

USDA grade group	*n*[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Prime	55	7.0 (±0.2)	7.2[a] (±0.2)	7.2[a] (±0.2)	6.8 (±0.2)	6.5 (±0.2)
Top Choice	62	6.9 (±0.2)	6.8[a] (±0.2)	6.6[b] (±0.2)	6.9 (±0.1)	6.2 (±0.2)
Low Choice	46	7.0 (±0.2)	6.8[a] (±0.2)	6.7[ab] (±0.2)	7.0 (±0.2)	6.1 (±0.2)
Select	48	6.5 (±0.2)	6.2[b] (±0.2)	6.1[b] (±0.2)	6.7 (±0.2)	5.7 (±0.2)
P-value		0.0940	0.0030	0.0026	0.4934	0.1326

[a-e]Least squares means in the same column without common superscript letters differ ($P<0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number of steaks.

Least squares means for sensory panel ratings of ribeye, top loin, and top sirloin steaks stratified by grade are reported in Tables 10, 11, and 12, respectively. Tenderness liking and tenderness level attributes were reported as significant for ribeye steaks stratified by grade. Prime was rated among the highest ($P < 0.05$) for consumer sensory panel ratings for tenderness like, whereas Top Choice and Select were among the lowest ($P < 0.05$). In regards to tenderness level ratings, Prime was rated higher ($P < 0.05$) in consumer panel ratings compared to Top Choice, Choice, and Select ribeye grades. Work by Guelker et al. (2013), reported Prime ribeye steaks as rated among the highest by consumers ($P < 0.05$) in all significant sensory attributes. Ungraded ribeye steaks were an additional grade category collected during the 2010 survey, and received among the lowest consumer ratings for overall liking, tenderness liking, and tenderness level ($P < 0.05$) (Guelker et al., 2013). Voges et al. (2007) reported a difference in consumer

preference for flavor liking, as consumers reported Select ribeye steaks highest ($P < 0.05$). Table 11 displays differences across grades were significant ($P < 0.05$) for the boneless top loin steaks in the tenderness level category only. Consumers viewed all grades of top loin steaks similarly ($P > 0.05$) when evaluating overall liking, tenderness liking, flavor liking and juiciness liking. Guelker et al. (2013) and Voges et al. (2007), both reported no significant difference across grades and sensory panel ratings for top loin foodservice steaks. In regards to top sirloin foodservice steaks reported in Table 12, there were no significant results in the comparison of all sensory ratings across all grades for top sirloin steaks. Guelker et al. (2013) reported differences ($P < 0.05$) in overall liking, flavor liking, and juiciness liking, as ungraded top sirloins received the highest consumer ratings. This may be due to tenderization or enhancement practices that the ungraded top sirloins may have received, but this information is not noted.

Table 10. Least squares means ± SE for sensory panel ratings[1] for foodservice ribeye steaks stratified by USDA grade group

USDA grade group	*n*[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Prime	20	7.3 (±0.3)	7.6[a] (±0.3)	7.7[a] (±0.3)	6.9 (±0.2)	7.0 (±0.3)
Top Choice	24	6.9 (±0.2)	6.9[b] (±0.3)	6.6[b] (±0.3)	7.0 (±0.2)	6.1 (±0.3)
Low Choice	15	7.2 (±0.3)	6.8[ab] (±0.3)	6.7[b] (±0.3)	7.4 (±0.3)	6.4 (±0.3)
Select	20	6.6 (±0.3)	6.1[b] (±0.3)	6.0[b] (±0.3)	6.8 (±0.2)	6.1 (±0.3)
P-value		0.1809	0.0032	0.0012	0.3650	0.1089

[a-c]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number. of steaks.

Table 11. Least squares means ± SE for sensory panel ratings[1] for foodservice top loin steaks stratified by USDA grade group

USDA grade group	*n*[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Prime	19	7.3 (±0.3)	7.7 (±0.3)	7.7[a] (±0.3)	6.9 (±0.2)	7.2 (±0.4)
Top Choice	18	7.2 (±0.3)	7.0 (±0.3)	6.8[b] (±0.3)	7.2 (±0.2)	6.8 (±0.4)
Low Choice	16	7.0 (±0.3)	7.0 (±0.3)	6.9[ab] (±0.3)	6.9 (±0.3)	6.2 (±0.4)
Select	12	6.8 (±0.3)	6.6 (±0.3)	6.4[b] (±0.4)	6.9 (±0.3)	5.8 (±0.5)
P-value		0.6487	0.0809	0.0479	0.8283	0.1211

[a-c]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number of steaks.

Table 12. Least squares means ± SE for sensory panel ratings[1] for foodservice top sirloin steaks stratified by USDA grade group

USDA grade group	*n*[2]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Juiciness like/dislike
Prime	16	6.6 (±0.3)	6.3 (±0.4)	6.1 (±0.4)	6.7 (±0.3)	5.2 (±0.4)
Top Choice	20	6.6 (±0.3)	6.6 (±0.3)	6.4 (±0.3)	6.6 (±0.3)	5.7 (±0.4)
Low Choice	15	6.7 (±0.4)	6.5 (±0.4)	6.4 (±0.4)	6.6 (±0.3)	5.6 (±0.4)
Select	16	6.1 (±0.3)	5.9 (±0.4)	6.0 (±0.4)	6.2 (±0.3)	5.3 (±0.4)
P-value		0.5670	0.6059	0.7163	0.7708	0.7378

[a-c]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

[1]Sensory panel ratings for like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy; flavor: 10 = extreme amount, 1 = none at all.

[2]Number of steaks.

4.6 Cook yields and times

Least squares means of cook yields and times for retail and foodservice steaks are reported in Table 13. There were no significant differences in cook yield ($P < 0.05$) in retail steaks. However, cook time was significant for retail steaks, with bottom round steaks taking the least amount of time to cook ($P < 0.05$) possibly due to the thinness of the retail cut. Porterhouse steaks took the longest ($P < 0.05$) time to cook, possibly due to the average thickness of the steaks and the presence of bone. A majority of boneless cuts took longer to cook compared to bone in cuts, possibly due to steak thickness. Foodservice steaks were significant ($P < 0.05$) in cook yield, as ribeye and top loin steaks had the highest percentage and top sirloin steaks were the lowest. Cook times were not significant ($P > 0.05$) within foodservice steaks.

Table 13. Least squares means ± SE for cook yields and times of retail and foodservice steaks.

Source/steak	Cook yield (%)	Cook times (s)
Retail		
Top blade	81.4 (±1.8)	912.2^{bc} (±95.8)
Ribeye, lip on, boneless	79.2 (±1.1)	1250.8^{a} (±61.2)
Ribeye, lip on, bone in	82.1 (±1.9)	1106.9^{ab} (±104.5)
Top loin, boneless	78.4 (±1.1)	1345.6^{a} (±58.5)
Top loin, bone in	81.7 (±2.2)	1202.8^{ab} (±121.4)
T-bone	82.8 (±1.8)	1271.6^{a} (±97.2)
Porterhouse	80.4 (±2.2)	1381.3^{a} (±117.3)
Top sirloin, boneless	77.7 (±1.1)	1324.9^{a} (±60.7)
Top round	78.5 (±2.1)	1238.8^{a} (±111.4)
Bottom round	78.4 (±2.1)	781.2^{c} (±111.4)
P-value	0.2349	<0.0001
Foodservice		
Ribeye	72.5^{a} (±0.6)	1263.8 (±32.5)
Top loin	74.0^{a} (±0.7)	1222.9 (±35.2)
Top sirloin	69.9^{b} (±0.7)	1246.6 (±35.5)
P-value	0.0003	0.6956

[a-c]Least squares means in the same column without common superscript letters differ ($P < 0.05$).

CHAPTER V

CONCLUSIONS

Most steaks evaluated in this survey increased in postfabrication aging time compared to the previous survey. This may be due in part to requirements of different branding programs or a change in managerial practices at the retail and processor level. The percentage of retail steaks labeled with a store brand or claim decreased from the previous two surveys.

Retail cuts decreased in WBSF values, compared to the previous tenderness survey, with the exception of T-bone, top round and bottom rounds steaks. Top loin and top sirloin foodservice steaks improved in average WBSF values. The numerical percentage of foodservice cuts presented in the "very tender" tenderness thresholds category has declined since the 2007 NBTS.

Retail consumer sensory panel results were similar to previous tenderness surveys as the top blade steak received high numerical ratings and the top and bottom round steak received among the lowest across all attributes. Foodservice consumer sensory panel ratings were also similar to previous findings.

Similar to the findings in previous tenderness surveys, cuts from the round require more industry attention in order to decrease average WBSF values and increase consumer acceptance. Consideration must also be taken regarding the single method of cooking for each of the cuts surveyed, as different forms of cooking may be more advantageous, depending on the cut. This leads to the importance of educating

consumers of the most beneficial methods of cooking various beef steaks. Retail and foodservice establishments may use these data as a current benchmark of US beef steak tenderness.

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APPENDIX A

FORM C

National Beef Tenderness Survey-2015
RETAIL-Store Survey

(Circle One)

Store #_____Chain_____ City_____ Date_____ Evaluation Team UF TAMU TTU UM NDSU

SELF SERVICE CASE								
Brands Available	***Claims****	***Enhanced Product*** *(circle one)*	***Tenderized*** *(circle one)*	***Quality Grades per Brand*** *(circle all that apply)*				
Retail Label Only:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
Store "Own" Brand:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
National/Other Brand 1:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
National/Other Brand 2:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
National/Other Brand 3:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
National/Other Brand 4:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed
National/Other Brand 5:		No Yes: _____% pump	No Yes	Prime	Top Choice	Choice	Select	No Grade Listed

*Claim Key		
Nat = Natural	DA = Dry Aged	AF = Antibiotic Free
Org = Organic	GF = Grass Fed	CT = Certified Tender
HF = Hormone Free	VF = Vegetarian Fed	ANG = Angus

Page 1 of 2

Entered by_____ Date_____ Checked by_____ Date_____

FORM C

National Beef Tenderness Survey-2015
RETAIL-Store Survey

Store #_____ Chain_____ City_____ Date_____ Evaluation Team (Circle One) UF TAMU TTU UM NDSU

FULL SERVICE CASE						
Brands Available	***Claims****	***Quality Grades per Brand*** *(circle all that apply)*				
Retail Label:		Prime	Top Choice	Choice	Select	No Grade Listed
Store "Own" Brand:		Prime	Top Choice	Choice	Select	No Grade Listed
Brand 1:		Prime	Top Choice	Choice	Select	No Grade Listed
Brand 2:		Prime	Top Choice	Choice	Select	No Grade Listed
Brand 3:		Prime	Top Choice	Choice	Select	No Grade Listed

FEATURED BEEF SALES			
	Retail Cut Name *(circle one)*	***Quality Grade of Sale Item*** *(circle all that apply)*	***Price per lb.*** *(check box if appl.)*
Sale 1:	TopBlade Ribeye Bl Ribeye BNLS Top Loin Bl Top Loin BNLS T-Bone Porterhouse Top Sirloin Top Round Bottom Round	Pr Top Ch Ch Se No Grade Listed	☐ with card
Sale 2:	TopBlade Ribeye Bl Ribeye BNLS Top Loin Bl Top Loin BNLS T-Bone Porterhouse Top Sirloin Top Round Bottom Round	Pr Top Ch Ch Se No Grade Listed	☐ with card
Sale 3:	TopBlade Ribeye Bl Ribeye BNLS Top Loin Bl Top Loin BNLS T-Bone Porterhouse Top Sirloin Top Round Bottom Round	Pr Top Ch Ch Se No Grade Listed	☐ with card

NOTES

Revised 09/17/2015

Page 2 of 2

Entered by_____ Date_____ Checked by_____ Date_____

FORM D

National Beef Tenderness Survey-2015
RETAIL-Box Information

Store #___________ Chain__________________ City__________________ Date_______________ Evaluation Team UF TAMU TTU UM NDSU

SUBPRIMAL/RETAIL CUT	***Bone-in/ Boneless (circle one)***	***Quality Grade (circle one)***	***Claim****	***Box Date (MM/DD/YYYY)***	***Establish-ment No.***
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			
TopBlade ShoulderClod Ribeye Strip Shortloin TButt TRnd BRnd	BI BNLS	Pr TopCh Ch Se NG			

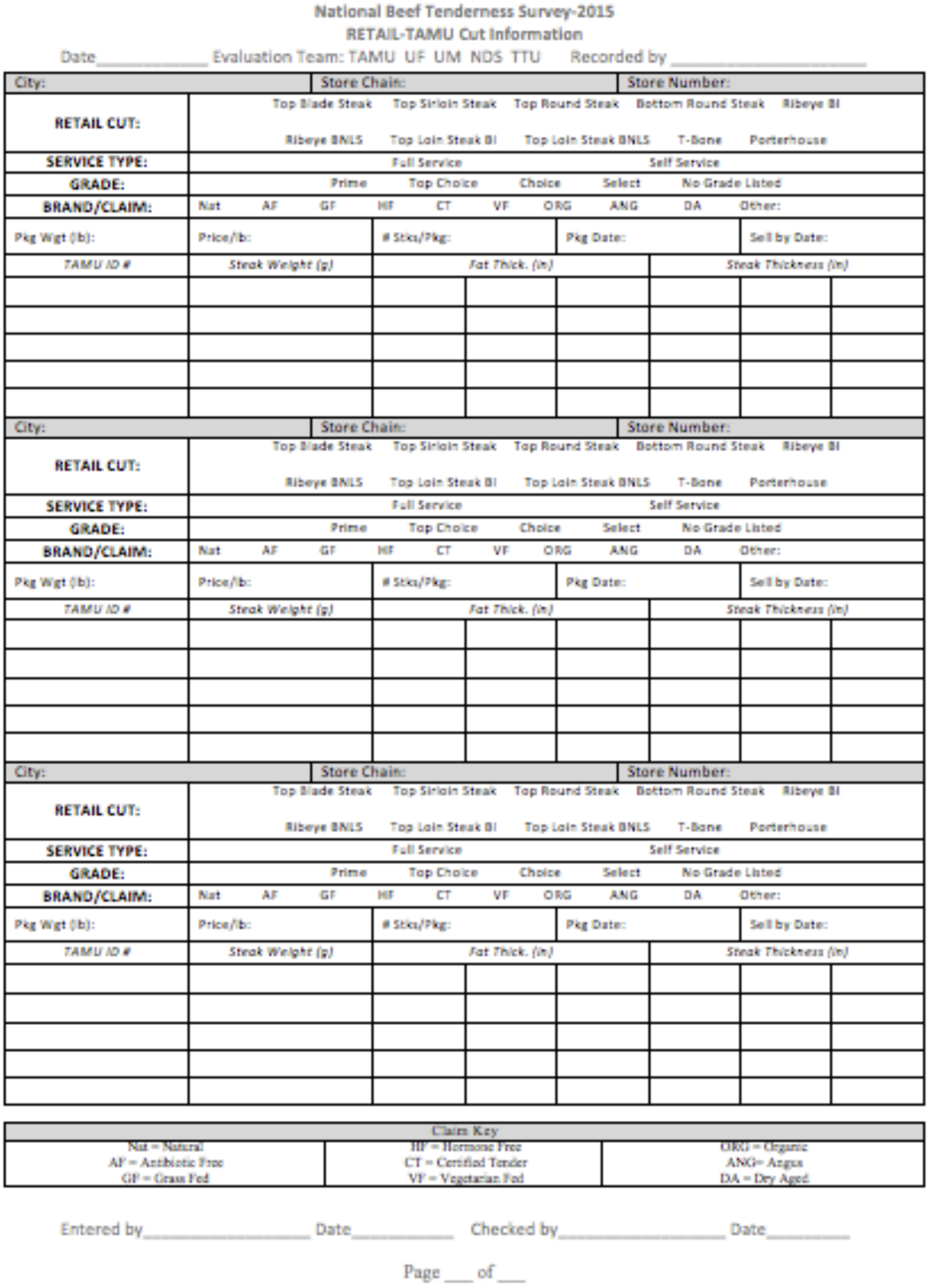
***Claim Key**

Nat = Natural Org = Organic HF = Hormone Free	DA = Dry Aged GF = Grass Fed VF = Vegetarian Fed	AF = Antibiotic Free CT = Certified Tender ANG = Angus

Revised 10/02/2015

Page ____ of ____

Entered by__________________________ Date________________ Checked by_______________________ Date____________



National Beef Tenderness Survey-2015

RETAIL-TAMU Cut Information

Date____________ Evaluation Team: TAMU UF UM NDS TTU Recorded by ____________________

City:		Store Chain:			Store Number:		
RETAIL CUT:	Top Blade Steak Top Sirloin Steak Top Round Steak Bottom Round Steak Ribeye BI Ribeye BNLS Top Loin Steak BI Top Loin Steak BNLS T-Bone Porterhouse						
SERVICE TYPE:	Full Service Self Service						
GRADE:	Prime Top Choice Choice Select No Grade Listed						
BRAND/CLAIM:	Nat AF GF HF CT VF ORG ANG DA Other:						
Pkg Wgt (lb):	Price/lb:	# Stks/Pkg:		Pkg Date:		Sell by Date:	
TAMU ID #	*Steak Weight (g)*	*Fat Thick. (in)*			*Steak Thickness (in)*		
City:		Store Chain:			Store Number:		
RETAIL CUT:	Top Blade Steak Top Sirloin Steak Top Round Steak Bottom Round Steak Ribeye BI Ribeye BNLS Top Loin Steak BI Top Loin Steak BNLS T-Bone Porterhouse						
SERVICE TYPE:	Full Service Self Service						
GRADE:	Prime Top Choice Choice Select No Grade Listed						
BRAND/CLAIM:	Nat AF GF HF CT VF ORG ANG DA Other:						
Pkg Wgt (lb):	Price/lb:	# Stks/Pkg:		Pkg Date:		Sell by Date:	
TAMU ID #	*Steak Weight (g)*	*Fat Thick. (in)*			*Steak Thickness (in)*		
City:		Store Chain:			Store Number:		
RETAIL CUT:	Top Blade Steak Top Sirloin Steak Top Round Steak Bottom Round Steak Ribeye BI Ribeye BNLS Top Loin Steak BI Top Loin Steak BNLS T-Bone Porterhouse						
SERVICE TYPE:	Full Service Self Service						
GRADE:	Prime Top Choice Choice Select No Grade Listed						
BRAND/CLAIM:	Nat AF GF HF CT VF ORG ANG DA Other:						
Pkg Wgt (lb):	Price/lb:	# Stks/Pkg:		Pkg Date:		Sell by Date:	
TAMU ID #	*Steak Weight (g)*	*Fat Thick. (in)*			*Steak Thickness (in)*		

Claim Key		
Nat = Natural AF = Antibiotic Free GF = Grass Fed	HF = Hormone Free CT = Certified Tender VF = Vegetarian Fed	ORG = Organic ANG= Angus DA = Dry Aged

Entered by__________________ Date___________ Checked by__________________ Date_________

Page ___ of ___

National Beef Tenderness Survey-2015
FOODSERVICE-TAMU Cut Information

Establishment_____ Chain_____ City_____ Date_____ Evaluation Team_____

Cut Name	TAMU ID	Steak Thickness (in)	Avg. Fat (in)	Grade	Brand	Tend	Stk. Weight (lb)	Pkg. Date	Box Date	Est. #	Misc.

Revised 08/13/2015

Entered by_____ Date_____ Checked by_____ Date_____

FORM E

National Beef Tenderness Survey-2015
FOODSERVICE-Information Form

Establishment_____ Chain_____ City_____ Date_____ Evaluation Team_____

Grade/Cut	Brand Designation	Claim	Pumped		Tenderization	
			Percentage Pumped	Sodium Content	Method	% Tenderized
Prime, Ribeye IMPS #1112A						
Top Choice, Ribeye IMPS #1112A						
Choice, Ribeye IMPS #1112A						
Select, Ribeye IMPS #1112A						
Prime, Top Loin Steak IMPS #1180						
Top Choice, Top Loin Steak IMPS #1180						
Choice, Top Loin Steak IMPS #1180						
Select, Top Loin Steak IMPS #1180						
Prime, Top Sirloin Butt IMPS #1184B						
Top Choice, Top Sirloin Butt IMPS #1184B						
Choice, Top Sirloin Butt IMPS #1184B						
Select, Top Sirloin Butt IMPS #1184B						

Revised 08/13/2015

Entered by_____ Date_____ Checked by_____ Date_____

FORM A

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM
CONSENT FORM

Project Title: National Beef Tenderness Survey - 2015

You are invited to take part in a research study being conducted by Dr. Jeffrey W. 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 to take part in the study, you will be asked to sign this consent form. 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?
The purpose of this study is to benchmark national beef tenderness.

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 750 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.

IRB NUMBER: IRB2015-0393
IRB APPROVAL DATE: 08/12/2015
IRB EXPIRATION DATE: 08/01/2020

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 Graduate Research Assistant Hillary Henderson at 832-457-6185 or hend4790@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.

STATEMENT OF CONSENT
I agree to be in this study and know that I am not giving up any legal rights by signing this form. The procedures, risks, and benefits have been explained to me, and my questions have been answered. I know that new information about this research study will be provided to me as it becomes available and that the researcher will tell me if I must be removed from the study. I can ask more questions if I want. A copy of this entire consent form will be given to me.

_____ _____
Participant's Signature Date

_____ _____
Printed Name Date

IRB NUMBER: IRB2015-0383
IRB APPROVAL DATE: 06/12/2015
IRB EXPIRATION DATE: 06/01/2020

INVESTIGATOR'S AFFIDAVIT:
Either I have or my agent has carefully explained to the participant the nature of the above project. I hereby certify that to the best of my knowledge the person who signed this consent form was informed of the nature, demands, benefits, and risks involved in his/her participation.

Signature of Presenter	Date
Printed Name	Date

IRB NUMBER: IRB2015-0393
IRB APPROVAL DATE: 06/12/2015
IRB EXPIRATION DATE: 06/01/2020

FORM B

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM
INFORMATION SHEET

Project Title: National Beef Tenderness Survey - 2015

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?
The purpose of this study is to benchmark national beef tenderness.

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 750 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.

IRB NUMBER: IRB2015-0383M
IRB APPROVAL DATE: 06/12/2015
IRB EXPIRATION DATE: 06/01/2016

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 Graduate Research Assistant Hillary Henderson at 832-457-6185 or hend4790@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

IRB NUMBER: IRB2015-0383M
IRB APPROVAL DATE: 08/12/2015
IRB EXPIRATION DATE: 08/01/2016

FORM E

Revised 3.9.16 ANA

National Beef Tenderness Survey 2015-2016
Consumer Panel Cooking Data

Cook Date: _____

Recorder:												
School Conducting Panel:						**Session Date:**				**Session Time:**		
TAMU ID #	**Group**	**Order**	**Random Number**	**Raw Weight (g)**		**Grill Temp (°C)**	**Temp On (°C)**	**Time On (24h)**		**Temp Off (°C)**	**Time Off (24h)**	**Cooked Weight (g)**

Entered by: _____ Date: _____ **Page __ of __** Checked by: _____ Date: _____

FORM C

Participant Number: _____

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

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

IRB NUMBER: IRB2015-0383
IRB APPROVAL DATE: 08/12/2015
IRB EXPIRATION DATE: 08/01/2020

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

FORM D

Participant Number _____
Sample Number _____

Group Time_____
Date_____

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Like Extremely

4. Indicate by placing a mark in the box your **LEVEL** of **TENDERNESS** of the meat product.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extremely Tough — Extremely Tender

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — Like Extremely

IRB NUMBER: IREC015-0369M
IRB APPROVAL DATE: 02/15/2016
IRB EXPIRATION DATE: 08/01/2020

Revised 3.9.16 ANA

National Beef Tenderness Survey 2015-2016
WBSF Cooking Data

Cook Date: _____

Recorder:									
TAMU ID #	**Raw Weight (g)**		**Grill Temp (°C)**	**Temp On (°C)**	**Time On (24h)**		**Temp Off (°C)**	**Time Off (24h)**	**Cooked Weight (g)**

Entered by: _____ Date: _____ **Page __ of __** Checked by: _____ Date: _____

National Beef Tenderness Survey: 2015-2016
Warner-Bratzler Shear Record

Recorded by _____ Date _____

TAMU ID	Shear 1	Shear 2	Shear 3	Shear 4	Shear 5	Shear 6	Shear 7	Shear 8	Shear 9	Shear 10

Revised 01/26/2016

Entered by _____ Date _____ **Page ____ of ____** Checked by _____ Date _____