TENDERNESS ASSESMENT OF BEEF STEAKS FROM US FOODSERVICE AND RETAIL ESTABLISHMENTS USING WARNER-BRATZLER SHEAR AND CONSUMER SENSORY PANEL RATINGS

A Thesis

by

MILES RYAN GUELKER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Animal Science

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Approved by:

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Committee Members, Rhonda K. Miller
Christopher Boleman
Head of Department, H. Russell Cross

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ABSTRACT

Tenderness Assessment of Beef Steaks from US Foodservice and Retail Establishments Using Warner-Bratzler Shear and Consumer Sensory Panel Ratings. (December 2011)

Miles Ryan Guelker, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Jeffrey W. Savell

Beef retail steaks from establishments in twelve US cities and beef foodservice steaks from establishments in five US cities were evaluated using Warner-Bratzler shear and consumer sensory panels. Postmortem aging times for retail establishments ranged from 1 to 358 d with a mean of 20.5 d, and those from foodservice establishments aging times ranged from 9 to 67 d with an average of 15.9 d. For retail, top blade had the lowest ($P < 0.05$) WBS values, while cuts from the round – top round and bottom round – had the highest ($P < 0.05$) WBS values. Top loin and ribeye steaks had the lowest ($P < 0.05$) WBS values compared to top sirloin foodservice steaks. Retail top blade steaks received the highest ($P < 0.05$) ratings by consumers for overall like, tenderness level, like tenderness, juiciness level, and like juiciness; and foodservice top loin steaks received the highest ($P < 0.05$) for tenderness level, like tenderness, flavor level, juiciness level, and like juiciness. USDA quality grade did have an effect on foodservice ribeye and top sirloin steaks for sensory panels. Prime foodservice ribeye steaks were rated highest ($P < 0.05$) for overall like, like tenderness, tenderness level, like juiciness, and juiciness level, whereas ungraded ribeye steaks were rated lowest ($P < 0.05$) for like tenderness and tenderness level. Ungraded foodservice top sirloin steaks were rated highest ($P < 0.05$) for overall like, like tenderness, like flavor, and like juiciness. Additional improvements to reduce the range of tenderness levels are necessary to increase consumer acceptability.

DEDICATION

I dedicate this work to my family and friends who have helped me become the person I am today. Without their unwavering support, none of this would have been possible.

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CHAPTER I

INTRODUCTION

There are a multitude of factors that determine consumer satisfaction of a beef steak, including tenderness, flavor, and juiciness. Each of these factors must be maximized in order to develop the most acceptable product and to maintain consumer confidence and trust. Throughout the years, different feeding regimens, management practices, additives, and processing technologies have influenced the eating quality of beef steaks. Meat protein sources are constantly competing to produce the best product, in terms of quality and safety, with the least input and at the lowest cost to the consumer. Consumer attitudes are constantly changing; therefore, it is important to track trends and perspectives in order to react. Additionally, it is imperative to establish any consequences new technologies exhibit on beef steaks.

The National Beef Tenderness Survey allows the industry to determine which cuts are acceptable to consumers, in terms of palatability, and to determine which cuts require additional improvement. This survey, which has been conducted in 1991, 1998, 2005, and 2010, offers valuable data to industry personnel and consumers. The National Cattlemen's Beef Association (NCBA) commissioned Texas A&M University to lead a cooperating effort with California Polytechnic State University, North Dakota State University, Oklahoma State University, Penn State University, Texas Tech University,

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Follows the style and format of *Meat Science*.

the University of Florida, and the University of Missouri. The objectives of this survey were to determine the tenderness of US foodservice and retail beef steaks using Warner – Bratzler shear force (WBS) and consumer sensory panels, to collect aging, branding, grade, tenderization, and enhancement information from store visits and product packaging, and to use moist-heat cookery for round cuts, in addition to grated, non-stick electric grills. The results and discussion of this thesis are based on the combined results of available data from collaborating universities.

CHAPTER II

REVIEW OF LITERATURE

The beef customer satisfaction studies revealed tenderness is an important component to consumers' eating experiences (Lorenzen et al., 1999; Neely et al., 1998, 1999; Savell et al., 1999). Factors that are attributed to determining beef palatability are tenderness, juiciness, and flavor, with tenderness being the driving factor in economic terms and meat quality since consumers are willing to pay a premium for guaranteed-tender meat products (Boleman et al., 1997; Dikeman, 1987; Miller, Carr, Ramsey, Crockett, & Hoover, 2001; Savell & Shackelford, 1992). The beef customer satisfaction studies were benchmark studies to relate production to the retail meat counter, and to determine if consumers were satisfied with beef palatability. Consumer ratings as influenced by types of beef steaks (top sirloin, top round, top loin), USDA quality grade groups (top Choice, low Choice, high Select, low Select), and US city (Chicago, IL; Houston, TX; Philadelphia, PA; San Francisco, CA) were assessed.

Neely et al. (1998) focused on the role of cut, USDA quality grade, and city on in-home consumer ratings. Top loin steaks were rated highest ($P < 0.05$) for all palatability attributes, and top round steaks were rated lowest ($P < 0.05$) for all palatability attributes. The highest USDA quality grade, Top Choice, was ranked highest ($P < 0.05$) for overall like of top loin and top round steaks. However, there was no cut × USDA quality grade interaction for overall like of top sirloin steaks. Consumers were not able to differentiate overall like differences between low Choice and high Select or between high Select and low Select of any steak type. Cut × city interaction was significant for all palatability attributes ($P < 0.05$), showing that consumer satisfaction of a cut is often driven by city-specific consumer attitudes.

The study by Lorenzen et al. (1999) involved cooking method and degree of doneness effects on the top loin steak. San Francisco and Philadelphia panelists cooked top loin steaks to a lower degree of doneness than panelists in Chicago and Houston, and outdoor grilling, followed by broiling, was the most prevalent cooking method in all cities. Consumers preferred top Choice steaks the most ($P < 0.05$), but consumers were unable to differentiate between low Choice and high Select and between high Select and low Select top loin steaks for overall like. Overall like scores were highest ($P < 0.05$) for steaks cooked to medium rare or lesser degrees of doneness. Ironically, consumers preferred ($P < 0.05$) medium and well done degrees of doneness over medium well for overall like. Juiciness ratings were influenced by quality grade as panelists rated top Choice steaks highest ($P < 0.05$) and low Select steaks lowest ($P < 0.05$). Panelists were not able to distinguish juiciness differences between low Choice and high Select. Top Choice and low Choice were rated highest ($P < 0.05$) for desirability of flavor, and low Select was rated lowest ($P < 0.05$). Consumers rated desirability of flavor highest ($P < 0.05$) for steaks cooked medium rare or less, and medium well was rated lowest ($P < 0.05$) for desirability of flavor. Additionally, intensity of flavor was highest ($P < 0.05$) for steaks cooked to medium rare or less. Consumers did not cook top loin steaks to a consistent degree of doneness; therefore, the variation of palatability factors for consumer satisfaction may be attributed to the consumer not understanding optimal methods of preparation to maximize satisfaction.

Savell et al. (1999) concentrated on cooking method and degree of doneness effects on the top sirloin steak. Top sirloin steaks were most often cooked to well done or higher degrees of doneness by outdoor grilling or broiling. USDA quality grade high Select was rated lowest ($P < 0.05$) for tenderness. Houston panelists rated top sirloin steaks highest for tenderness ($P < 0.05$) and San Francisco the lowest ($P < 0.05$). Cooking method × degree of doneness effect on tenderness and cooking method × degree of doneness effect on juiciness were significant ($P < 0.05$) and showed the highest ratings at medium rare or less degree of doneness.

Neely et al. (1999), focusing on cooking method and degree of doneness effects on the top round steak, found that moist-heat cookery methods produced higher consumer palatability ratings for top round steaks, which is expected due to the higher amount of connective tissue inherent to the cut. Consumers in Houston rated top round steaks highest ($P < 0.05$) for overall like, and panelists from Philadelphia rated top round steaks lowest for overall like ($P < 0.05$). Higher ratings were given to steaks cooked to lower degrees of doneness, regardless of the grade or cooking method; however, well done was the most prevalent degree of doneness in all cities. Data show customer satisfaction of the top round steak was dependent upon cooking method and city-specific attitudes.

Behrends et al. (2005), looking at USDA quality grade and marination effects on consumer evaluations of top round steaks, found that grilling was the most common form of cooking, and medium well or higher degrees of doneness was the most prevalent endpoint cooking temperature. Top Choice top round steaks received higher ratings than high Select for overall like ($P < 0.001$), tenderness ($P = 0.004$) , juiciness ($P = 0.003$) , and like flavor ($P < 0.0001$). Overall like was highly ($P < 0.0001$) correlated to tenderness, juiciness, like flavor, and amount of flavor. Philadelphia consumers that used braising cookery method rated steaks higher ($P < 0.05$) for all palatability attributes compared to any cookery method used by consumers in Chicago. Additionally, marination × degree of doneness and cooking method × degree of doneness interactions were found.

Lorenzen et al. (2003) reported trained sensory panel ratings and WBS force values. Top loin was rated the highest ($P < 0.05$) for overall tenderness and cooked beef flavor intensity by the panel. Top sirloin was rated the highest ($P < 0.05$) for flavor intensity. Top round was rated the lowest ($P < 0.05$) for overall tenderness, flavor intensity, and cooked beef flavor intensity. Additionally, top round was reported as having the most ($P < 0.05$) connective tissue across all USDA quality grades compared to other cuts. There was a clear division ($P < 0.05$) for low Choice and top Choice top loin and top round steaks compared to high Select and low Select.

The beef customer satisfaction studies indicate a great challenge to the beef industry. City-specific marketing should be employed to realize the highest return of investment as each city presents different preferences. Cooking method and degree of doneness varies with each city, and these consumer-controlled areas influence the eating experience and satisfaction of a steak. Consumer education of appropriate cooking methods should be undertaken by the market to ensure the best eating experience.

Luchak et al. (1998) reported sensory, chemical, and cooking characteristics of retail beef cuts differing in intramuscular and external fat. It was determined that, regardless of the cut, a lower internal temperature endpoint resulted in higher panel ratings for juiciness, muscle fiber tenderness, and overall tenderness, in addition to lower WBS values. Thus, the lower internal temperature endpoint would help ensure consumer satisfaction.

Sullivan and Calkins (2011) analyzed published literature for WBS values and sensory ratings of beef steaks. A Pearson correlation coefficient of WBS and sensory tenderness means of -0.84 ($P = 0.001$) was reported. This reasserts the predictability of consumer satisfaction of beef steak tenderness with WBS values and it allows the industry to identify a multitude of cuts which may underutilized.

Retail cuts from the rib and loin are highly marketable because of the traditional association with higher palatability attributes. However, retail cuts from the chuck and the round are often used for ground beef because of the higher connective tissue content of the muscles, generating a fraction of the possible revenue (Belew, Brooks, McKenna, & Savell, 2003; Harris, Miller, Savell, Cross, & Ringer, 1992). In addition, there has been a paradigm shift of the American consumer from planning a meal in advance and cooking roasts to have for several days to now preferring quicker, more convenient meals (Huffman et al., 1996). For this reason, it is in the best interest of the beef industry to salvage and market those retail cuts from the chuck and the round that are tender and to identify the retail cuts from all primals that need to be improved from a tenderness standpoint.

Belew et al. (2003) conducted WBS force evaluations of 40 bovine muscles to determine tenderness categories of different muscles. Tenderness categories were based on confidence intervals reported by Shackelford, Morgan, Savell, and Cross (1991); cuts were placed into one of the following groups: “very tender” (WBS < 3.2 kg (31.4 N)) , “tender” (3.2 kg (31.4 N) < WBS < 3.9 kg (38.2 N)), “intermediate” (3.9 kg (38.2 N) < WBS < 4.6 kg (45.1 N)), “tough” (WBS > 4.6 kg (45.1 N)). The *M. infraspinatus*, the muscle of the top blade steak, and the *M. psoas major*, a muscle in the porterhouse and T-bone steak, were placed into the “very tender” category. The *M. longissimus thoracis*, *M. longissimus lumborum*, and the *M. gluteus medius*, a muscle of the ribeye steak, a muscle of the top loin, and a muscle of the top sirloin, respectively, were placed into the “tender” category. The *M. gluteobiceps*, a muscle of the bottom round, and the *M. semimembranosus*, a muscle of the top round, were among the toughest muscles and were placed in the intermediate category. All of the cuts were prepared on flat-top grills, a form of dry-heat, which is not the ideal form of cooking for cuts from the round due to the inherently higher amounts of connective tissue.

Kolle et al. (2004) looked at effects of blade tenderization, enzymatic tenderization, and salt/phosphate injection (enhancement) on tenderness of individual muscles of the beef round when cooked using dry and moist-heat. Salt/phosphate injection resulted in the lowest ($P < 0.05$) WBS force values for dry-heat cookery, and each tenderization method resulted in lower ($P < 0.05$) WBS force values; however, few differences were observed with moist-heat cookery. Control moist-heat cookery steaks had a higher prevalence of steaks in the “very tender” and “tender” categories used by

Belew et al. (2003) compared to dry-heat cookery steaks; thus, there was less room for improvement in tenderness for the moist-heat steaks.

In 1990, Texas A&M University conducted the first National Beef Tenderness Survey to determine the tenderness of various beef cuts in the retail case using Warner-Bratzler shear (WBS) force and trained sensory panels (Morgan et al., 1991). Although the survey showed problems with beef tenderness, more importantly, it gave the industry a benchmark in order to improve tenderness. National average postfabrication aging times for the chuck, rib, loin, and round primals were 15, 18, 20, and 16 d, respectively. Average postfabrication aging times for all retail cuts was 17 d, with a range of 3 to 90 d. From the chuck primal, mean WBS values for all cuts was 3.72 kg (36.5 N). WBS values were lowest ($P < 0.05$) for top blade steak at 3.05 kg (29.9 N). Roasts from the chuck tended to have lower WBS values and higher sensory panel ratings than their steak counterparts. This may be due to the longer cooking time required for roasts which allows for the solubilization of collagen. For cuts from the rib and loin primal, mean WBS values for all cuts were 3.36 kg (33.0 N) and 3.17 kg (31.1 N), respectively. WBS force values and palatability ratings were similar ($P > 0.05$) for all cuts, with the exception of the tenderloin steak that possessed the lowest ($P < 0.05$) average WBS force value at 2.61 kg (25.6 N), and had the highest palatability ratings for overall tenderness ($P < 0.05$) and connective tissue amount ($P < 0.05$). Top sirloin steak was the toughest ($P < 0.05$) cut from the loin, 3.56 kg (34.9 N), and had the lowest palatability ratings for overall tenderness ($P < 0.05$) and connective tissue amount ($P < 0.05$). Round cuts had the highest ($P < 0.05$) overall mean WBS values at 4.31 kg (42.3 N). Top round steak had the highest ($P < 0.05$) mean WBS values, 5.23 kg (51.3 N), and the lowest palatability ratings for myofibrillar tenderness ($P < 0.05$) and overall tenderness ($P < 0.05$). Round tip roasts were more tender ($P < 0.05$) than other round cuts. For the rib and loin, the percentage of cuts which would have WBS values greater than 4.6 kg (45.1 N), "tough" category, was 8.0% and 5.3%, respectively. Additionally, ribeye steaks had the highest percentage of cuts in the "tough" category, 10.2%, and tenderloin steaks had the lowest percentage, 1.8%. The chuck had a much higher percentage of cuts that had WBS values above 4.6 kg (45.1 N) at 15.3%. The percentage of top blade steaks which possessed WBS values above 4.6 kg (45.1 N) was 3.6%. The round, arguably the toughest primal, possessed the largest percentage (35.8) of cuts that had a WBS value above 4.6 kg (45.1 N). The percentage of top round steaks and bottom round steaks that would be classified as "tough" was 70.1% and 41.3%, respectively. Since 1991, numerous antemortem and postmortem programs aimed at increasing beef tenderness have been verified and utilized by the meat industry as part of an ongoing effort to increase consumer satisfaction and confidence in the beef product.

In the successive surveys of 1998 and 2005, foodservice cuts were added, and a consumer sensory panel was used instead of a trained sensory panel because it is the consumers abilities to distinguish among tenderness levels that will ultimately determine the success of the retail cut, in addition to Warner-Bratzler shear force (Brooks et al., 2000; Miller et al., 2001; Morgan et al., 1991; Voges et al., 2007)

The 1998 survey revealed many improvements in beef steak tenderness and changes in marketing. The chuck roll, top round and eye of round steaks possessed the least ($P <$

0.05) amount of external fat compared to other cuts. Steaks from the loin had more external fat than other retail steaks. Steaks originating from the rib and loin were similar in steak thickness, while bottom round steaks were among the thinnest ($P < 0.05$) steaks at 1.62 cm. At the foodservice level, ribeye and top loin steaks were similar in external fat thickness, and top butt steaks had considerably less ($P < 0.05$) external fat. Ribeye steaks were cut the thinnest ($P < 0.05$) and top butt steaks were cut the thickest ($P < 0.05$). With the 1991 survey showing top sirloin steaks to be tougher than other steaks from the loin primal, the increase in steak thickness might have been the industry's attempt to increase tenderness since the thicker steak would require longer cooking times. Mean subprimal postfabrication aging times for all cuts at the retail level was 19 d, with a range of 2 to 61 d. Bone-in strip loins had the shortest aging times, while bone-in ribeyes had the longest aging times. Lorenzen et al. (1998) reported that a 14 d aging time optimizes tenderness of all steaks. Bone-in strip loins also had the highest percentage of subprimals aged less than 14 d, 45.5%, while all subprimals from the chuck had the lowest percentage of cuts aged less than 14 d, 26.7%. Subprimal postfabrication aging times at the foodservice level ranged from 5 to 67 d, with a mean of 32 d. All top sirloin steaks were aged for more than 14 d; however, the percentage of boneless ribeye, bone-in ribeye, and strip loin subprimals aged less than 14 d was 20.0%, 33.3%, and 26.7%, respectively. Overall, approximately one-third of retail subprimals and one-fifth of foodservice subprimals were not aged optimally. For retail subprimals from the rib and loin, USDA quality grade affected ($P < 0.05$) WBS values for T-bone/porterhouse steaks, but had no effect on ribeye, top loin, or top sirloin steaks. All ribeye and top loin steaks in each USDA quality grade group had WBS values ≤ 3.0 kg (29.4 N), except for top loin steaks in the Prime quality grade group. USDA quality grade had no effect on WBS values of steaks derived from the chuck and round primals ($P > 0.05$). For foodservice steaks, USDA quality grade did not have an effect on WBS values of top loin steaks; however, all quality grade groups had WBS values below 2.62 kg (25.7 N). Prime ribeye steaks had the lowest ($P < 0.05$) WBS values compared to all other quality grade groups of ribeye steaks. There were no differences in WBS values of ribeye steaks from Top Choice, Choice, Select, and No Roll quality grade categories. Top Choice sirloin steaks had lower ($P < 0.05$) WBS values than Choice and No Roll top sirloin steaks, but Top Choice did not differ ($P > 0.05$) from Prime top sirloin steaks. Compared to the 1991 survey, a considerably lower percentage of steaks had WBS values above 4.6 kg (45.1 N) and were classified as "tough". The percentage of ribeye, porterhouse, T-bone, top loin and top sirloin steaks that had WBS values above 4.6 kg (45.1 N) were 1.5%, 1.8%, 0.0%, 0.7%, and 0.8%, respectively. Furthermore, the percentage of top round and bottom round steaks with a WBS value above 4.6 kg (45.1 N) was 15.4% and 52.6%, respectively. The sharp decreases in WBS values above 4.6 kg (45.1 N) can be partially attributed to advancements made in antemortem and postmortem tenderization practices and methods. Prime retail ribeye steaks were rated highest ($P < 0.05$) for overall like than all other quality grade groups evaluated. Sensory ratings for retail top sirloin, clod, and top round steaks did not differ among USDA quality grade groups. There were no differences observed for foodservice top loin, top sirloin, or ribeye steaks among the various USDA quality grade groups.

The 2005 survey updated information from previous surveys and detailed changes that had been introduced in the industry. Subprimal postfabrication aging times at the retail level ranged from 3 to 83 d, with an average of 22.6 d. For all subprimals, a total of 19.6% were aged less than 14 d. Top round had the highest percentage of subprimals aged less than 14 d, 46.4%, and bone-in ribeyes had the lowest percentage of subprimals aged less than 14 d, 3.0%. At the foodservice level, mean postfabrication aging times for all subprimals was 30.1 d, with a range of 7 to 136 d. A total of 29.5% of subprimals were aged less than 14 d at the foodservice level, with ribeyes making up the largest portion aged less than 14 d, 37.2%. At the retail outlet, external fat thickness was lowest ($P < 0.05$) for top round steaks and highest for T-bone steaks ($P < 0.05$). Retail bottom round steaks were the thinnest ($P < 0.05$) steaks and boneless ribeye, bone-in ribeye, top loin, and bone-in top loin steaks were the thickest ($P < 0.05$). Foodservice top sirloin steaks possessed the least ($P < 0.05$) amount of external fat. Furthermore, foodservice top sirloin steaks were cut the thickest ($P < 0.05$), whereas ribeye steaks were cut the thinnest ($P < 0.05$). Retail bottom round steaks possessed the highest ($P < 0.05$) mean WBS values at 36.0 N (3.7 kg), while retail boneless top loin steaks possessed the lowest ($P < 0.05$) WBS values at 20.8 N (2.1 kg). Foodservice top loin steaks had the lowest ($P < 0.05$) mean WBS values; however, there was no difference in mean WBS values of foodservice ribeye and top sirloin steaks. For retail steaks, 100.0% of bone- ribeye steaks and bone-in top loin steaks were classified as “very tender” and had a WBS value less than 31.4 N (3.2 kg). Additionally, boneless ribeye, boneless top loin, T-bone, and porterhouse steaks had at least 90.0% classified in the “very tender” category. Only the

T-bone, top round steak, bottom round steak, and eye of round steak exhibited WBS values over 38.3 N. Furthermore, only round cuts (top round, bottom round, eye of round) were shown to have WBS values above 45.1 N (4.6 kg) and be classified in the "tough" category. Retail bone-in top loin, boneless top loin, ribeye, T-bone, and porterhouse received the highest ($P < 0.05$) sensory ratings for overall like and like tenderness. Conversely, round cuts, including the top round, bottom round, and eye of round, received the lowest ($P < 0.05$) sensory ratings for overall like and like tenderness. Bone-in top loin and porterhouse received the highest ($P < 0.05$) ratings for tenderness, while cuts from the round received the lowest ($P < 0.05$) tenderness scores from the panel. Bone-in ribeye, boneless ribeye, top loin, bone-in top loin, T-bone, and porterhouse steaks received the highest sensory ratings for like flavor and beef flavor, whereas the top round, bottom round, and eye of round steaks were often rated lowest by the consumer panel. Foodservice 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. No differences were observed for like flavor and beef flavor in foodservice steaks. Stratifying each foodservice cut into USDA quality grade groups revealed USDA Select ribeye steaks received higher ($P < 0.05$) ratings for like flavor than other quality grades. No other palatability differences were found across quality grade groups for ribeye steaks. Furthermore, no differences in palatability characteristic ratings were found among grade groups for top loin steaks. Prime top sirloin steaks received higher ($P < 0.05$) ratings than other quality grade groups for tenderness and juiciness. The continuous monitoring of beef tenderness through the surveys has allowed the industry to make comparisons and improve beef cut tenderness for a high return of investment.

The National Beef Tenderness Survey – 2010 was conducted much in the same manner as previous surveys. One alteration was the collection of steaks throughout a 12-month time frame to help account for possible seasonality of product in retail and foodservice outlets. Another major addition was using moist-heat cookery as a cooking method for retail cuts from the round. The three previous surveys have consistently shown that round cuts were the least tender compared to cuts from the rib and loin. The choice of common grilling methods to cook all retail cuts was so that data could be compared across cuts and years. However, electric grills used in the surveys are not the most advantageous to the round cuts. With moist-heat, the added water ensures that the collagen is completely hydrolyzed (Aberle, Forrest, Gerrard, & Mills, 2001; Kolle et al., 2004). Therefore, in order to maintain accurate data to compare, round cuts were cooked using the electric grills; in addition, a subsample of round cuts were cooked using moist-heat cookery. Another feature of the present survey was to collect samples from wholesale clubs to gather information from these sources that are of increasing importance in beef marketing. It was our goal to modify the protocols followed in the tenderness surveys to make them relevant, but to continue to collect some of the same historic information so that our measures of tenderness can be compared from year to year.

CHAPTER III

MATERIALS AND METHODS

3.1. Product selection

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; San Francisco, CA; Denver, CO; Las Vegas, NV; Tampa, FL; Atlanta, GA; Kansas City, MO; Houston, TX; Chicago, IL; and Seattle, WA. Over a 12-month time period, each city was sampled once between March 2010 and February 2011.

In each city, two to three retail chains, representing at least one-third of the total area market share, were sampled for product in four stores per chain; thus, a total of 8 to 12 supermarket stores per metropolitan area were sampled. In addition, if a club retail store existed in the city and was not included in the one-third market share, one store of the club chain representing the largest market share was sampled. Representatives of the National Cattlemen's Beef Association's retail marketing team assisted with identifying and obtaining permission from the retail chains that were surveyed. Corporate retail contacts were asked to propose the individual retail stores of their respective chain to sample. Store managers were notified of the impending sampling visit and dates and times were coordinated between each individual store and the university responsible for sampling.

Within each store, brand names and grades of product available, as well as postfabrication aging times, as a measure postmortem age, were recorded. Retail cuts were shipped overnight to Texas A&M University in insulated containers with dry ice and were processed under refrigerated conditions (2-4 °C) upon arrival. Steaks were removed from store packaging and all information available was recorded, including brand designation, marketing claims, enhancement with percentage pumped, sodium content, and form of tenderization, along with any other important information. Each steak was measured for average external fat thickness and steak thickness, identified individually, vacuum-packaged, and frozen at -40 °C. Average external fat thickness was determined by calculating the average of three separate fat thickness measurements in order to best represent the entire steak. Steak thickness was taken by one measurement in the middle of the steak.

The following cuts were sampled from the retail case and Universal Product Code (UPC) (Industry-Wide Cooperative Meat Identification Standards Committee, 2003) was used for naming: top blade steak (URMIS 1166); ribeye steak, lip on, boneless (URMIS 1203); ribeye steak, lip on, bone-in (URMIS 1197); top loin steak, boneless (URMIS 1404); top loin steak, bone-in (URMIS 1398); T-bone steak (URMIS 1369); porterhouse steak (URMIS 1330); top sirloin steak, boneless, cap off (URMIS 1426); top round steak (URMIS 1553); and bottom round steak (URMIS 1466).

Steaks were assigned randomly to be used either for WBS evaluation or for consumer sensory panels using a random number generator of Microsoft Excel. After freezing, steaks assigned to consumer sensory panels were randomly assigned to one of eight collaborating universities using the random number generator of Microsoft Excel. Steaks were shipped overnight in insulated containers with dry ice to the designated university.

In five cities (Houston, TX; Tampa, FL; Denver, CO; Las Vegas, NV; Philadelphia, PA), collaborators also sampled one foodservice establishment, evaluating each USDA quality grade of subprimals that the establishment fabricated into steaks. Postfabrication aging times were recorded, along with brand designation, marketing claims, enhancement (with percentage pumped), sodium content, and method of tenderization. Steaks were shipped to Texas A&M University and were processed under the same conditions as the retail cuts. The following cuts were sampled from foodservice establishments and Institutional Meat Purchase Specifications (IMPS) (USDA, 1996) descriptions were used for naming: ribeye roll steak (IMPS 1112); top loin steak, boneless (IMPS 1180); and top sirloin butt steaks, center-cut, boneless (IMPS 1184B).

Foodservice steaks were vacuum packaged, frozen, and shipped to the University of Missouri in the same manner as retail cuts. Steaks were assigned randomly by Texas A&M University to be used either for WBS evaluation or for consumer sensory panels using random number generator of Microsoft Excel. In the instance that an enhanced and non-enhanced pair of steaks from the same subprimal was available, enhanced and non-enhanced steaks were divided evenly and randomly to be used for WBS or consumer sensory panel.

3.2. Dry-heat cookery

Steaks were thawed in a 4 °C cooler for 48 hours prior to cooking. Steaks from the round were assigned randomly to be cooked using moist-heat cookery in a convection oven or on a grated, non-stick electric grill (Hamilton Beach™ Indoor/Outdoor Grill). All other retail cuts were cooked on grated, non-stick electric grills. The grills were pre-heated 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 yield percentages were determine from weights recorded before and after cooking, and total cooking time was recorded for individual steaks. All retail steaks were flipped upon reaching an internal temperature of 35 °C, and steaks were removed from the cooking surface upon reaching an internal temperature of 70 °C. After achieving 70 °C, steaks were weighed, and then placed on a tray. Overlapping was avoided. Cooked steaks were covered with plastic wrap before being placed in a cooler for approximately 12 h at 2-4 °C. Internal temperature was monitored with a thermocouple (Omega™ HH501BT, Stamford, CT) using a 0.02 cm diameter, iron-constantan Type-T thermocouple wire. Cook yield was determined by the following equation:

$$\textit{Cook yield (\%)} = (\textit{cooked weight} / \textit{raw weight}) \times 100$$

3.3. Moist-heat cookery

A subset of top round and bottom round steaks were allocated to moist-heat cookery. Cooking yield percentages were determine from weights recorded before and after cooking, and total cooking time was recorded for individual steaks. Steaks from the round were cooked using moist-heat cookery in a convection oven using a Calphalon Everyday Nonstick 8½ or 6-Quart Dutch oven (anodized aluminum). Steaks were thawed in a 4 °C cooler for 48 hours prior to cooking. The oven was pre-heated for 15 min to an approximate temperature of 177 °C. After achieving 70 °C, steaks were removed from the oven, weighed, and then placed on a tray. Overlapping was avoided. Cooked steaks were covered with plastic wrap before being placed in a cooler for approximately 12 h at 2-4 °C. Internal temperature was monitored with a thermocouple (Omega^{TM} HH501BT, Stamford, CT) using a 0.02 cm diameter, iron-constantan Type-T thermocouple wire.

3.4. Warner – Bratzler shear

Steaks for WBS were cooked in the same manner as consumer sensory panel steaks. Cooking yield percentages were determine from weights recorded before and after cooking, and total cooking time was recorded for individual steaks. Steaks were trimmed of visible connective tissue to expose muscle fiber orientation. At least six 1.3 cm cores were removed from each muscle. 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 removed parallel to the muscle fibers and 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 an 11.3 kg load cell, and a 1.02 cm thick V-shape 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 mean peak shear force of the cores was used for statistical analysis. WBS values were converted using the following equation:

$$WBS\ force\ (N) = WBS\ force\ (kg) \times 9.80665002864$$

3.5. Consumer panel

Consumer sensory panels were conducted at Texas A&M University, Oklahoma State University, Texas Tech University, University of Florida, Penn State University, University of Missouri, and North Dakota State University. Panelists were recruited from surrounding communities by randomly calling possible participants and verifying they were suitable and willing consumers. A demographic questionnaire was filled out and a consent form was signed by each panelist. Steaks were assigned randomly to serving days using a random number generator. Each panelist was given unsalted crackers and distilled water between samples. Each panelist received two 1.27 cm cubes of each sample and evaluated eight random samples during the session. Samples were characterized using 10-point scales 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 flavor (10 = like extremely; 1 = dislike extremely), level of beef flavor (10 = extremely 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).

3.6. Statistical analysis

Data were analyzed using PROC means, and mean separation was conducted for significance between treatments, when appropriate, using PROC GLM with Pdiff option with an alpha-level ($P < 0.05$) (SAS Institute, Inc., Cary, North Carolina).

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Post-fabrication aging times

Subprimal post-fabrication aging times at retail establishments averaged 20.5 d (Table 1) with a range of 1-358 d. The average is lower than found by Voges et al. (2007) with an average of 22.6 d. The range of aging times is wider than found by Voges et al. (2007) with a range of 3-83 d, Brooks et al. (2000) with a range of 2-61 d, and Morgan et al. (1991)with a range of 3-90 d. Bone-in ribeye steaks had the lowest percentage of boxes aged less than 14 d, whereas eye of rounds had the highest percentage. The mean percentage of subprimals aged less than 14 d was 35.7, which is higher than the 19.6% reported for NBTS 2006 (Voges et al., 2007).

Post-fabrication aging times for subprimals at the foodservice level (Table 2) revealed an average aging time of 28.1 d. This is similar to the times reported by Voges et al. (2007), with an average aging time of 30.1 d. The range of aging times for all subprimals was 9-67 d, with each subprimal having a similar range. These data show a narrower range in aging time than did Voges et al. (2007).

Table 1
Post-fabrication aging times (d) for subprimal cuts audited in the cold storage facilities of retail stores

Subprimal	*n*[a]	Mean	SD	Min[b]	Max[c]	% <14 d[d]
Shoulder clod	175	20.3	10.4	1	51	27.2
Ribeye roll	221	19.6	13.6	2	112	34.8
Bone-in ribeye	90	31.5	37.4	6	358	11.1
Strip loin	232	21.6	24.9	2	334	36.2
Bone-in strip loin	79	29.5	17.0	2	69	20.0
Short loin	163	19.1	15.1	2	91	44.2
Top sirloin	250	20.3	10.4	1	51	32.4
Top round	190	16.4	9.8	2	47	46.6
Bottom round	128	17.2	10.1	3	63	41.5
Eye round	100	17.3	12.8	5	76	48.5
Overall	1628	20.5	17.5	1	358	35.7

[a] *n* = number of packages.
[b] Min = minimum value.
[c] Max = maximum value.
[d] % <14 d = percentage of subprimals aged less than 14 d.

Table 2
Post-fabrication aging times (d) for subprimal cuts audited at the foodservice level

Subprimal	*n*[a]	Mean	SD	Min[b]	Max[c]	% <14 d[d]
Ribeye	144	29.3	16.1	13	67	10.5
Top loin	144	29.8	15.7	9	61	15.8
Top sirloin	120	24.7	15.5	9	66	6.2
Overall	408	28.1	15.9	9	67	11.4

[a] *n* = number of packages.
[b] Min = minimum value.
[c] Max = maximum value.
[d] % <14 d = percentage of subprimals aged less than 14 d.

4.2. Product information

Approximately 64% of retail cuts were labeled with a store brand. Steak thickness, external fat thickness, and steak weight are reported in Table 3. Steaks from the rib and loin were cut the thickest ($P < 0.05$), while steaks from the round and chuck were cut the thinnest ($P < 0.05$). Top sirloin steaks were cut the thickest at 2.89 cm compared to the thinnest steak, bottom round, which was cut at 1.59 cm. Mean external fat thickness ranged from 0.12, top round, to 0.49, bone-in top loin steak.

Foodservice steak thickness, external fat thickness, and steak weight are reported in Table 4. Top sirloin steaks possessed less ($P < 0.05$) fat when compared to ribeye steaks and top loin steaks. Top loin steaks weighed the least ($P < 0.05$) at 0.33 kg and top sirloin steaks were the heaviest at 0.40 kg. Steak thickness averaged between 2.91 and 2.95 cm. External fat thickness means are higher than those found by Voges et al. (2007).

4.3. Warner – Bratzler shear force

WBS values for retail cuts are reported in Table 5. Bottom round and top round steaks had the highest ($P < 0.05$) WBS values compared to all other cuts. Top blade had the lowest WBS values compared to all other cuts. These data are similar to those

Table 3
Least squares means ± standard errors for steak thickness, external fat thickness, and steak weight of retail cuts

Steak	n^a	Steak thickness, cm	External fat thickness, cm	Steak weight, kg
Top blade	123	1.75±0.06f	0.15±0.02f	0.17±0.01h
Ribeye, lip-on, bnls	200	2.79±0.05a	0.45±0.02abc	0.38±0.01e
Ribeye, lip-on, bone-in	77	2.53±0.08cd	0.47±0.03ab	0.45±0.02cd
Top loin	181	2.77±0.05ab	0.42±0.02bcd	0.31±0.01f
Top loin, bone-in	71	2.59±0.08bc	0.49±0.03a	0.37±0.02e
T-bone	125	2.44±0.06cd	0.41±0.02cd	0.49±0.01bc
Porterhouse	48	2.33±0.10d	0.48±0.03ab	0.52±0.02ab
Top sirloin, bnls, cap off	258	2.88±0.04a	0.38±0.01de	0.43±0.01d
Top round	110	2.07±0.06e	0.12±0.02f	0.58±0.02a
Bottom round	113	1.59±0.06f	0.33±0.02e	0.24±0.02g
P > F		<0.0001	<0.0001	<0.0001

Within a column, means lacking a common letter (a-h) differ ($P < 0.05$).
[a] *n* = number of steaks

Table 4
Least squares means ± standard errors for steak thickness, external fat thickness, and steak weight of foodservice cuts

Steak	n^a	Steak thickness, cm	External fat thickness, cm	Steak weight, kg
Ribeye	152	2.95±0.03	0.42±0.04a	0.36±0.02ab
Top loin	168	2.91±0.03	0.50±0.04a	0.33±0.02b
Top sirloin	144	2.94±0.03	0.32±0.04b	0.40±0.02a
P > F		0.7356	0.0042	0.0229

Within a column, means lacking a common letter (a and b) differ ($P < 0.05$).
[a] *n* = number of steaks

reported by Voges et al. (2007), which stated the shoulder, eye of round, top round, and bottom round had the highest WBS at 27.8, 33.2, 29.6, and 36.0 N, respectively. Additionally, Voges et al. (2007) reported top loin, bone-in top loin, bone-in ribeye, T-bone, and porterhouse steaks to have the lowest WBS values. Enhanced steaks did not differ ($P > 0.05$) from the non-enhanced counterparts. Although the WBS values were unaffected, enhancement may have played a role in other palatability attributes.

Least squares means for WBS values of foodservice cuts are presented in Table 6. Top loin and ribeye steaks had lower ($P < 0.05$) WBS values compared to top sirloin steaks. All cuts had low WBS values, which agrees with Voges et al. (2007).

Tenderness categories developed by Belew et al. (2003) and Shackelford et al. (1991) are based on WBS values and were used to determine percentage of retail (Table 7) and foodservice (Table 8) cuts that fell into each category. Top round, bottom round, bone-in top loin, and boneless top loin steaks were found to have WBS values over 45.1 N. The total percentage of top round and bottom round cuts with a WBS value over 45.1 N is lower than that reported in the 2006 survey, but no other steaks were found to have a WBS value over 45.1 N by Voges et al. (2007). A higher percentage of cuts were found to have lower WBS values compared to Voges et al. (2007), however, the range of tenderness within the steak type is wider. Consistent cooking methods allowed for the comparison of tenderness between cuts sampled in 2006. However, the single cooking method did not allow to optimize different cooking methods for certain cuts that contain higher amounts of connective tissue (Brooks et al., 2000).

Top loin steaks had the highest percentage of steaks in the “very tender” category, WBS < 31.4 N. Top sirloin steaks had the highest percentage of steaks in the “tender”, “intermediate”, and “tough” categories, 31.4-38.3, 38.3-45.1, and >45.1 N, respectively. Least squares means for WBS values of foodservice cuts stratified by USDA quality grade are reported in Table 9. Prime had the lowest ($P < 0.05$) mean WBS value, and Select and ungraded had the highest ($P < 0.05$) mean WBS value. These data differ from that reported by Voges et al. (2007), which did not find significant differences across grades for WBS values. However, differences were found by Brooks et al. (2000) for ribeye and top sirloin steaks.

Table 5
Least squares means and standard errors (SE) for Warner – Bratzler shear values (N) of retail steaks

Steak	n[a]	Mean, N	SE
Top blade	52	21.5b	1.0
Ribeye, lip-on, bnls	84	24.2b	0.7
Ribeye, lip-on, bone-in	31	23.9b	1.2
Top loin	79	23.3b	0.8
Top loin, bone-in	29	24.6b	1.2
T-bone	48	23.1b	1.0
Porterhouse	20	23.6b	1.5
Top sirloin, bnls, cap off	103	24.1b	0.7
Top round	44	29.8a	1.0
Bottom round	45	31.2a	1.0
P > F		<0.0001	

Within a column, means lacking a common letter (a and b) differ ($P < 0.05$).
[a] n = number of steaks

Table 6
Least squares means and standard errors (SE) for Warner – Bratzler shear values (N) of foodservice steaks

Steak	n[a]	Mean, N	SE
Ribeye	77	27.3b	0.7
Top loin	84	25.8b	0.7
Top sirloin	72	30.2a	0.7
P > F		<0.0001	

Within a column, means lacking a common letter (a and b) differ ($P < 0.05$).
[a] n = number of steaks

Table 7
Percentage distribution of retail steaks stratified into tenderness categories

Steak	"Very Tender" WBS < 31.4 N	"Tender" 31.4 N < WBS < 38.3 N	"Intermediate" 38.3 N < WBS < 45.1 N	"Tough" WBS > 45.1 N
Top blade	91.89	5.41	2.70	
Ribeye, lip- on, bnls	95.45	4.55		
Ribeye, lip-on, bone-in	95.65	4.35		
Top loin	84.78	10.87	2.17	2.17
Top loin, bone-in	71.74	15.22	8.70	4.35
T-bone	95.56	4.44		
Porterhouse	91.11	8.89		
Top sirloin, bnls, cap off	91.11	6.67	2.22	
Top round	76.09	13.04	6.52	4.35
Bottom round	47.37	23.68	23.68	5.26

Table 8
Percentage distribution of foodservice steaks stratified into tenderness categories

Steak	"Very Tender" WBS < 31.4 N	"Tender" 31.4 N < WBS < 38.3 N	"Intermediate" 38.3 N < WBS < 45.1 N	"Tough" WBS > 45.1 N
Ribeye	81.08	14.86	4.05	
Top loin	83.78	13.51		2.70
Top sirloin	58.11	32.43	5.41	4.05

Table 9
Least squares means ± standard errors for Warner – Bratzler shear values (N) of foodservice steaks by USDA quality grade

USDA grade		
Prime	25.1c	0.8
Top Choice	27.4b	0.8
Low Choice	26.6bc	0.7
Select	30.6a	0.8
Ungraded	31.9a	1.4
P > F	<0.0001	

Within a column, means lacking a common letter (a-c) differ ($P < 0.05$).

Table 10
Demographic attributes of consumers that participated in the retail (universities combined) and foodservice sensory panels

Item	Retail		Foodservice	
	n	%	*n*	%
	1019		144	
Age, yr				
<20	46	4.68	20	13.89
20-29	303	30.86	32	22.22
30-39	127	12.93	22	15.28
40-49	168	17.11	27	18.75
50-59	255	25.97	26	18.06
≥60	83	8.45	17	11.81
Income, US$				
<20,000	279	28.73	41	29.08
20,000-29,000	125	12.87	27	19.15
30,000-39,000	133	13.70	16	11.35
40,000-49,000	122	12.56	21	14.89
50,000-59,000	133	13.70	19	13.48
≥60,000	179	18.43	17	12.06
Gender				
Male	370	37.68	74	51.39
Female	612	62.32	70	48.61
Working status				
Not employed	88	8.84	12	8.05
Full-time	136	13.65	21	14.09
Part-time	536	53.82	80	53.69
Student	236	23.69	36	24.16
Ethnicity				
Caucasian	875	89.29	121	82.88
Black	31	3.16	5	3.42
Hispanic	19	1.94	3	2.05
American Indian	32	3.27	1	0.68
Asian or Pacific Islander	6	0.61	11	7.53
Other	17	1.73	5	3.42

Table 10 Continued

Item	Retail		Foodservice	
	n	%	*n*	%
Household				
1	187	19.06	25	17.36
2	326	33.23	68	47.22
3	200	20.39	26	18.06
4	177	18.04	16	11.11
5	57	5.81	8	5.56
≥6	34	3.47	1	0.69
Beef Use				
At home				
0	39	3.99	5	3.47
1	137	14.01	24	16.67
2	279	28.53	39	27.08
3	293	29.96	48	33.33
4	161	16.46	17	11.81
5	69	7.06	11	7.64
≥6				
Restaurant				
0	34	3.47	19	13.10
1	210	21.43	66	45.52
2	437	44.59	36	24.83
3	186	18.98	10	6.90
4	65	6.63	12	8.28
5	48	4.90	2	1.38
≥6				
Degree of doneness				
Rare	25	2.53	9	6.16
Medium rare	365	36.94	53	36.30
Medium	256	25.91	43	29.45
Medium well	242	24.49	35	23.97
Well done	100	10.12	6	4.11
Cooking method				
Broiling	68	6.71	3	2.03
Panbroiling	29	2.86	4	2.70
Panfrying	50	4.94	10	6.76
Roasting	67	6.61	15	10.14
Braising	14	1.38	3	2.03

Table 10 Continued

Item	Retail		Foodservice	
	n	%	*n*	%
Stewing	28	2.76	4	2.70
Grilling	757	74.73	109	73.65
Microwave	0	0.0	0	0.0

4.4. Retail consumer sensory evaluations

Consumer demographic information is reported in Table 10 for retail and foodservice consumer panelists. Data from all collaborating universities conducting consumer sensory panels were combined. Least squares means for sensory panel ratings of retail steaks is presented in Table 11. Top blade steak received the highest ($P < 0.05$) ratings by consumers for overall like, like tenderness, tenderness level, like juiciness, and juiciness level. The top blade and boneless ribeye received the highest ($P < 0.05$) 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. This concurs with data reported by Voges et al. (2007). Steaks from the rib, loin, and chuck were consistently rated highest ($P < 0.05$) for like flavor, flavor level, like juiciness, and juiciness level, whereas steaks from the sirloin and round were rated the lowest ($P < 0.05$) for the same attributes. This agrees with Voges et al. (2007) which exhibited the same trend.

Table 11

Least squares means ± standard errors for sensory panel ratings (like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; flavor: 10 = extreme amount, 1 = none at all) for retail steaks

Steak	*n*[a]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Flavor level	Juiciness like/dislike	Juiciness level
Top blade	267	6.4±0.1a	6.8±0.1a	6.8±0.1a	6.3±0.1a	6.1±0.1ab	6.5±0.1a	6.5±0.1a
Ribeye, lip-on, bnls	439	6.3±0.1ab	6.3±0.1b	6.2±0.1b	6.3±0.1a	6.2±0.1a	6.0±0.1b	5.8±0.1b
Ribeye, lip-on, bone-in	182	5.9±0.1cd	6.1±0.1bc	6.1±0.1bc	5.7±0.1c	5.6±0.1cd	5.7±0.1bc	5.7±0.1bc
Top loin, bnls	421	6.1±0.1abc	6.2±0.1bc	6.2±0.1b	6.1±0.1ab	6.1±0.1ab	5.9±0.1b	5.8±0.1b
Top loin, bone-in	149	6.1±0.1abc	6.2±0.2bc	6.2±0.2bc	5.9±0.1bc	5.9±0.1abc	5.9±0.1b	5.7±0.1bcd
T-bone	346	5.9±0.1cd	5.9±0.1cd	5.8±0.1cd	5.9±0.1bc	5.9±0.1bc	5.7±0.1bc	5.7±0.1bc
Porterhouse	148	5.9±0.2bcd	6.0±0.2bcd	5.9±0.2bcd	6.1±0.2ab	6.2±0.2ab	5.6±0.2bcd	5.6±0.2bcd
Top sirloin, bnls	706	5.7±0.1d	5.6±0.1d	5.6±0.1d	5.7±0.1c	5.7±0.1c	5.5±0.1cd	5.5±0.1cde
Top round	278	5.1±0.1e	5.0±0.1e	5.0±0.1e	5.2±0.1d	5.3±0.1d	5.3±0.1d	5.3±0.1de
Bottom round	251	5.1±0.1e	5.0±0.1e	5.0±0.1e	5.2±0.1d	5.3±0.1d	5.3±0.1d	5.2±0.1e
P > F		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Within a column, means lacking a common letter (a-e) differ ($P < 0.05$).

[a] *n* = number of steaks

4.5. Foodservice consumer sensory evaluations

Least squares means for sensory panel ratings of foodservice steaks are reported in Table 12. Top loin steaks received the highest (*P* < 0.05) rating for most attributes, including like tenderness, tenderness level, flavor level, like juiciness, and juiciness level. Voges et al. (2007) found that top loin steaks, in addition to ribeye steaks, were rated the highest. Least squares means for sensory panel ratings of ribeye, top loin, and top sirloin steaks stratified by grade are reported in Tables 13, 14, and 15, respectively. USDA Choice and ungraded ribeye steaks received the lowest (*P* < 0.05) ratings for overall like than did all other grades. USDA Prime ribeye steaks received the highest (*P* < 0.05) ratings for overall like, like tenderness, tenderness level, like juiciness, and juiciness level. This differs from Voges et al. (2007) and Brooks et al. (2000), which did not find any differences for ribeye steaks across quality grade groups, other than like flavor. No differences were found among grade groups for top loin steaks, which agrees with Voges et al. (2007) and Brooks et al. (2000), which did not find any differences across grades for sensory panel ratings. Ungraded top sirloin steaks received the highest (*P* < 0.05) ratings for overall like, like flavor, and like juiciness than other grades, which may be attributed to tenderization and enhancement practices. This differs from Voges et al. (2007), which found that Prime top sirloin steaks received the highest ratings for like tenderness and juiciness level.

Table 12
Least squares means ± standard errors for sensory panel ratings (like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; flavor: 10 = extreme amount, 1 = none at all) for foodservice steaks

Steak	*n*[a]	Overall like/dislike	Tenderness like/dislike	Tenderness level	Flavor like/dislike	Flavor level	Juiciness like/dislike	Juiciness level
Ribeye	152	6.8±0.1	6.8±0.1b	6.8±0.1b	6.8±0.1	6.7±0.1b	6.6±0.1b	6.6±0.1b
Top loin	144	7.3±0.1	7.5±0.1a	7.4±0.1a	7.2±0.1	7.2±0.1a	7.2±0.1a	7.1±0.1a
Top sirloin	168	7.0±0.1	6.9±0.1b	6.8±0.1b	7.0±0.1	6.9±0.1b	6.9±0.1ab	6.8±0.1ab
$P > F$		0.0591	<0.0001	0.0004	0.1544	0.0238	0.0037	0.0029

Within a column, means lacking a common letter (a and b) differ ($P < 0.05$).
[a] *n* = number of steaks

Table 13

Least squares means ± standard errors for sensory panel ratings (like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; flavor: 10 = extreme amount, 1 = none at all) for foodservice ribeye steaks stratified by USDA grade

Sensory rating	Group					P > F
	Prime	Top Choice	Low Choice	Select	Ungraded	
n[a]	32	32	40	40	8	
Overall like/dislike	7.5±0.2a	6.9±0.2ab	6.6±0.2b	7.0±0.2ab	6.1±0.4b	0.0155
Tenderness like/dislike	7.8±0.2a	7.4±0.2ab	6.8±0.2c	7.1±0.2bc	5.1±0.4d	<0.0001
Tenderness level	7.8±0.2a	7.3±0.2ab	6.7±0.2b	7.1±0.2b	5.0±0.5c	<0.0001
Flavor like/dislike	7.1±0.2	6.9±0.3	6.7±0.2	7.0±0.2	6.5±0.5	0.6311
Flavor level	7.0±0.2	7.0±0.2	6.6±0.2	6.7±0.2	6.3±0.5	0.4991
Juiciness like/dislike	7.4±0.3a	6.4±0.3b	6.1±0.2b	6.7±0.2ab	6.7±0.5ab	0.0042
Juiciness	7.4±0.3a	6.2±0.3b	6.0±0.2b	6.6±0.2ab	6.6±0.5ab	0.0015

Within a row, means lacking a common letter (a-d) differ ($P < 0.05$).

[a] *n* = number of steaks

Table 14
Least squares means ± standard errors for sensory panel ratings (like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; flavor: 10 = extreme amount, 1 = none at all) for foodservice top loin steaks stratified by USDA grade

Sensory rating	Group					P > F
	Prime	Top Choice	Low Choice	Select	Ungraded	
n[a]	32	47	40	40	9	
Overall like/dislike	7.2±0.2	7.4±0.2	7.1±0.2	7.2±0.2	7.8±0.5	0.7116
Tenderness like/dislike	7.6±0.2	7.6±0.2	7.5±0.2	7.6±0.2	7.2±0.5	0.9430
Tenderness level	7.5±0.2	7.3±0.2	7.5±0.2	7.5±0.2	7.0±0.5	0.8458
Flavor like/dislike	7.0±0.2	7.3±0.2	7.1±0.2	7.0±0.2	7.6±0.5	0.7020
Flavor level	7.0±0.2	7.4±0.2	7.1±0.2	7.0±0.2	7.5±0.5	0.4651
Juiciness like/dislike	7.2±0.3	7.0±0.2	7.2±0.2	6.9±0.2	7.6±0.5	0.6755
Juiciness	7.1±0.3	6.9±0.2	7.2±0.2	7.0±0.2	7.6±0.5	0.7593

[a] *n* = number of steaks

Table 15
Least squares means ± standard errors for sensory panel ratings (like/dislike: 10 = like extremely, 1 = dislike extremely; tenderness: 10 = very tender, 1 = not at all tender; juiciness: 10 = very juicy, 1 = not at all juicy; flavor: 10 = extreme amount, 1 = none at all) for foodservice top sirloin steaks stratified by USDA grade

Sensory rating	Group					*P* > F
	Prime	Top Choice	Low Choice	Select	Ungraded	
n[a]	32	32	40	24	16	
Overall like/dislike	6.9±0.2b	6.7±0.2b	7.0±0.2b	6.7±0.3b	7.9±0.3a	0.0308
Tenderness like/dislike	6.7±0.3	6.5±0.3	7.1±0.2	6.6±0.3	7.5±0.4	0.1377
Tenderness level	6.7±0.2	6.5±0.3	7.2±0.2	6.6±0.3	7.3±0.3	0.1905
Flavor like/dislike	6.8±0.2b	6.7±0.2b	6.8±0.2b	6.9±0.3b	7.8±0.3a	0.0278
Flavor level	6.6±0.2	6.8±0.2	6.7±0.2	6.7±0.3	7.6±0.3	0.1390
Juiciness like/dislike	6.7±0.2b	6.5±0.2b	6.9±0.2b	6.8±0.3b	7.7±0.3a	0.0332
Juiciness	6.7±0.2	6.6±0.2	6.8±0.2	6.9±0.3	7.1±0.3	0.7102

Within a row, means lacking a common letter (a and b) differ ($P < 0.05$).
[a] *n* = number of steaks

4.6. Moist-heat cookery

WBS values were not decreased (*P* > 0.05) by moist-heat cookery methods (Table 16). For all moist-heat cookery steaks, the mean WBS value was 32.5 N. For bottom round steaks the mean WBS value was 36.4 N, while top round steaks were 30.3 N. Compared to non-enhanced steaks cooked with dry-heat, the top round steaks were similar in mean WBS value, and the bottom round steaks had a higher mean WBS value.

Table 16
Mean WBS values of top round and bottom round steaks cooked with dry-heat and moist-heat

	Moist-heat cookery		Dry-heat cookery	
	Mean, N	SD	Mean, N	SD
Top round	30.3	8.9	30.0	8.8
Bottom round	36.4	5.2	31.2	8.0

4.7. Cook yields and times

Least squares means of cook yields and times for retail steaks are reported in Table 17. T-bone steaks had the highest (*P* < 0.05) cooking yield of retail steaks, while top sirloin steaks had the lowest (*P* < 0.05) yield. Cooking times were longest (*P* < 0.05) for boneless ribeye and T-bone steaks and shortest (*P* < 0.05) for bottom round steaks. Bone-in steaks, generally, had higher cooking yields; however, they required longer cooking times. Least squares means of cook yields and times for foodservice steaks are reported in Table 18. There were no differences (*P* > 0.05) in cook for cook yield of foodservice steaks; however, top loin steaks required the longest (*P* < 0.05) cook times.

Cook yield differences between retail and foodservice steaks can be attributed to altitude and humidity differences inherent to the location of the universities.

Table 17
Least squares means ± standard errors for cook yields and times of retail steaks

Steak	Cook yield (%)	Cook time (s)
Top blade	82.0±0.7bcd	946±74bc
Ribeye, lip- on, bnls	82.7±0.6bcd	1194±58a
Ribeye, lip-on, bone-in	83.4±0.9abc	1155±93ab
Top loin, bnls	83.8±0.6ab	1039±60ab
Top loin, bone-in	84.2±1.0ab	1100±98ab
T-bone	84.7±0.7a	1157±72a
Porterhouse	82.7±1.1abcd	1149±114ab
Top sirloin, bnls	81.1±0.5d	1148±51ab
Top round	81.4±0.8cd	1058±78ab
Bottom round	82.3±0.7bcd	747±76c
P > F	0.0008	0.0004

Within a column, means lacking a common letter (a-c) differ ($P < 0.05$).

Table 18
Least squares means ± standard errors for cook yields and times of foodservice steaks

Steak	Cook yield (%)	Cook time (s)
Ribeye	75.1±0.8	1172±46b
Top loin	74.9±0.8	1309±46a
Top sirloin	71.1±0.8	1184±48ab
P > F	0.0704	0.0005

Within a column, means lacking a common letter (a and b) differ ($P < 0.05$).

CHAPTER V

CONCLUSIONS

Most steaks evaluated in this study were considered tender. When compared to previous surveys, not all WBS values decreased, however, all of the WBS values are similar to those in the 2006 survey. This may be due to increased attention given to cuts from the round since the last survey, and a possible plateau of beef tenderness. Numerous programs focusing on beef tenderness are evident and will continue to play a role in maximizing beef tenderness and consumer satisfaction.

The extended aging times at the retail level may be attributed to the economy. The subprimals with aging times greater than those reported in previous surveys, bone-in ribeye and boneless strip loin, are not the most inexpensive cuts and with the decreased level of disposable income in the US, these cuts may have been discriminated against due to the cost to the consumer. Possibly, the subprimals were held frozen for an extended period of time before being sold; however, there is not a means to determine if this was, in fact, the case.

Although round cuts had the highest WBS values, more attention may need to be focused on consumer education of proper preparation and cooking techniques to ensure consumer satisfaction. Retail and foodservice establishments will use these data as a benchmark of current US beef tenderness.

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