CONSUMER ACCEPTANCE AND SHEAR FORCE VALUES OF TOP SIRLOIN STEAKS PREPARED USING SOUS VIDE VERSUS FLAT-TOP GRILL COOKERY METHODS

A Thesis

by

JENNA LEA HUNT

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Chair of Committee,	Jeffrey W. Savell
Co-Chair of Committee,	Kerri B. Gehring
Committee Member,	Chris R. Kerth
Head of Department,	G. Cliff Lamb

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ABSTRACT

This study compared consumer acceptance ratings and tenderness measurements of aged (14, 28, and 35 d) top sirloin butt steaks prepared with one of following treatments: (1) Non-blade tenderized, cooked via sous vide (internal temperature of 63 °C for 90 min), chilled, reheated; (2) Non-blade tenderized, cooked via sous vide, (internal temperature of 58 °C for 150 min), chilled, reheated; (3) Blade tenderized, cooked on flat-top grill (internal temperature of 70 °C); (4) Non-blade tenderized, cooked on flat-top grill (internal temperature of 70 °C). Steaks from the sous vide treatment with a lower temperature, longer time, and blade tenderized steaks cooked on a flat-top grill differed ($P < 0.05$) in Warner-Bratzler Shear force values at 14 and 35 d age when compared to other cooking treatments. No differences ($P > 0.05$) in consumer panelist ratings for flavor liking and juiciness liking were seen between cooking treatments regardless of aging times. Consumer panelists' scores for tenderness liking were highest ($P < 0.002$) for steaks cooked via sous vide at a lower temperature, and longer time when aged for 14 d. Consumer panelists' visual appraisal scores showed differences ($P < 0.004$) in steaks aged for 28 d. However, no ($P > 0.05$) differences in consumer panelists' visual appraisal scores for steaks aged for 14 or 35 d were found. Additionally, no ($P > 0.05$) differences were seen in consumer panelist visual ratings for steak presentation or overall liking of interior surfaces. Data from this study can be used to benefit the foodservice industry by providing insight on sous vide cooking of beef top sirloin steaks compared to other traditional cookery methods.

DEDICATION

This work is dedicated to my parents. Thank you for providing me with the opportunity to pursue my graduate degree. Your endless support, encouragement, and love will never go unnoticed.

Above all, I dedicate this work to the Almighty God. Thank You for Your grace and guidance, and for giving me the wisdom, strength, power of mind and the determination to pursue my study. With You, all things are possible.

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NOMENCLATURE

d	day
ºC	degrees Celsius
cm	centimeter
FSIS	Food Safety and Inspection Service
g	gram
h	hour
IMPS	Institutional Meat Purchase Specifications
kg	kilogram
M.	muscle
min	minute
NBTS	National Beef Tenderness Survey
N	Newton
USDA	United States Department of Agriculture
WBS	Warner-Bratzler Shear

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CHAPTER I

INTRODUCTION

According to the 2015 National Beef Tenderness Survey (Martinez et al., 2017), top sirloin steaks destined for foodservice had lower consumer panel ratings for all sensory attributes and higher shear force values than ribeye and top loin steaks. While blade tenderization can be used to improve the tenderness of top sirloin steaks (George-Evins, Unruh, Waylan, & Marsden, 2004), it presents a food safety concern because pathogens can be translocated from the surface to the interior of the steak (Luchansky, Phebus, Thippareddi, & Call, 2008; Ray et al., 2010). From a foodservice standpoint, this creates a potential risk for consumers who order their steaks cooked to a lower degree of doneness. Sous vide, a French term that translates to ‘under vacuum,’ uses a low temperature-long time relationship in cooking that might improve consistency of tenderness in the top sirloin steaks. Sous vide cooking involves placing the food product in a heat-stable package, sealing it under a vacuum, and then immersing it into a hot water bath at precisely controlled temperature and time conditions (Baldwin, 2012). The products can be served directly from the package after cooking, reverse seared/browned and served, or chilled for subsequent reheating or serving cold. Sous vide cooking has been used by chefs in restaurants for many years, however, the technology could potentially be used on a larger scale by further processors before products are sold to foodservice, thereby, reducing cook times in a restaurant.

CHAPTER II

REVIEW OF LITERATURE

2.1. History of top sirloin steaks

As the increase for brand-identified retail beef products continues to grow across the beef industry, the need for higher quality beef products also has escalated. The result of these expectations from the producers and packers has inadvertently spread to consumers, who also have increased their standards of beef quality and the eating experience that is provided. Eating quality, or palatability of beef, can be directly related to several factors. Tenderness is the most important factor that affects beef palatability (George-Evins et al., 2004). Research has shown that consumers can identify differences in tenderness and are willing to pay more for beef that is more tender (Boleman et al., 1997; Miller, Carr, Ramsey, Crockett, & Hoover, 2001). Of all beef steaks offered at the foodservice level, top sirloin steaks are known to be among the toughest from the rib and loin and vary most in terms of tenderness. Top sirloin steaks are typically known to be a less expensive option on restaurant menus compared to other beef steaks, making them a more desirable choice financially. Research regarding the tenderness and other related factors of top sirloin steaks dates back several decades. Through the 1990 National Beef Tenderness Survey (NBTS), top sirloin steaks were found to be the least tender cut, in conjunction with lower sensory panel ratings compared to other beef steaks from the loin (Morgan et al., 1991). During the 1998 NBTS, Choice top sirloin steaks were found to have the highest numerical Warner- Bratzler shear (WBS) force values (Brooks et al., 2000), yet WBS force values were lower than what was reported in the 1990 NBTS previously mentioned. In 2005, the NBTS reported that foodservice top sirloin steaks ranked evenly with ribeye steaks in terms of WBS force values, but had lower consumer ratings for overall like/ dislike, like/ dislike tenderness, tenderness, like juiciness, and juiciness than ribeye and top loin steaks (Voges et al., 2007). Voges et al. (2007) also reported that foodservice top sirloin steaks had the highest numerical percentage of steaks qualifying as both "tender" and "tough." These data could support the need for a cooking method that decreases variability across top sirloin steaks. The 2010 NBTS showed that food service top sirloin steaks were found to once again have the highest WBS force values compared to other foodservice steaks from the loin and rib, but were ranked lower than steaks derived from the round, a noticeably less tender primal (Guelker et al., 2013). According to the 2015 NBTS, top sirloin steaks destined for foodservice had lower consumer panel ratings for all sensory attributes than ribeye and top loin steaks (Martinez et al., 2017). However, the 2015 NBTS did show WBS values of top sirloin steaks to decrease from previous surveys, proposing that over time, top sirloin steaks have become slightly more tender (Martinez et al., 2017).

A constant challenge within the beef industry is improving tenderness while decreasing variation. Several technologies that assist with improving tenderness and decreasing variation have been developed and used for decades. One of the most popular technologies across the industry is mechanical tenderization, known as blade/ needle tenderization (George-Evins et al., 2004; King et al., 2009). The process is performed on products in the raw state, as either subprimals, wholesale cuts or steaks. Blade tenderization uses a set of blades to penetrate through muscle tissue, causing disruption of the muscle fibers and connective tissue, thus improving tenderness. Research has shown that the use of blade tenderization can improve tenderness and decrease the inconsistency of tenderness in cuts that are known to be less tender (Glover, Forrest, Johnson, Bramblett, & Judge, 1977). Through increased tenderness, other factors related to palatability such as overall liking and flavor liking also are enhanced. While the mechanical mechanism of blade tenderization is known to improve beef tenderness, it has several limitations including multiple food safety concerns. Because mechanical tenderization disrupts the integrity of the muscle, all mechanically tenderized product are considered 'nonintact' by the Food Safety and Inspection Service (USDA-FSIS, 2015). This is due to contamination concerns surrounding the potential of pathogenic microorganisms on the surface of a product being translocated to the interior, through injecting blades/ needles. Due to cost and inefficiency, other mechanical tenderization technologies to improve tenderness have not been implemented in the industry. Processors will continue to extensively research other methods for improving tenderness and other beef quality attributes in tougher cuts like top sirloins, while preserving the integrity and safety of the product.

2.2. Meat tenderness

Appearance, flavor, juiciness, and tenderness are all important factors when considering the value and quality of meat. In relation to palatability, tenderness and flavor are the two most influential factors (Sullivan & Calkins, 2011). Meat tenderness can be attributed to a multitude of factors including connective tissue, intramuscular fat, contractile state, and postmortem proteolysis (Belew, Brooks, McKenna, & Savell, 2003). The relationship between tenderness and concentration of connective tissue within a muscle is known as the “background effect.” Mostly comprised of the protein collagen, the amount of connective tissue within a muscle directly affects tenderness (Sullivan & Calkins, 2011). Muscles that contain higher amounts of connective tissue include those used for locomotion, primarily located in the thoracic and pelvic limbs. The greater the amount of connective tissue, the less tender the meat. Harris, Miller, Savell, Cross, and Ringer (1992) found that the inconsistency of tenderness in top sirloin steaks could be attributed specifically to the amount of collagen, lower collagen solubility, and the difference in myofibrillar structure. The high amounts of collagen found in top sirloin steaks are not surprising, considering the *M. gluteus medius* is used as a locomotive muscle in the hindlimb. Sullivan and Calkins (2011) also showed that the solubility of connective tissue is related to the tenderness of beef muscles. The degree of solubility of connective tissue can be correlated to an animal’s physiological age. As animals age, the connective tissue will form greater amounts of heat-stable cross-linkages within the collagen, making it less soluble when heated. Thus, the older an animal is, the less tender the meat will be. Cross, Carpenter, and Smith (1973) findings support this by demonstrating the relationship between age groups of cattle by total precent of soluble collagen with WBS force values. The amount of soluble collagen was highest in the oldest chronological aged cattle, resulting in higher WBS force values, thus supporting the concept that older animals result in tougher meat. However, during heating, connective tissue will shrink and eventually solubilize. As more collagen melts, the connective tissue within the muscle will continue to break down, contributing to increased tenderness. Sous vide cooking uses a low temperature-long time relationship that could possibly positively influence the solubilization of connective tissue and reduce the incidence of toughness in "intermediate" beef muscles.

Intramuscular fat, also known as marbling in meat, has been highly attributed to meat tenderness. Intramuscular fat is deposited within the perimysium layer that surrounds the muscle fiber. This is known as the last fat depot to be deposited and can be directly related to the nutrition and growth stage of the live animal. Intramuscular fat surrounds the individual muscle fibers, adding a layer of lipid that provides lubrication. Through the addition of the lipid layer, the protein matrix is diluted, which lowers the bulk density of the fiber, overall reducing the amount of force needed to chew or cut through the meat (Smith & Carpenter, 1974). Therefore, directly relating the amount of intramuscular fat to the bulk density or lubrication effect. Intramuscular fat positively affects meat tenderness and overall flavor. As the amount of intramuscular fat increases, consumers sensory ratings of overall like, tenderness, juiciness and flavor, all increase (O'Quinn, Legako, Brooks, & Miller, 2018).

Another factor that contributes to meat tenderness is contractile state of the muscle. This is directly related to muscle ultrastructure, as the myofibril bundles that combine to make a muscle, are comprised of individual sarcomeres. The sarcomere is a structural unit of a myofibril and is the location of contraction (Aberle, Forrest, Gerrard, & Mills, 2012). In the live animal, muscle contraction requires energy. The actin and myosin myofibrillar proteins utilize the molecule adenosine triphosphate, also referred to as ATP, which provides the energy needed for a muscle to contract. During the conversion of muscle to meat (postmortem), this process is slowed down, and the amount of energy available for the myofibrillar proteins to utilize is eventually depleted, resulting in the muscles becoming stiff. This is commonly referred to as rigor mortis. The stiffness of the muscles is a consequence of the overlapping of the sarcomeres within the myofibril. The greater the amount of overlap, the more tough a muscle will be. The chilling of carcasses and carcass suspension can be controlled to limit the amount of overlap over sarcomeres within the muscle (Hostetler, Carpenter, Smith, & Dutson, 1975; Savell, Mueller, & Baird, 2005).

Studies have shown that meat stored for an extended period, under refrigerated storage conditions, called aging, improved meat tenderness. Aging of beef has become a vital method used to meet the demand for high quality eating experiences. The increase in tenderness through postmortem aging has been attributed to endogenous proteolytic enzymes in the muscle. These enzymes weaken the integrity of structural proteins found at the sarcomere level. Initially, structural changes begin at the Z disks with the degradation of the proteins desmin and titin (Aberle et al., 2012). These proteins are responsible for holding myofibrillar proteins in place, and when degradation of them occurs, the myofibril is weakened, resulting in a more tender meat product (Aberle et al., 2012). Improving tenderness through postmortem storage is almost completely accredited to degradation of myofibrillar proteins. The effects of postmortem aging have been extensively examined. Extended aging times have been proven to increase tenderness in top sirloins. Inversely, certain extended aging periods could show discrepancies in consumer acceptance of tenderness (Colle et al., 2015).

2.3. Sous vide cooking

Since the 1990s, sous vide cooking has increasingly become a more widely used method of cooking throughout the food service industry and within the homes of consumers (Baldwin, 2012; Rinaldi et al., 2014). Sous vide cooking uses a low temperature-long time relationship that during heating, causes connective tissue to shrink and eventually solubilize, thus increasing tenderness. In addition to tenderness, improved juiciness, and texture also have been reported during sous vide cooking compared to traditional cooking methods (Armstrong & McIlveen, 2000; Rinaldi et al., 2014). Unlike other traditional cooking methods, sous vide cooking utilizes high controlled heating to cook raw product, within a vacuum-sealed, heat-stable package. The use of vacuum sealed bags allows for heat to be evenly transferred from the water to all parts of the product. Additionally, it decreases the amount of protentional contamination during storage, and inhibits off-flavors and flavor losses after cooking, thus improving shelf-life (Baldwin, 2012; Church & Parsons, 2000; Rinaldi et al., 2014). The use of highly controlled temperatures for cooking could be the greatest benefit of sous vide cooking. The precise control of temperature while cooking allows for the most consistent cooking of product with the opportunity of almost perfect duplicability (Baldwin, 2012). In addition to this, products can be cooked at a lower temperature to attain the preferred degree of doneness in conjunction with desired tenderness, while reaching the required temperature of lethality to provide a safe product that is not over cooked (Baldwin, 2010, 2012; Ruiz-Carrascal, Roldan, Refolio, Perez-Palacios, & Antequera, 2019). Moreover, cuts of meat that are traditionally known to be "tough" can see improved tenderness at a lower degree of doneness. However, both weight losses and moisture losses have been found to be an effect of low temperature cooking of both turkey and pork (Roldán, Antequera, Martín, Mayoral, & Ruiz, 2013). The denaturing of myofibrillar proteins that occurs during cooking from 40-90 °C and in collagen from 56-62 °C greatly increases water loss within the product (Tornberg, 2005; Vaudagna et al., 2002). Sous vide cooking of steaks creates a poached appearance which is not typically desirable (Baldwin, 2012). Therefore, the products are often served with a sauce or seared after cooking to allow the Maillard reaction or browning of the surface to occur. In addition to providing a more traditional appearance, the Maillard reaction also contributes to the development of desirable meat flavors (Mottram, 1998).

2.4. Analysis of tenderness

Warner-Bratzler shear force values were shown to increase significantly in top sirloin steaks as temperatures increased compared to other cuts (Lorenzen et al., 2003). The correlation of increased endpoint temperatures and increasing WBS values indicates a need for lower temperature cooking in top sirloin steaks in order to reach desired tenderness. Several researchers have reported decreases in shear force values for beef muscles cooked utilizing sous vide (Hansen, Knøchel, Juncher, & Bertelsen, 1995; Mortensen, Frøst, Skibsted, & Risbo, 2012; Rinaldi et al., 2014; Vaudagna et al., 2002). Christensen et al. (2012) reported that sous vide cookery decreased shear force and increased collagen solubility in longissimus and semitendinosus muscles of pigs.

Furthermore, Roldán et al. (2013)improved the tenderness in lamb longissimus dorsi muscles and Mortensen et al. (2012) found sous vide cooking significantly improved the tenderness of beef semitendinosus muscle while not affecting the flavor profile. Additionally, increasing the sous vide cooking temperature from 50 to 65 °C resulted in lower shear force values for semitendinosus muscles cooked for 90, 150, and 270 minutes (Vaudagna et al., 2002), and shear force decreased when meat was cooked at 62 °C compared to 59 °C (Hansen et al., 1995). Most of the available data on sous vide cooking and beef tenderness only compares different sous vide temperature and time combinations and not to more traditional cooking methods.

In addition to WBS force values, the American Meat Science Association (AMSA 2016) also has recognized the importance of using a comparative approach that includes consumer tenderness surveys. Consumer sensory panels are imperative in understanding how the general public perceives a product. Consumer acceptability and satisfaction control the demand of products within the meat industry and understanding changes in consumer preference is of the upmost importance. Consumer sensory panels for beef research are typically designed to measure overall like, juiciness, flavor and tenderness through a 9-point hedonic scale. These subjective measurements provide an insight to consumer acceptability and preference

CHAPTER III

MATERIALS AND METHODS

3.1. Product collection

Individually packaged USDA Choice (USDA, 2017) top sirloin butts (*n* = 240), similar to the North American Meat Institute North American Meat Institute (2014) Institutional Meat Purchasing Specifications (IMPS) 184B, were obtained from the collaborating purveyor. Top sirloin butts (*n* = 80/ aging time) were aged under refrigeration (0 to 2 °C) for 14, 28, or 35 d. Following each aging time, subprimals were assigned to one of the following treatments: (1) non-blade-tenderized subprimal (*n* = 20/ aging time); fully cooked to lethality temperature with a higher temperature, shorter cook time sous vide process, followed by chilling and warming on a flat-top grill, (2) non-blade-tenderized subprimal (*n* = 20/ aging time); fully cooked to lethality temperature with a lower temperature, longer cook time sous vide process, followed by chilling and warming on a flat-top grill, (3) blade tenderized subprimal (*n* = 20/ aging time); cooked to a lethality temperature on a flat-top grill, and (4) non-blade-tenderized subprimal (*n* = 20/ aging time); cooked to a lethality temperature on a flat-top grill.

All top sirloin butts were removed from their packaging and trimmed of any visible discoloration and/ or remaining excess surface fat. After trimming, top sirloin butts assigned to treatment 3 were blade tenderized with one pass through a Ross™ Tenderizer (Model No. 1053; Ross Industries Inc., Midland, Virginia). Then, subprimals for all treatments were cut perpendicular to muscle fibers into five portions (3.6 cm) using a Grasselli (NSL 800; Albinea, Italy) slicer. Portions were identified as 1, 2, 3, 4, and 5, cranial to caudal, with only portions 2 and 3 used for this project. From these two portions, four steaks (IMPS 1184B Top Sirloin Butt Steaks, Center-cut, Boneless (IM); 145 to 204 g, n = 80/ aging time/ treatment) were hand cut. Two steaks were labeled (with the same random three-digit code) with waterproof paper for consumer sensory panels (n = 40/ aging time/ treatment; 480 total), one steak was labeled for Warner-Bratzler Shear (WBS) force (n = 20/ aging time/ treatment; 240 total), and one steak was labeled for visual consumer appraisals (n = 20/ aging time/ treatment; 240 total). All steaks were individually packaged under vacuum in a heat-stable package with a rollstock machine (Multivac R150; Kansas City, MO) using Sealed Air, Food Care Division (Charlotte, NC) Item No. T7230B (3.0 mil top web with an Oxygen Transmission Rate (OTR) of 4 [cc/ m^2/ day @ 23 °C, 0% R.H.]) and Item No. T7045B (4.5 mil bottom web with an OTR of 3 [cc/ m^2/ day @ 23 °C, 0% R.H.]). Individually packaged steaks then were weighed on an Ohaus Valor 4000w digital scale (Model No. V41XWE15T; Ohaus Corporation, Parsippany, NJ).

Steaks (n = 80/ aging time) assigned to treatment 1 were cooked in an Armor Inox Thermix™ Sous Vide System (Serial No. AF19080167; Armor Inox, Mauron, France) to achieve an internal steak temperature of 63 °C for 90 min. Internal steak temperatures were monitored continuously with the Armor Inox Thermix computer software system through a probe inserted directly into the geometric center of one extra steak. Temperature of water within the tank was monitored continuously with the Armor Inox Thermix computer software system through two tank probes located on either end of the tank. Steaks (*n* = 80/ aging time) assigned to treatment 2 were cooked in the same commercial sous vide system to achieve an internal steak temperature of 58 °C for 150 min. After cooking, steaks assigned to both sous vide treatments were rapidly cooled in the sous vide system to 2 °C within 6.5 h to comply with the USDA-FSIS Compliance Guideline for Stabilization.

Cooked and chilled steaks from the sous vide treatments 1 and 2 and raw steaks for the treatments 3 (*n* = 80/ aging time) and 4 (*n* = 80/ aging time) were boxed, placed into insulated containers with refrigerant materials, and transported to the Rosenthal Meat Science and Technology Center (College Station, TX). Upon arrival, steaks were stored under refrigeration (2 to 4 °C) for no longer than 7 d until analyses were performed.

3.2. Dry-heat cookery

Steaks (*n* = 480 for consumer sensory panel; *n* = 192 for visual consumer appraisals, and *n* = 240 for WBS) were reheated/ cooked on one of two Star International commercial flat-top grills (Model 536TGF and 524TGF; Star International, St. Louis, MO) preheated to an approximate surface temperature of 210 ± 3 °C. Internal steak temperatures were monitored using a thermocouple reader (Model THS-298-721; ThermoWorks, American Fork, UT) and a 0.02-cm diameter, copper-constantan Type-T thermocouple wire (Omega Engineering, Stanford, CT), inserted into the geometric center of each steak. Previously cooked sous vide steaks from treatments 1 and 2 were heated to an internal temperature of 21 °C, flipped, and removed from the grill when the final internal temperature reached 46 °C. Raw steaks from treatments 3 and 4 were flipped at an internal temperature of 35 °C and removed from the grill when the final internal temperature reached 70 °C. Internal steak temperatures were verified periodically by inserting a Thermapen (Model MK4; ThermoWorks) into the geometric center of each steak. Raw weight, initial internal steak temperature, grill temperature, time on, final internal steak temperature, time off, and a final weight were collected. Final weight was recorded after all cooking/ reheating steps were completed. Total yield (%) ([final weight (g) / raw, unpackaged weight (g)] ×100) was calculated based upon the raw, unpackaged steak weight and the final steak weight, which was recorded after all cooking/reheating steps had been completed (Table 1). Cooked steaks intended for WBS force evaluation were placed on plastic trays in a single layer, covered with plastic wrap, and stored at refrigerated conditions (2 to 4 °C) for approximately 12 to 16 h. Steaks assigned to consumer sensory panels and visual consumer appraisals were held in an Alto-Shaam, oven set at 60 °C (Model 100-TH; Alto-Shaam Inc., Menomnee Falls, WI) for no more than 20 min before serving or visual assessment to consumer panelists.

3.3. Sensory panel

3.3.1. Consumer sensory panel

Consumer sensory panel procedures were approved by the Texas A&M Institutional Review Board for the Use of Humans in Research (Protocol number: IRB2019-0788M). Panelists (*n* = 224; demographics in Tables 2 and 3) were recruited from the Bryan/ College Station area using an existing database.

Consumer sensory panel steaks (*n* = 160/ aging time; 480 total) were reheated/ cooked as described previously. For each panel, the two steaks (previously labeled with the same random number for consumer sensory panels) from each treatment of corresponding subprimals, were cut into cuboidal portions (approximately 1.27 cm × 1.27 cm × steak thickness) and mixed pieces were served as a single sample (n = 80/ aging time; 240 total). Steaks were served to panelists in seated in individually partitioned sensory areas with red theater lighting to prevent panelist bias for degree of doneness. Consumer sensory panels were designed to be completed in 12 sessions (4 per week) with five groups of four panelists per session. Consumer sensory panelists were served steaks from a single aging time (n = 80 steaks/ aging time) over three consecutive weeks. Steaks were assigned to each session group in a manner to achieve uniform representation of treatments across panel days and were served in a previously determined blind and random order. Therefore, each panelist assessed four samples, one from each treatment, and each sample was evaluated by four panelists. Purified bottled water and individually packaged unsalted tops saltine crackers were provided for palate cleansing between samples. Panelists were asked to evaluate samples using a 9-point scales (1 = dislike extremely; 9 = like extremely) for overall liking, flavor liking, tenderness liking, and juiciness liking.

3.3.1. Visual consumer appraisals

After completing the sensory evaluation for all steaks, consumers were divided into two groups (n = 10/ group). Of the steaks (n = 240) assigned to visual appraisal, 192 were cooked as described above. For visual consumer appraisals, cooked steaks (n = 64/ aging time) were presented, in treatment pairs, on white plates, under fluorescent lighting, to each group of panelists (n = 8 visual appraisal steaks/ group or 16 visual appraisal steaks/ session). The steak placed on the left of each plate was presented with the initial grill side up and the steak placed on the right side of each plate was presented with the initial grill side down. Panelists were asked to verbally discuss the overall appearance of the exterior of each steak and comments were transcribed by a moderator. After the group discussion, individual panelists were asked to rate overall liking of the exterior steak surface using a 9-point scales (1 = dislike extremely; 9 = like extremely) and to provide written comments describing the exterior appearance of each steak. The steak placed on the right side of the plate in each pair then was cut in half to expose the interior of the steak. Panelists were asked to verbally discuss the overall appearance of the interior of the steak and comments were again transcribed by a moderator. Lastly, individual panelists were asked to rate overall liking of the steak interior using a 9-point scale (1 = dislike extremely; 9 = like extremely) and provide written comments describing the interior appearance of the steak sample. At the conclusion of each session, each panelist was provided with a $25 gift card for their time and contribution to this research.

3.4. Warner-Bratzler shear force

Chilled steaks (n = 80/ aging time) were allowed to equilibrate to room temperature (approximately 1.5 h), then trimmed of visible connective tissue to expose muscle fiber orientation. A handheld coring device was used to remove cores parallel to the muscle fibers. Cores with excess fat or connective tissue were discard. A minimum of three (1.3-cm diameter) cores were obtained from the *M. gluteus medius*. Cores were sheared once, perpendicular to the muscle fibers, using a TMS-Pro Food Texture

Analyzer (Mecmesin Ltd., Slinfold, UK), 250 N load cell, and a 1.02 cm V-shaped blade with a 60° angle and a half-round peak at a cross speed of 200 mm/ min. The equipment was calibrated before the start of the data collection and after every 10 steaks. The peak force (N) needed to shear each core was recorded, and the mean peak force was used for statistical analysis.

3.5. Statistical analyses

All data analyses were performed using JMP® Pro, Version 15.2.1 (SAS Institute Inc., Cary, NC). Consumer demographic frequencies were determined using the Distribution function of JMP. All other data were evaluated for differences between cooking treatments within a given aging time using the Fit Mixed function of JMP to produce an analysis of variance. Least squares means comparisons were conducted, when appropriate, using the student's t-test with an alpha-level < 0.05. For all data types, cooking treatment and subprimal ID were included as main and random effects, respectively. Per the American Meat Science Association sensory guidelines (AMSA, 2016), group, serve order, and session date also included as random effects in the model for consumer sensory panelist scores. Consumer visual appraisal scores were analyzed as previously described with steak presentation and serve order as additional fixed and random effects, respectively.

CHAPTER IV

RESULTS AND DISCUSSION

4.1. Total yield

Total yield (%) was calculated to determine if there were any notable differences in final steak yield based on cooking treatment within an aging time (Table 1). Top sirloin steaks that were aged for 14 d showed significant differences ($P < 0.011$) in total yield. Total yield between cooking treatments was most notable for steaks that were aged for 28 d, as differences ($P < 0.0001$) with treatment 4 steaks having a greater yield than all other treatments. However, there were no differences found among treatments 1, 2, or 3 within the 28 d aging time. There were no differences ($P > 0.05$) between cooking treatments for 35 d aged steaks. The total yield in this study, across all aging times and cooking treatments, was generally 7 to 10% less than cooking yields recently reported for low Choice, top sirloin steaks cooked to a medium degree of doneness in a study by Olson et al. (2019).

4.2. Warner-Bratzler shear force evaluation

Mean Warner-Bratzler shear force values (N) for top sirloin steaks ($n = 80$ steaks/ aging time) for all cooking treatments within an aging time are shown in Table 4. Significant differences ($P < 0.0001$) were seen across cooking treatments for all three aging times. For 14 d and 35 d aging times, treatments 2 and 3 had lower ($P < 0.0001$) shear force values than treatments 1 and 4. Steaks from all cooking treatments when aged for 28-days showed significant differences ($P < 0.0001$) in WBS force values with steaks from treatment 1 having the highest WBS force values among all cooking treatment steaks that were aged for 28-days.

Interestingly, the significant differences in WBS shear force values between treatment 1 and treatment 2 sous vide steaks are inconsistent with the findings of Vaudagna et al. (2002). Vaudagna et al. (2002) found for beef muscles cooked sous vide showed decreased shear force values as the temperature was increased from 50 to 65 ºC, with cooking times between 90 and 360 min having no significant effect on shear force values. Mean WBS force values for steaks cooked in treatment 1 were found to be among the highest values within this study across all aging times. Similar findings by Uttaro, Zawadski, and McLeod (2019) showed decreased tenderness from collagen shrinkage that occurs at temperatures near 65 ºC. Similarly, treatment 4 steaks produced numerically higher shear force values when compared to treatment 2 and treatment 3 steaks. Therefore, steaks from treatment 2 and treatment 3, consistently produced the lowest WBS force values in the 14 and 35 d aging times. Similar findings to those of treatment 3 steaks in terms of decreased WBS force values in blade tenderized *gluteus medius* steaks were shown in a study conducted by King et al. (2009). King et al. (2009) found *gluteus medius* steaks that were blade tenderized had lower ($P < 0.05$) slice shear force values than non-blade tenderized steaks. In relation to aging time for blade tenderized steaks found in treatment 3, King et al. (2009) also had comparable slice shear force findings. King et al. (2009) found that increasing aging time from 12 to 26-days for blade tenderized *gluteus medius* steaks increased the extent of postmortem proteolysis ($P < 0.05$). Additional research may be needed to identify the effects of aging times on WBS force values in steaks cooked using sous vide methods.

Regardless of aging times and cooking treatments, is it important to note that all WBS values shown in Table 4 qualify for the "very tender" tenderness category (WBS force values < 3.2 kg [< 31.4 N]) determined by Belew et al. (2003). Therefore, our data suggest no negative impacts by any of the cooking treatments on tenderness in top sirloin steaks. Additionally, these data indicate sous vide cooking, when done using a lower temperature, longer time method, could produce similar results to those of blade tenderized steaks. These results imply promising progress for achieving desired tenderness without using blade tenderization.

4.3. Consumer sensory panel

Least squares means of consumer panelists' scores for overall liking, flavor liking, tenderness liking, and juiciness liking of top sirloin steaks stratified by cooking treatment within an aging time are provided in Table 5. Differences ($P < 0.002$) in tenderness liking were identified among cooking treatments for steaks aged for 14 d. Consumers scores for tenderness liking of steaks from treatment 2 were higher than all other cooking treatments. Panelists' tenderness scores for steaks from treatment 2 are consistent with the WBS force values previously mentioned. There were no differences ($P > 0.05$) across cooking treatments in terms of panelists' scores for overall liking, flavor liking, and juiciness liking for 14 d aged product.

When comparing cooking treatments for steaks aged for 28 d, steaks from treatment 2 had greater ($P < 0.020$) overall liking ratings than treatment 1 and treatment

4. However, there was no difference in overall liking ratings between treatment 2 and treatment 3. A similar trend in consumer ratings was found when evaluating tenderness liking. Steaks from treatment 2 showed higher ($P < 0.002$) tenderness liking ratings than those of treatment 1 and 4. Additionally, there was no difference in tenderness liking between treatment 2 and treatment 3. For flavor liking and juiciness liking, there were no differences ($P > 0.05$) detected amongst cooking treatments.

Mirroring our findings for treatment 4 steaks aged for 35 d, Savell, McKeith, Murphey, Smith, and Carpenter (1982) reported no effect of increased aging time on sensory panel flavor and juiciness ratings in non-blade tenderized steaks. The inability of consumers to detect differences in tenderness could potentially be explained by the findings of Miller et al. (2001). Miller et al. (2001) suggested that WBS force values of < 3.0 kg (< 29.4 N) would result in 100% consumer satisfaction of tenderness. WBS data collected on steaks aged for 35 d in all cooking treatments was below the 3.0 kg (< 29.4 N) threshold, shown in Table 5, respectively.

Generally, when considering all aging times independently, consumer panelists ratings for top sirloin steaks from treatment 2, cooked via sous vide, with a lower temperature, longer time cooking method were among the highest for all four palatability attributes compared to all other cooking treatments. These data indicate that lower temperature, longer time sous vide cooking methods could serve as an alternative to blade tenderization throughout the food service industry.

4.4. Consumer visual appraisals

One major objective of this study was to compare consumer acceptability of exterior and interior surfaces of top sirloin steaks using four different cooking treatments. Because sous vide is typically a temperature and time-controlled approach and most food products cooked via sous vide have an unappealing poached or boiled appearance, unless seared during reheating. However, having a burnt, overcooked, or over charred appearances from re-heating also have been expressed as possible concerns, therefore, understanding the visual differences of exterior and interior surfaces between cooking methods is important.

Least squares means of consumer visual appraisal scores by aging time, for overall liking of exterior surfaces of top sirloin steaks stratified by cooking treatment and steak presentation are shown in Table 6. There were no differences ($P > 0.05$) between cooking treatments for overall liking of exterior surfaces for 14 d and 35 d age steaks. However, steaks aged for 28 d showed significant differences ($P < 0.05$) for overall liking of exterior surfaces. Additionally, there were no differences ($P > 0.05$) in panelists' scores for overall like based on steak presentation for any aging time.

Least square means of consumer visual appraisal scores by aging time, for overall liking of interior surfaces of top sirloin steaks stratified by cooking treatment and steak presentation are shown in Table 7. No differences were seen across cooking treatments for consumer ratings of overall liking of interior surface for steaks aged for 14 d and 35 d. Interestingly, consumer overall interior liking ratings for steaks aged 28 d were higher ($P < 0.015$) for treatment 2 steaks than treatment 1 and 3 but were not different than treatment 4. Remarkably, findings from consumers data denotes that there is no concern for consumers' visual acceptance of steaks cooked sous vide compared to other more traditional cooking methods.

CHAPTER V

CONCLUSIONS

The foodservice industry is responsible for meeting the demands of consumers wanting consistent and favorable experiences at the restaurant level. Tenderness is one of the leading palatability attributes that drives consumer acceptability of an eating experience. This research shows that steaks cooked via sous vide, using a lower temperature, longer time combination (treatment 2) were usually comparable to steaks that have been blade tenderized and cooked on a flat-top grill (treatment 3) based on WBS force values, sensory attributes, and visual appraisals. Although significant differences were discovered, all cooking methods and aging times produced steaks with WBS force values that were well within what is considered the “very tender” tenderness category as defined by Belew et al. (2003). From a visual standpoint, there were no differences detected in consumer ratings among cooking treatments for overall liking of exterior surfaces and steak side presentation. Additionally, differences in consumer ratings for overall like of interior steak surfaces were only significant in steaks aged for 28-days, with ratings being higher for sous vide cooked steaks using a lower temperature, longer time cooking method. These results demonstrate consumer acceptability of all steaks from a visual standpoint, regardless of cooking treatment. Further research on the impact of aging times on sous vide cooked products may be useful. Nevertheless, it was determined that top sirloin steaks cooked via sous vide, utilizing a low temperature, long time combination, followed by chilling and reheating could serve as an alternative preparation method. This could greatly impact the beef industry by allowing further processors to produce more consistent products in terms of tenderness and other attributes on a larger scale destined for foodservice operations, which should result in more consistent eating experiences by the consumer.

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APPENDIX A

TABLES

Table 1. Least squares means for total yield[a] (%) stratified by cooking treatment[b] within aging time[c] for all steaks.

	Number of steaks	Total yield (%)
14-day age		
Treatment 1	76	70.3b
Treatment 2	76	71.8a
Treatment 3	76	70.0b
Treatment 4	76	70.8ab
SEM		0.004
P-value		0.011
28-day age		
Treatment 1	76	70.6b
Treatment 2	76	71.7b
Treatment 3	76	70.9b
Treatment 4	76	73.4a
SEM		0.004
P-value		<0.0001
35-day age		
Treatment 1	76	71.4
Treatment 2	76	72.3
Treatment 3	76	72.2
Treatment 4	76	73.0
SEM		0.004
P-value		0.109

Means within a column and aging treatment lacking a common letter (a-b) differ ($P < 0.05$).
[a] Total yield (%) = [final weight after cooking/ reheating (g) / raw, unpackaged weight (g)] ×100. Final weight was recorded after all cooking/ reheating steps were completed.
[b] Treatment: treatment 1 = steaks from non-blade-tenderized subprimals, fully cooked to 63 ºC for 90 min with sous vide process, followed by warming on a flat-top grill; treatment 2 = steaks from non-blade-tenderized subprimals, fully cooked to 58 ºC for 150 min with sous vide process, followed by warming on a flat-top grill; treatment 3 = steaks from blade tenderized subprimals, fully cooked to 70 ºC on a flat-top grill; treatment 4 = steaks from non-blade-tenderized subprimals, fully cooked to 70 ºC on a flat-top grill.
[c] Aging time: consumer sensory panelists were served steaks from a single aging time over three consecutive weeks.

Table 2. Demographic attributes of consumer panelists (n = 224).

Item	Frequency (%)
Gender	
Male	50.0
Female	49.5
Did not disclose	0.5
Age (yr)	
< 20	12.5
21 to 25	27.7
26 to 35	21.9
36 to 45	11.2
46 to 55	12.5
56 to 65	9.4
≥ 66	4.9
Current working status	
Not employed	8.0
Full-time	41.1
Part-time	13.4
Student	47.0
Household income (US$)	
< 25,000	19.6
25,000 to 49,999	16.5
50,000 to 74,999	15.2
75,000 to 99,000	15.6
≥ 100,000	33.0
Food allergies or dietary restriction?	
No	95.5
Yes	4.5
Do you or any of your immediate family work for a market research firm, advertising firm, or food manufacturing company?	
No	99.0
Yes	1.0
Ethnicity	
Caucasian	69.2
Hispanic	16.5
Asian or Pacific Islander	11.2
Black	5.0
American Indian	0.5
Other	0.9
Do you eat meat?	
No	0.0
Yes	100.0

Table 3. Consumer panelists (n = 224) consumption patterns.

Item	Frequency (%)
Meat types consumed	
Chicken	99.6
Pork	96.0
Beef	100.0
Fish	89.7
Overall beef consumption	
Daily	5.8
5 or more times per wk	12.5
3 or more times per wk	49.1
1 time per wk	23.7
1 time every 2wks	6.7
Less than once every 2 wks	2.2
At home beef consumption	
0 times per wk	4.9
1 time per wk	28.6
2 times per wk	32.1
3 times per wk	25.0
4 times per wk	4.9
5 or more times per wk	5.8
In restaurant beef consumption	
0 times per wk	6.3
1 time per wk	42.9
2 times per wk	28.6
3 times per wk	17.9
4 times per wk	2.2
5 or more times per wk	2.7
Did not disclose	0.4
Preferred degree of doneness for beef	
Rare	4.9
Medium rare	23.7
Medium	5.4
Medium well	51.3
Well done	17.0
Purchase tendencies for beef	
Grass-fed	21.4
Traditional	81.7
Aged	5.3
Organic	9.4

Table 4. Least squares means of Warner-Bratzler shear force values (N) stratified by cooking treatment[a] within aging time[b] for all steaks.

	Aging time[b]		
Treatment[a]	14-day age	28-day age	35-day age
1	26.3a	24.9a	22.6a
2	18.4b	19.3bc	16.7b
3	20.5b	17.9c	18.6b
4	27.8a	21.5b	21.4a
SEM	1.1	0.9	0.9
P-value	<0.0001	<0.0001	<0.0001

Means within a column lacking a common letter (a-c) differ ($P < 0.05$).

[a] Treatment: treatment 1 = steaks from non-blade-tenderized subprimals, fully cooked to 63 ºC for 90 min with sous vide process, followed by warming on a flat-top grill; treatment 2 = steaks from non-blade-tenderized subprimals, fully cooked to 58 ºC for 150 min with sous vide process, followed by warming on a flat-top grill; treatment 3 = steaks from blade tenderized subprimals, fully cooked to 70 ºC on a flat-top grill; treatment 4 = steaks from non-blade-tenderized subprimals, fully cooked to 70 ºC on a flat-top grill.

[b] Aging time: steaks from a single aging time (n = 80 steaks/ aging time) were assessed over three consecutive weeks.

Table 5. Least squares means of consumer panelists' scores[a] for overall liking, flavor liking, tenderness liking, and juiciness liking of top sirloin steaks stratified by cooking treatment[b] within aging time[c].

	Number of steaks	Overall liking	Flavor liking	Tenderness liking	Juiciness liking
14-day age					
Treatment 1	20	6.4	6.1	6.3b	5.7
Treatment 2	20	7.1	6.5	7.4a	6.5
Treatment 3	20	6.4	6.3	5.9b	5.4
Treatment 4	20	6.2	6.5	6.0b	5.8
SEM		0.3	0.3	0.3	0.5
P-value		0.068	0.691	0.002	0.124
28-day age					
Treatment 1	20	6.2b	6.4	5.9b	5.8
Treatment 2	20	7.0a	6.6	7.3a	6.6
Treatment 3	20	6.4ab	6.1	6.6ab	5.7
Treatment 4	20	6.4b	6.5	6.1b	6.2
SEM		0.3	0.3	0.3	0.6
P-value		0.020	0.331	0.002	0.050
35-day age					
Treatment 1	20	6.2	5.8	6.4	5.9
Treatment 2	20	6.4	6.0	6.5	6.2
Treatment 3	20	6.1	6.1	6.1	5.5
Treatment 4	20	6.3	6.4	6.1	5.8
SEM		0.3	0.3	0.3	0.4
P-value		0.815	0.163	0.471	0.310

Means within an attribute and aging time lacking a common letter (a-b) differ ($P < 0.05$).

[a] Consumers used the following scales: overall liking (1 = dislike extremely; 9 = like extremely), flavor liking (1 = dislike extremely; 9 = like extremely), tenderness liking (1 = dislike extremely; 9 = like extremely) and juiciness liking (1 =dislike extremely; 9= like extremely).

[b] Treatment: treatment 1 = steaks from non-blade-tenderized subprimals, fully cooked to 63 ºC for 90 min with sous vide process, followed by warming on a flat-top grill; treatment 2 = steaks from non-blade-tenderized subprimals, fully cooked to 58 ºC for 150 min with sous vide process, followed by warming on a flat-top grill; treatment 3 = steaks from blade tenderized subprimals, fully cooked to 70 ºC on a flat-top grill; treatment 4 = steaks from non-blade-tenderized subprimals, fully cooked to 70 ºC on a flat-top grill.

[c] Aging time: consumer sensory panelists were served steaks from a single aging time over three consecutive weeks.

Table 6. Least squares means of consumers' visual appraisal scores[a] by aging time[b] for overall liking of exterior surfaces of top sirloin steaks stratified by cooking treatment[c] and steak presentation[d] main effects.

	Aging time		
	14-day age	28-day age	35-day age
	Overall liking		
Treatment			
1	5.1	5.0bc	4.6
2	5.8	5.5ab	5.0
3	5.7	4.5c	4.8
4	5.3	5.9a	5.3
SEM	0.3	0.3	0.3
P-value	0.240	0.004	0.548
Steak presentation			
First grill side	5.7	5.3	5.2
Second grill side	5.3	5.1	4.7
SEM	0.2	0.2	0.2
P-value	0.202	0.348	0.157

Means within an attribute and aging time lacking a common letter (a-c) differ ($P < 0.05$).

[a] Consumers used the following scale: overall liking of the exterior surface (1 = dislike extremely; 9 = like extremely).

[b] Aging time: consumer sensory panelists were served steaks from a single aging time (n = 64 steaks/ aging time) over three consecutive weeks.

[c] Treatment: treatment 1 = steaks from non-blade-tenderized subprimals, fully cooked to 63 ºC for 90 min with sous vide process, followed by warming on a flat-top grill; treatment 2 = steaks from non-blade-tenderized subprimals, fully cooked to 58 ºC for 150 min with sous vide process, followed by warming on a flat-top grill; treatment 3 = steaks from blade tenderized subprimals, fully cooked to 70 ºC on a flat-top grill; treatment 4 = steaks from non-blade-tenderized subprimals, fully cooked to 70 ºC on a flat-top grill.

[d] Steak presentation: First grill side steaks were served on the left side of the plate and were served with the first side of the steak the touched the grill presented up. Second grill side steaks were served on the right side of the plate and were served with the second side that touched the grill presented up.

Table 7. Least squares means of consumers' visual appraisal scores[a] by aging time[b] for overall liking of interior surfaces of top sirloin steaks stratified by cooking treatment[c].

	Aging time		
	14-day age	28-day age	35-day age
Treatment			
1	5.8	3.7b	4.5
2	6.3	5.6a	4.2
3	5.4	4.0b	4.4
4	5.5	5.0ab	4.9
SEM	0.4	0.5	0.6
P-value	0.547	0.015	0.809

Means within an attribute and aging time lacking a common letter (a-b) differ ($P < 0.05$).

[a] Consumers used the following scale: overall liking of the exterior surface (1 = dislike extremely; 9 = like extremely).

[b] Aging time: consumer sensory panelists were served steaks from a single aging time (n = 64 steaks/ aging time) over three consecutive weeks.

[c] Treatment: treatment 1 = steaks from non-blade-tenderized subprimals, fully cooked to 63 ºC for 90 min with sous vide process, followed by warming on a flat-top grill; treatment 2 = steaks from non-blade-tenderized subprimals, fully cooked to 58 ºC for 150 min with sous vide process, followed by warming on a flat-top grill; treatment 3 = steaks from blade tenderized subprimals, fully cooked to 70 ºC on a flat-top grill; treatment 4 = steaks from non-blade-tenderized subprimals, fully cooked to 70 ºC on a flat-top grill.

APPENDIX B

FIGURES

Figure 1. Demographics questionnaire

Date:
Session Time:

INSTRUCTIONS

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

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

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

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

Thank you very much for your help with this study.

DEMOGRAPHICS BALLOT

Please circle each appropriate response:

1. Please indicate your gender:

    Male   Female

2. Which of the following best describes your age?

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

3. Please indicate your current working status:

    Not employed   Part-time
    Full-time   Student

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

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

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

    No   Yes

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Date:
Session Time:

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

No	Yes

7. Please indicate your ethnic background:

White	Black
Hispanic	American Indian
Asian or Pacific Islander	Other

8. Do you eat meat?

No	Yes

9. Which of the following meats do you eat?

Chicken	Beef
Pork	Fish

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

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

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

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

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

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

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

Grass-fed	Aged
Traditional	Organic

Figure 2. Consumer panelist ballot

Date ____________________ **Participant No.**

Session Time _____________ **Sample No.**

INTRUCTIONS

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

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

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

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

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

____

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

____

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Figure 3. Consumer visual appraisal ballot

Date ____________________

Session Time 6:00 PM ________

VISUAL APPRAISAL BALLOT

A moderator will guide you through the visual assessment of each of two steaks. Briefly, you will assess the exterior appearance of two steaks, one cut and one un-cut. You also will evaluate the visual appearance of the interior of the cut steak.

UNCUT STEAK

Sample No. ____________________

1. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the **EXTERIOR** steak surface.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

2. Please provide comments describing the **EXTERIOR** of this meat sample.

____

____

CUT STEAK

Sample No. ____________________

1. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the **EXTERIOR** steak surface.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

2. Please provide comments describing the **EXTERIOR** of this meat sample.

____

____

3. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the **INTERIOR** steak surface.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Dislike Extremely — No Preference — Like Extremely

4. Please provide comments describing the **INTERIOR** of this meat sample.

____

____

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~~IRB APPROVAL DATE:~~ 03/05/2021

Figure 4. Subprimal assignments

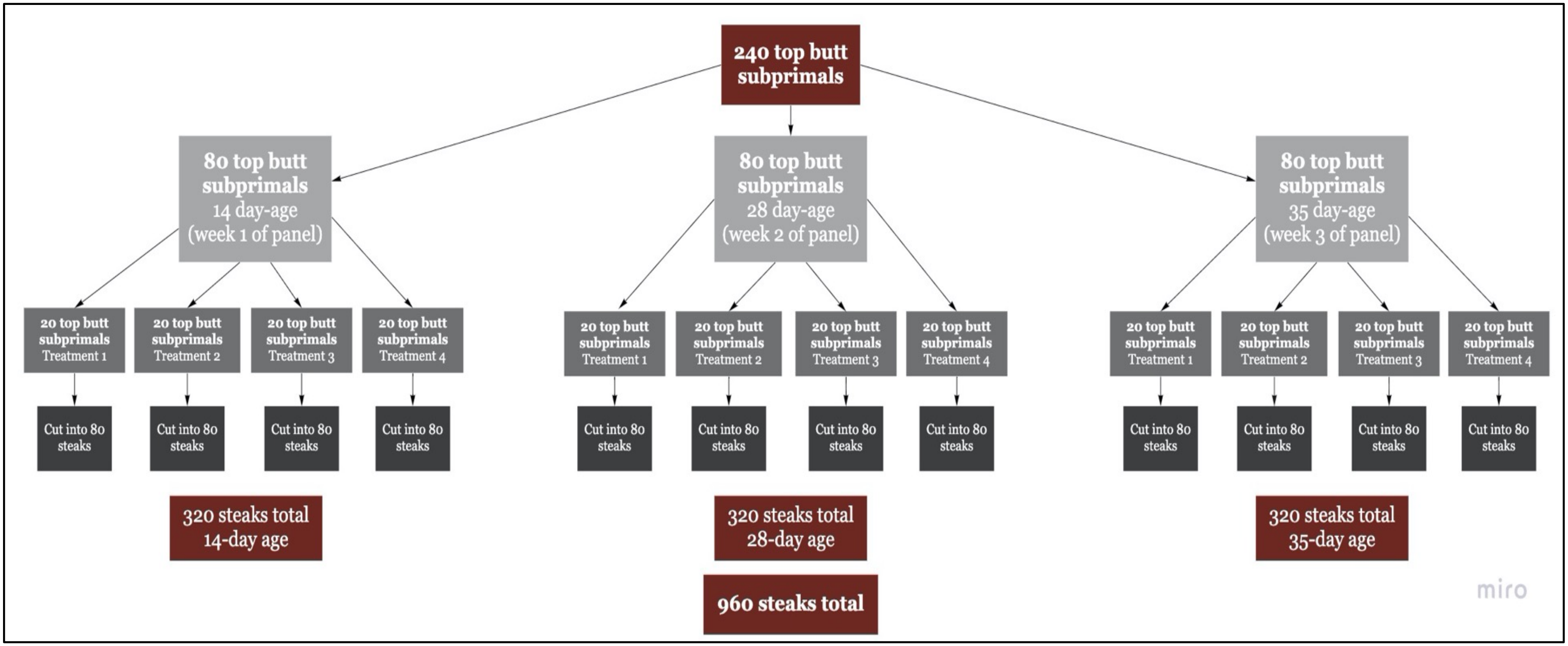

Figure 5. Steak assignments