IMPACT OF ELEVATED AGING TEMPERATURES ON TENDERNESS, SHELF LIFE, AND CONSUMER ACCEPTABILITY OF BEEF

A Thesis

by

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ABSTRACT

This study evaluated differences in tenderness and palatability attributes of steaks derived from subprimals subjected to conventional or elevated aging temperatures. After a total of 7 days of aging at 0.0 to 1.1 °C, paired subprimals (ribeye, lip-on; strip loin; shortloin; and top sirloin butt) were allocated to 7 additional days of aging at one of the following treatments: (1) conventional temperatures of 0.0 to 1.1 °C, or (2) elevated temperatures of 3.3 to 4.4 °C.

After 14-day aging, purge was quantified, pH measured, and odor evaluated, before cutting subprimals into steaks for color evaluation. Top sirloin butts subjected to elevated aging temperatures had higher ($P < 0.05$) bloody/serumy scores indicating stronger odor development. After the 5-day shelf life study, higher ($P < 0.05$) sour and bloody/serumy odor scores were detected from T-bone/porterhouse steaks subjected to elevated aging temperatures when compared to conventional aging. For both the ribeye and T-bone/porterhouse steak types, color uniformity/discoloration ratings were higher ($P < 0.05$) for the elevated aging treatment indicating more discoloration. Special considerations should be given to the subprimal types selected for use in an elevated aging temperature environment to maintain shelf life characteristics. No differences ($P = 0.66$) in WBS force values were seen between aging treatments. There also were no differences ($P > 0.05$) in any of the four beef palatability attributes seen between aging treatments. Aging beef at elevated versus conventional temperatures did not result in improved palatability and would not be a viable process.

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NOMENCLATURE

$CaCl_2$	Calcium Chloride
PVC	Polyvinyl Chloride
WBS	Warner-Bratzler shear
IMPS	Institutional Meat Purchase Specifications

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CHAPTER I

INTRODUCTION

Aging of beef greatly increases tenderness, giving the consumer a more desirable eating experience. Though postmortem aging is not thoroughly understood, many theories suggest the proteolysis of myofibril proteins plays an important role. Calpains are believed to be one of the major proteolytic enzymes involved in postmortem aging (Koohmaraie, 1992; Koohmaraie, Schollmeyer, & Dutson, 1986). Calpains are endogenous enzymes that are activated by calcium. Calcium is stored within the sarcoplasmic reticulum and mitochondria, and once calcium enters the sarcoplasm, calpain is activated resulting in proteolytic changes. The degradation of titin, nebulin, desmin, and troponin-t results in disruption of cross-linking, leading to weakening and fragmentation of myofibrils (Huff-Lonergan et al., 1996).

Postmortem aging storage temperatures can be controlled to potentially increase tenderness. Increasing the ambient temperature during chilling has been shown to influence proteolysis and tenderness of beef (Whipple, Koohmaraie, Dikeman, & Crouse, 1990). Koohmaraie (1992) evaluated the effects of pH, temperature, and inhibitors on the proteolytic activity of skeletal muscle. Data showed rate of autolysis was significantly decreased by lower temperatures during aging. Based on this finding, increased product temperature during aging accommodates increased autolysis of key muscle proteins (Koohmaraie, 1992).

Tenderness is the most determinant of beef palatability and consumer acceptance (Mueller et al., 2006). In commercial retail practices, the average aging time is 17 days, but can vary from 1 to 3 days to several months (Guelker et al., 2013; Juarez, Larsen, Klassen, & Aalhus, 2013). Retailers are looking for new ways to decrease retail aging times while still

achieving adequate meat tenderness. One of the most widely used methods to increase muscle tenderness is mechanical tenderization, which uses needles or blades to disrupt the muscle fibers. (Parrish, 1977). However, blade tenderization treatments have been noted to having increased purge loss and problems with juiciness (Glover, Forrest, Johnson, Bramblett, & Judge, 1977). Additionally, the process of blade tenderization could transfer pathogenic bacteria located on the surface to the interior of the product; therefore, increasing risk of foodborne infection (Phebus, Thippareddi, Sporing, Marsden, & Kastner, 2000).

King et al. (2009) compared the effectiveness of blade tenderization and extended postmortem storage at different refrigerated temperatures and concluded that aging top sirloin subprimals at elevated temperatures increased tenderness of steaks after aging. This study was designed to compare quality attributes of steaks derived from subprimals aged for 14 days at conventional temperatures (0.0 to 1.1 °C) versus those aged for 7 days at conventional temperatures followed by 7 days at elevated temperatures (3.3 to 4.4 °C). This study evaluated different subprimal types, and as a result, provides retailers with new and advanced options for managing aging periods and temperatures while optimizing beef tenderness.

CHAPTER II

LITERATURE REVIEW

Factors such as meat color, flavor, tenderness, and method of cookery play a major role in consumer acceptability. The consumer perception, and economic conditions challenge the beef industry to produce a consistent, palatable and affordable product. The texture of meat is of utmost importance to consumer acceptance. According to the 2010 National Beef Tenderness Survey, consumers are willing to pay a premium for guaranteed-tender meat products (Guelker et al., 2013).

2.1 Postmortem Carcass Chilling

Carcass chilling has primarily been used to ensure food safety, increase the shelf life, and to reduce shrinkage (Savell, Mueller, & Baird, 2005). Reducing carcass surface temperatures to about -1 to 4 °C controls bacteria growth on the carcass (Gill & Newton, 1978). Storage temperature can greatly affect the enzymatic degradation and affect muscle tenderness. Various carcass and storage characteristics can affect the process in which a carcass undergoes rigor mortis. Cold shortening is the dramatic decrease in muscle temperature prior to the onset phase of rigor. When the carcass is cooled too rapidly, there is a possibility of inducing muscle toughening. This toughening of the muscle is caused because the sarcoplasmic reticulin does not function properly; therefore, the sarcoplasmic reticulin cannot bind calcium, resulting in an abundance within the muscle. In addition, there is still ATP left in the muscle, making the muscle contract at a maximum level (Savell et al., 2005). Maximum level of contraction within the muscle results in larger fiber diameter due to the sliding of filaments over one another causing the muscle to be less tender.

Carcass conditions can prevent cold shortening of muscle fibers. The increasing subcutaneous fat on carcasses was found to increase tenderness. Bowling, Smith, Carpenter, Dutson, and Oliver (1977) compared tenderness differences of forage versus grain-finished carcasses. The grain-finished carcasses had twice as much subcutaneous fat as forage-finished beef. The grain-finished beef had lower shear force values compared to forage-finished beef with lower subcutaneous fat at conventional chilling temperatures. Increase in subcutaneous fat either decreased the rate of chilling due to greater amounts of insulation or increased total mass, allowing the carcass to chill slower and increase enzymatic activity.

In addition to changing the carcass characteristics of beef, methods in the slaughter process have been shown to reduce cold shortening. Electrical stimulation helps decrease cold shortening by using up the excess ATP within the muscle (Bendall, Ketteridge, & George, 1976). Introducing an electrical current through the carcass will increase the rate of glycolysis, lowering the pH and reducing the overall time of rigor mortis. The time and temperature carcasses are held could affect the probability of induction of cold shortening. The effects of aging has been shown to be more effective if the carcasses are maintained above 7 – 10 °C until the onset of rigor (Hannula & Puolanne, 2004). Carcass chilling is an extremely important factor and sets the stage for future proteolytic enzymatic degradation during the aging period.

Postmortem temperature and pH have been shown to be related to meat tenderness (Marsh, Lochner, Takahashi, & Kragness, 1981). Both factors affect the enzymatic proteolysis of myofibrillar proteins. During the chilling process, maintaining a relatively high muscle pH and temperature promoted the degradation of important myofibrillar proteins (Yates, Dutson, Caldwell, & Carpenter, 1983). Further research has suggested that muscle

temperature and cooling rates have been shown to have the greatest effect on beef tenderness. Whipple et al. (1990) conducted a study on the effects of high-temperature condition on enzymatic activity and tenderness of beef. In this study, eleven carcasses were collected with alternate sides subjected to a control and treatment group. Control sides were chilled at -1 °C for 24 hours, the alternate sides were held at 22 °C for 6 hours, then chilled at -1 °C for 18 hours and were designated as the high-temperature conditioning. The temperature of the *longissimus* muscle remained higher for high-temperature conditioning at 3, 6, 9, and 12 hours postmortem. In addition, the high-temperature conditioned carcasses had resulted in an increased rate of pH decline. After day one postmortem, the *longissimus* muscle had a lower shear force value in high-temperature conditioned beef compared to controlled. However, there was no difference in sensory panel scores. Conditioning carcasses at high-temperatures during rigor results in beef products that will be more tender in a shorter period.

2.2 Aging

Research has found meat stored for increased time at refrigerated storage postmortem, called aging, improved meat tenderness. Aging allows endogenous proteolytic enzymes in muscle to tenderize meat. Aging process involves storing carcasses, primals, subprimals, or steaks for sufficient time, at refrigerated temperatures to maximize palatability characteristics such as tenderness, juiciness, and flavor. Protein proteolysis of structural proteins has been determined to be one of the main causes for increased tenderness postmortem (Koohmaraie, 1992).

During postmortem aging, one of the first observable changes in ultrastructure of postmortem muscle is in myofibrils (Aberle, Forest, Gerrard, & Mills, 2001). Muscle becomes more extensible the longer it is aged. Desmin and titin are the proteins that undergo

proteolytic degradation resulting in loss of the Z-disks and aid in determining meat tenderness. Desmin is an intermediate filament protein localized at the Z-disk in skeletal muscle (Richardson, 1981). Intermediate filaments like desmin, connect adjacent myofibrils at the level of their Z-lines and the myofibrils to other cellular structures. The location of desmin is an important factor in maintaining structural stability. Desmin surrounds the Z-lines of myofibrils, once degradation occurs, it results in loss of structure to the Z-line and increases tenderness. Titin is the largest protein found in mammalian tissues, and also the third most abundant (Huff Lonergan, Zhang, & Lonergan, 2010). In skeletal muscle, titin is an integral part of forming the Z-line as it spans half the length of the sarcomere and thus aids in sarcomere alignment. Titin has been shown to degrade postmortem and be associated with improved tenderness (Aberle et al., 2001).

Nebulin is a mega-protein that extends from the Z-line to actin. Degradation of nebulin postmortem could weaken actin linkages at the Z-line and thereby weaken the structure of the muscle cell (Aberle et al., 2001). Actin is the second most abundant protein in muscle fibers and has not been considered to under major changes during postmortem aging period (Aberle et al., 2001). The weakening of the myofibrils yields a higher proportion of smaller fragments in meat (Nishimura, Liu, Hattori, & Takahashi, 1998). Based on the fragmentation concept, the myofibril fragmentation index has been used as an indication of meat tenderness, and postmortem tenderization.

Many hypotheses have been researched to determine the causes of degradation of myofibrillar proteins during postmortem aging. A study conducted by Goll et al. (1983) indicated that the proteinases have to be present and have access to activation substrates for protein degradation to occur. Researchers have investigated the role of calcium dependent

proteases known as calpains. Calpains were found to be the primary cause for an increase in postmortem tenderization caused by structural protein degradation (Olson, Parrish, Dayton, & Goll, 1977). Calpains cause the breakdown in Z-disk structural proteins such as desmin. A study conducted by Morgan, Miller, Mendez, Hale, and Savell (1991) examined the effect of injecting calcium chloride ($CaCl_2$) into the muscles from cow carcasses. The injection of $CaCl_2$ accelerated postmortem aging and improved ultimate meat tenderness. Though the mechanism through which calcium chloride infusion accelerates postmortem proteolysis is unknown, it is believed, based on these studies the primary mode of action of calcium is through activation of calpains (Koohmaraie, Babiker, Merkel, & Dutson, 1988). Calpain is regulated by an endogenous inhibitor calpastatin, which has been found in all tissues that contain calpains (Huff-Lonergan et al., 1996).

Meat products can be aged by two methods: wet aging and dry aging. Wet aging refers to postmortem aging of meat products in a vacuum package and is the most common practice in the meat industry. In United States beef processing plants, beef is vacuum-packaged and distributed to retailers. Wet aging is utilized to prolong shelf-life and palatability of beef during extended periods of shipment and storage. Dry aging is a process whereby beef carcasses, primals, and/or subprimals are stored, without protective packaging, at refrigeration temperatures. This process allows the natural enzymatic and biochemical process that results in improved tenderness and development of unique flavor to occur (Campbell, Hunt, Levis, & Chambers, 2001). Products designated to dry aged products are stored in an area with controlled temperature, relative humidity, and air velocity. Even with these controlled environments a great amount of loss due to moisture and trimming of the

dried exterior surface results in decreased yields and is less often used compared to traditional wet aging techniques (Campbell et al., 2001).

In a study conducted by Pierson and Fox (1976), wholesale ribs from ten yearling bulls were selected from carcasses that were chilled for 24 hours at 3 °C. Wholesale ribs were subjected to either a high-temperature (20 °C) or controlled (3 °C) aging conditions. Shear force values decreased linearly ($P < 0.01$) as aging time at 3 °C increased. However, a significant quadratic effect between shear force and aging time was seen at 20 °C with the absolute lowest shear force values occurring after 5 days. This study indicated that subjecting subprimals to high-temperatures can increase muscle tenderness in beef products even after the onset of rigor.

2.3 Blade Tenderization

Consumers can distinguish differences in beef tenderness and are willing to pay more for a more tender product (Miller, Carr, Ramsey, Crockett, & Hoover, 2001). A great industry challenge has been to decrease variation and improve tenderness through antemortem and postmortem practices. Blade tenderization is a common practice shown to improve tenderness through the physical disruption of muscle fibers and connective tissue. Connective tissue is one component that has a significant impact on meat tenderness (Aberle et al., 2001). Collagen is the most abundant type of connective tissue in beef products. The three main layers of connective tissue are endomysium, perimysium, and epimysium. Endomysium is the inner layer that surrounds the muscle fiber. Perimysium is the connective tissue that surrounds the muscle bundle. Epimysium is the outer layer and provides primary support and structure for the entire muscle. Both epimysium and perimysium play roles in meat tenderness due to their inability to be removed during fabrication.

The effects of intramuscular connective tissue on tenderness have been extensively examined. There are many different factors that influence the amount of connective tissue, such as muscle location, animal age, and breed (Savell, Smith, & Carpenter, 1977). As the animal increased in age, the amount of insoluble collagen increased and meat tenderness decreased. Muscles that are responsible for repetitive motions, tend to have a greater amount of intramuscular connective tissue. The combination of these factors can cause an increase in variation in meat tenderness.

Consistency is key within the food service industry to ensure consumers enjoy their eating experience. Blade tenderization has been shown to be an effective way to reduce variability and inconsistency in tenderness and improve overall palatability (Jeremiah, Gibson, & Cunningham, 1999). Mechanically tenderized beef has been defined as nonintact product by the Food Safety and Inspection Service (FSIS-USDA, 1999). The process of blade tenderization raised the concern that tenderized steaks may harbor pathogenic bacteria internally. When a large number of bacteria contaminate the subprimal surface, those pathogens could potentially be translocated to the interior of the muscle (Phebus et al., 2000). Transferring bacteria contamination to the interior of the muscle may increases the risk of foodborne infection if steaks are not thoroughly cooked to a proper internal temperature.

2.4 Color

Consumer appeal is also an extremely important factor when selecting steaks. As a consumer initially walks to a retail case their concentration and focus goes directly to what they see first, the product color and packaging (Mancini & Hunt, 2005). Consumers routinely use color as a reason to select or reject a meat product. The main component in the contribution to meat color is myoglobin. The product's color is determined by the interaction

between myoglobin chemistry and light absorbance and reflectance (AMSA, 2012). Myoglobin is a water-soluble protein that is responsible for meat color. The three main chemical states of meat color are oxymyoglobin, deoxymyoglobin, and metmyoglobin. These three chemical states are a result of the chemical reactions that take place with myoglobin.

Meat color is also impacted by handling and storage. Once beef is exposed to air, it slowly blooms to a bright cherry-red color (Lee, Apple, Yancey, Sawyer, & Johnson, 2008). This bright cherry-red color is the ideal color at the retail store. This color is a result of oxygen binding to the myoglobin molecule resulting in oxymyoglobin (Lee et al., 2008). Beef that is vacuum packaged results in a dark purple-red color and is referred to as deoxymoglobin (Aberle et al., 2001). Factors such as high temperatures, low oxygen atmospheres, and spoilage bacteria can reduce oxygen tension on the meat surface and result in the grown, tan or green color (Seideman, Cross, Smith, & Durland, 1984). This color transformation is referred to as metmyoglobin.

Factors during storage that affect meat color are the temperature of the product and the length of time the product is stored. Discoloration is an indicator of freshness and wholesomeness to the consumer (McKenna et al., 2005). Fresh meat is typically packaged in trays and overwrapped with polyvinyl chloride (PVC) film. In many retail settings, the overwrapped trays are displayed in a climate-controlled, open topped, display case. Over time, meat is inevitably exposed to oxygen regardless of how it is displayed. Retail shelf life studies are beneficial for industry. Conducting such studies give insight to various factors and their effect on shelf-life. Jeremiah and Gibson (2001) conducted a study on the influence of storage temperature and time on color stability in beef cuts. In this study three different temperatures (-1.5, 2, and 5 °C) were evaluated. Storage at -1.5 °C resulted in the greatest

color stability, the most desirable retail appearance, and longest storage time. As temperature increased, color stability decreased and odor development increased. (Jeremiah & Gibson, 2001).

2.5 Meat Quality Evaluation

Marketing is a practice used by many retailers to promote their business and increase sales. However, consumer satisfaction is assumed to be the more significant determinant in repetitive sales and new customers (Miller et al., 2001). Meat products are similar to any other product in that they are developed, produced, and marketed to appeal to the customer. Consumer studies are used to collect and understand consumer response to the food products and variables or factors that are being studied in order to ensure they will have high consumer acceptance (Resurreccion, 2004).

Objective evaluations allow for the comparison of different treatments as well as ascertaining their effect on a characteristic. However, they do not provide information concerning product acceptability or preference for one kind of meat over another (Destefanis, Brugiapaglia, Barge, & Dal Molin, 2008). Consumer panels are great predictors of how the public perceives a product. Consumer acceptability and satisfaction is the driver of the meat industry and being able to gain insight on their demand is of utmost importance. Measurements commonly associated with consumer sensory panels are tenderness, juiciness, flavor, overall like, and overall acceptability (Miller et al., 2001). Subjective measures such as consumer panels give more insight for consumer desirability.

Instrumental measurements of tenderness are commonly used in research. Warner-Bratzler shear (WBS) force is the most utilized analysis method. The WBS force is the

measurement of force required to shear across a muscle fiber. These values replicate the amount of force to penetrate, bite, mince, compress, and stretch the meat.

CHAPTER III

MATERIALS AND METHODS

3.1 Product Collection

Paired subprimals were selected from a commercial beef processing facility. USDA yield grade 2 or 3, Choice carcasses (n = 12) were selected for this study (USDA, 2016). Carcasses were fabricated to comply with the Institutional Meat Purchase Specifications (IMPS), as described by the North American Meat Institute (2014). Four subprimals types, ribeye, lip-on (IMPS 112A), strip loin (IMPS 180), shortloin (IMPS 174), and top sirloin butt (IMPS 184) were selected for this study. Subprimals were packaged into individual bags, boxed, aged for 5 days at 0.0 to 1.1 °C, and then shipped to Rosenthal Meat Science and Technology Center at Texas A&M. The pack date was identified as day 0 for the aging period on all subprimals selected.

3.2 Aging Temperature Treatment Design

Upon arrival at Rosenthal Meat Science and Technology Center, all boxes were opened and packages were checked for leakers. For subprimals identified as leakers (n = 11), purge accumulation was quantified prior to repackaging, and that value was later added to the respective subprimal purge totals after aging. Following purge quantification of subprimals identified as leaker they were repackaged and placed back into their respective boxes. Then, all subprimals were subjected to the same temperature of 0.0 to 1.1 °C for an additional 2 days of aging. After a total of 7 days of aging at 0.0 to 1.1 °C, subprimals were randomly allocated to 7 additional days of aging at one of the following treatments: (1) conventional temperatures of 0.0 to 1.1 °C, or (2) elevated temperatures of 3.3 to 4.4 °C. Ambient

temperatures of each of the two storage areas were monitored using Dickson Data Loggers (Model SP425; Dickson, Addison, IL). Data loggers recorded temperatures every minute for both conventional and elevated aging periods. Mean ambient storage temperatures are presented in Figure 1.

3.3 Purge, Odor, pH, and Color Evaluation

After the 14-day aging period, subprimals were evaluated for purge quantification, pH, odor, and lean color. Purge quantification was conducted by taking an initial in the bag weight (packaged weight) of the subprimal. The subprimals was weighed after bag removal (unpackaged weight), and then the original bag was rinsed free of purge with water, dried, and weighed (bag weight). Net weight was calculated by subtracting the bag weight from the packaged weight. Purge quantification was calculated by subtracting the unpackaged weight from net weight. Values for purge accumulation of leakers was added to this end value and used for data analysis.

Odor evaluation was conducted using a 6-member trained panel at the end of the aging period using AMSA (2016) sensory guidelines as a reference. Immediately after packages were opened, odor was evaluated. Individually, members of the trained panel evaluated the odor attributes based on a 10-point scale. Odor attributes included: sweet (0 = none; 9 = strong odor), sour (0 = none; 9 = strong odor), plastic (0 = none; 9 = strong odor) and bloody serumy (0 = none; 9 = strong odor).

Following odor evaluation, pH was measured for each subprimal using a digital pH meter (Model IQ 150; Spectrum Technologies, Aurora, IL). Using the round tipped probe, pH was measured on the lean surface of each subprimal at three different locations and

averaged as the pH for subprimal. To ensure accuracy the pH meter was calibrated after every 60th measurement.

Following pH evaluation, subprimals were fabricated into steaks. Using a bandsaw with a boneless saw blade, ribeye, lip-on and strip loins were cut into 2.54-cm thick ribeye and strip loin steaks, respectively. Shortloins were cut to 2.54-cm thick T-bone/porterhouse steaks on a bandsaw using a bone-in saw blade. Top sirloin butts were fabricated by hand into 2.54-cm thick center cut sirloin steaks. Following steak fabrication, a 30-minute bloom time was allowed before instrumental and visual assessment of color were conducted. Instrumental color measurements were taken in three different locations using a Hunter MiniScan EZ (HunterLab, Reston, VA) colorimeter averaged to represent the value for that steak. For each measurement, CIE *L**, *a*,* and *b** color space values were recorded for each steak. To ensure accuracy the Hunter MiniScan EZ was calibrated after every 60th measurement. Visual assessment of lean color (1=extremely bright cherry-red or bright red; 8=extremely dark red), fat color (1=white; 5=yellow), bone color (1=bright reddish-pink to red; 7=black discoloration), and discoloration/uniformity (1=none; 5=extreme); (where applicable) were performed by a 6-member trained panel using AMSA (2012) meat color measurement guidelines as a reference. After color evaluation, steaks designated for sensory and shear force analyses were labeled, vacuum-packaged, and stored frozen (approximately -10 °C). Steaks designated for shelf-life evaluation were placed in styrofoam retail trays and overwrapped using polyvinyl chloride (PVC) film.

3.4 Shelf Life Evaluation

For the evaluation of shelf-life, tray packed steaks were placed in a “retail-like” refrigerated (approximately 4 °C) setting with 1600 lx fluorescent lighting (Lithonia

Lighting, Aculty Lighting Group, Inc., Conyers, GA) using cool white bulbs to simulate a retail display case. The steaks were held under these conditions for 5 days, then each steak was evaluated for instrumental and visual assessment of color and odor using the same methods previously described.

3.5 Warner-Bratzler Shear Force Evaluation

Steaks were thawed under refrigerated conditions (approximately 4 ˚C) for 48 hours Before cooking, steaks were weighed, and initial internal temperatures recorded. Steaks were cooked on a 2.54-cm thick flat top Star Max 536TGF 36 in (91.44 cm) Countertop Electric Griddle with Snap Action Thermostatic Controls (Star International Holding Inc. Company, St. Louis, MO) set to 176 ˚C. Grill surface temperature were recorded at the beginning and end of cooking. All steaks were flipped upon reaching an internal temperature of 35 ˚C, and removed from the grill upon reaching an internal temperature of 70 ˚C. Internal temperatures were monitored with thermocouples and a thermocouple reader (Omega™ HH506A, Stamford, CT) using 0.02 cm diameter, copper constantan Type-T thermocouple wires. Upon reaching a final internal temperature of 70 ˚C, thermocouples were removed from each steak, and steak weights were recorded. Cooked steaks were covered with PVC and cooled for 16 to 18 hours at approximately 2 to 4˚C.

Cooled steaks equilibrated (approximately 30 minutes) to room temperature before being trimmed of visible fat and heavy connective tissue to expose muscle fiber orientation. At least six 1.3 cm cores were removed from each steak. The *M. longissimus lumborum* was the only muscle sampled for T-bone/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 500 mm/min

using a 10 kg load cell, and a 1.02 cm thick V-shape blade with a 60° angle and a half-round peak. The peak force (N) needed to shear each core was recorded, and the mean peak shear force of the cores were used for statistical analysis.

3.6 Sensory Evaluation

Consumer sensory panel methods were approved by the Institutional Review Board (Protocol number: IRB2015-0497M). Panelists (n = 71) were recruited from the Bryan/College Station area using an existing consumer database. Panelists were asked to complete a demographics ballot (Table 1 and Figure 4) as well as a consent form (Figure 5) before beginning the panel.

For sensory evaluation, steaks were thawed and cooked using the methods previously described. Upon reaching a final internal temperature of 70 ˚C, steaks destined for sensory panel were cut into cuboidal portions (approximately 1.27 cm x 1.27 cm x steak thickness) and served warm to consumer panelists in individual booths equipped with red theater gel lights. Samples were served in a random order and identified with random three-digit codes. Unsalted tops saltine crackers and double distilled, deionized water were provided to panelists to cleanse their palate between samples.

Panelists then were asked to evaluate steak attributes based on a 9-point scales using the ballot shown in Figure 6. Attributes included: overall liking (1 = dislike extremely; 9 = like extremely), flavor liking (1 = dislike extremely; 9 = like extremely), juiciness liking (1 = dislike extremely; 9 = like extremely), and tenderness liking (1 = dislike extremely; 9 = like extremely). Consumer panelists were given a $25 gift card for their participation in the study.

3.7 Statistical Analysis

All data were analyzed using PROC GLM of SAS (SAS Institute Inc., Cary, NC), where main effects and significant two-way interactions were included in the model. Data were analyzed to evaluate the aging differences between elevated and conventional aging temperatures. Least squares means were be calculated; where ANOVA testing indicated significance, means were separated using the PDIFF procedure and $\alpha < 0.05$. Main effects were defined as subprimal, aging treatment and their interaction. If the interaction was not significant ($P > 0.05$), then a final model was analyzed with treatment and subprimal as main effects.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Purge, Odor, pH and Color Evaluation

Purge quantification was conducted to determine if there were any differences in the amount of purge accumulated during the different aging temperatures. There were no differences ($P > 0.05$) seen between subprimal types or aging treatments for purge values (data not present).

Results from the odor evaluation conducted by trained panelists for subprimal type and aging treatment main effects are shown in Table 2. Strip loins were shown to have among the lowest odor scores ($P < 0.05$), for sweet odor compared to the other subprimal types. Treatment differences were seen ($P < 0.05$) for both sweet and sour odors, with higher odor values recorded for the elevated aging treatment. Only bloody/serumy odor values were impacted by a combined subprimal type and aging treatment effect (Table 3), among the highest bloody/serumy scores were top sirloin butt and shortloin subprimals subjected to an elevated aging temperature. Top sirloin butt subprimals subjected to elevated aging temperatures had higher ($P < 0.05$) bloody/serumy scores indicating stronger odor development when aged at elevated temperatures.

Least squares means for pH stratified by subprimals are shown in Table 4. Shortloin and top sirloin subprimals had higher ($P < 0.05$) pH values than ribeye and strip loin subprimals.

Least squares means for CIE color space values (L^*, a^*, and b^*) are shown in Table 5. Among all three color space values, treatment differences ($P < 0.05$) were present for strip loin steaks. Strip loin steaks had higher lightness (L^*) values and lower a^*, and b^* values at

elevated temperatures. A decreased a^* value is indicative of less red pigmentation moving more towards a green color. T-bone/porterhouse steaks differed ($P < 0.05$) from other steak type x treatment combinations for both L^* and b^* values. When comparing L^* values across subprimals, T-bone/porterhouse steaks displayed the lowest ($P < 0.05$) L^* values indicating a darker color lean. A decreased ($P < 0.05$) b^* value was shown in T-bone/porterhouse steaks subjected to elevated subprimal aging temperature. Lastly, a decreased ($P < 0.05$) L^* value was seen for ribeye steaks that were subjected to elevated aging temperatures, indicating a darkened lean color compared to the ribeyes subjected to the control treatment.

Trained panelist color score results are presented in Table 6. Strip loin steaks had the lowest ($P < 0.05$) lean color value compared to the other steak types. Lower lean color values indicate a brighter color of lean, which agreed with the findings from the instrumental color data presented earlier. There was no difference ($P > 0.05$) in bone color of T-bone/porterhouse steaks based on treatment differences. Color uniformity/discoloration was the only trained panel color attribute to significant difference across subprimal type and aging treatment main effects (Table 7). T-bone/porterhouse steaks expressed the highest scores ($P < 0.05$) for color uniformity/discoloration, indicating less uniform color, as well as some level of discoloration across the lean surfaces of those steaks. Color uniformity/discoloration also differed ($P < 0.05$) between aging treatments, shown by a lower uniformity/discoloration score for steaks subjected to elevated aging temperature.

4.2 Shelf Life Evaluation

After the 5 day retail shelf-life period, steaks were evaluated for odor and color. Least squares means for sweet and plastic odor ratings are presented in Table 8. A higher ($P < 0.05$) sweet odor score was seen for center-cut sirloins compared to the other steak types.

Sour and bloody/serumy odor values were impacted by a combined subprimal type x aging treatment interaction effect (Table 9). Higher ($P < 0.05$) sour and bloody/serumy odor scores were detected from T-bone/porterhouse steaks subjected to elevated aging temperatures when compared to conventional aging temperatures for the same steak type.

Instrumental color also was evaluated on steaks following the retail shelf-life period. Least squares means of CIE color space values (L^*, a^*, and b^*) for steak type and aging treatment main effects are shown in Table 10. Color measurements for center-cut sirloin steaks were among the lowest ($P < 0.05$) values recorded for color space values and subprimal types. In addition, a^* values were lower ($P < 0.05$) for products aged at an elevated temperature when compared to conventional aging.

Least squares means of trained panel color ratings are recorded in Table 11. Center-cut sirloin steaks had higher ($P < 0.05$) lean color values. These higher color values indicate that center-cut sirloin steaks had darker color lean and was in agreement with the lower L^* values discussed earlier. Strip loin steaks differed ($P < 0.05$) in fat color, shown by a lower value among panelists compared to other steak types. Lower fat colors score indicate a whiter fat color. Color uniformity/discoloration values were impacted by a combined subprimal type x aging treatment interaction effect (Table 11). For both the ribeye and T-bone/porterhouse steak types, color uniformity/discoloration ratings were higher ($P < 0.05$) for the elevated aging treatment, as compared to the control within each steak type. A study conducted by McKenna et al. (2005) looked at factors impacting the discoloration of 19 different bovine muscles. Findings from this study suggest most of the "high" color stable muscles had b^* values that were somewhat high, whereas lower b^* values indicate lower color stability. Following the retail aging study, ribeye steaks possessed the lowest b^* values as well as the

highest color panel scores for uniformity/discoloration among other steak types. Both the instrumental and panel color evaluations agreed with the findings of McKenna et al. (2005) indicating lower *b** values had lower color stability.

4.3 Warner-Bratzler Shear Force Evaluation

Differences ($P < 0.05$) were seen among steak types for WBS values. Strip loin steaks had the lowest shear force values (Table 13). No differences ($P = 0.66$) in WBS force were seen between aging treatments. Similar findings were shown in a study conducted by Carpenter, Beebe, Smith, Hoke, and Vanderzant (1976). In this study, top sirloins butts were fabricated at 1 to 7.2 °C, stored at 0 or 5.5 °C, and no differences in WBS force values were found due to temperature of postmortem aging. In contrast to our findings, King et al. (2009) evaluated the effect of blade tenderization, aging time, and aging temperature on tenderness of top butts. Their findings concluded a difference in slice shear force values when subjected to an elevated aging temperature of 3.3 °C compared to control of -0.5 °C. When comparing mean WBS force values by steak type from this study to the tenderness categories outlined by Belew, Brooks, McKenna, and Savell (2003), steaks from ribeye, lip-on, striploin, and top sirloin butt subprimals qualify for the "very tender" category (classified by WBS values < 3.2 kg [< 31.38 N]), suggesting no negative treatment impact on tenderness for those subprimals.

4.4 Sensory Evaluation

One major objective of this study was to determine if consumers could identify palatability differences among steaks derived from subprimals aged at different ambient temperatures. Consumer panelist scores for four beef palatability attributes stratified by steak types are provided in Table 14. When comparing all steak types, strip loin steaks rated the highest ($P < 0.05$) in overall liking, and tenderness liking categories. T-bone/porterhouse

steaks derived from shortloins received among the lowest ($P < 0.05$) rating for tenderness. Consumer tenderness ratings for both strip loin and T-bone/porterhouse agree with the WBS force data discussed previously. Generally, when considering all steak types, consumer panelists ratings for strip loin steaks were among the highest for all four palatability attributes across both treatments. For aging treatments, there were no differences ($P < 0.05$) in any of the four beef palatability attributes. Similar findings were seen in a study conducted by Carpenter et al. (1976). Top sirloin butts chilled at 1 °C and stored at 0 or 5.5 °C for 14 days showed no difference in all four beef palatability attributes.

CHAPTER V

CONCLUSIONS

Tenderness is one of the leading palatability attributes that determines the consumer perception of a given eating experience. Because of the resulting tenderness advantages, aging of beef subprimals has become an industry-wide practice. However, subprimal aging can create storage challenges for beef packers and retailers. In traditional retail practices, the average aging time is 17 days resulting in a large accumulation of product in retail coolers. Increasing the temperature in holding coolers at the retail level may be used to decrease aging days while still achieving the same tenderness levels as conventionally aged subprimals. The objective of this study was to determine if subjecting subprimals to elevated aging temperatures following an initial 7 d age at conventional temperatures would result in increased tenderness and consumer attributes while not sacrificing shelf life attributes.

Findings from this study indicate that aging subprimals at an elevated temperature during the last 7 days of aging did not increase tenderness values and common palatability attributes (tenderness, juiciness, flavor) of beef steaks. During the retail study, development of odor and discoloration was shown for some subprimals subjected to the elevated aging temperatures. Therefore, special considerations should be given to the subprimal types selected for use in an elevated aging temperature. Further research on the impact of subjecting subprimals to elevated aging temperatures earlier in the aging process may be useful.

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APPENDIX A

TABLES

Table 1. Demographic background of consumer panelists (n = 71) for steak evaluations

Item	Frequency (%)
Gender	
Male	42.25
Female	57.75
Age, years	
≤ 20	8.45
21 to 25	33.80
26 to 35	18.31
36 to 45	16.90
46 to 55	15.49
56 to 65	5.63
≥ 66	1.41
Working Status	
Not employed	5.71
Full-time	41.43
Part-time	10.00
Part-time Student	8.57
Student	34.29
Income US$	
< 25,000	29.58
25,000 to 49,999	14.08
50,000 to 74,999	19.72
75,000 to 99,999	12.68
≥ 100,000	23.94

Table 2. Least squares means of trained panelists scores for beef odor attributes[a] for subprimal type and aging treatment[b] main effects

Main effects	Sweet	SEM	Sour	SEM	Plastic	SEM
Subprimal						
Ribeye	0.5	0.06	1.0a	0.12	0.7	0.09
Strip loin	0.3	0.07	0.4b	0.13	0.4	0.10
Short loin	0.5	0.07	0.7ab	0.13	0.5	0.10
Top sirloin	0.5	0.06	1.0a	0.12	0.7	0.08
P-value	$P = 0.0691$		$P = 0.0222$		$P = 0.0817$	
Treatment						
Conventional	0.3b	0.04	0.5b	0.09	0.5	0.06
Elevated	0.6a	0.04	1.0a	0.09	0.5	0.06
P-value	$P < 0.0001$		$P = 0.0002$		$P = 0.7124$	

Means within a beef odor attribute value and within a main effect lacking a common letter (a, b) differ ($P < 0.05$).

[a] Panelists used the following scale: sweet (0=none; 9=strong odor), sour (0=none; 9=strong odor), and plastic (0=none; 9=strong odor).

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 3. Least squares means of trained panelists scores for bloody/serumy odor attribute[a] stratified by subprimal x aging treatment[b] ($P = 0.0462$)

Subprimal	Conventional	SEM	Elevated	SEM
Ribeye	0.8b	0.13	0.6b	0.13
Strip loin	0.6b	0.15	0.6b	0.14
Short loin	0.6b	0.14	1.0ab	0.14
Top sirloin	0.7b	0.12	1.2a	0.13
P-value		$P = 0.0462$		

Means within a beef odor attribute lacking a common letter (a, b) differ ($P < 0.05$).

[a] Panelists used the following scale: bloody/serumy (0=none; 9=strong odor).

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 4. Least squares means of pH values stratified by subprimal

Subprimal	pH	SEM
Ribeye	5.77b	0.027
Strip loin	5.69b	0.030
Short loin	5.97a	0.027
Top sirloin	5.91a	0.027
P-value	$P < 0.0001$	

Means within a subprimal type and lacking a common letter (a, b) differ ($P < 0.0001$).

Table 5. Least squares means of CIE color space values (L*, a*, b*) stratified by steak type × aging treatment [a]

	L*				a*				b*			
Steaks	Conventional	SEM	Elevated	SEM	Conventional	SEM	Elevated	SEM	Conventional	SEM	Elevated	SEM
Ribeye	44.81b	0.41	43.58cd	0.40	19.22c	0.46	19.98c	0.46	16.10e	0.30	16.33de	0.30
Strip loin	44.63bc	0.49	46.40a	0.47	25.46a	0.50	22.94b	0.51	18.69b	0.36	17.14cd	0.35
T-bone/porterhouse	39.24f	0.44	40.53e	0.45	20.56c	0.56	19.53c	0.54	20.02a	0.33	18.80b	0.33
Center-cut sirloin	42.80d	0.40	42.65d	0.43	22.81b	0.50	22.80b	0.49	17.28c	0.30	17.07cd	0.32
P-value		$P = 0.0021$				$P = 0.0062$				$P = 0.0200$		

Means within a color measurement lacking a common letter (a to f) differ ($P < 0.05$).

[a] Following initial 7-d conventional aging (0.0 to 1.1 °C), subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 6. Least squares means of trained panelists scores for beef color attributes[a] stratified by steak type

Steaks	Lean Color	SEM	Fat Color	SEM	Bone Color	SEM
Ribeye	4.48a	0.08	1.0ab	0.01	N/A	N/A
Strip loin	4.05b	0.09	1.0b	0.02	N/A	N/A
T-bone/porterhouse	4.60a	0.09	1.1a	0.02	2.6	0.08
Center-cut sirloin	4.55a	0.08	N/A	N/A	N/A	N/A
P-value	$P = 0.0002$		$P = 0.0342$		N/A	

Means within a color panel attribute lacking a common letter (a, b) differ ($P < 0.05$).

[a] Panelists used the following scale: lean color (1=extremely bright cherry-red or bright red; 8=extremely dark red), fat color (1=white; 5=yellow), and bone color (1=bright reddish-pink to red; 7=black discoloration).

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C) (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 7. Least squares means of trained panelists scores for discoloration/uniformity color attribute[a] stratified steak type and aging treatment [b] main effects

Main effects	Discoloration/Uniformity	SEM
Steaks		
Ribeye	1.1b	0.03
Strip loin	1.0b	0.04
T-bone/porterhouse	1.4a	0.04
Center-cut sirloin	1.1b	0.03
P-value	$P < 0.0001$	
Treatment		
Conventional	1.2a	0.02
Elevated	1.1b	0.02
P-value	$P = 0.0157$	

Means within a color uniformity and within a main effect lacking a common letter (a, b) differ ($P < 0.05$).

[a] Panelists used the following scale: discoloration/uniformity (1=none; 5=extreme)

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 8. Least squares means of trained panelists scores for beef odor attributes[a] after 5-day shelf life study stratified by steak type

Steaks	Sweet	SEM	Plastic	SEM
Ribeye	0.4b	0.07	0.7	0.10
Strip loin	0.3b	0.07	0.7	0.12
T-bone/porterhouse	0.4b	0.08	0.6	0.11
Center-cut sirloin	0.8a	0.07	0.9	0.10
P-value	$P < 0.0001$		$P = 0.1718$	

Means within a color panel attribute lacking a common letter (a, b) differ ($P < 0.05$).
[a] Panelists used the following scale: sweet (0=none; 9=strong odor), and plastic (0=none; 9=strong odor).

Table 9. Least squares means of trained panelist scores for sour and bloody/serumy odor attributes[a] after 5-day shelf life study stratified by steak type x aging treatment[b]

	Sour				Bloody/Serumy			
Steaks	Conventional	SEM	Elevated	SEM	Conventional	SEM	Elevated	SEM
Ribeye	0.5de	0.16	0.6de	0.16	1.8bcd	0.15	1.7bcd	0.15
Strip loin	0.3e	0.18	0.7cde	0.18	1.8bcd	0.17	1.5d	0.17
T-bone/porterhouse	0.9bcd	0.17	1.9a	0.17	1.6cd	0.16	2.1ab	0.16
Center-cut sirloin	1.1bc	0.15	1.3b	0.16	2.3a	0.14	2.0abc	0.15
P-value		$P = 0.0391$				$P = 0.0407$		

Means within a beef odor attribute lacking a common letter (a to e) differ ($P < 0.05$).

[a] Sour (0=none; 9=strong odor), and bloody serumy (0=none; 9=strong odor)

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 10. Least squares mean of CIE color space values (L*, a* and b*) after 5-day shelf life study for steak type and aging treatment [a] main effects

Main effects	L*	SEM	a*	SEM	b*	SEM
Steaks						
Ribeye	42.34a	0.68	11.50bc	0.59	15.78c	0.63
Strip loin	43.69a	0.73	13.06ab	0.65	18.14a	0.67
T-bone/porterhouse	39.61b	0.76	14.47a	0.63	18.01ab	0.70
Center-cut sirloin	36.65c	0.66	10.93c	0.57	16.24bc	0.61
P-value	$P < 0.0001$		$P = 0.0006$		$P = 0.0254$	
Treatment						
Conventional	40.40	0.49	13.16a	0.43	17.60	0.45
Elevated	40.75	0.51	11.82b	0.44	16.49	0.47
P-value	$P = 0.6211$		$P = 0.0338$		$P = 0.0941$	

Means within a color space value and within a main effect lacking a common letter (a-c) differ ($P < 0.05$).

[a] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 11. Least squares means of trained panelist scores for beef color attributes[a] after 5-day shelf life study stratified by steak type

Steaks	Lean Color	SEM	Fat Color	SEM	Bone Color	SEM
Ribeye	5.23b	0.17	1.6a	0.07	N/A	N/A
Strip loin	4.86b	0.19	1.4b	0.08	N/A	N/A
T-bone/porterhouse	4.99b	0.18	1.6a	0.07	3.4	0.07
Center-cut sirloin	6.40a	0.16	N/A	N/A	N/A	N/A
P-value	$P < 0.0001$		$P < 0.0001$		N/A	

Means within a color panel attribute lacking a common letter (a, b) differ ($P < 0.05$).

[a] Panelist used the following scale: lean color (1=extremely bright cherry-red or bright red; 8=extremely dark red), fat color (1=white; 5=yellow), and bone color (1=bright reddish-pink to red; 7=black discoloration).

Table 12. Least squares mean of trained panelist scores for discoloration/uniformity color attribute[a] after 5-day shelf life study stratified by steak type x aging treatment[b]

Steaks	Conventional	SEM	Elevated	SEM
Ribeye	2.7b	0.20	3.7a	0.21
Strip loin	1.4c	0.22	2.0c	0.23
T-bone/porterhouse	1.9c	0.21	3.1ab	0.23
Center-cut sirloin	3.0b	0.20	3.0b	0.20
P-value		*P* = 0.0101		

Means within a color uniformity attribute lacking a common letter (a, b, c) differ ($P < 0.05$).

[a] Panelist used the following scale: discoloration/uniformity (1=none; 5=extreme)

[b] Subprimals were assigned randomly to one of two aging treatments: (1) aging at conventional temperatures (0 to 1.1 °C), (2) aging at elevated temperatures (3.3 to 4.4 °C).

Table 13. Least squares means of Warner-Bratzler shear (WBS) values stratified by steak type

Steaks	WBS (N)	SEM
Ribeye	31.26a	1.93
Strip loin	24.23b	1.93
T-bone/porterhouse	33.15a	1.93
Center-cut sirloin	28.28ab	1.85
P-value	$P = 0.0122$	

Means within a subprimal type and lacking a common letter (a, b) differ ($P < 0.05$).

Table 14. Least squares means of consumer panelist scores[a] for beef palatability attributes stratified by steak type

Steaks	Overall Like	SEM	Flavor Like	SEM	Tenderness Like	SEM	Juiciness Like	SEM
Ribeye	5.9b	0.18	6.1	0.17	5.7bc	0.20	5.6	0.21
Strip loin	6.6a	0.17	6.5	0.17	6.7a	0.20	6.2	0.21
T-bone/porterhouse	5.9b	0.18	6.1	0.17	5.3c	0.20	5.7	0.21
Center-cut sirloin	6.1b	0.17	6.2	0.17	6.1b	0.20	5.8	0.21
P-value	$P = 0.0166$		$P = 0.2889$		$P < 0.0001$		$P = 0.1712$	

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

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

APPENDIX B

FIGURES

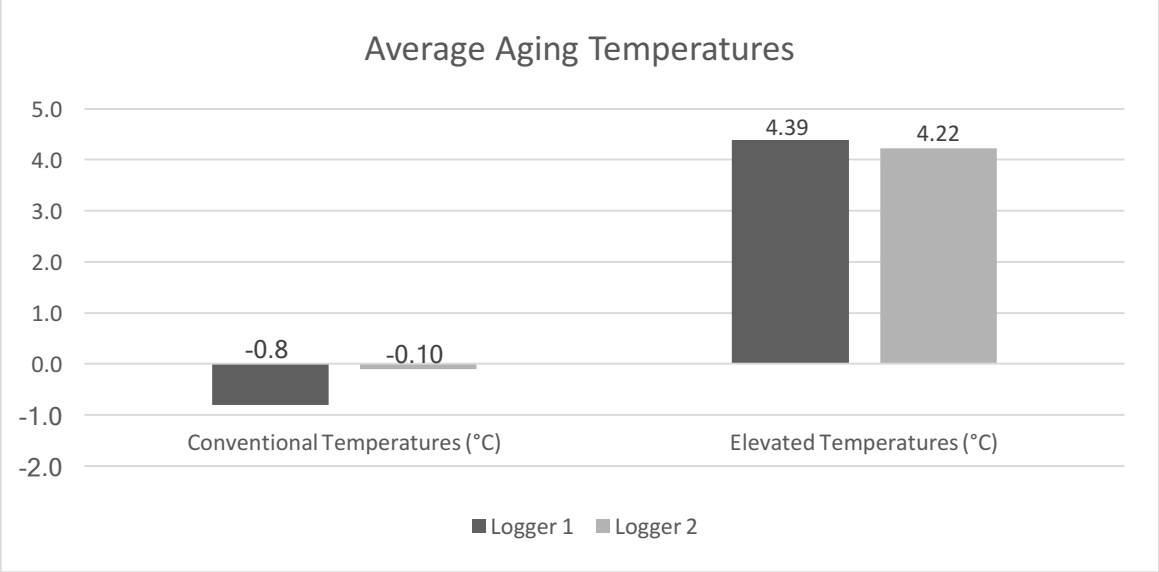

Figure 1. Mean ambient storage temperatures (°C) from data loggers used to monitor cold storage for each aging treatment (two aging treatments were used: (1) conventional temperatures (0 to 1.1 °C), (2) elevated temperatures (3.3 to 4.4 °C) over a 7 day aging treatment period.

To be conducted post 30 minute bloom:

Lean Color

1= Extremely bright cherry-red or bright brick red
2= Bright cherry-red or bright brick-red
3= Moderately bright cherry-red or bright brick-red
4= Slightly bright cherry-red or bright brick-red
5= Slightly dark cherry-red or bright brick-red
6= Moderately dark red
7= Dark red
8= Extremely dark red

Bone Marrow Color

1= Bright reddish-pink to red
2= Dull pinkish-red
3= Slightly grayish-pink or grayish-red
4= Grayish-pink or grayish-red
5= Moderately gray
6= All gray or grayish-black
7= Black discoloration

Fat Color

1= White
2= Creamy white
3= Slightly yellow
4= Moderately yellow
5= Yellow

Discoloration/Uniformity

1= None
2= Slight
3= Small
4= Moderate
5= Extreme

Figure 2. Lean color, bone marrow color, fat color and discoloration/uniformity standards used for this study.

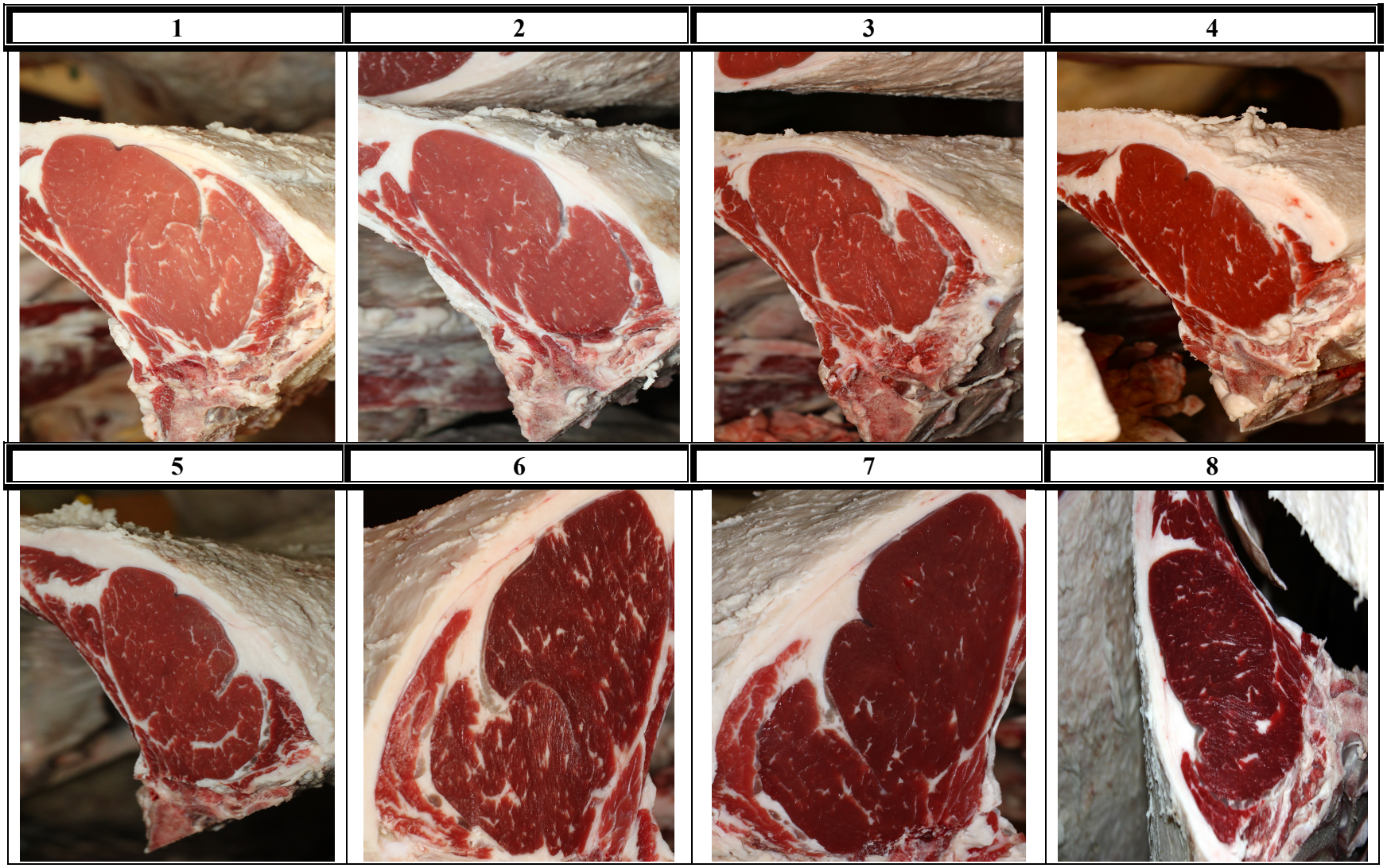

Figure 3. NCBA elevated aging temperature project lean color photos

Figure 4. Demographic questions form

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

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

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):

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

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

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

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

    Grass-fed Aged
    Traditional Organic

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Figure 5. Consumer panelist consent form

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM
CONSENT FORM

Project Title: Impact of elevated aging temperatures on tenderness, shelf life, and consumer acceptability of beef

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

Why Is This Study Being Done?
To determine differences in quality attributes of steaks derived from subprimals aged at conventional temperatures versus those aged at elevated temperatures

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

_____ _____
Participant's Signature Date

_____ _____
Printed Name Date

IRB NUMBER: IRB2015-0497M
IRB APPROVAL DATE: 08/17/2015
IRB EXPIRATION DATE: 08/15/2020

TEXAS A&M UNIVERSITY HUMAN SUBJECTS PROTECTION PROGRAM
CONSENT FORM

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

_____	_____
Signature of Presenter	Date
_____	_____
Printed Name	Date

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Figure 6. 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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