CREATING DRY-AGED TRADITIONAL AND VALUE-ADDED BEEF CUT PROGRAMS FOR DOMESTIC AND INTERNATIONAL MARKETS

By

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FOR DOMESTIC AND INTERNATIONAL MARKETS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Fresh meat is aged to enhance the palatability of the product and has become a key role for the high expectations and demands of today's industry for both retail and foodservice. Today, there are two forms of aging: wet aging in which subprimals are stored in vacuum packages and dry aging in which beef carcass or subprimals are storedwithout any type of protective packaging in refrigerated conditions. Dry and wet aging results in flavor development and more tender meat (Warren and Kastner, 1992; Miller et al., 1997; Campbell et al., 2001).

For centuries, dry aging was a common way for butchers to preserve and tenderize beef. Dry aging is a costly endeavor due to temperature control, relative humidity, and airflow needed for proper dry aging to occur to achieve proper moisture loss. Also, since dry-aged subprimals must be evenly distributed to ensure proper drying, a greater amount of cooler space is required when compared to wet aged products that can be stacked and boxed while aging, not requiring as much cooler space. As dry aging time is extended, fabrication loss, trimming time, and amount of trim is increased (Campbell et al., 2001). Although wet aged beef represents the majority of aging systems (> 95%), there are still some meat purveyors producing dry-aged product for upscale restaurants and hotels.

With the introduction of vacuum packaged boxed beef, wet aging is the most commonly used aging practice. Wet aging has allowed the beef industry to store boxed beef in refrigerated storage rooms and distribution warehouses in a strategic manner for any number of days. This provides the processor with increased flexibility to age meat and produce a more consistent product. Since most subprimals are vacuum-packaged before cutting into steaks or roasts, wet aging can also take place during shipping. Dry-aged beef products have primarily been a niche item in the upscale restaurant/food service business. However, many international beef clients have experienced these items while in the U.S., and they desired to have that same opportunity in their home country. For example, high end restaurants in Japan, Taiwan, Korea, and Indonesia are beginning to offer dry-aged beef items. With that in mind the U.S. Meat Export Federation (USMEF) has received inquiries from many international customers about the opportunity for the U.S. beef industry to offer dry-aged beef cuts.

CHAPTER II

REVIEW OF LITERATURE

Dry aging may be more of an art than a science (Savell, 2009). It has been reported that beef sustains 8 to 10% shrinkage during dry aging, irrespective of how well the temperature, humidity, and air flow are controlled (Bishoff, 1984). Consequently, beef primals shrink 0.2 to 0.3%, on average, for every 24 h of dry aging, making dry aging a costly process, requiring a high degree of control (Bishoff, 1984). Practically all beef in the U.S. is vacuumed packaged at the packer level; however, dry-aging specific subprimals at the retail level may enhance overall palatability while creating a premium price for beef products (Miller et al., 1997). When eating dry aged beef, it is typically described as having a buttery, rich, nutty, and/or earthy flavor profile (Savell, 2009).

Wet aged beef is packaged in a sealed barrier film and is held at a temperature above freezing (Sitz, 2006). When vacuum packaging was developed, it allowed the packers, processors, and retailers to gain back the economic losses incurred from trim loss and shrinkage. Hodges et al. (1974) demonstrated the advantages of vacuum packaging from a shrinkage and shelf-life standpoint without sacrificing palatability traits found in unpackaged beef. The growth of boxed beef, for the most part, transformed how steaks and roasts were prepared for food service and retail channels, making the dry aging process a minor contributor to the current aging processes used in purveying and retailing beef today. Only a limited number of scientific studies have compared dry versus wet agedbeef. Campbell et al. (2001) focused primarily on food service applications and found that consumers are willing to pay a premium for the high expectations that are associated with eating dry-aged beef . Before dry aging beef can begin, there are a few guidelines that have to be considered: days of aging, storage temperature, relative humidity and airflow.

Dry Aging: Days of Aging

Days of aging vary greatly in research as well as in the industry. Smith (2007) found no differences in overall like, flavor like, tenderness like and level of tenderness when aging (dry and wet combined) for periods of 14, 21, 28, and 35 d. However, when Warner-Bratzler shear force values were compared over these four aging periods, a17% reduction in shear force from 14 to 35 d was documented, showing that, at least from an objective standpoint, tenderness improvements were still occurring post 14 d (Smith, 2007). It has been documented that establishing the number of dry aging days is more of a preference by the purveyor than anything scientific (Savell, 2009).

Dry Aging: Storage Temperature

Temperature of storage is critical because if it is below the freezing temperature for meat (-2 to -3°C), the enzymatic processes involved with aging will slow. If the storage temperature is above freezing, the enzymatic process of aging will improve palatability the greatest; however, the risk of microbial spoilage can increase. There has been no scientific research that has assessed the effect of dry aging temperatures on the quality, shrinkage, or palatability of the meat. Storage temperatures have been reported between 0 and 4°C (Savell, 2009; Campbell et al. 2001; Parrish et al. 1991; Oreskovich et al. 1988; Miller et al. 1985; Smith, 2007).

Dry Aging: Relative Humidity

Relative humidity (RH) is a major concern regarding the storage of dry-aged meat. If RH is too high, bacterial growth can occur causing off-flavors and odors; and if it is too low, excessive shrinkage will take place (Savell, 2009). Relative humidity can also be different depending on the climate of the area where the dry aging is taking place. The more arid the climate, the lower the relative humidity is going to be. There is no scientific literature comparing the effect of RH levels on the characteristics of dry-aged beef, however, these studies used a RH of around 80% (Campbell et al. 2001; Parrish et al. 1991; Warren and Kastner 1992; Smith 2007; Ahnström et al. 2006).

From a research perspective, airflow has not been studied. Nonetheless, there are some guidelines that should be followed. Special wire racks, perforated shelves, trees or hooks are used to hold product for dry aging so that all surfaces are exposed to the cold temperatures to allow for uniform drying and allow minimum spoilage and resulting off-odor development (Savell, 2009). Often times there are fans to help keep the air circulating around the product as well as ultraviolet lights to help prohibit microbial spoilage.

Dry Aging: Flavor Effects

Dry-aged beef has a unique flavor profile compared to wet-aged beef. Campbell et al. (2001) conducted one of the most extensive studies to date on the effects of dry aging on beef flavor. They evaluated Certified Angus Beef strip loins and shortloins that were first vacuum packaged to stimulate initial packaging and shipping conditions (7 or 14 d), followed by various times of dry aging (0, 7, 14 or 21 d) before vacuum packaging and storage (0, 2, 9 or 16 d; Campbell et al., 2001). Campbell et al. (2001) found that with at least 14 d of dry aging, aged flavor and brown roasted flavor increased significantly compared to those cuts dry aged for fewer days or that were not dry-aged at all. They also found that aged flavor peaked at 9 d of vacuum storage after the dry aging period and actually declined when stored at 16 d indicating some benefits of dry aging were slightly reversed with the additional vacuum packaged storage period (Campbell et al., 2001).

Warren and Kastner (1992) obtained U.S. Choice strip loins at 3 d postmortem and, after obtaining an unaged sample from each strip loin to serve as the unaged treatment, either vacuumed-aged or dry-aged each strip loin for 11 d. A trained taste panel evaluated cooked steaks for a variety of flavors intensities. Dry-aged steaks had higher ($P < 0.05$) beefy and brown roasted flavor intensities than the unaged or vacuum-aged steaks (Warren and Kastner, 1992). Vacuum-aged steaks had a significantly higher bloody/serumy and sour flavor intensities than the unaged steaks (Warren and Kastner, 1992). There were no differences in metallic flavor intensities between unaged and vacuum-aged steaks.

There have been several other studies that have not found increased flavor intensity in dry-aged beef. Parrish et al. (1991) used both trained and untrained sensory panels to evaluate steaks from dry-aged and wet-aged (21 d) U.S. Prime, Choice and Select ribs and loins. Neither panel found flavor intensity or flavor desirability differences between the aging treatments (Parrish et al., 1991). Oreskovich et al. (1988) found no differences in beef flavor intensity between dry-aged beef and beef aged in polyvinyl chloride film or in vacuum packages for 7 d. Laster (2007) and Smith (2007) did not find flavor-like differences between steaks from dry- and wet-aged shortloins. Smith (2007) did find an interaction for level of beef flavor where steaks from U.S. Select, dry-aged shortloins were similar to steaks from U.S. Choice, dry-aged shortloins, but steaks from U.S. Select, wet-aged shortloins had less ($P < 0.05$) beef flavor from steaks from U.S. Choice, wet-aged shortloins.

There have been situations where panelists favored wet-aged steaks over dry-aged steaks. Sitz et al. (2006) found that wet-aged U.S. Prime steaks had significantly higher flavor desirability and overall acceptability scores than dry-aged Prime steaks. Proximate analysis of wet-aged and dry-aged steaks and found, although the dry-aged Prime steaks had significantly less moisture and more protein than wet-aged Prime steaks, the wet-aged Prime steaks had significantly more fat (11.56% for dry aged versus 16.16% for wet-aged; Stitz et al., 2006). The premise was that this increased level of fat in the wet-aged steaks contributed to the higher flavor desirability scores compared to the dry-aged steak.

Dry Aging: Tenderness Effect

Campbell et al. (2001) stated that panelists found steaks aged 14 d to be significantly more tender compared to those dry-aged treatments for 7 d or the controls. Dry aging for 21 d did not result in steaks that were rated more tender by the panelists; however, Warner-Bratzler shear force was significantly lower for those dry-aged 21 d, compared to steaks dry-aged for shorter periods (Campbell et al. 2001). Campbell et al. (2001) declared tenderness continued to improve in the vacuum-storage period that followed the initial dry aging treatment, indicating biochemical and structural changes that occur in postmortem aging continue at some level.

Warren and Kastner (1992) found that both vacuum aging and dry aging for 11 d resulted in tenderness scores that were significantly higher than the unaged controls. However, the method of aging vacuum or dry did not differ in tenderness. Parrish et al. (1991) found that rib and loin steaks from their wet aging treatment were significantly more tender than the rib and loin steaks from their dry aging treatment. The authors gave no explanation for this but did comment that the panel scores for steaks from both the dry and wet aging treatments were quite high (Parrish et al., 1991).

Sitz et al. (2006) in a study designed to investigate the willingness to purchase dry and wet aged products found that there were no tenderness differences between dry-aged (vacuumed packaged for 30 d dry aging followed by 7 d in a vacuum packaging for shipping and storing before cutting) and wet-aged (vacuumed packaged for 37 d) steaks from U.S. Choice strip loins; however, following the same aging protocols for U.S. Prime strip loins, wet-aged steaks were significantly more tender than dry aged steaks. For both the Prime and Choice comparisons, Warner-Bratzler shear force values did not differ between the dry and wet aged steaks (Sitz et al., 2006).

Oreskovich et al. (1988) obtained strip loins from U.S. Good (equivalent to the U.S. Select grade today) carcasses and aged product for 7 d either without packaging (dry-aged) or with polyvinyl chloride film (steaks only) or vacuum packaging (as steaks or as subprimals). Oreskovich et al. (1988) found steaks from dry-aged strip loins did not differ in consumer tenderness ratings or Warner-Bratzler shear force compared to steaks stored in polyvinyl chloride or vacuum bags or when steaks were cut from strip loins stored in vacuumed bags.

Smith (2007) compared steaks from dry-aged and wet-aged shortloins, and Laster (2007) compared steaks from dry-aged and wet-aged bone-in ribeyes, bone-in strip loins, and top sirloin butts. The only tenderness difference between dry-aged and wet-aged steaks occurred in the bone-in ribeye group (Laster, 2007) where panelists gave wet-aged steaks significantly higher tenderness like scores. In both of these studies (Smith, 2007 and Laster, 2007), consumers generally found significant grade effects for most palatability traits, but did not find differences between steaks from dry- versus wet-aged treatments.

Dry Aging: Juiciness Effects

Campbell et al. (2001) found panelists rated steaks juicer as dry aging time increased. Steaks from the 21 d dry aging treatment were significantly juicer than those from the 14 d treatment, which were significantly juicer than those from the controls (0 d) or 7 d treatment. Campbell et al. (2001) stated that increased aging resulted in significantly juicer steaks and attributed this finding to the possible loss in water holding capacity. It was thought that more juices were released as the meat was chewed since the surface of the meat had a significant amount of moisture loss.

Consumers

The beef industry consistently produces steaks of the same quality grade that vary in tenderness (Miller at al., 2001). Customer satisfaction for beef steaks is a complex issue because of the interrelated effects of cut, USDA quality grade, and demographics on palatability (Neely et al., 1998). According to Platter et al. (2001), the beef quality attribute considered most important to the consumer in the home or restaurant is tenderness followed by flavor and juiciness. Miller et al. (2001) reported that as beef steaks become tougher, flavor and juiciness have a greater effect on consumer satisfaction.

Conclusion

Dry aging is a very costly endeavor. Due to revenue losses in salable yield, retail and food service prices are much higher. There should be no question why wet aged beef ultimately dominates the market. The ability to improve tenderness, while controlling shrinkage, with vacuum-packaged aging has made this a widely used system in the beef industry (Savell, 2009). Research on dry aging is varied because it encompasses many different factors and has been directed toward economic and domestic sensory qualities. There is more interest among the international market for dry aged product. Additional research should be conducted to determine if there is a need for dry aged beef and the process of exporting such product for international markets.

CHAPTER III

CREATING DRY-AGED TRADITIONAL AND VALUE-ADDED BEEF CUT PROGRAMS FOR DOMESTIC AND INTERNATIONAL MARKETS

ABSTRACT

The present study was conducted to develop a dry aging program that would maximize flavor and shelf-life along with ensuring the safety characteristics of traditional and the value cuts destined for domestic and international consumers. Beef ribeye rolls (n = 24), short ribs (n = 96), short loins (n = 48), and top sirloin butts (n = 60) were randomly assigned to one of four aging protocols. These subprimals (n = 228) were randomly assigned to one of three treatments, frozen, wet- or dry- aging, and to one of three periods, 0, 14 or 28 d. Aging protocol 1 was wet-aged for 14 or 28 d and dry-aged for 0, 14, or 28 d. Aging protocol 2 was wet-aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and wet-aged for an additional 14 or 28 d. Aging protocol 3 was wet aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and frozen for 14 or 28 d. Aging protocol 4 was frozen for 14 or 28 d and dry aged for 0, 14, or 28 d. Sensory, Warner-Bratzler shear (WBS) force evaluation, and proximate analysis (PROX) were conducted to determine palatability

characteristics. Aging protocols (AP) 1, 3 and 4 were found to be superior ($P < 0.01$) in terms of improving the flavor of coulotte steaks when compared to their AP 2 counterparts. Aging protocols 1 and 3 were found to be superior ($P < 0.01$) for improving the flavor of beef steaks from the shortloin when compared to AP 2. Consumers preferred the flavor of 28 d dry-aged boneless short rib steaks over the 0 d dry-aged steak ($P < 0.02$). The effect of aging period on WBS values of retail beef cuts was not significant ($P > 0.05$). Moisture loss percentages displayed a significant ($P < 0.01$) difference with the coulotte having the highest percentage moisture followed by export ribs, while short ribs boneless contained the lowest amount. Aging protocols proved to have considerable effect on consumer evaluation of various palatability characteristics for beef steaks, especially those steaks from the coulotte, export rib and shortloins. Consumers could not detect any sensory characteristics differences between AP for the sirloin, bone-in and boneless short ribs. Dry-aging periods of 14 to 28 d have appeared to be effective in producing the desired results of this process, but there does not appear to be a magical threshold where sufficient time is required beyond 14 d to truly call this beef "dry-aged" from a performance standpoint.

INTRODUCTION

The aging of meat is a common practice in the industry that has proven to increase overall palatability through increased tenderness and flavor development. Wet aging is the most common aging method, allowing packers, processors, and retailers to vacuum package product in order to reduce shrink and avoid excess trimming. Dry aging provides unique palatability traits with increased loss from shrink and excessive trim. Both aging methods achieve increased tenderness, but develop quite different flavor profiles (Campbell et al. 2001; Warren & Kastner, 1992). Dry-aged beef has been said to have a beefy, brown/roasted flavor while wet-aged product can produce bloody/serumy and metallic flavor.

Enhanced flavor, and other palatability improvements, contributes to the perception that dry-aged beef is a premium product demanding a higher price in the market place. Retailers are constantly looking for new ways to generate consumer appeal. Dry-aging has become one of the latest trends among chefs in the United States and in many Asian countries. Therefore, the objective of this study is to develop a dry aging program that would maximize flavor and shelf-life along with ensuring the safety characteristics of traditional and value beef cuts for domestic and international consumer

MATERIALS AND METHODS

The Oklahoma State University Institutional Review Board (IRB) approved the experimental protocol used in the study (See Appendix A).

Product Selection

United States Department of Agriculture (USDA) U.S. Choice subprimals were purchased from a major beef processor. Subprimals were fabricated according to Institutional Meat Purchasing Specifications (IMPS USDA, 2006) and North American Meat Processors Association (NAMP, 2007). Beef rib, ribeye roll, lip-on, bone-in export style (IMPS #109 E; n = 24); beef rib, short ribs, trimmed (IMPS #123B; n = 96); beef loin, short loin, short-cut (IMPS #174; n = 48); and beef loin, top sirloin butt boneless, (IMPS #184; n = 60) were fabricated, vacuum packaged, and shipped via refrigerated truck to Outwest Meat Company, Las Vegas, NV. From each of the four subprimals purchased six different steaks were derived. Export ribs were used to produce bone-in ribeye steaks, short ribs produced bone-in and boneless short ribs, t-bone steaks were derived from the shortloin, and the top sirloin butt was fabricated into the coulotte steaks and the sirloin steaks.

Aging Protocols

Subprimals were received (7 d postmortem) at Outwest Meat Company in Las Vegas, NV, and were randomly placed in an aging protocol (AP) (Table 3.1). These subprimals (n = 228) were randomly assigned to one of three treatments, frozen, wet- or dry- aging, and to one of three periods, 0, 14 or 28 d. Aging protocol 1 was wet-aged for 14 or 28 d and dry-aged for 0, 14, or 28 d. Aging protocol 2 was wet-aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and wet-aged for an additional 14 or 28 d. Aging protocol 3 was wet aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and frozen for 14 or 28 d. Aging protocol 4 was frozen for 14 or 28 d and dry aged for 0, 14, or 28 d. Subprimals were removed from the bag and weighed to determine the green weight of the subprimal. All subprimals were stored in a cooler at an average temperature of 0.27°C ± 0.91 with a relative humidity of 83.3% ± 5.26 for the allotted aging period. After the dry-aging period was complete, subprimals were weighed and the weights were recorded. The recorded weights were used to calculate the amount of shrink caused by the dry aging process.

Fabrication Yield

Upon completion of each aging period, cutting tests were preformed in a retail cutting room at Outwest Meat Company, Las Vegas, NV. Experienced meat cutters employed by Outwest Meat Company fabricated subprimals. Initial fabrication included removal of dry surfaces, excess fat and removal of tails on shortloins and ribeye rolls. Tray-ready retail cuts were produced as described by Voges et al. (2006), and external and seam fat was removed on individual cuts. Steak weights were measured and recorded. The steaks were packaged using a Roll Stock Machine (Model R1-420 Rollstock 8600, Kansas City, MO). Packaged steaks were placed in a TCB Manufacturing (GYCC, Giant Yacht Club, La Porte, IN) soft-sided cooler bags and packed with blue ice in preparation to be transported to the Robert M. Kerr Food and Agricultural Products Center (FAPC) at Oklahoma State University via commercial air line. Upon arrival at FAPC, the steaks were sorted for consumer sensory (SEN) evaluation, Warner-Bratzler shear (WBS) force determination, or proximate analysis (PROX).

Export Ribs

Both the anterior and posterior ends were faced on the band saw to remove the dried out surface. Using a Biro band saw (Model 3334; Marblehead, OH), ribeye rolls (n = 48 halves) were fabricated into 1.9 cm-thick Beef Rib, Rib Steak, Bone In (U.P.C. #1103; referred to as bone-in ribeye steaks). Universal Product Codes (U.P.C.), established by the Industry-Wide Cooperative Meat Identification Standards Committee (2003), were used to identify cuts. Beginning from the anterior end of the of the export rib, steak one was designated for WBS force, steaks two through four were selected for SEN, and steak five was used for PROX.

Shortloins

Both the anterior and posterior ends were faced on the band saw to remove the dried out surface was trimmed of excess fat. Using the band saw, shortloins (n = 48) were fabricated into 1.9 cm-thick Beef Loin, (U.P.C. #1174; referred to as T-bone steaks). Beginning from the anterior end of the of the shortloin, steak one was designated for WBS, steaks two through four were selected for SEN, and steak five was used for PROX.

Coulotte

The Beef Loin, Top Sirloin, Cap individual muscle (IM; IMPS # 184D) was removed from the Beef Loin, Top Sirloin Butt, Boneless. After separation, the top sirloin cap (n = 60) was fabricated into Beef Loin, Top Sirloin Cap Steak, Boneless IM (U.P.C. #184D; referred to as coulotte steaks) was fabricated into 1.9 cm-thick with external fat trimmed to a level of 0.2 cm. Beginning from the anterior end, steak one was designated for WBS, steaks two through four were selected for SEN, and steak five was used for PROX.

Top sirloin butt

Both the anterior and posterior ends were faced to remove the dried out surface. Beef Loin, Top Sirloin Butt, Center Cut, Boneless, Cap Off IM (IMPS #184B; n = 60) was fabricated into 1.9 cm-thick Beef Loin, Top Sirloin Butt Steak, Boneless (U.P.C. # 1184; referred to as sirloin steaks). Beginning from the anterior end of the of the top sirloin butt, steak one was designated for WBS, steaks two through four were selected for SEN, and steak five was used for PROX.

Short Rib Bone-in

Both the ventral and dorsal ends were faced to remove the dried out surface and excess fat was trimmed. Beef Short Rib, Bone In (n = 48; U.P.C. # 1123; referred to as short rib bone-in steaks) were fabricated into 0.6 cm-thick strips. Beginning from the anterior end of the of the short rib, steak one was designated for WBS, steaks two through four were selected for SEN, and steak five was used for PROX.

Short Rib Boneless

Both the ventral and dorsal ends were faced to remove the dried out surface and excess fat was trimmed. The bones were removed from Beef Short Rib, to make Beef Short Rib, Boneless (n = 48; U.P.C. #1123D; referred to as short rib boneless steaks) were fabricated into 0.6 cm-thick strips. Beginning from the anterior end of the of the short rib, steak one was designated for WBS, steaks two through four were selected for SEN, and steak five was used for PROX.

Consumer Panels

Consumer panelists (n = 134) for coulotte steaks, bone-in ribeye steaks, T-bone steaks, bone-in short ribs steaks, boneless short ribs steaks, and top sirloin steaks were recruited. Upon arrival at the sensory facility, panelists were asked to fill out a demographic survey (See Appendix B). Panelists were also asked to fill out a survey on their consumption and eating preferences.

Frozen steaks selected for sensory evaluation were removed from the freezer 24 h prior to cooking and allowed to thaw in a walk-in cooler (2°C). Steaks were cooked on an impingement oven (XLT Ovens, Model 3240TS2, BOFI, Wichita, KS) to an internal temperature of 70ºC. Following cooking two 1 cm x 1cm x 1.9 cm cubes from steaks representing individual subprimals randomly were served to panelists.

Panelists were asked to evaluate twelve samples using an 8-point scale for like of flavor (1 = dislike extremely; 8 = like extremely); like oftenderness (1 = dislike extremely; 8 = like extremely); juiciness like (1 = extreme like; 8 = extreme dislike); overall desirability (1 = dislike extremely; 8 = like extremely; Appendix C). Distilled, deionized water and unsalted crackers were provided to each panelist to cleanse their palate between samples. Consumers had the opportunity to participate on the panel up to two times, evaluating each treatment only once.

Warner-Bratzler Shear Force

Steaks designated for objective tenderness (WBS) were removed from either the freezer or the cooler and allowed to thaw at 4ºC for 24 h, prior to cooking or the cooler. The steaks were cooked on an impingement oven (XLT Ovens, Model 3240TS2, BOFI, Wichita, KS) to an internal temperature of 70ºC. Once steaks were cooked, they were chilled at 4ºC for 24 h period. To determine WBS, six cores (1.27 cm in diameter) were taken from each steak parallel to the muscle fiber orientation. Cores were sheared once using an Instron Universal Testing Machine (model 4502; Instron Corp., Canton, MA) with a Warner-Bratzler head, at a speed of 200 mm/min. Peak force (kg) of the cores was recorded using an IBM PS2 (Model 55SX) equipped with software supplied by the

Instron Corporation. Peak WBS values were determined by the six cores averaging for a final tenderness value.

Proximate Analysis

Samples for (PROX) were stored in whirl packages, frozen and then allowed to thaw prior to the analysis using the methods previously mentioned for WBS. Once samples were thawed, they were powder homogenized with the use of a Waring blender (model 51BL31, Waring, Torrington, CT) and two, 1 to 3 g samples were secured in filter paper (Whatman #41, 15 cm) with a smooth paper clip. Secured samples were weighed, placed in a 102ºC forced air oven for 24 h. The samples were removed and allowed to cool for approximately 45 min in a desiccator and reweighed (sample, paper, and clip). Each of the dried samples were placed in a soxhlet unit where heated petroleum ether drips through the sample for a 24 h period, extracting fat. Samples were dried for approximately 20 min in a desiccator. After cooling, samples were reweighed for final lipid content (AOAC, 1990). Weights of the two samples taken before and after initial heating were averaged and used to determine a final moisture content value, whereas final weight after ether extraction and drying were averaged for a final lipid content value.

Statistical analysis

The experiment was conducted as a randomized design and data were analyzed by cut only for sensory. Data were analyzed using the GLIMMIX procedure of SAS Version 9.2 (Cary, NC). The fixed effects of AP and ethnicity and their interaction and the random effects of sample and sample by panelist were included in the model for sensory attributes. Fixed effects of AP and the random effect of sample were included in the model for WBS, cut yield, dry yield, cook loss, moisture, and fat content. Denominator degrees of freedom for statistical analyses were determined using the Kenward-Roger method. Comparisons among means were conducted using pairwise t-tests. The predetermined significance level was set at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Consumer Panels

Table 3.2 portrays the demographic information for the sensory panelists involved in this study. The large percentage of the participants were between the ages of 21-29 (43%), made less than US $19,000 (37%), and worked full time (50%). Table 3.3 indicates that 37% of the panelists consumed beef at least twice a week while 46% of all meals contained a meat item. Table 3.4 documents that 83% of the participants were the primary shopper in the household. Consumers stated that they preferred beef to other meats due to the taste in 65% of the responses. Only 37% of the participants had any knowledge of dry-aged meat.

Means and their standard deviations of consumer sensory panels for overall desirability are provided in Table 3.5. Aging Protocol 2 produced steaks, which in many cases (approximately 50%), that were spoiled and deteriorated to the point that they were not consumable. Fabricating the subprimals after dry-aging increases the surface area allowing for more oxidation and the introduction of new microflora causing increased microbial growth. Bone-in ribeye, T-bone, and bone-in short rib steaks had severe bone souring making many of the steaks inedible. Many of the steaks that were not acceptable by consumers were produced by AP 2. Coulotte steaks tended to be accepted by consumer panelists in AP 1 and 4 by having a numerical ranking above 5.15. However, the sirloins generated many steaks that received a lower ranking (5.00 or below) for AP 1 and 4. Consumer panelists gave acceptable rankings to the export ribs, shortloins, bone-in short ribs, and boneless short ribs for AP 1. Aging protocol 3 tended to produce acceptable rankings for overall desirability, nevertheless, the coulotte steaks were given an undesirable ranking.

The greatest reason for dry aging beef is to further enhance the flavor notes that are generally associated with products. Information included in Table 3.6 overviews the influence of the various AP and ethnicity on consumer sensory characteristics of cooked beef coulotte steaks. In this investigation, several of the AP (1, 3 and 4) were found to be superior ($P < 0.01$) in flavor like of coulotte steaks when compared to their AP 2 counterparts (Table 3.6). These results are in agreement with Campbell et al. (2001) who determined the Certified Angus Beef® brand strip loins and shortloins which were vacuum packed to simulate initial wet aging and shipping (7 or 14 d), followed by various times of dry aging (7, 14 or 21 d) exhibited more aged and brown-roasted flavor compared to traditionally-wet aged beef cuts. This improvement in flavor resulted in higher ($P < 0.05$) overall desirability ratings for coulotte steaks from AP 1, 3, or 4. It should be noted that Caucasian and Mainland Chinese consumers preferred ($P < 0.01$) the juiciness of the coulotte steaks in comparison to low juiciness ratings from Korean consumers.

Table 3.7 overviews the influence of the various aging protocols (AP) and ethnicity on consumer sensory characteristics of cooked beef bone-in ribeye steaks. This study showed that AP 1 and 3 were ranked higher (P < 0.02) for flavor over AP 2. Caucasians and Taiwanese consumer panelists rated (Table 3.7) the bone-in ribeye steaks the highest for tenderness, juiciness, and desirability compared to the other cuts while giving significantly (P < 0.05) higher ratings than Korean taste panelists.

In the present study, no significant (P > 0.05) differences were found for flavor, tenderness, juiciness, and desirability between AP 1, 2, 3, or, 4 of sirloin steaks as shown by Table 3.8. In agreement, Smith (2007) found overall like, flavor like, level of beef flavor, level of tenderness, juiciness like, level of juiciness, and purchase appeal attributes displayed no significant differences between dry- and wet-aged short loins. Sitz et al. (2006) found no significant differences between dry- and wet-aged strip loins for flavor, juiciness, or overall acceptability. Parrish et al. (1991) detected no significant differences in juiciness, flavor intensity, flavor desirability, or overall palatability between dry-and wet-aged ribs and loins.

Data included in Table 3.9 summarizes the influence of the various AP and ethnicity on consumer sensory characteristics of cooked beef steaks from the shortloin. Aging Protocol 1 and 3 were found to be superior (P < 0.01) for improving the flavor of beef steaks from the shortloin when compared to AP 2 (Table 3.9). The flavor improvement resulted in higher (P < 0.01) overall desirability ratings for T-bone steaks from AP1 and 3. Caucasian and Mainland Chinese consumers preferred (P < 0.03) the juiciness of the t-bone steaks in comparison Korean consumers.

Table 3.10 overviews the influence of the various AP and ethnicity on consumer sensory characteristics of cooked beef short rib bone-in steaks. No differences (P > 0.05) were found for AP or ethnic group. These results agree with a study preformed by Laster (2007) no significant differences were found for flavor, tenderness, and juiciness between dry- and wet- aged bone-in ribeye steaks. Mainland Chinese and Koreans had a tendency to rank the short rib bone-in steaks higher than the Caucasians. Due to low numbers of Taiwanese panelists means were unestimatable (Table 3.10).

The effects of AP and ethnicity on consumer sensory characteristics of cooked beef short ribs boneless steaks are displayed in Table 3.11. Although not significant AP 4 had a tendency to have a higher consumer panel rating compared to AP 1, 2, or 3. Sitz et al. (2006) found no significant differences between dry- and wet-aged strip loins for flavor, juiciness, or overall acceptability. Parrish et al. (1991) detected no significant differences in juiciness, flavor intensity, flavor desirability, or overall palatability between dry-and wet-aged ribs and loins. Taiwanese and Koreans tended to rank the short rib bone-in steaks higher than the Caucasians (Table 3.11).

Warner-Bratzler shear force

Table 3.12 outlines the influence of various AP and cuts for WBS, dry-aging yields, cutting yields, cook loss, the amount of moisture and fat among retail beef steaks. In this study, the effect of aging period on WBS values of retail beef cuts was not significant ($P > 0.05$). This data supports results of to Sitz et al. (2006) who stated that for both Prime and Choice comparisons, WBS values did not differ between the dry- and wet- aged steaks. Oreskovich et al. (1988) found that steaks from dry aged striploins did not differ in WBS compared to steaks stored in polyvinyl chloride or vacuum bags or when steaks were cut from the striploins stored in vacuum bags.

Dry-aging yields are presented in Table 3.12 with shortloins having the highest dry-aged yields, followed by export rib, coulotte, and sirloin. Bone-in short ribs and boneless short ribs had lower (P < 0.01) dry-aging yield. Cutting yields were significantly (P < 0.01) different with AP 1, 2 and 3 having a higher fabrication-yield than AP 4. Laster, (2007) stated gross cut loss percentages increased with increased aging time for both Top Choice and Select ribeye rolls. Cook loss had no significant (P > 0.05) difference with main effect.

Moisture percentages displayed a (P < 0.01) difference with the coulotte having the highest percentage of moisture while short ribs boneless contained the lowest percentage. The percentage of fat was (P < 0.01) different between each sub primal, with the short ribs both bone-in and boneless contained the most fat followed by the export rib, shortloin, and coulotte. Sirloin contained the lowest percentage of fat (Table 3.12). Table 3.13 shows the 0 d dry-aged coulotte steak contained a (P < 0.04) higher percentage of moisture that the 14 d or 28 d dry-aged steak. As for the bone-in short ribs, the 0 d dry-aged steak showed a higher amount of moisture than the 28 d dry-aged steak.

Relative Temperature and Humidity

Temperature of a dry-aging room is a crucial part of the dry-aging process. If the temperature is too low the enzymatic process that is involved in the aging process will slow and if it is too high the enzymatic process can cause spoilage resulting in off-odors and off-flavors. In this study, subprimals were stored at the average temperature of 0.26°C ± 0.91 (Figure 3.1). This agrees with Smith (2007) and Parrish et al. (1991) that used aging coolers set at 0-1° C. As for relative humidity, the aging cooler had an average of 83.28% ± 5.26 (Figure 3.1). Again, Smith (2007) stored dry aged product in a cooler with 83 ± 11% relative humidity and Parrish et al. (1991) used a relative humidity range of 80-85%.

CONCLUSION

Aging protocols proved to have considerable effect on consumer evaluation of various palatability characteristics for beef steaks, especially those steaks from the coulotte, export rib and shortloins. Consumers could not detect any sensory characteristics differences between AP for the sirloin, bone-in and boneless short ribs. Therefore, combinations of wet aging, freezing and dry-aging may not have a large impact on the consumer's perception as long as the steaks are consumed soon after dry aging. While bone-in and boneless short ribs received high ratings from the consumer panelists, dry-aging short ribs may not be economical due to approximately 20% loss during the aging process.

As for ethnic groups, Koreans tended to give the traditional cuts lower ratings than the bone-in and boneless short ribs. The Caucasians tended to rate the traditional cuts higher than either of the short ribs. Dry-aging periods of 14 to 28 d appeared to be effective in producing the desired results of this process, but there does not appear to be a magical threshold where sufficient time is required beyond 14 d to truly call this beef "dry-aged" from a performance standpoint.

Table 3.1. Description for the Aging Protocols (AP)

Description	Aging Protocols		
AP 1-Chilled beef sold to an export market where they will dry age this product upon arrival	Wet aging for 14 or 28 d	Dry-aged for 0, 14 or 28 d	
AP 2- Beef that is dry aged in the U.S., then exported to an export customer as chilled product	Wet aging for 14 or 28 d	Dry-aged for 0, 14 or 28 d	Wet aging for 14 or 28 d
AP 3- Beef that is dry aged in the U.S. and then exported to an export customer as a frozen product	Wet aging for 14 or 28 d	Dry-aged for 0, 14 or 28 d	Froze for 14 or 28 d
AP 4- Beef that is sold frozen to an export customer where it is will undergo a dry aging process upon arrival	Froze for 14 or 28 d	Dry-aged for 0, 14 or 28 d	

Table 3.2. Demographic information of consumer sensory panelist (n = 134) for steak evaluation

Trait	No. of Consumers	Percent
Gender		
Male	59	44.0
Female	75	56.0
Ethnicity		
Caucasian	57	42.5
Mainland Chinese	39	29.2
Taiwanese	9	6.7
Korean	29	21.6
Birth Country		
United States	57	42.5
Mainland China	39	29.1
Taiwan	9	6.7
Korea	27	20.2
Other	2	1.5
Last Visit to Home Country		
< 6 months	86	64.2
6 months-1 year	20	14.9
> 1 year-2 years	13	19.7
> 2 years	15	11.2
Age, years		
≤ 20	6	4.5
21-29	58	43.2
30-39	23	17.2
40-40	32	23.9
50-59	9	6.7
≥ 60	6	4.5
Household Income, U.S.$		
≤ 19,000	49	37.0
19,000-19,999	7	5.4
20,000-29,999	9	6.7
30,000-39,999	9	6.7
40,000-49,000	7	5.4
50,000-59,999	19	14.2
≥ 60,000	33	24.6
Education		
Elementary	3	2.3
High School	13	9.7
College	59	44.0
Graduate School	59	44.0
Work Status		
Unemployed	7	5.2
Part-time	24	17.9
Fill time	67	50.0
Student	36	26.0

Table 3.3.Demographic information of sensory panelists (n = 134) for the number of times the consumer consumes the product in a week

Item	No. of Consumers	Percent
Beef Consumption		
0	1	0.70
1	21	15.7
2	50	37.3
3	35	26.1
4	8	6.0
5	11	8.2
> 5	8	6.0
Pork Consumption[a]		
0	7	5.2
1	40	30.0
2	57	42.5
3	18	13.3
4	6	4.5
5	2	1.5
> 5	4	3.0
Poultry Consumption[a]		
0	7	5.2
1	40	30.0
2	46	34.3
3	25	18.6
4	10	7.6
5	3	2.2
> 5	3	2.2
Fish Consumption[a]		
0	36	26.9
1	56	42.0
2	19	14.2
3	19	14.2
4	1	7.0
5	3	2.2
> 5	0	0.0
No Meat Consumption		
0	61	45.5
1	38	28.4
2	23	17.2
3	7	5.2
4	0	0.0
5	2	1.5
> 5	3	2.2

Table 3.4. Demographic information for sensory panel (n = 134) for steak evaluation

Item	No. of Consumers	Percent
Preferred Degree of doneness		
Rare	5	3.6
Medium Rare	34	25.3
Medium	40	30.0
Medium Well	36	27.0
Well Done	19	14.1
Primary Shopper in Home		
Yes	111	82.6
No	23	17.4
Days to Eat Out, per week		
0	16	11.7
1	64	47.8
2	29	21.4
3	16	11.7
4	7	5.2
5	3	2.2
> 5	0	0.0
Most Important Palatability Trait		
Tenderness	54	40.3
Flavor	64	48.0
Juiciness	16	11.7
Typical Beef Preparation		
Grill	80	59.5
Pan Fry	21	16.0
Shabu Shabu	8	6.0
Other	25	18.6
Why Prefer Beef to Other Meats		
Taste	87	64.8
Tenderness	14	10.5
Brand Loyalty	4	3.0
Cost	15	11.2
Flavor	14	10.5
Knowledge of Dry-Aged Beef		
Yes	84	62.7
No	50	37.3

Table 3.5. Means ± SD for aging protocols (AP) on consumer sensory panels for overall desirability[1] of retail beef steaks (n = 338)

Aging Protocol						CUL[2]	ER[2]	SIR[2]	SL[2]	SRBI[2]	SRBL[2]
AP	FZ 1[3]	WA 1[3]	DA[3]	FZ 2[3]	WA 2[3]						
1	0	14	0	0	0	5.27 ± 2.07 (n = 2)	5.13 ± 1.95 (n = 2)	5.00 ± 2.00 (n = 2)	5.75 ± 1.91 (n = 2)	5.90 ± 2.05 (n = 2)	6.15 ± 1.83 (n = 2)
1	0	14	14	0	0	5.15 ± 1.31 (n = 2)	4.73 ± 1.57 (n = 2)	4.50 ± 1.76 (n = 2)	5.26 ± 1.61 (n = 2)	6.67 ± 0.87 (n = 2)	5.87 ± 2.14 (n = 2)
1	0	14	28	0	0	5.80 ± 1.40 (n = 2)	5.92 ± 1.93 (n = 2)	5.90 ± 1.52 (n = 2)	6.20 ± 1.48 (n = 2)	5.88 ± 1.96 (n = 2)	6.25 ± 1.67 (n = 2)
1	0	28	0	0	0	5.50 ± 1.23 (n = 2)	5.35 ± 1.37 (n = 2)	4.57 ± 1.59 (n = 2)	5.43 ± 1.87 (n = 2)	4.96 ± 2.18 (n = 2)	5.13 ± 1.98 (n = 2)
1	0	28	14	0	0	5.00 ± 1.65 (n = 2)	5.06 ± 1.64 (n = 2)	4.78 ± 1.93 (n = 2)	5.45 ± 1.32 (n = 2)	5.46 ± 1.84 (n = 2)	5.47 ± 1.77 (n = 2)
1	0	28	28	0	0	6.08 ± 2.33 (n = 2)	5.08 ± 1.56 (n = 2)	4.92 ± 1.56 (n = 2)	5.85 ± 1.68 (n = 2)	5.82 ± 1.66 (n = 2)	5.46 ± 1.39 (n = 2)
2	0	14	0	0	14	4.60 ± 1.79 (n = 2)	5.14 ± 1.67 (n = 2)	3.80 ± 1.30 (n = 2)	4.44 ± 1.64 (n = 2)	6.20 ± 1.30 (n = 2)	5.40 ± 1.14 (n = 2)
2	0	14	0	0	28	-	5.11 ± 1.87 (n = 2)	-	-	-	-
2	0	14	14	0	14	4.83 ± 2.48 (n = 2)	2.82 ± 1.17 (n = 2)	-	-	4.80 ± 2.74 (n = 1)	5.00 ± 2.06 (n = 2)
2	0	14	14	0	28	-	4.11 ± 1.53 (n = 2)	3.78 ± 2.22 (n = 1)	4.45 ± 2.29 (n = 1)	-	-
2	0	14	28	0	14	4.44 ± 1.81 (n = 2)	4.67 ± 2.44 (n = 1)	-	5.13 ± 1.45 (n = 2)	-	-
2	0	14	28	0	28	-	-	4.00 ± 1.45 (n = 2)	-	-	-
2	0	28	0	0	14	3.42 ± 1.78 (n = 2)	-	-	4.00 ± 1.66 (n = 2)	3.88 ± 2.35 (n = 1)	-
2	0	28	0	0	28	4.00 ± 2.40 (n = 1)	-	5.63 ± 1.63 (n = 2)	-	-	-
2	0	28	14	0	14	-	4.89 ± 2.43 (n = 1)	-	-	-	-
2	0	28	14	0	28	-	4.82 ± 2.17 (n = 2)	-	-	-	-
2	0	28	28	0	14	4.75 ± 2.43 (n = 2)	4.00 ± 2.16 (n = 2)	3.17 ± 1.17 (n = 2)	3.50 ± 1.38 (n = 2)	-	3.67 ± 1.07 (n = 2)
2	0	28	28	0	28	-	-	-	-	-	-
3	0	14	0	14	0	4.40 ± 1.82 (n = 2)	5.17 ± 1.94 (n = 2)	4.75 ± 2.06 (n = 2)	5.83 ± 1.51 (n = 2)	6.00 ± 1.41 (n = 2)	4.80 ± 1.92 (n = 2)
3	0	14	0	28	0	5.33 ± 2.27 (n = 2)	5.23 ± 1.38 (n = 2)	5.36 ± 1.36 (n = 2)	6.00 ± 2.74 (n = 2)	6.00 ± 1.33 (n = 2)	6.07 ± 1.38 (n = 2)
3	0	14	14	14	0	5.82 ± 0.87 (n = 2)	5.50 ± 1.58 (n = 2)	6.36 ± 1.45 (n = 2)	5.50 ± 1.97 (n = 2)	5.00 ± 1.50 (n = 2)	5.43 ± 1.40 (n = 2)
3	0	14	14	28	0	5.25 ± 0.95 (n = 2)	5.75 ± 2.62 (n = 2)	5.00 ± 1.22 (n = 2)	6.00 ± 0.89 (n = 2)	5.01 ± 1.41 (n = 2)	5.88 ± 1.24 (n = 2)
3	0	14	28	14	0	5.94 ± 1.55 (n = 2)	5.89 ± 0.93 (n = 2)	5.63 ± 1.60 (n = 2)	6.36 ± 1.59 (n = 2)	6.43 ± 1.02 (n = 2)	4.00 ± 2.10 (n = 2)
3	0	14	28	28	0	3.75 ± 2.06 (n = 2)	4.33 ± 1.78 (n = 2)	5.88 ± 0.99 (n = 2)	6.37 ± 0.99 (n = 2)	5.00 ± 1.58 (n = 2)	6.67 ± 1.50 (n = 2)
3	0	28	0	14	0	4.27 ± 1.28 (n = 2)	4.74 ± 1.66 (n = 2)	5.19 ± 1.56 (n = 2)	5.50 ± 0.70 (n = 2)	4.88 ± 2.16 (n = 2)	4.88 ± 2.19 (n = 2)
3	0	28	0	28	0	6.50 ± 0.93 (n = 2)	6.71 ± 0.76 (n = 2)	6.89 ± 1.17 (n = 2)	5.22 ± 1.80 (n = 2)	6.29 ± 1.80 (n = 2)	5.56 ± 2.01 (n = 2)
3	0	28	14	14	0	5.78 ± 1.71 (n = 2)	6.07 ± 1.38 (n = 2)	5.00 ± 1.96 (n = 2)	4.14 ± 1.88 (n = 2)	6.33 ± 1.00 (n = 2)	6.25 ± 1.16 (n = 2)
3	0	28	14	28	0	5.56 ± 1.94 (n = 2)	5.88 ± 1.64 (n = 2)	4.91 ± 1.56 (n = 2)	4.91 ± 0.94 (n = 2)	4.75 ± 1.26 (n = 2)	6.00 ± 1.41 (n = 2)
3	0	28	28	14	0	6.50 ± 1.60 (n = 2)	6.50 ± 0.55 (n = 2)	5.66 ± 1.83 (n = 2)	5.71 ± 1.53 (n = 2)	4.76 ± 2.63 (n = 2)	6.35 ± 1.39 (n = 2)
3	0	28	28	28	0	7.25 ± 0.46 (n = 2)	5.57 ± 1.71 (n = 2)	6.13 ± 1.81 (n = 2)	6.25 ± 0.89 (n = 2)	6.13 ± 1.55 (n = 2)	6.50 ± 0.76 (n = 2)
4	14	0	0	0	0	5.64 ± 1.84 (n = 2)	5.27 ± 1.61 (n = 2)	4.27 ± 1.75 (n = 2)	4.55 ± 1.92 (n = 2)	5.82 ± 1.68 (n = 2)	5.64 ± 1.84 (n = 2)
4	14	0	14	0	0	5.45 ± 1.64 (n = 2)	5.22 ± 1.48 (n = 2)	4.75 ±1.48 (n = 2)	4.75 ± 1.89 (n = 2)	5.70 ± 2.20 (n = 2)	6.20 ± 2.07 (n = 2)

4	14	0	28	0	0	6.07 ± 1.39 (n = 2)	5.11 ± 1.20 (n = 2)	5.14 ± 2.41 (n = 2)	4.67 ± 1.72 (n = 2)	5.78 ± 1.72 (n = 2)	6.07 ± 1.94 (n = 2)
4	28	0	0	0	0	5.91 ± 1.12 (n = 2)	3.39 ± 1.64 (n = 2)	4.78 ± 1.73 (n = 2)	4.52 ± 1.68 (n = 2)	5.29 ± 1.78 (n = 2)	5.87 ± 1.49 (n = 2)
4	28	0	14	0	0	6.38 ± 1.02 (n = 2)	4.75 ± 1.98 (n = 2)	4.22 ± 2.41 (n = 2)	5.12 ± 1.93 (n = 2)	5.53 ± 1.36 (n = 2)	4.40 ± 1.80 (n = 2)
4	28	0	28	0	0	5.63 ± 1.85 (n = 2)	5.40 ± 0.97 (n = 2)	5.70 ± 1.16 (n = 2)	6.20 ± 1.23 (n = 2)	6.60 ± 1.07 (n = 2)	6.21 ± 1.47 (n = 2)

[1]8 = Extremely like; 1 = extremely dislike.

[2]CUL = Cloulotte; ER = export rib; SIR = sirloin; SL = short loin; SRBI = short rib bone-in; SRBL = short rib boneless

[3]Number of days held in: FZ 1 = Freeze 1; WA 1 = wet-age 1; DA = dry-age; FZ 2 = freeze 2; WA 2 = wet age 2

Table 3.6. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail coulotte beef steaks (n = 62)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.53[b]	5.57	5.44	5.36[a]
2 (n = 14)	3.88[c]	5.90	5.25	4.23[b]
3 (n = 24)	5.53[b]	5.63	5.29	5.30[a]
4 (n = 12)	5.86[a]	6.04	5.99	5.78[a]
P > F	< 0.01	0.50	0.16	0.02
SEM	0.27	0.27	0.27	0.30
Ethnicity				
Caucasian (n = 57)	5.52	6.16[a]	5.99[a]	5.49[a]
Mainland Chinese (n = 39)	5.33	5.74[ab]	5.63[a]	5.30[ab]
Taiwanese(n = 9)	5.36	5.87[ab]	5.49[ab]	5.27[ab]
Korean (n = 29)	4.59	5.38[b]	4.86[b]	4.62[b]
P > F	0.27	0.05	< 0.01	0.05
SEM	0.25	0.25	0.24	0.26
AP 1, Caucasian	5.90	6.20	6.23	5.84
AP 1, Mainland Chinese	5.60	5.66	5.88	5.50
AP 1, Taiwanese	5.32	4.82	4.76	4.96
AP 1, Korean	5.32	5.59	4.89	5.14
AP 2, Caucasian	4.40	6.28	5.56	4.46
AP 2, Mainland Chinese	4.06	5.63	5.17	4.28
AP 2, Taiwanese	4.00	6.95	6.05	5.10
AP 2, Korean	3.05	4.74	4.20	3.09
AP 3, Caucasian	5.99	6.08	6.10	5.82
AP 3, Mainland Chinese	6.06	5.79	5.73	5.70
AP 3, Taiwanese	5.98	5.92	5.03	5.56
AP 3, Korean	4.09	4.74	4.30	4.13
AP 4, Caucasian	5.79	6.08	6.06	5.83
AP 4, Mainland Chinese	5.59	5.86	5.75	5.74
AP 4, Taiwanese	6.15	5.80	6.10	5.46
AP 4, Korean	5.90	6.44	6.05	6.09
P > F	0.38	0.40	0.39	0.48
SEM	0.49	0.49	0.47	0.51

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2] 8=Extremely like; 1=extremely dislike.

[a,b] Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.7. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail bone-in ribeye beef steaks (n = 62)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.40[a]	5.51	5.00	5.13
2 (n = 14)	4.25[b]	5.37	4.73	4.42
3 (n = 24)	5.97[a]	5.05	5.05	5.52
4 (n = 12)	5.19[ab]	4.92	4.71	4.60
P > F	0.02	0.43	0.86	0.70
SEM	0.34	0.33	0.36	0.34
Ethnicity				
Caucasian(n = 57)	5.15	5.65[a]	5.23[a]	5.08[a]
Mainland Chinese (n = 39)	4.99	4.93[ab]	4.79[a]	4.82[ab]
Taiwanese (n = 9)	5.81	5.80[a]	5.65[a]	5.61[a]
Korean (n = 29)	4.86	4.47[b]	3.81[b]	4.16[b]
P > F	0.39	< 0.01	< 0.01	0.03
SEM	0.29	0.28	0.31	0.30
AP 1, Caucasian	5.28	5.60	5.21	5.06
AP 1, Mainland Chinese	5.73	5.65	5.12	5.59
AP 1, Taiwanese	5.59	5.85	5.81	5.53
AP 1, Korean	4.99	4.94	3.84	4.32
AP 2, Caucasian	4.69	5.83	5.34	4.94
AP 2, Mainland Chinese	3.70	3.98	4.02	3.70
AP 2, Taiwanese	4.54	7.75	6.10	5.53
AP 2, Korean	4.08	3.90	3.47	3.52
AP 3, Caucasian	5.79	5.87	5.43	5.44
AP 3, Mainland Chinese	5.30	5.40	5.44	5.42
AP 3, Taiwanese	7.51	4.33	5.42	6.44
AP 3, Korean	5.28	4.59	3.91	4.78
AP 4, Caucasian	4.84	5.29	4.96	4.87
AP 4, Mainland Chinese	5.21	4.70	4.59	4.58
AP 4, Taiwanese	5.60	5.26	5.26	4.94
AP 4, Korean	5.09	4.44	4.04	4.00
P > F	0.57	0.16	0.90	0.15
SEM	0.57	0.57	0.60	0.58

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2] 8=Extremely like; 1=extremely dislike.

a,b Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.8. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail sirloin beef steaks (n = 57)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.38	5.23	4.92	4.78
2 (n = 9)	5.68	5.49	5.21	5.15
3 (n = 24)	5.94	5.86	5.12	5.65
4 (n = 12)	5.34	4.80	4.51	4.69
$P > F$	0.34	0.07	0.48	0.06
SEM	0.31	0.33	0.35	0.33
Ethnicity				
Caucasian (n = 57)	5.21	5.38	4.88	4.96
Mainland Chinese (n = 39)	5.38	4.94	4.74	4.78
Taiwanese (n = 9)	6.29	5.74	5.65	5.41
Korean (n = 29)	5.46	5.34	4.48	5.12
$P > F$	0.11	0.09	0.20	0.46
SEM	0.28	0.28	0.31	0.28
AP 1, Caucasian	5.48	5.14	4.64	4.98
AP 1, Mainland Chinese	5.32	5.16	5.08	4.67
AP 1, Taiwanese	5.89	5.48	5.84	4.91
AP 1, Korean	4.83	5.15	4.12	4.57
AP 2, Caucasian	3.94	5.50	4.66	4.25
AP 2, Mainland Chinese	4.88	4.42	4.03	4.28
AP 2, Taiwanese	6.89	6.06	5.74	5.12
AP 2, Korean	7.03	5.97	6.43	6.95
AP 3, Caucasian	6.50	5.76	5.43	5.64
AP 3, Mainland Chinese	5.93	5.56	5.39	5.61
AP 3, Taiwanese	6.85	6.69	6.13	6.88
AP 3, Korean	4.91	5.45	3.52	4.47
AP 4, Caucasian	5.37	5.12	4.80	4.98
AP 4, Mainland Chinese	5.38	4.60	4.48	4.57
AP 4, Taiwanese	5.56	4.71	4.90	4.74
AP 4, Korean	5.07	4.79	3.87	4.47
$P > F$	0.17	0.74	0.30	0.25
SEM	0.53	0.54	0.59	0.59

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2] 8=Extremely like; 1=extremely dislike.

[a,b] Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.9. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail shortloin beef steaks (n = 57)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.69[a]	5.48	5.39	5.51[a]
2 (n = 9)	4.57[b]	5.32	4.74	4.39[b]
3 (n = 24)	5.95[a]	5.73	5.21	5.66[a]
4 (n = 12)	5.22[ab]	4.77	4.90	4.76[b]
P > F	< 0.01	0.12	0.18	0.01
SEM	0.27	0.30	0.34	0.28
Ethnicity				
Caucasian (n = 57)	5.29	5.53	5.43[a]	5.17
Mainland Chinese (n = 39)	5.52	5.36	5.31[a]	5.27
Taiwanese (n = 9)	5.52	5.30	5.07[ab]	5.40
Korean (n = 29)	5.10	5.11	4.42[b]	4.47
P > F	0.58	0.64	0.03	0.12
SEM	0.25	0.27	0.28	0.26
AP 1, Caucasian	5.74	5.89	5.90	5.75
AP 1, Mainland Chinese	5.81	5.51	5.81	5.51
AP 1, Taiwanese	6.00	5.41	5.25	5.93
AP 1, Korean	5.21	5.12	4.59	4.85
AP 2, Caucasian	4.23	5.65	5.23	4.34
AP 2, Mainland Chinese	4.91	5.32	4.99	4.68
AP 2, Taiwanese	4.75	5.08	4.49	4.73
AP 2, Korean	4.40	5.22	4.27	3.79
AP 3, Caucasian	5.73	5.66	5.43	5.61
AP 3, Mainland Chinese	6.08	5.54	5.40	5.80
AP 3, Taiwanese	6.00	5.80	5.23	5.94
AP 3, Korean	6.00	5.83	4.78	5.29
AP 4, Caucasian	5.46	4.93	5.17	4.98
AP 4, Mainland Chinese	5.29	5.06	5.03	5.09
AP 4, Taiwanese	5.33	4.85	5.33	5.00
AP 4, Korean	4.81	4.25	4.06	3.96
P > F	0.97	0.98	0.99	0.99
SEM	0.51	0.54	0.56	0.51

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2]8=Extremely like; 1=extremely dislike.

a,b Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.10. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail short rib bone-in beef steaks (n = 52)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.72	6.34	6.24	5.78
2 (n = 4)	NA[3]	NA[3]	NA[3]	NA[3]
3 (n = 24)	5.46	5.87	5.45	5.46
4 (n = 12)	5.90	6.25	6.37	5.19
P > F	0.11	0.66	0.06	0.14
SEM	0.28	0.27	0.25	0.25
Ethnicity				
Caucasian (n = 57)	4.95	5.71[b]	5.73	5.16
Mainland Chinese (n = 39)	5.41	6.37[a]	6.29	5.73
Taiwanese (n = 9)	-	-	-	-
Korean (n = 29)	5.69	5.83[b]	5.89	5.30
P > F	0.20	0.05	0.22	0.26
SEM	0.25	0.25	0.23	0.24
AP 1, Caucasian	5.57	5.88	5.70	5.57
AP 1, Mainland Chinese	5.56	5.97	6.24	5.69
AP 1, Taiwanese	-	-	-	-
AP 1, Korean	5.97	6.78	6.56	5.87
AP 2, Caucasian	-	-	-	-
AP 2, Mainland Chinese	-	-	-	-
AP 2, Taiwanese	-	-	-	-
AP 2, Korean	-	-	-	-
AP 3, Caucasian	5.19	5.71	5.59	5.47
AP 3, Mainland Chinese	5.40	6.56	6.80	5.79
AP 3, Taiwanese	-	-	-	-
AP 3, Korean	5.12	4.46	4.87	4.60
AP 4, Caucasian	5.55	5.51	5.69	5.19
AP 4, Mainland Chinese	5.84	6.29	6.26	6.12
AP 4, Taiwanese	-	-	-	-
AP 4, Korean	6.40	6.52	6.72	6.36
P > F	0.87	0.09	0.39	0.48
SEM	0.53	0.54	0.49	0.53

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2] 8=Extremely like; 1=extremely dislike.

[3] NA (Not Applicable)- AP 2 (28 days wet aged/28 days dry aged/28 days wet aged) produced many steaks (approximately 50%) that were spoiled and deteriorated to the point that they were not consumable.

a,b Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.11. Effects of aging protocols (AP)[1] and ethnicity on consumer sensory panel for retail short rib boneless beef steaks (n = 54)

Item	Flavor[2]	Tenderness[2]	Juiciness[2]	Desirability[2]
AP				
1 (n = 12)	5.69	6.34	6.28	5.95
2 (n = 6)	4.58	6.01	5.32	4.82
3 (n = 24)	5.78	6.29	6.21	5.77
4 (n = 12)	6.11	6.36	6.23	6.14
P > F	0.08	0.90	0.27	0.16
SEM	0.35	0.35	0.31	0.32
Ethnicity				
Caucasian (n = 57)	5.01^{b}	5.71^{b}	5.68	5.23
Mainland Chinese (n = 39)	5.58^{ab}	6.00^{ab}	5.88	5.61
Taiwanese (n = 9)	5.62^{ab}	6.78^{a}	5.97	5.82
Korean (n = 29)	5.95^{a}	6.60^{a}	6.51	6.02
P > F	0.04	0.02	0.07	0.14
SEM	0.30	0.29	0.26	0.30
AP 1, Caucasian	5.22	5.88	5.88	5.27
AP 1, Mainland Chinese	5.87	6.18	6.18	5.93
AP 1, Taiwanese	5.88	6.29	6.29	6.41
AP 1, Korean	5.77	6.74	6.74	6.17
AP 2, Caucasian	3.77	4.91	4.91	4.50
AP 2, Mainland Chinese	5.10	5.43	5.43	5.12
AP 2, Taiwanese	4.38	5.08	5.08	4.85
AP 2, Korean	5.09	5.87	5.87	4.82
AP 3, Caucasian	5.67	6.06	6.06	5.68
AP 3, Mainland Chinese	5.72	5.86	5.86	5.67
AP 3, Taiwanese	5.80	6.03	6.03	5.55
AP 3, Korean	5.93	6.91	6.91	6.19
AP 4, Caucasian	5.36	5.87	5.87	5.47
AP 4, Mainland Chinese	5.64	6.04	6.4	5.72
AP 4, Taiwanese	6.40	6.49	6.49	6.48
AP 4, Korean	7.01	6.51	6.51	6.87
P > F	0.71	0.98	0.98	0.87
SEM	0.59	0.47	0.47	0.58

[1] Treatment 1- wet aged/dry aged; treatment 2- wet aged/dry aged/wet aged; treatment 3 wet aged/dry aged/frozen; treatment 4- frozen/dry aged.

[2] 8=Extremely like; 1=extremely dislike.

[a,b] Means in the same column, within a main effect or interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.12. Effects of cuts and aging protocols (AP)[1] and ethnicity for Warner-Bratzler shear (WBS) values, dry aging yields (%), cut yields (%), cook loss (%), moisture (%), and fat (%) for retail beef steaks (n = 361)

Item	WBS (N)	Dry Yield (%)	Cut Yield (%)	Cook Loss (%)	Moisture (%)	Fat (%)
Cut						
Coulotte (n = 60)	38.82	85.90^{bc}	44.43	18.03	63.37^{a}	9.12^{d}
Export Rib (n = 61)	33.27	88.24^{ab}	50.02	13.77	56.30^{bc}	15.68^{b}
Sirloin (n = 59)	37.89	85.24^{c}	43.98	14.71	59.29^{bc}	5.18^{e}
Shortloin (n = 63)	33.95	90.36^{a}	46.92	12.91	51.92^{cd}	12.45^{c}
Short Rib Bone-in (n = 58)	35.07	82.09^{d}	55.01	8.18	45.54^{d}	22.76^{a}
Short Rib Boneless (n = 60)	36.52	81.54^{d}	50.44	7.29	46.19^{cd}	22.46^{a}
P > F	0.25	< 0.01	0.09	0.08	< 0.01	< 0.01
SEM	1.50	1.08	3.17	16.93	17.60	0.99
AP						
1 (n = 72)	34.26	87.39	55.00^{a}	17.38	61.41	14.01
2 (n = 73)	36.81	84.33	53.47^{a}	15.73	56.41	15.30
3 (n = 144)	34.90	85.06	52.92^{a}	11.46	50.96	15.80
4 (n = 72)	35.37	85.46	42.45^{b}	5.36	44.96	13.75
P > F	0.52	0.05	< 0.01	0.13	0.85	0.19
SEM	1.22	0.88	2.58	16.93	17.60	0.80
Coulotte, AP 1	35.59	91.04	37.73^{b}	23.46	70.67	7.32
Coulotte, AP 2	34.16	84.36	47.56^{a}	19.33	63.61	9.69
Coulotte, AP 3	36.67	80.86	37.82^{b}	19.71	57.51	11.96
Coulotte, AP 4	34.02	87.32	34.61^{c}	9.62	53.68	7.52
Export Rib, AP 1	34.32	88.03	45.37^{b}	20.06	64.69	16.38
Export Rib, AP 2	29.91	87.48	49.58^{b}	16.74	60.24	17.18
Export Rib, AP 3	32.55	89.79	51.61^{a}	12.68	54.32	16.00
Export Rib, AP 4	36.18	87.67	33.54^{c}	5.59	45.97	13.14
Sirloin, AP 1	36.28	85.68	63.70^{a}	20.37	66.92	7.12
Sirloin, AP 2	36.87	85.81	53.96^{b}	16.94	62.43	6.57
Sirloin, AP 3	40.50	86.54	63.19^{a}	13.24	57.96	4.34
Sirloin, AP 4	37.65	82.92	64.06^{a}	8.30	49.86	5.20
Shortloin, AP 1	32.06	91.48	45.06	18.01	61.83	11.57
Shortloin, AP 2	33.44	87.90	43.75	15.77	56.91	8.50
Shortloin, AP 3	32.06	91.47	40.03	9.55	51.43	13.81
Shortloin, AP 4	38.04	90.60	48.85	8.31	37.49	15.95
Short Rib Bone-in, AP 1	35.20	85.11	62.21^{b}	12.13	51.72	22.09
Short Rib Bone-in, AP 2	38.73	80.62	59.37^{b}	10.68	46.46	24.68
Short Rib Bone-in, AP 3	33.14	80.79	66.72^{a}	6.84	43.70	22.52
Short Rib Bone-in, AP 4	33.04	81.85	61.76^{b}	3.08	40.29	21.74
Short Rib Boneless, AP 1	31.87	83.00	62.94^{a}	10.25	52.65	19.58
Short Rib Boneless, AP 2	46.87	79.81	61.63^{a}	14.90	48.79	25.20
Short Rib Boneless, AP 3	34.22	80.92	61.28^{a}	6.75	40.82	26.15
Short Rib Boneless, AP 4	32.95	82.42	55.90^{b}	2.73	42.49	18.92
P > F	0.15	0.40	0.02	0.04	< 0.01	0.09

SEM	3.02	2.10	3.28	17.06	17.71	1.97

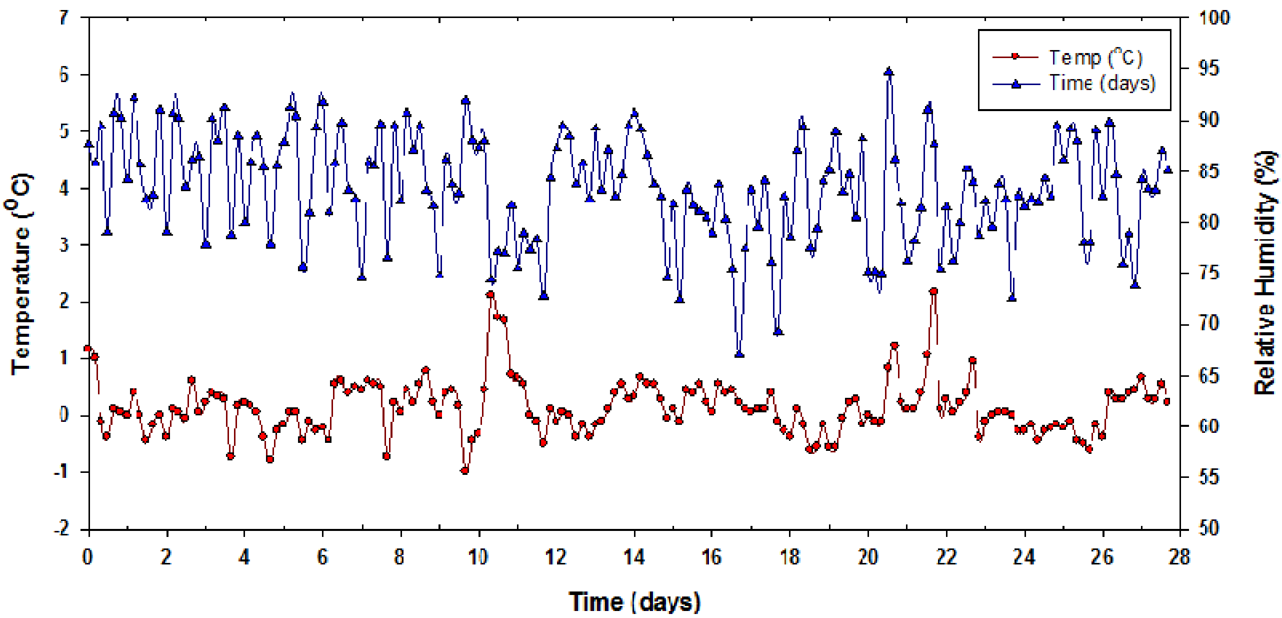
[a,b,c,d,e] Means in the same column, within a main effect or within cut interaction, with superscripts that do not have a common letter differ ($P < 0.05$).

Table 3.13. Effects of days of dry aging on moisture (%) in beef steaks (n = 361)

Item	0 d	14 d	28 d	*P* > F	SEM
Cut					
Coulotte (n = 60)	73.32[a]	69.13[b]	68.90[b]	0.04	1.40
Export Rib (n = 61)	63.24	62.45	59.85	0.27	1.55
Sirloin (n = 59)	66.82	65.95	64.45	0.62	2.41
Shortloin (n= 63)	64.21	61.84	61.30	0.58	1.97
Short Rib Bone-in (n = 58)	56.94[a]	53.95[ab]	49.89[b]	0.01	2.25
Short Rib Boneless (n = 60)	60.95	56.67	55.89	0.19	3.06

[a,b] Means in the same row with superscripts that do not have a common letter differ ($P < 0.05$).

Figure. 3.1. Temperature and humidity records for all subprimals in Outwest Meat dry aging room for 28 d



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APPPENDICES

APPENDIX A

Sensory Evaluation

Informed Consent Form

CREATING DRY-AGED TRADITIONAL AND BEEF VALUE CUT PROGRAMS FOR DOMESTIC AND INTERNATIONAL MARKETS

The following document contains important research information concerning your participation in this research study. Please read all the information carefully. Your participation in this project is voluntary and you may, at anytime, stop participating.

1. This research study is being conducted through Oklahoma State University.
2. The purpose of this research study is to determine palatability differences, if any, in beef products.
3. The beef products were made with ingredients at levels approved by FDA and USDA.
4. The beef product samples will be served to you, and you will be expected to evaluate samples and mark a ballot with your impression of the characteristics listed on the ballot.
5. The investigators consider your participation in this study to be a minimal risk as defined in 45 CFR 46 ("minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during performance or routine physical or psychological examinations or tests").
6. You will be trained to evaluate tenderness, juiciness and flavor components of beef product.
7. You will be asked to participate in 25 – 15 minute sessions. Session dates and times will be scheduled once all panelists are identified.
8. You are encouraged to ask any questions about procedures.
9. You will not be asked to make any identifying marks on the ballots and efforts are being made to maintain the confidentiality of your responses. Any written results will discuss group findings and will not include information that will identify you.
10. In case of injury or illness resulting from this research study, emergency medical treatment will be available at the University Health Center. No funds have been set aside by Oklahoma State University to compensate you in the event of illness or injury.
11. You will be provided with candy and/or breath mints upon completion of each session.

This research study has been reviewed and approved by the Institutional Review Board for Human Subjects in Research at Oklahoma State University. If you have questions about your rights as a research volunteer, you may contact Dr. Shelia Kennison, IRB Chair, 219 Cordell North, Stillwater, OK 74078, 405-744-3377 or irb@okstate.edu.

For questions about the research study, contact:
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Brad Morgan, PI   Participant

Department of Animal Science   Oklahoma State University   Stillwater, OK 74078

Okla. State Univ.
IRB
Approved 1/12/10
Expires 1/11/11
IRB # AG-10-1

APPENDIX B

OSU DRY AGING PROJECT
Demographics

Panelist Number: __________________

Circle the answer that best describes you.

1. Gender: Male Female

2. Ethnicity: Caucasian Japanese Mainland Chinese Taiwanese Korean Other

3. What is your birth country?

U.S. Mainland China TaiwanKorea Other

4. When was the last time you visited your home country?

< 6 months 6 months - 1 year > 1 year - 2 years > 2 years

5. Age: ≤ 20 21-29 30-39 40-49 50-59 ≥ 60

6. Household Income, US $:

≤ 19,000 19,000-19,999 20,000-29,999 30,000-39,999 40,000-49,999 50,000-59,999 ≥ 60,000

7. Working Status:

Unemployed Full-time Part-time Student

8. Preferred Degree of doneness:

Rare (Red center)
Medium Rare (Red/pink center)
Medium (Light pink center)
Medium Well (Pink/gray center)
Well Done (Hot, gray center)

9. Last Educations Completed:

Elementary High School College Graduate School

10. Are you primary shopper of household? Yes No

APPENDIX B

11. Average number of times per week **<u>beef</u>** is consumed as a portion of an evening meal:

0 1 2 3 4 5 > 5

12. Average number of times per week **<u>pork</u>** is consumed as a portion of and evening meal:

0 1 2 3 4 5 > 5

13. Average number of times per week **<u>poultry</u>** is consumed as a portion of an evening meal:

0 1 2 3 4 5 > 5

14. Average number of times per week **<u>fish</u>** is consumed as a portion of an evening meal:

0 1 2 3 4 5 > 5

15. Average number of times per week an evening meal does **<u>not</u>** include meat:

0 1 2 3 4 5 > 5

16. Average number of times per week an evening meal is consumed **<u>outside</u>** the home:

0 1 2 3 4 5 > 5

17. Beef palatability attribute considered most important to the panelist:

Tenderness Flavor Juiciness

18. What is the typical way you prepare beef?

Grilling Pan-frying Shabu Shabu Other ___________

19. Why do you prefer beef over the other meats?

Taste Tenderness Brand Loyalty Cost Flavor

20. Have you heard of dry aged beef?

APPENDIX C

OSU Dry-Aging Study
Instructions

Thank you for your participation in this study. Your assistance is very much appreciated.
The objective of this study is to evaluate dry age beef. Please take your time and evaluate the samples given to you carefully. Please proceed at your own pace. The sampling will take about **30 minutes**. Please answer the following questions as completely as possible. If you have any questions, please ask the monitor.
It should be noted that **BOLD LETTERS** throughout the questionnaire will give you directions on how to complete the evaluation. Answer questions 1 through 4 for each sample that you are served.

- Each product will have a number designated on the container in which it is served.
- Please write the number on each sample as it is served.
- Make sure that the number on the sample matches the number on the top of the page of the ballot.
- Let your monitor know when you want to begin.
- Prior to tasting each sample, please take a bit of cracker and then drink some water provided in the cup.

Now, please turn the page and begin tasting the beef samples. Thank you very much for your opinion.

PANELIST NUMBER ___________________________________

APPENDIX C
Sensory Ballot

Sample number_______________

1. Mark the box your **OVERALL LIKE/DISLIKE** for the **FLAVOR** of this sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extreme Like Extreme Dislike

What did you **Like/Dislike** about the **Flavor** of this sample?

____

2. Mark the box your **OVERALL LIKE/DISLIKE** for the **TENDERNESS** of this sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extreme Like Extreme Dislike

What did you **Like/Dislike** about the **Tenderness** of this sample?

____

3. Mark the box your **OVERALL LIKE/DISLIKE** for the **JUICINESS** of this sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extreme Li Extreme Dislike

What did you **Like/Dislike** about the **Juiciness** of this sample?

____

4. Mark the box your **OVERALL LIKE/DISLIKE** for the **DESIRABILTY** of this sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

Extreme Like Extreme Dislike

Prior to tasting the next sample, please take a bite of cracker and then rinse with the water provided in the cup.

VITA

Kacie Jo George

Candidate for the Degree of

Master of Science

Thesis: CREATING DRY-AGED TRADITIONAL AND VALUE-ADDED BEEF CUT PROGRAMS FOR DOMESTIC AND INTERNATIONAL MARKETS

Major Field: Animal Science

Biographical: Born in Findlay, OH on November 7, 1985 to Heidi Gourley.

Education: Graduated from Big Foot High School, Walworth, WI in June 2004. Received a Bachelor or Science in Animal Science from Oklahoma State University Stillwater, OK in May 2009. Completed the requirements for the Master of Science in Animal Science at Oklahoma State University, Stillwater, Oklahoma in May, 2011.

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Experience: Employed by the Food and Agricultural Processing Center in Stillwater, OK as an undergraduate employee in the meat lab. Employed by Oklahoma State University as a graduate research and teaching assistant.

Professional Memberships: American Meat Science Association

Name: Kacie George Date of Degree: May 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: CREATING DRY-AGED TRADITIONAL AND VALUE-ADDED BEEF CUT PROGRAMS FOR DOMESTIC AND INTERNATIONAL MARKETS

Pages in Study: 61 Candidate for the Degree of Master of Science

Major Field: Animal Science

Scope and Method of Study: The present study was conducted to develop a dry aging program that would maximize flavor and shelf-life along with ensuring the safety characteristics of traditional and the value cuts destined for domestic and international consumers. Beef ribeye rolls (n = 24), short ribs (n = 96), short loins (n = 48), and top sirloin butts (n = 60) were randomly assigned to one of four aging protocols. These subprimals (n = 228) were randomly assigned to one of three treatments, frozen, wet- or dry- aging, and to one of three periods, 0, 14 or 28 d. Aging protocol 1 was wet-aged for 14 or 28 d and dry-aged for 0, 14, or 28 d. Aging protocol 2 was wet-aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and wet-aged for an additional 14 or 28 d. Aging protocol 3 was wet aged for 14 or 28 d, dry-aged for 0, 14, or 28 d, fabricated into steaks, vacuum packaged and frozen for 14 or 28 d. Aging protocol 4 was frozen for 14 or 28 d and dry aged for 0, 14, or 28 d. Sensory, Warner-Bratzler shear (WBS) force evaluation, and proximate analysis (PROX) were conducted to determine palatability characteristics.

Findings and Conclusions: Aging protocols (AP) 1, 3 and 4 were found to be superior ($P < 0.01$) in terms of improving the flavor of coulotte steaks when compared to their AP 2 counterparts. Aging protocols 1 and 3 were found to be superior ($P < 0.01$) for improving the flavor of beef steaks from the shortloin when compared to AP 2. Consumers preferred the flavor of 28 d dry-aged boneless short rib steaks over the 0 d dry-aged steak ($P < 0.02$). The effect of aging period on WBS values of retail beef cuts was not significant ($P > 0.05$). Moisture loss percentages displayed a significant ($P < 0.01$) difference with the coulotte having the highest percentage moisture followed by export ribs, while short ribs boneless contained the lowest amount. Aging protocols proved to have considerable effect on consumer evaluation of various palatability characteristics for beef steaks, especially those steaks from the coulotte, export rib and shortloins. Consumers could not detect any sensory characteristics differences between AP for the sirloin, bone-in and boneless short ribs. Dry-aging periods of 14 to 28 d have appeared to be effective in producing the desired results of this process, but there does not appear to be a magical threshold where sufficient time is required beyond 14 d to truly call this beef "dry-aged" from a performance standpoint.

ADVISER'S APPROVAL: Dr. Brad Morgan