TENDERNESS, FLAVOR, AND YIELD ASSESSMENTS OF DRY-AGED BEEF

A Thesis

by

MEGAN ANN LASTER

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

MASTER OF SCIENCE

December 2007

Major Subject: Animal Science

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Approved by:

Chair of Committee:	Jeffrey W. Savell
Committee Members:	Davey B. Griffin
	Joe D. Townsend
Head of Department:	Gary R. Acuff

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ABSTRACT

Tenderness, Flavor, and Yield Assessments of Dry-Aged Beef.

(December 2007)

Megan Ann Laster, B.S., Texas A&M University

Chair of Advisory Committee: Dr. Jeffrey W. Savell

Top Choice (n = 48) and Select (n = 48) paired bone-in ribeye rolls, bone-in strip loins, and boneless top sirloin butts were assigned randomly to one of two aging treatments (dry or wet) and aged 14, 21, 28 or 35 days. Sensory and Warner-Bratzler shear (WBS) evaluation was conducted to determine palatability characteristics. WBS values and consumer ratings showed wet-aged ribeye steaks to be more tender than their dry-aged counterparts. WBS values for ribeye and top sirloin steaks decreased with increased aging time. Consumer ratings for tenderness like increased with increased aging time for beef steaks from all three subprimals. No significant differences were found for consumer evaluation of top sirloin steaks. Top Choice ribeye and top loin steaks received higher consumer ratings for overall like and juiciness attributes when compared to Select steaks. Cutting tests were performed at the end of each aging period to determine retail yields and processing times. Retail cutting tests showed dry-aged subprimals had lower total saleable yield percentages and increased processing times compared to wet-aged subprimals. Cooler shrink and gross cut loss percentages increased with increased aging time for both Top Choice and Select subprimals.

DEDICATION

This paper is dedicated to my parents, Dennis and Cynthia, and to my sisters, Sara and Erin. I just want to thank them for all of their love and support.

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Last, but not least, I would like to recognize my family. Mom, Dad, Sara, and Erin-I would not have been able to do this without your love and support. I have appreciated every sacrifice you guys have made for me and our family. I love you!

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CHAPTER I

INTRODUCTION AND REVIEW OF LITERATURE

Aging of fresh beef for retail and foodservice has become essential in today's industry to meet the high demands and expectations of an exceptional eating experience by consumers each time they consume beef. The aging process involves storing meat at refrigerated temperatures to maximize palatability characteristics such as tenderness, juiciness, and flavor. With tenderness being the most important palatability attribute desired by consumers, it is apparent that aging of beef products is essential to maximize the tenderness of certain beef cuts.

Two methods of aging, dry and wet, give retailers and purveyors options when deciding which aging process can most effectively benefit their individual operation. Dry aging refers to beef carcasses or wholesale cuts held at refrigerated temperatures without any type of protective packaging. On the contrary, wet aging refers to the storage of vacuum packaged beef cuts at refrigerated temperatures. With the introduction of vacuum packaged boxed beef, wet aging has been the most commonly used aging method for numerous years. With great ease, boxes can be held in refrigerated storage rooms and distribution warehouses in a strategic manner for any number of days, giving processors more flexibility to age meat and produce more tender and more consistent products.

This thesis follows the style of *Meat Science.*

Although wet aging of beef represents the majority of aging systems, there are a small number of meat purveyors producing dry aged product for upscale restaurants and hotels. They must maintain drying facilities that control temperature, relative humidity, and air flow for proper dry aging to occur. Also, since dry-aged cuts cannot be stacked like wet-aged cuts, a greater amount of space is required for dry aging of beef products versus boxed, wet aged products.

Dry aging of beef has succeeded in foodservice outlets because of its prestigious aura and the "idea" that one will have a wonderful eating experience when consuming dry-aged beef. This eating experience is created from the ability of beef to develop unique and distinct flavors that result from the drying process. The understanding as to why dry-aged beef acquires these unique flavors is still unknown; however, studies have shown that these flavors are detectable by trained and consumer panels. In the Warren and Kastner (1992) study, trained panelists determined that vacuum packaged lean samples had more intense sour and bloody/serumy attributes with increased metallic notes when compared to dry-aged strip loins, whereas dry-aged strip loins had a beefier, more brown/roasted flavor ($P < 0.05$). Similarly, Campbell et al. (2001) found that 14 and 21 d dry-aged strip steaks rated higher for dry-aged flavor, beef flavor, and brown roasted flavor attributes when compared to those steaks aged for 0 or 7 d. A consumer sensory study performed by Sitz et al. (2006) evaluated dry versus wet aging of Prime and Choice strip loins. Consumers rated wet-aged Prime strip loin steaks significantly higher for flavor and overall acceptability when compared to dry-aged Prime steaks. However, consumers could not detect any differences in flavor or overall acceptability

for dry-aged Choice strip loin steaks versus wet-aged Choice strip loin steaks. Other studies (Minks and Stringer, 1972; Parrish et al., 1991; Oreskovich et al., 1988; Smith, 2007) have found minute or no differences in flavor, flavor intensity, or flavor desirability when comparing dry- versus wet-aged beef products.

Many of these same studies have also evaluated the effect, if any, that dry and wet aging have on tenderness attributes of beef products. Studies evaluated beef products for tenderness with either a trained or consumer sensory panel, and some type of instrumental analysis (Warner-Bratzler or Instron shear force). Warren and Kastner (1992), Minks and Stringer (1972), Campbell et al. (2001), and Oreskovich et al. (1988) found no significant differences in tenderness when dry- and wet-aged products were compared. Sitz et al. (2006) found no tenderness differences between the dry- and wet-aged Choice strip loin steaks; however, their consumers rated the wet-aged Prime strip loin steaks higher for tenderness than the dry-aged products. Warner-Bratzler shear force evaluation results from this study did not detect tenderness differences between the Prime products; nevertheless consumers did perceive a difference. Furthermore, trained and consumer panels in the Parrish et al. (1991) study found that wet-aged steaks were significantly more tender when compared to the dry-aged steaks.

It is evident from above that palatability attributes such as tenderness, juiciness, and flavor of dry- versus wet-aged beef products have been investigated; however, little research has been done to evaluate the cutting losses that are associated with dry-aged product and its effect on price at the foodservice and retail levels. Smith (2007) performed retail cutting tests on dry- and wet-aged Choice and Select beef short loins

aged 14, 21, 28, or 35 days. This study found that wet-aged short loins, across all aging periods, had significantly higher total saleable yield percentages when compared to their dry-aged counterparts. As aging time increased, total saleable yield tended to decrease in both dry and wet treatments. This loss should be expected with the increased aging time. Furthermore, dry-aged short loins had higher ($P < 0.05$) cooler shrink percentages and increased cutting times when compared to all aging periods within the wet aging treatment. Minks and Stringer (1972) also reported significant weight loss of dry-aged ribs and loins when compared to the vacuum packaged counterparts.

In order to make up for the substantial yield losses and increased processing times that are associated with the dry aging process, meat purveyors and retailers are required to increase prices for the sale and distribution of dry-aged product. Smith (2007) evaluated the realizable profit for saleable components of short loins. With prices held constant, this study found profit dollars on beef loin porterhouse steaks, although not significant, were higher for all wet-aged steaks across all aging days (14, 21, 28, and 35) when compared to their dry-aged counterparts. Net sales value and margin percent for the wet-aged steaks were significantly higher than the dry-aged porterhouse steaks. Clearly, buying and selling wet-aged product leads to increased net sales values, margin dollars, and margin percents when compared to producing dry-aged product. However, retailers have seen the effects dry-aging has had on the foodservice industry, and are willing to investigate the impact dry aging has on characteristics such as shrink, shelf-life, microbial counts, but most importantly saleable yields. Retailers want to know if it is economically feasible to participate in such a process as this one.

Therefore, the objectives of this research were to perform cutting tests to more adequately understand the economics of dry aging beef, evaluate processing yields and times associated with dry aging beef, and to determine the impact of dry aging on the tenderness and flavor of beef steaks from Select and Top Choice ribeye rolls, strip loins, and top sirloin butts, in order to help retailers make informative decisions on deciding how to best market their product.

CHAPTER II

MATERIALS AND METHODS

Product selection

Carcasses (n = 27) with Modest or Moderate marbling, representing the upper two-thirds US Choice grade commonly referred to as Top Choice in the US beef industry, and carcasses (n = 27) that represented the entire range of Slight marbling for the US Select grade were randomly selected by trained Texas A&M personnel from a major beef processor (USDA, 1997).

Paired beef subprimals – Beef Rib, Ribeye Roll, Lip-On, Bone In (Export Style) (similar to IMPS #109E) (n=108), Beef Loin, Strip Loin, Bone In (similar to IMPS #175) (n=108), and Beef Loin, Top Sirloin Butt, Boneless (similar to IMPS #184) (n=108) as defined by Institutional Meat Purchasing Specifications (IMPS) and described by USDA (1996) and NAMP (2003) were followed through the fabrication process, vacuum packaged, and shipped via refrigerated truck to the Rosenthal Meat Science and Technology Center (RMSTC) at Texas A&M University.

Aging treatments

Subprimals were received (9 d postmortem) at the RMSTC and a random set of six subprimals of each type and grade group (n=36) were cut into 2.54 cm steaks, vacuum packaged, and immediately frozen. These steaks served as the baseline for tenderness and flavor assessments. The remaining subprimals (n=288) (6 replications x 2 grade groups x 3 subprimals x 4 aging periods x 2 aging treatments) were randomly

assigned to one of two treatments, dry or wet aging, and to one of four aging periods, 14, 21, 28 or 35 days. Each carcass side (right and left) were represented equally among the aging treatments. Subprimals assigned to the dry aging treatment were weighed initially in the bag and weighed after bag removal to determine the amount of purge in the bag. The recorded weights would later be used to calculate the amount of shrink caused by the dry aging process. The subprimals then were placed on a stainless steel wire rack in the aging cooler. The subprimals assigned to the wet aging treatment were weighed in the vacuum package bag and placed back in the shipping boxes for the duration of the specified aging period. All subprimals were stored in a cooler at an average temperature of -0.6 °C (standard deviation = 1.8 °C) and an average relative humidity of 78% (standard deviation = 9.3%) for the allotted aging period.

Retail cutting tests

At the end of each specific aging period, cutting tests were performed in a retail cutting room at the Rosenthal Meat Science and Technology Center at Texas A&M University. Subprimals were fabricated by experienced meat cutters employed by Texas A&M University. Retail cutting tests began with any trimming deemed necessary by the cutters before retail cuts could be fabricated. This included removal of dried surfaces, removal of tails on strip loins and ribeye rolls, or chining of strip loins and was recorded as precut trimming weights. Cutters then produced tray-ready retail cuts, as described by Voges et al. (2006), and removed external and seam fat if necessary on individual cuts. After each cutting test, Texas A&M personnel recorded weights of all fabricated components: steaks, lean trim, stew meat, stir fry, fat trim, bone, bone dust, and waste.

Weights were summed to ensure that at least 99% of the initial subprimal weight was recovered. For ribeye rolls and strip loins, band saws were cleaned of bone dust after every sixth subprimal. The bone dust was weighed and averaged across the six previous subprimals that were cut on that particular saw. Top sirloin butts were cut on a band saw equipped with a boneless saw blade, and no bone dust was recorded. Using handheld stopwatches, personnel recorded the time necessary to complete each cutting test and total time was reported.

Wet-aged cutting tests

Ribeye rolls

Vacuum packaged ribeye rolls were weighed in the bag (in bag weight), then taken out of the bag and reweighed (out of bag weight). In order for a purge loss value to be calculated, vacuum package bags then were washed, dried, and weighed. Using the band saw, ribeye rolls were cut into 2.54 cm-thick Beef Ribeye Steaks Lip-On BI (U.P.C. #1197) (referred to as ribeye steaks). Universal Product Codes (U.P.C.), established by the Industry-Wide Cooperative Meat Identification Standards Committee (2003), were used to identify retail cuts. If necessary, steaks were trimmed to an external fat level of 0.3 cm. Beginning from the posterior end of the ribeye roll, steak one was designated for Warner-Bratzler shear (WBS) force determination, steaks two and three selected for consumer sensory evaluation, and steaks four and five reserved as extra steaks. For the 35 day cutting only, steaks six and seven were selected for use in a preference question for sensory evaluation.

Strip loins

Vacuum packaged strip loins were weighed in the bag (in bag weight), then taken out of the bag and reweighed (out of bag weight). In order for a purge loss value to be calculated, vacuum package bags then were washed, dried, and weighed. Using the band saw, strip loins were chined (body of vertebra removed to a point, deleting the spinal groove) and if necessary, the tail was removed. This operation was included in the waste trimming time. The trimmed strip loin was reweighed and its weight recorded as the subprimal ready to cut weight. The chine was weighed as pre-cut trimming bone weight. Trimmed strip loins then were cut into 2.54 cm-thick Beef Top Loin Steaks (U.P.C. #1398) (referred to as top loin steaks). If necessary, steaks were trimmed to an external fat level of 0.3 cm and a tail length of no longer than 1.27 cm. Beginning from the anterior end of the strip loin, steak one was designated for WBS force determination, steaks two and three selected for consumer sensory evaluation, and steaks four and five reserved as extra steaks. For the 35 day cutting only, steaks six and seven were selected for use in a preference question for sensory evaluation.

Top sirloin butts

Vacuum packaged top sirloin butts were weighed in the bag (in bag weight), then taken out of the bag and reweighed (out of bag weight). For a purge loss value to be calculated, vacuum package bags were washed, dried, and weighed. No pre-trimming was required and subprimals were immediately cut into 2.54 cm-thick Beef Loin Top Sirloin Steaks Bnls (U.P.C. #1422) (referred to as top sirloin steaks). If necessary, steaks were trimmed to an external fat level of 0.3 cm. One total cutting time was

recorded for wet-aged top sirloin butts. Beginning from the posterior end of the subprimal, steak one was designated for WBS force determination, steaks two and three selected for consumer sensory evaluation, and steaks four and five reserved as extra steaks. For the 35 day cutting only, steaks four and five were selected for use in a preference question for sensory evaluation. Steaks six and seven, if available, were reserved for extra steaks.

Dry-aged cutting tests

Ribeye rolls

Dry aged ribs were weighed prior to cutting to determine an initial cut weight. Both anterior and posterior ends were faced on the band saw to remove the dried out surface tissue sometimes referred to as the "crust" and a time was recorded. The faced rib was then reweighed to get a subprimal ready-to-cut weight. The waste weight was recorded as pre-cut trimming (crust) weight. Steaks were cut in the same manner as the wet-aged steaks. After steaks were cut, they were individually trimmed of dried surface tissue along the rib bone and the external surface that might have been missed previously. All dried surface tissue was classified as "waste." Steak designation for shear force determination and sensory evaluation was the same as stated above for the wet-aged steaks.

Strip loins

Dry-aged strip loins were weighed prior to cutting to determine an initial cut weight. Both anterior and posterior ends were faced on the band saw to remove the dried surface tissue and the chine was removed. The faces were weighed as the pre-cut

trimming (crust) weight and the chine was weighed as pre-cut trimming bone weight and the time was recorded. The trimmed strip loin was reweighed and the weight was recorded as the subprimal ready-to-cut weight. Steaks were cut in the same manner as the wet-aged steaks. After steaks were cut, they were individually trimmed of dried surface tissue along the external surface that might have been missed previously. All dried surface tissue was classified as "waste." All steaks were trimmed to an external fat level of 0.3 cm and a tail length of no longer than 1.27 cm. Steak designation for shear force determination and sensory evaluation was the same as stated above for wet-aged steaks.

Top sirloin butts

Dry-aged top sirloin butts were weighed prior to cutting to determine an initial cut weight. Steaks were cut in the same manner as the wet-aged steaks. Steaks were individually trimmed of any dried surface tissue and external fat was trimmed to 0.3 cm. Only one total cutting time was recorded for dry-aged top sirloin butts. Steak designation for shear force determination and sensory evaluation was the same as stated above for wet-aged steaks.

Consumer panels

Consumer panelists for ribeye steaks (n=80), top loin steaks (n=91), and top sirloin steaks (n=90) were recruited from the Bryan/College Station area using an existing consumer database. Upon arrival at the sensory facility, panelists were asked to fill out a demographic survey (Table 1). Steaks selected for sensory evaluation were removed from the freezer 48 hours prior to cooking and allowed to thaw in a walk-in cooler (2°C). Steaks were cooked on indoor electric grills (Hamilton Beach Indoor/Outdoor Grill, Hamilton Beach/Proctor Silex, Inc., Southern Pines, NC) and temperature was continuously monitored by the use of Omega trendicators (Omega Engineering, Inc., Stamford, CT) fitted with type-T thermocouples. Steaks were cooked to an internal temperature of 35°C, flipped, and cooked to a final temperature of 70°C. The *M. longissimus thoracis* from ribeye steaks, the *M. longissimus lumborum* from top loin steaks, and the *M. gluteus medius* from sirloin steaks were used for evaluation. Two 1.27 cm cube samples from steaks representing individual subprimals randomly were served to panelists while seated in individual sensory booths with controlled lighting..

Table 1
Demographic information of sensory panelists (n=261) for steak evaluation

Item	Frequency Percent (n)
Age, years	
< 21	4.2 (11)
22-29	31.0 (81)
30-39	14.9 (39)
40-49	18.4 (48)
50-59	20.7 (54)
≥ 60	10.7 (28)
Income, US$	
< 20,000	27.4 (71)
20,000-29,000	2.7 (7)
30,000-39,000	8.5 (22)
40,000-49,000	5.8 (15)
50,000-59,000	4.6 (12)
≥ 60,000	51.0 (132)
Household size, number of people	
1	18.1 (47)
2	42.3 (110)
3	17.7 (46)
4	15.4 (40)
5	2.7 (7)
≥ 6	3.9 (10)
Work Status	
Not employed	16.1 (42)
Part-time	8.4 (22)
Full-time	60.5 (158)
Student	14.9 (39)
Gender	
Male	52.5 (137)
Female	47.5 (124)
Nationality	
White	84.3 (220)
African American	1.2 (3)
Hispanic	6.5 (17)
American Indian	2.3 (6)
Asian	5.8 (15)

Consumers first were submitted to a two-sided directional difference test in which they were given a paired sample and were asked which sample they preferred (Meilgaard, Civille, & Carr, 2007). These paired samples consisted of one thirty-five day, dry aged and one thirty-five day, wet aged sample of Top Choice or Select grade. Panelists were asked to evaluate the remaining twelve samples using 10-point scales for overall like (**OLIKE**)(1=dislike extremely; 10=like extremely), flavor like (**FLAV**)(1=dislike extremely; 10=like extremely); level of beef flavor (**FLVBF**)(1=extremely bland or no flavor; 10=extremely flavorful or intense), tenderness like (**TEND**)(1=dislike extremely; 10=like extremely), level of tenderness (**LEVTEND**)(1=extremely tough; 10=extremely tender), juiciness like (**JUIC**)(1= dislike extremely; 10=like extremely), and level of juiciness (**LEVJUIC**)(1=extremely dry; 10=extremely juicy). Purchase appeal (**PURCH**)(1=definitely would not buy; 5=definitely would buy), the last question, used a 5-point scale. After the panelists finished their evaluations of all the samples, they were asked to complete a questionnaire to identify their individual perception of dry aged beef (Table 2). Sessions were designed to evaluate one subprimal at a time. Consumers had the opportunity to participate up to three times, evaluating each subprimal only once. Consumers were given a monetary award of $25 for each session they participated in.

Table 2
Exit interview of sensory panelists (n=261) for steak evaluation

Item	Frequency Percent (n)
Are you familiar with the term aging?	
Yes	80.8 (210)
No	19.2 (50)
Is aging a positive/negative term?	
Positive	86.2 (218)
Negative	13.8 (35)
Have you ever eaten dry aged beef?	
Yes	34.6 (90)
No	13.9 (36)
Not Sure	51.5 (134)
Perceptions of dry aged beef	
Better Than Other Beef	22.4 (58)
Same as Other Beef	8.5 (22)
Not Sure	65.3 (169)
Other	3.9 (10)
Meat/Food safety of dry aged beef	
Safer	11.6 (30)
Less Safe	8.9 (23)
Same as Other Beef	33.0 (85)
Not Sure	46.5 (120)
Would you spend US$2.20 more per kg for dry aged beef?	
Yes	33.9 (87)
No	66.2 (170)

Warner-Bratzler shear force determination

Steaks designated for WBS force determination were removed from the freezer 48 hours prior to cooking and allowed to thaw in a walk-in cooler (2°C). Shear steaks were cooked and monitored in the same manner as the sensory steaks. Cooking yield percentages were determined from weights recorded before and after cooking. Total cooking time also was recorded for individual steaks. Steaks were covered and held overnight in a refrigerated cooler (2°C). Steaks were removed from the cooler and allowed to equilibrate to room temperature before coring. Six 1.27 cm cores were removed parallel to the muscle fibers from the *M. longissimus thoracis* from ribeye steaks, the *M. longissimus lumborum* from top loin steaks, and the *M. gluteus medius* from sirloin steaks. Each core was sheared perpendicular to the muscle fibers using the Universal Testing System Machine (United 5STM-500, Huntington Beach, CA), equipped with a 25 lb (11.3 kg) load cell with a Warner-Bratzler shear attachment. The average of six cores was used to determine WBS force values.

Statistical analysis

The effects of aging treatment, aging period, USDA quality grade, aging treatment x aging period, aging treatment x USDA quality grade, aging period x USDA quality grade were analyzed by analysis of variance programs using SAS PROC GLM (SAS Institute, Cary, NC). Interactions that were not significant were removed from the model. The p-diff option at $P < 0.05$ was used to separate least squares means when significant differences occurred. Box-Cox transformation was used to ensure normal

distribution for analysis of consumer data. Strip loin consumer data was analyzed using internal temperature endpoint as a covariate.

CHAPTER III

RESULTS AND DISCUSSION

Consumer panels

Table 1 portrays the demographic information for the sensory panelists involved in this study. The largest majority of participants were between the ages of 22-29 (31.0%), making less than US$20,000 (27.4%), and worked full time (60.5%). Not in tabular form, 51.34% (134) of the panelists indicated they consumed beef in their home at least five times per week or more. On average, only 4.37% (11) said they consumed beef at a restaurant zero times per week, with 31.75% (80) consuming beef at a restaurant two times per week.

Table 2 shows the exit interview for all panelists involved in this study. Out of 261 panelists, 34.6% (90) stated they had previously eaten dry aged beef, 13.9% (36) had never eaten dry aged beef, and 51.5% (134) were not sure. Also, 11.6% (30) of the panelists perceived dry aged beef to be safer than other beef, 8.9% (23) of them thought dry aged beef was less safe, and 46.5% (120) were not sure on the safety of dry aged beef. Only 33.9% (87) of the panelists stated they would spend US$2.20 more per kg for dry aged beef.

The effects of aging treatment on palatability characteristics of beef ribeye steaks are shown in Table 3. Wet-aged ribeye steaks received higher ($P = 0.0361$) ratings than their dry-aged counterparts for TEND. This is similar to Parrish et al. (1991) who found wet-aged steaks had higher ($P < 0.01$) scores for tenderness. In the present study, no significant differences were found for OLIKE, FLAV, FLVBF, LEVTEND, JUIC,

LEVJUIC, or PURCH between dry- and wet-aged ribeye teaks. These results agree with studies performed by Smith (2007), Sitz et al. (2006), and Parrish et al. (1991). In Smith (2007), 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. In the present study, the effect of aging period on palatability characteristics of beef ribeye steaks had no significant ($P. > 0.05$) impact on any of the palatability attributes. However, TEND and LEVTEND ratings tended to increase with increased aging time. The effects of USDA quality grade on palatability characteristics of Top Choice and Select ribeye steaks are also shown in Table 3. For OLIKE, JUIC, and LEVJUIC, Top Choice ribeye steaks were rated higher ($P < 0.05$) than Select ribeye steaks. This is also similar to Smith (2007) where Choice steaks rated significantly higher for overall like, juiciness, and level of juiciness when compared to Select steaks.

Parrish et al. (1991) also found significant differences between Choice and Select ribeye steaks for juiciness and overall palatability. In the present study, one significant interaction, aging period x aging treatment, was found for OLIKE and is presented in Figure 1. Consumers rated 14 d wet-aged ribeye steaks and 35 d dry-aged ribeye steaks higher ($P = 0.0478$) than 14 d dry-aged ribeye steaks.

Table 3
Least squares means of palatability characteristics of beef steaks from ribeye rolls for consumer (n = 80 consumers) evaluation stratified by aging treatment, aging period, and USDA quality grade

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
Aging treatment									
Dry aged	48	-	6.6	6.6	7.0b	7.0	6.3	4.2	2.6
Wet aged	48	-	6.7	6.7	7.3a	7.3	6.4	4.2	2.5
P > F		-	0.6365	0.5108	0.0361	0.0682	0.4509	0.9737	0.2199
Aging period[g]									
14 d	24	-	6.8	6.9	7.0	7.0	6.4	4.3	2.6
21 d	24	-	6.6	6.5	7.0	7.0	6.2	4.1	2.5
28 d	24	-	6.6	6.6	7.1	7.1	6.4	4.3	2.5
35 d	24	-	6.6	6.7	7.5	7.5	6.6	4.3	2.4
P > F		-	0.8852	0.5265	0.3363	0.3766	0.6574	0.7287	0.8238
USDA quality grade									
Top Choice	48	7.0a	6.8	6.8	7.3	7.3	6.6a	4.4a	2.4
Select	48	6.7b	6.6	6.6	7.1	7.0	6.2b	4.1b	2.6
P > F		0.0474	0.3372	0.3030	0.2785	0.2627	0.0426	0.0499	0.1819
RMSE[a]		3.44	3.32	3.65	3.79	3.76	2.68	1.30	0.12

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] 5=Definitely would buy; 1=definitely would not buy.
[g] Table values do not include additional nine day postmortem aging due to shipment of product.

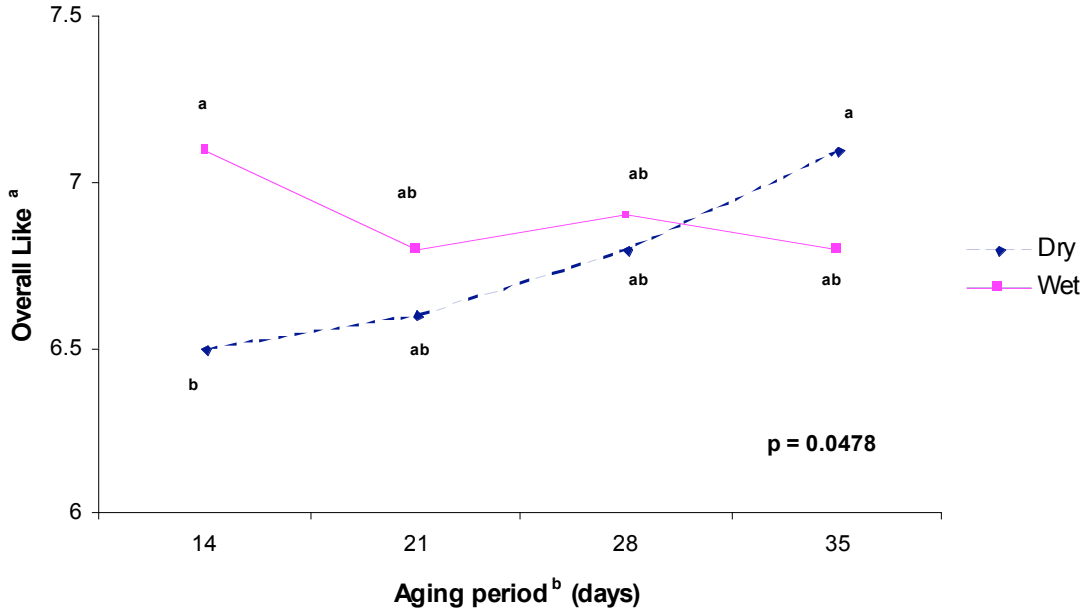

Fig. 1. Least squares means for Overall Like for beef steaks from ribeye rolls for consumer evaluation stratified by aging period x aging treatment. Means lacking a common letter (a-b) differ ($P < 0.05$).

[a]10 = Like extremely; 1 = Dislike extremely.

[b] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 4 shows the effect of aging treatment, aging period, and USDA quality grade on the palatability characteristics of beef steaks from strip loins. Although no significant differences between aging treatments for any of the attributes were found, wet-aged top loin steaks had higher ratings for FLVBF, TEND, LEVTEND, JUIC, and LEVJUIC compared to dry-aged top loin steaks. Aging period also had no significant effect on the attributes; however, TEND and LEVTEND ratings tended to increase with increased aging time. USDA quality grade had a significant impact on the ratings of many attributes. Top Choice top loin steaks rated higher ($P < 0.05$) for OLIKE, FLAV, FLVBF, JUIC, and LEVJUIC than Select top loin steaks. As stated earlier, these data are similar to Smith (2007) and Parrish et al. (1991) who found significantly higher ratings for Choice steaks when compared to Select steaks for many sensory attributes. Contrarily, PURCH ratings for Select top loin steaks were higher ($P = 0.0106$) than Top Choice steaks.

Effects of aging treatment, aging period, and USDA quality grade on the palatability characteristics of beef sirloin steaks from top sirloin butts are shown in Table 5. No main effects significantly impacted palatability characteristics evaluated by the panelists. Although not significant, Top Choice top sirloin steaks had higher ratings than Select top sirloin steaks for the following attributes: OLIKE, FLAV, TEND, LEVTEND, JUIC, and LEVJUIC.

Table 4
Least squares means of palatability characteristics of beef steaks from strip loins for consumer (n = 91 consumers) evaluation stratified by aging treatment, aging period, and USDA quality grade

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
Aging treatment									
Dry aged	48	7.0	6.9	6.8	7.3	7.3	6.6	6.6	2.3
Wet aged	48	7.0	6.9	6.9	7.5	7.5	6.8	6.7	2.3
P > F		0.6520	0.7649	0.6197	0.0727	0.0945	0.2706	0.4252	0.4734
Aging period [g]									
14 d	24	6.8	6.9	6.8	7.2	7.2	6.6	6.5	2.4
21 d	24	7.2	7.1	6.9	7.4	7.4	6.7	6.6	2.2
28 d	24	7.1	6.9	6.9	7.4	7.4	6.8	6.7	2.4
35 d	24	7.0	6.8	6.7	7.5	7.6	6.8	6.7	2.3
P > F		0.5839	0.3790	0.6096	0.5201	0.4210	0.8613	0.7627	0.5488
USDA quality grade									
Top Choice	48	7.2a	7.1a	7.0a	7.5	7.5	6.9a	6.9a	2.2b
Select	48	6.8b	6.7b	6.7b	7.2	7.2	6.5b	6.4b	2.4a
P > F		0.0365	0.0311	0.0434	0.1665	0.1150	0.0100	0.0124	0.0106
RMSE[a]		3.70	3.82	3.80	3.99	4.01	3.29	3.25	0.03

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] 5=Definitely would buy; 1=definitely would not buy.
[g] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 5
Least squares means of palatability characteristics of beef steaks from top sirloin butts for consumer (n = 90 consumers) evaluation stratified by aging treatment, aging period, and USDA quality grade

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
Aging treatment									
Dry aged	48	6.1	6.2	6.3	6.0	5.9	5.5	5.2	2.8
Wet aged	48	6.1	6.2	6.3	6.0	6.0	5.6	5.3	2.8
P > F		0.7013	0.7793	0.7434	0.6625	0.5583	0.7888	0.4022	0.8766
Aging period[g]									
14 d	24	5.9	6.1	6.1	5.5	5.4	5.5	5.2	2.9
21 d	24	6.0	6.1	6.2	6.0	5.9	5.5	5.2	2.8
28 d	24	6.3	6.4	6.5	6.3	6.2	5.5	5.2	2.7
35 d	24	6.2	6.3	6.3	6.3	6.2	5.6	5.3	2.7
P > F		0.3942	0.4165	0.3246	0.0540	0.0780	0.9123	0.9211	0.4037
USDA quality grade									
Top Choice	48	6.2	6.3	6.3	6.1	6.0	5.7	5.3	2.7
Select	48	6.0	6.2	6.3	5.9	5.8	5.4	5.1	2.9
P > F		0.3555	0.5097	0.9851	0.3540	0.5775	0.2299	0.2923	0.1263
RMSE[a]		2.85	2.84	2.84	2.51	2.15	1.83	1.39	0.27

[a]RMSE = Root Mean Square Error from Analysis of Variance.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] 5=Definitely would buy; 1=definitely would not buy.
[g] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 6 contains frequencies portraying consumers' preference of aging treatment using a 2-sided directional difference test. Although there were no significant differences, consumers tended to prefer the wet-aged ribeye and top sirloin steaks to the dry-aged steaks. Conversely, dry-aged top loin steaks tended to be preferred over the wet-aged top loin steaks.

Table 7 presents least squares means for cooking temperatures, cooking times, and cooking yields from consumer evaluations of beef ribeye, top loin, and top sirloin steaks. No main effects were significant for ribeye steaks. One significant interaction, aging period x USDA quality grade, was found for total cooking time (Figure 2) in top loin steaks. Thirty-five day Select top loin steaks had significantly shorter cooking times when compared to the other grade and aging day combinations. Aging treatment significantly affected cooking yield in top sirloin steaks. Dry-aged top sirloin steaks had higher (P = 0.0005) cooking yield percentages when compared to wet-aged top sirloin steaks. Figure 3 presents a significant interaction between aging treatment and USDA quality grade for total cooking time for top sirloin steaks. Similarly to the top loin steaks, dry-aged Top Choice and dry-aged Select top sirloin steaks had shorter (P = 0.0285) cooking times than their wet- aged counterparts. Likewise, Warren and Kastner (1992) found, although not significantly different, cooking time and cooking loss percentage were lowest for dry-aged samples when compared to vacuum packaged strip loin samples.

Table 6
Frequency of consumer preference of aging treatment on paired 35 day-aged, Top Choice and Select subprimals when submitted to a 2-sided directional difference test

Aging treatment	Ribeye steaks		Top loin steaks		Top sirloin steaks	
	Frequency %	Number of Consumers	Frequency %	Number of Consumers	Frequency %	Number of Consumers
Dry aged	45.0	36	53.9	49	44.4	40
Wet aged	55.0	44	46.2	42	55.6	50

Table 7
Least squares means for cooking temperatures, cooking times, and cooking yields of beef steaks from ribeye rolls, strip loins, and top sirloin butts used in consumer evaluation stratified by aging treatment, aging period, and USDA quality grade

Subprimal		Ribeye steaks			Top loin steaks			Top sirloin steaks		
Main Effects	N	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)
Aging treatment										
Dry aged	48	70.0	13.5	83.7	70.4	13.9	86.9	70.4a	-	79.1a
Wet aged	48	70.6	14.3	84.4	70.5	14.0	85.8	70.3b	-	76.6b
P > F		0.3534	0.0520	0.6736	0.3211	0.6237	0.4416	0.0159	-	0.0005
Aging period [b]										
14 d	24	70.9	13.6	79.4	70.3	-	86.1	70.4	16.7a	76.9
21 d	24	70.4	13.8	86.9	70.4	-	85.2	70.3	16.2a	77.2
28 d	24	70.2	14.5	85.3	70.5	-	86.4	70.3	15.4ab	78.2
35 d	24	69.8	13.8	84.5	70.4	-	87.9	70.3	14.3b	78.9
P > F		0.4783	0.5771	0.0615	0.3906	-	0.5181	0.9515	0.0068	0.0961
USDA quality grade										
Top Choice	48	70.5	14.2	84.0	70.5a	-	86.0	70.4	-	77.9
Select	48	70.1	13.6	84.1	70.3b	-	86.8	70.3	-	77.8
P > F		0.4511	0.2547	0.9717	0.0294	-	0.5272	0.1810	-	0.8892
RMSE[a]		4.56	2.84	12.07	0.55	2.63	11.41	0.36	2.99	5.72

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] Table values do not include additional nine day postmortem aging due to shipment of product.

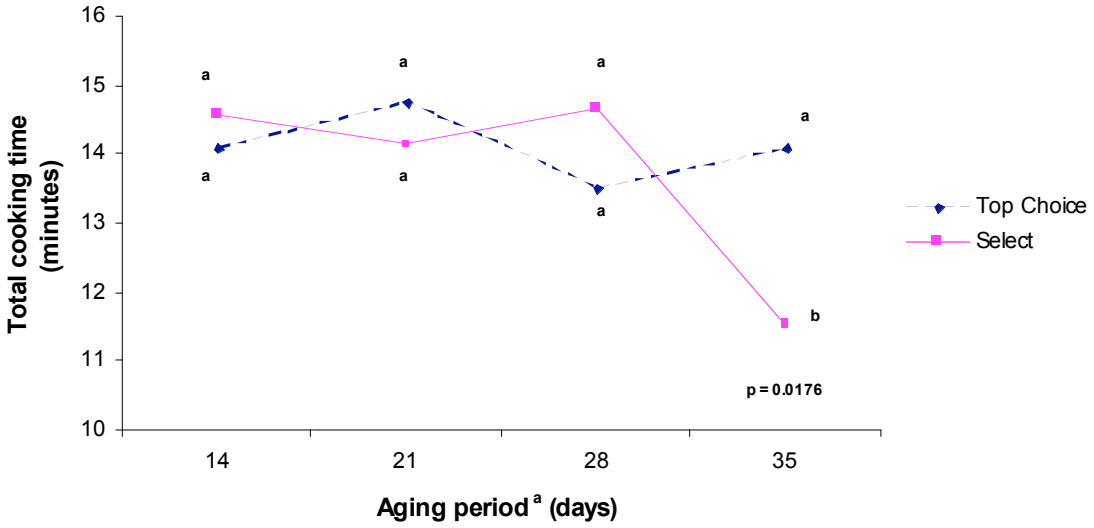

Fig. 2. Least squares means for total cooking time of beef steaks from strip loins for consumer evaluation stratified by aging period x USDA quality grade. Means lacking a common letter differ ($P < 0.05$).

[a] Table values do not include additional nine day postmortem aging due to shipment of product.

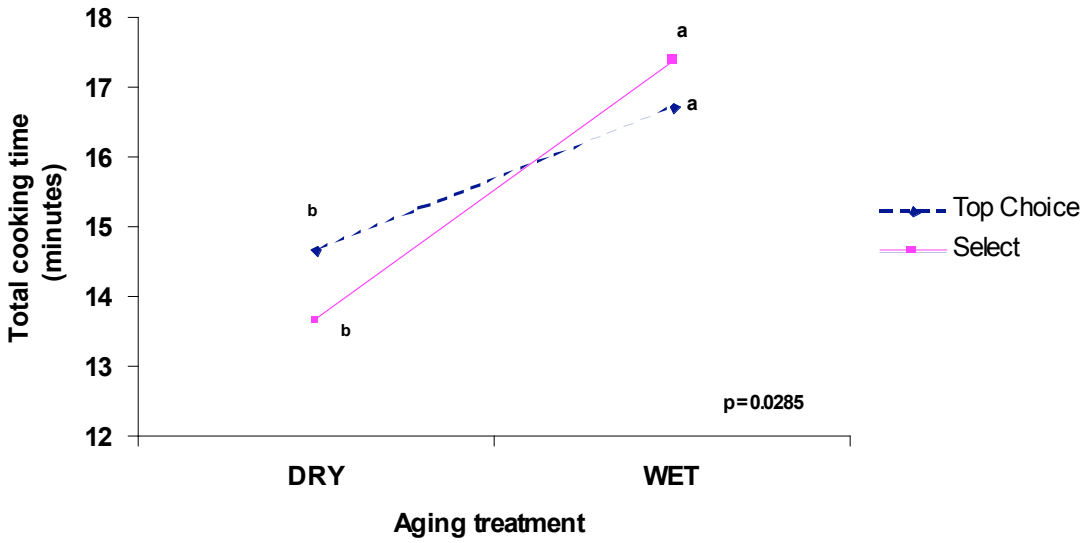

Fig. 3. Least squares means for total cooking time of beef steaks from top sirloin butts for consumer evaluation stratified by aging treatment x USDA quality grade. Means lacking a common letter differ ($P < 0.05$).

Warner-Bratzler shear force determination

Least squares means for cooking temperatures, cooking times, cooking yields, and WBS values for beef steaks subjected to shear force determination are presented in Table 8. Aging treatment significantly impacted WBS values of ribeye steaks. Wet-aged ribeye steaks had lower (P = 0.0064) WBS values than dry-aged ribeye steaks. Furthermore, USDA quality grade significantly affected total cooking time for ribeye steaks. Top Choice ribeye steaks had longer (P = 0.0133) cooking times than Select ribeye steaks.

Cooking yield percentages of top loin steaks were significantly impacted by aging treatment. Dry-aged top loin steaks had higher (P = 0.0009) cooking yield percentages compared to wet-aged top loin steaks. Figure 4 shows the least squares means for total cooking time of top loin steaks. 35 d Select top loin steaks had shorter (P = 0.0311) cooking times than other grade and aging day combinations. Also, 14 d Select top loin steaks had the longest cooking time when compared to other combinations.

Aging treatment and aging period for top sirloin steaks significantly affected total cooking time, cooking yield, and WBS values. Wet-aged top sirloin steaks had longer (P = 0.0003) cooking times, higher (P = 0.0145) WBS values, and lower (P = 0.0235) cooking yield percentages when compared to dry-aged top sirloin steaks. The longer cooking times and lower cooking yield percentages for wet-aged top sirloin steaks mimics results from top sirloin steaks cooked for consumer evaluation stated earlier. One significant interaction, aging day x USDA quality grade, was found for WBS values in top sirloin steaks and is presented in Figure 5. Fourteen day Select steaks had the highest (P = 0.0020) WBS values and 28 d Top Choice steaks had the lowest WBS values compared to other aging day and USDA grade combinations. Aging 21 and 35 d had similar effects on WBS values in top sirloin steaks; therefore aging a minimum of 21 days would be beneficial to increase tenderness of top sirloin steaks.

Table 8
Least squares means for cooking temperatures, cooking times, cooking yields, and Warner-Bratzler shear (WBS) values of beef steaks from ribeye rolls, strip loins, and top sirloin butts used for WBS evaluation stratified by aging treatment, aging period, and USDA quality grade

Subprimal		Ribeye steaks				Top loin steaks				Top sirloin steaks			
Main Effects	N	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)
Aging treatment													
Dry aged	48	70.5	12.6	89.4	18.3a	70.4	12.1	91.8a	17.5	70.3	12.6b	84.7a	20.4b
Wet aged	48	70.4	12.4	90.2	16.4b	70.4	12.8	89.0b	18.0	70.3	15.2a	80.6b	22.3a
P > F		0.6641	0.7504	0.4952	0.0064	0.9016	0.2924	0.0009	0.2998	0.9525	0.0003	0.0235	0.0145
Aging period [b]													
14 d	24	70.7	12.0	89.0	18.3	70.4	-	89.6	18.7	70.4	14.9	83.0	-
21 d	24	70.5	13.0	89.4	17.2	70.3	-	90.2	17.8	70.2	14.7	81.0	-
28 d	24	70.2	12.3	91.7	17.7	70.6	-	90.5	17.0	70.2	12.5	84.8	-
35 d	24	70.4	12.7	89.2	16.1	70.4	-	91.2	17.5	70.3	13.4	81.8	-
P > F		0.0852	0.6378	0.2623	0.1724	0.5175	-	0.3803	0.3618	0.5354	0.1669	0.2118	-
USDA quality grade													
Top Choice	48	70.5	13.2a	89.6	16.8	70.3	-	90.3	17.7	70.3	13.4	83.1	-
Select	48	70.5	11.8b	90.0	17.9	70.5	-	90.4	17.8	70.3	14.4	82.2	-
P > F		0.7488	0.0133	0.6538	0.1410	0.1840	-	0.9283	0.8688	0.4410	0.2622	0.5249	-
RMSE[a]		0.72	2.93	6.15	3.38	0.57	3.16	3.89	2.72	0.51	3.23	8.60	3.64

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] Table values do not include additional nine day postmortem aging due to shipment of product.

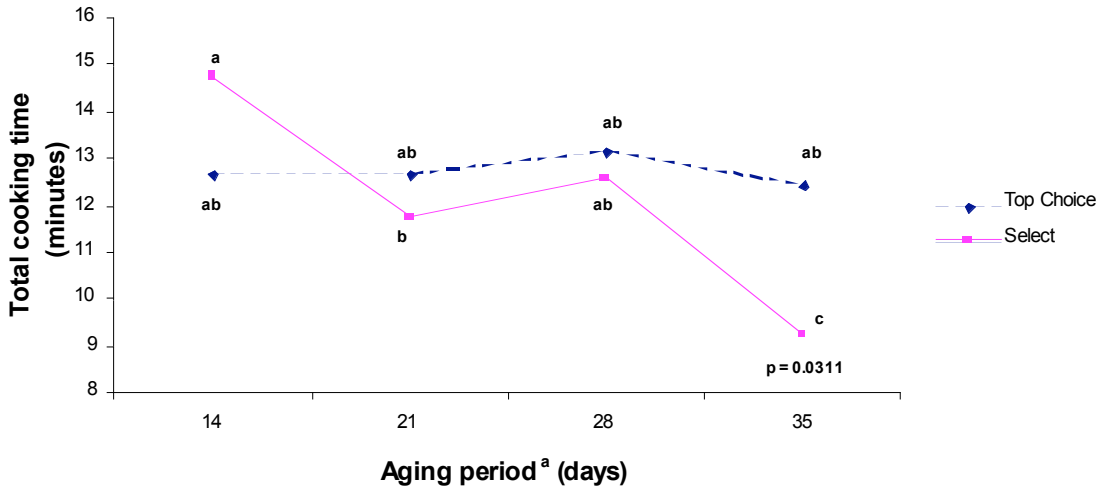

Fig. 4. Least squares means for total cooking time of beef steaks from strip loins designated for Warner-Bratzler shear force evaluation. Aging period x USDA quality grade is shown. Means lacking a common letter differ ($P < 0.05$).
[a] Figure values do not include additional nine day postmortem aging due to shipment of product.

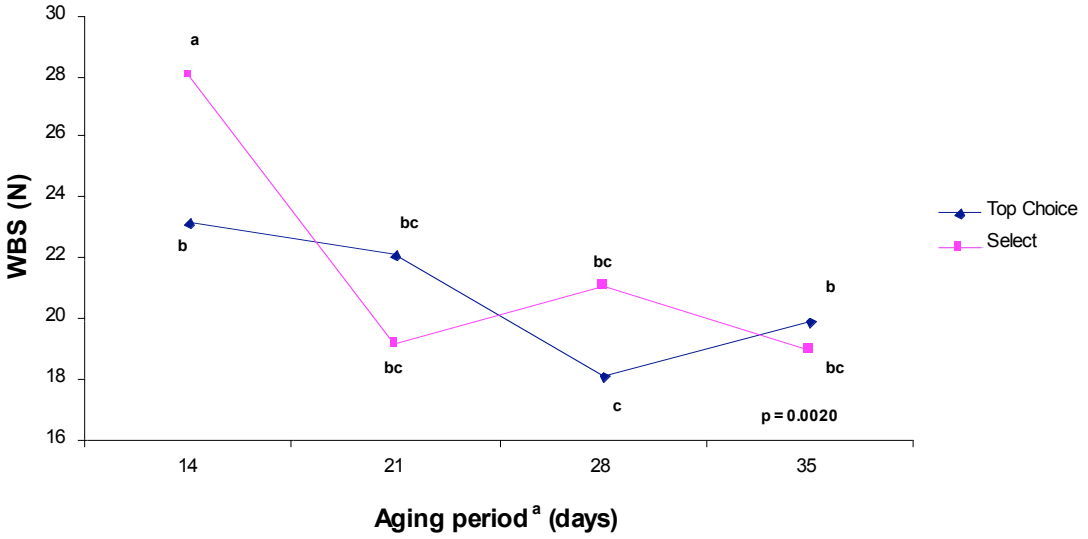

Fig. 5. Least squares means for Warner-Bratzler shear force values of beef steaks from top sirloin butts stratified by aging period x USDA quality grade. Means lacking a common letter differ ($P < 0.05$).

[a] Figure values do not include additional nine day postmortem aging due to shipment of product.

Least squares means of palatability characteristics for baseline ribeye steaks evaluated by consumers is shown in Table 9. Top Choice ribeye steaks received higher ($P < 0.05$) ratings for LEVTEND, JUIC, and LEVJUIC compared to Select ribeye steaks. However, PURCH ratings were higher ($P = 0.0163$) for Select ribeye steaks than Top Choice ribeye steaks. This is similar to information presented earlier on aged ribeye steaks, where Top Choice ribeye steaks were rated higher ($P < 0.05$) for JUIC and LEVJUIC when compared to Select ribeye steaks. Parrish et al. (1991) and Smith (2007) also found similar results. Table 10 presents the least squares means for palatability characteristics for baseline top loin steaks. Top Choice top loin steaks rated significantly higher for level of beef flavor compared to Select top loin steaks. Although not significant, Top Choice top loin steaks had higher ratings than Select top loin steaks for the following characteristics: OLIKE, FLAV, JUIC, and LEVJUIC. Least squares means for palatability characteristics for baseline top sirloin steaks are presented in Table 11. Even though no significant differences were found, Select top sirloin steaks rated higher for TEND, LEVTEND, and JUIC than Top Choice top sirloin steaks. These results contrast data observed from ribeyes and strip loins in the present study. Also, this is quite contradictory to studies performed by Parrish et al. (1991) and Smith (2007) who found these attributes to be rated significantly higher for Choice steaks than Select steaks.

Table 9
Least squares means for palatability characteristics of baseline steaks from ribeye rolls for consumer evaluation

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
USDA quality grade									
Top Choice	6	6.3	6.5	6.7	6.2	6.3a	6.8a	6.5a	2.6b
Select	6	5.4	5.6	5.8	5.1	5.1b	5.1b	4.6b	3.4a
P > F		0.1145	0.1446	0.1377	0.0520	0.0288	0.0063	0.0025	0.0163
RMSE[a]		3.66	3.60	3.90	3.80	3.81	2.77	1.38	0.11

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] 5=Definitely would buy; 1=definitely would not buy.

Table 10
Least squares means for palatability characteristics of baseline steaks from strip loins for consumer evaluation

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
USDA quality grade									
Top Choice	6	6.2	6.8	6.8a	5.7	5.7	6.1	6.1	3.0
Select	6	5.8	6.0	5.9b	5.7	5.7	5.7	5.4	3.0
P > F		0.4810	0.0809	0.0441	0.9731	0.9345	0.4631	0.1540	0.8393
RMSE[a]		3.72	3.89	3.90	4.07	4.06	3.38	3.24	0.03

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] 10=Like extremely; 1=dislike extremely.
[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.
[d] 10=Extremely tender; 1=extremely tough.
[e] 10=Extremely juicy; 1=extremely dry.
[f] 5=Definitely would buy; 1=definitely would not buy.

Table 11

Least squares means for palatability characteristics of baseline steaks from top sirloin butts for consumer evaluation

Main effects	N	Overall Like[b]	Flavor Like[b]	Level of Beef Flavor[c]	Tenderness Like[b]	Level of Tenderness[d]	Juiciness Like[b]	Level of Juiciness[e]	Purchase[f]
USDA quality grade									
Top Choice	6	5.7	6.2	3.6	4.8	4.8	5.1	4.9	3.2
Select	6	5.8	6.2	3.6	5.6	5.4	5.4	5.1	2.8
P > F		0.9230	0.9972	0.9676	0.0844	0.1924	0.4614	0.6867	0.1770
RMSE[a]		2.77	3.00	2.91	2.58	2.19	1.83	1.38	0.27

[a] RMSE = Root Mean Square Error from Analysis of Variance.

[b] 10=Like extremely; 1=dislike extremely.

[c] 10=Extremely flavorful or intense; 1=extremely bland or no flavor.

[d] 10=Extremely tender; 1=extremely tough.

[e] 10=Extremely juicy; 1=extremely dry.

[f] 5=Definitely would buy; 1=definitely would not buy.

In Table 12, least squares means for cooking temperatures, cooking times, cooking yields, and WBS values are presented for baseline steaks from ribeyes, strip loins, and top sirloin butts. The only significant difference found was for cooking time among top loin steaks. Top Choice top loin steaks had longer (P = 0.0367) cooking times than Select top loin steaks. Moreover, there was a trend amongst top loin and top sirloin steaks that cooking yield percentages were higher for Top Choice steaks compared to Select steaks. Although not significant, WBS values for ribeye and top sirloin steaks were higher for the Select steaks when compared to the Top Choice steaks; however, the Select top loin steaks showed to have lower WBS values than the Top Choice top loin steaks. Baseline ribeye, top loin, and top sirloin steaks were cut to serve as a baseline for flavor and tenderness, however these were not analyzed with the other treatment combinations. By comparing the data in the aforementioned tables, trends may be deduced.

Table 12
Least squares means for cooking temperatures, cooking times, cooking yields, and WBS values of baseline steaks from ribeye rolls, strip loins, and top sirloin butts used for WBS evaluation

Subprimal		Ribeye steaks				Top loin steaks				Top sirloin steaks			
Main Effects	N	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)	Internal Temperature Endpoint (Celsius)	Total Cook Time (minutes)	Cook Yield (%)	WBS (N)
USDA quality grade													
Top Choice	6	70.2	15.2	87.2	24.0	71.0	14.3a	94.0	23.3	70.3	13.0	85.5	25.5
Select	6	70.9	12.5	87.7	25.8	70.2	12.3b	89.7	22.9	70.8	14.3	81.3	29.8
$P > F$		0.1855	0.1299	0.7686	0.6572	0.1399	0.0367	0.4915	0.9090	0.3819	0.4475	0.2141	0.2611
RMSE[a]		0.83	2.80	3.04	6.91	0.94	1.44	10.32	6.05	0.95	2.92	5.53	6.26

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.

Retail cutting tests

Interaction of USDA quality grade and aging period, and its effect on retail yield and by-product percentages of ribeye rolls are shown in Table 13. No significant differences were found; however, cooler shrink for Top Choice and Select ribeye rolls was highest at 35 d. Smith (2007) also found cooler shrink was highest ($P > 0.05$) at 35 d for both Choice and Select short loins. Also, cooler shrink and gross cut loss percentages increased with increased aging time for both Top Choice and Select ribeye rolls.

Aging treatment x aging period is shown in Table 14 for ribeye rolls. Wet-aged ribeye rolls for all aging periods produced a significantly higher percentage of ribeye steaks compared to those that were dry aged. Twenty-eight and 35 d dry-aged ribeye rolls produced the lowest ($P < 0.05$) percentage of ribeye steaks and had the highest ($P < 0.05$) percentage of waste, which would be expected with increased aging time. Twenty-one day and 35 d wet-aged ribeye rolls had the lowest ($P < 0.05$) percentage of waste when compared to other treatment and day combinations. Furthermore, the interaction of aging treatment and aging period significantly impacted cooler shrink ($P < 0.0001$), gross cut loss ($P < 0.0001$), and total saleable yield ($P = 0.0005$) percentages of ribeye rolls. Across all aging periods, dry-aged ribeye rolls had higher ($P < 0.05$) percentages of cooler shrink and gross cut loss when compared to those that were wet aged, with 35 d dry aged having the highest. On the other hand, wet-aged ribeye rolls for all aging periods had significantly higher total saleable yields than any of the dry-aged ribeye rolls. This mirrors the Smith (2007) study in that the wet-aged short loins

Table 13
Least squares means ± SEM[a] of retail yields (%) for fabrication of ribeye rolls (n = 96) stratified by USDA quality grade x aging period[e]

Item	UPC[b]	Top Choice				Select				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Retail yield										
Ribeye steaks	1197	77.5 ± 1.0	73.8 ± 1.0	72.2 ± 1.0	72.6 ± 1.0	77.7 ± 1.0	76.7 ± 1.0	74.3 ± 1.0	72.3 ± 1.0	0.3424
Beef for stew	1727	0.9 ± 0.6	3.3 ± 0.6	1.4 ± 0.6	2.5 ± 0.6	1.2 ± 0.6	1.3 ± 0.6	1.1 ± 0.6	2.7 ± 0.6	0.1634
Lean trimmings (90% lean)	1653	1.83 ± 0.47	0.86 ± 0.47	0.97 ± 0.51	0.36 ± 0.47	1.49 ± 0.47	1.81 ± 0.47	1.09 ± 0.47	1.03 ± 0.47	0.5450
Fat		4.4 ± 0.9	5.3 ± 0.9	3.1 ± 0.9	3.1 ± 0.9	3.2 ± 0.9	2.1 ± 0.9	2.5 ± 0.9	2.5 ± 0.9	0.4419
Waste (crust included)		10.0 ± 0.9	8.7 ± 0.9	15.5 ± 0.9	12.6 ± 0.9	10.7 ± 0.9	9.6 ± 0.9	13.9 ± 0.9	12.6 ± 0.9	0.5407
Bone		0.46 ± 0.50	2.28 ± 0.50	0.02 ± 0.50	0.96 ± 0.50	0.65 ± 0.50	2.47 ± 0.50	0.06 ± 0.50	0.92 ± 0.50	0.9942
Cooler shrink		3.4 ± 0.3	4.1 ± 0.3	4.7 ± 0.3	6.2 ± 0.3	3.7 ± 0.3	4.7 ± 0.3	6.0 ± 0.3	6.6 ± 0.3	0.3092
Purge		0.10 ± 0.03	0.10 ± 0.03	0.08 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.12 ± 0.03	0.09 ± 0.03	0.10 ± 0.03	0.9712
Fab cut loss[c]		0.3 ± 0.1	0.5 ± 0.1	0.4 ± 0.1	0.8 ± 0.1	0.2 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.2 ± 0.1	0.0675
Gross cut loss[d]		3.7 ± 0.3	4.6 ± 0.3	5.2 ± 0.3	7.0 ± 0.3	3.9 ± 0.3	5.0 ± 0.3	6.0 ± 0.3	6.8 ± 0.3	0.3522
Total saleable yield		80.2 ± 1.1	78.0 ± 1.1	74.9 ± 1.2	75.5 ± 1.1	80.4 ± 1.1	79.7 ± 1.1	76.6 ± 1.2	76.0 ± 1.1	0.8575

[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 14
Least squares means ± SEM[a] of retail yields (%) for fabrication of ribeye rolls (n = 96) stratified by aging treatment x aging period[e]

Item	UPC[b]	Dry aged				Wet aged				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Ribeye steaks	1197	70.5b ± 0.9	66.7c ± 0.9	63.6d ± 1.0	61.7d ± 0.9	84.7a ± 0.9	83.7a ± 0.9	82.9a ± 0.9	83.3a ± 0.9	0.0023
Beef for stew	1727	0.34c ± 0.61	2.18ab ± 0.61	0.30c ± 0.61	1.59bc ± 0.61	1.76bc ± 0.61	2.40ab ± 0.61	2.19ab ± 0.61	3.60a ± 0.61	0.4480
Lean trimmings (90% lean)	1653	1.33 ± 0.41	0.38 ± 0.41	0.18 ± 0.45	0.22 ± 0.41	1.99 ± 0.41	2.29 ± 0.41	1.86 ± 0.41	1.18 ± 0.41	0.3902
Fat		2.5 ± 0.6	1.7 ± 0.6	0.0 ± 0.6	0.0 ± 0.6	5.1 ± 0.6	5.7 ± 0.65	5.5 ± 0.6	5.6 ± 0.6	0.0508
Waste (crust included)		16.8b ± 0.9	17.3b ± 0.9	24.2a ± 1.0	22.8a ± 0.9	4.0cd ± 0.9	1.0e ± 0.9	5.4c ± 0.9	2.5de ± 0.9	0.0010
Bone		0.5 ± 0.3	1.9 ± 0.3	0.0 ± 0.3	0.3 ± 0.3	0.6 ± 0.3	2.8 ± 0.3	0.1 ± 0.3	1.5 ± 0.3	0.1434
Cooler shrink		6.8d ± 0.3	8.4c ± 0.3	10.0b ± 0.4	12.3a ± 0.3	0.2e ± 0.3	0.3e ± 0.3	0.7e ± 0.3	0.5e ± 0.3	<0.0001
Purge		0.14 ± 0.03	0.15 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.05 ± 0.03	0.08 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.3386
Fab cut loss[c]		0.2 ± 0.1	0.4 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.4 ± 0.1	0.5 ± 0.1	0.8 ± 0.1	0.1051
Gross cut loss[d]		7.0d ± 0.3	8.8c ± 0.3	10.4b ± 0.3	12.5a ± 0.3	0.6e ± 0.3	0.7e ± 0.3	0.8e ± 0.3	1.2e ± 0.3	<0.0001
Total saleable yield		72.2b ± 1.0	69.3c ± 1.0	64.3d ± 1.1	63.5d ± 1.0	88.4a ± 1.0	88.4a ± 1.0	86.9a ± 1.0	88.1a ± 1.0	0.0005

Means within the same row lacking a common letter (a-e) differ (P < 0.05).
[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Table values do not include additional nine day postmortem aging due to shipment of product.

for all four aging periods had significantly higher total saleable yield than their dry-aged counterparts.

Least squares means of retail yield percentages for fabrication of strip loins stratified by USDA quality grade x aging period is shown in Table 15. Top Choice, 14 d strip loins had the lowest ($P < 0.05$) gross cut loss compared to the other grade and aging period combinations. Although not significant, cooler shrink increased with each aging period for both Top Choice and Select strip loins, supporting the previous ribeye roll results.

Table 16 presents aging treatment x aging period for strip loins. Interestingly, 28 d, dry-aged strip loins displayed the highest ($P < 0.05$) percentage of waste. Moreover, this aging treatment and aging period interaction had a significant impact on cooler shrink of strip loins. All dry-aged strip loins had a greater ($P < 0.05$) amount of cooler shrink when compared to their wet-aged counterparts, with 28 and 35 d, dry-aged strip loins exhibiting the highest ($P < 0.05$) percentage of cooler shrink. This also supports ribeye results found in this study, as well as the study by Smith (2007). Furthermore, 28 and 35 d, dry-aged strip loins had the highest ($P < 0.05$) gross cut loss compared to other day and aging treatment combinations.

Table 15
Least squares means ± SEM[a] of retail yields (%) for fabrication of strip loins (n = 96) stratified by USDA quality grade x aging period[f]

Item	UPC[b]	Top Choice				Select				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Retail yield										
Strip steaks	1398	49.7 ± 2.0	51.6 ± 2.0	46.3 ± 2.0	46.3 ± 2.0	53.3 ± 2.0	48.9 ± 2.0	51.0 ± 2.0	48.1 ± 2.0	0.2669
Vein steaks[e]		12.2 ± 1.0	13.2 ± 1.0	10.7 ± 1.0	11.5 ± 1.0	13.4 ± 1.0	13.2 ± 1.0	10.6 ± 1.0	12.0 ± 1.0	0.9078
Beef for stew	1727	2.1 ± 0.6	2.6 ± 0.6	0.8 ± 0.6	1.4 ± 0.6	3.0 ± 0.6	3.0 ± 0.6	2.0 ± 0.6	1.6 ± 0.6	0.8120
Lean trimmings (90% lean)	1653	0.43 ± 0.56	1.08 ± 0.56	2.55 ± 0.56	1.50 ± 0.56	0.24 ± 0.56	0.19 ± 0.56	1.70 ± 0.56	1.65 ± 0.56	0.7432
Fat		21.4 ± 2.9	9.4 ± 2.9	14.2 ± 2.9	19.4 ± 2.9	15.5 ± 2.9	15.4 ± 2.9	11.2 ± 2.9	13.0 ± 2.9	0.1383
Waste (crust included)		1.9 ± 1.8	9.2 ± 1.8	11.0 ± 1.8	5.5 ± 1.8	2.1 ± 1.8	4.7 ± 1.8	9.6 ± 1.8	8.0 ± 1.8	0.2555
Bone		2.9 ± 0.6	2.6 ± 0.6	1.0 ± 0.6	1.0 ± 0.6	2.7 ± 0.6	1.1 ± 0.6	0.8 ± 0.6	0.7 ± 0.6	0.5709
Cooler shrink		3.9 ± 0.4	5.1 ± 0.4	6.2 ± 0.4	6.3 ± 0.4	5.2 ± 0.4	5.6 ± 0.4	5.9 ± 0.4	6.6 ± 0.4	0.2175
Purge		0.11 ± 0.05	0.20 ± 0.06	0.18 ± 0.05	0.15 ± 0.05	0.07 ± 0.05	0.13 ± 0.05	0.19 ± 0.05	0.11 ± 0.05	0.3553
Fab cut loss[c]		0.6 ± 0.2	0.5 ± 0.2	0.9 ± 0.2	0.7 ± 0.2	0.7 ± 0.2	0.7 ± 0.2	0.3 ± 0.2	0.2 ± 0.1	0.3141
Gross cut loss[d]		4.5c ± 0.4	5.6b ± 0.4	7.0a ± 0.4	6.9a ± 0.4	5.9ab ± 0.4	6.2ab ± 0.4	6.2ab ± 0.4	6.8a ± 0.4	0.0468
Total saleable yield		64.5 ± 2.0	68.4 ± 2.0	60.4 ± 2.0	60.8 ± 2.0	70.0 ± 2.0	65.2 ± 2.0	65.3 ± 2.0	63.4 ± 2.0	0.1427

Means within the same row lacking a common letter (a-c) differ (P < 0.05).
[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Identified as vein steak only if *M. gluteus medius* present on both sides of steak.
[f] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 16
Least squares means ± SEM[a] of retail yields (%) for fabrication of strip loins (n = 96) stratified by aging treatment x aging period[f]

Item	UPC[b]	Dry aged				Wet aged				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Retail yield										
Strip steaks	1398	48.4 ± 0.9	47.0 ± 0.9	45.0 ± 0.9	43.4 ± 0.9	54.6 ± 0.9	53.6 ± 0.9	52.2 ± 0.9	51.0 ± 0.9	0.8968
Vein steaks[e]		11.7 ± 0.9	11.6 ± 0.9	8.6 ± 0.9	9.1 ± 0.9	14.0 ± 0.9	14.7 ± 0.9	12.7 ± 0.9	14.4 ± 0.9	0.3592
Beef for stew	1727	1.9 ± 0.4	1.9 ± 0.4	0.8 ± 0.4	1.2 ± 0.4	3.2 ± 0.4	3.7 ± 0.4	2.0 ± 0.4	1.8 ± 0.4	0.5928
Lean trimmings (90% lean)	1653	0.10 ± 0.39	0.35 ± 0.39	1.38 ± 0.39	0.93 ± 0.39	0.57 ± 0.39	0.91 ± 0.39	2.86 ± 0.39	2.22 ± 0.39	0.4601
Fat		16.6ab ± 1.6	10.1c ± 1.6	6.3c ± 1.6	14.6b ± 1.6	20.3a ± 1.6	14.7b ± 1.6	19.1ab ± 1.6	17.7ab ± 1.6	0.0116
Waste (crust included)		3.2cd ± 1.8	9.0b ± 1.8	16.0a ± 1.8	7.6bc ± 1.8	0.7d ± 1.8	4.9bcd ± 1.8	4.6bcd ± 1.8	5.9bc ± 1.8	0.0345
Bone		2.6 ± 0.4	1.4 ± 0.4	0.6 ± 0.4	0.8 ± 0.4	3.0 ± 0.4	2.3 ± 0.4	1.1 ± 0.4	0.9 ± 0.4	0.7098
Cooler shrink		8.2c ± 0.3	9.5b ± 0.3	11.2a ± 0.3	11.9a ± 0.3	1.0d ± 0.3	1.2d ± 0.3	0.8d ± 0.3	0.9d ± 0.3	<0.0001
Purge		0.15 ± 0.04	0.12 ± 0.04	0.08 ± 0.04	0.14 ± 0.04	0.16 ± 0.04	0.21 ± 0.03	0.13 ± 0.04	0.16 ± 0.04	0.7246
Fab cut loss[c]		0.7 ± 0.2	0.6 ± 0.2	0.9 ± 0.2	0.2 ± 0.2	0.6 ± 0.2	0.5 ± 0.2	0.3 ± 0.2	0.7 ± 0.2	0.0588
Gross cut loss[d]		8.9c ± 0.3	10.1b ± 0.3	12.0a ± 0.3	12.1a ± 0.3	1.5d ± 0.3	1.7d ± 0.3	1.1d ± 0.3	1.6d ± 0.3	<0.0001
Total saleable yield		62.1 ± 1.0	60.8 ± 1.0	55.9 ± 1.0	54.7 ± 1.0	72.4 ± 1.0	72.9 ± 1.0	69.8 ± 1.0	69.5 ± 1.0	0.1115

Means within the same row lacking a common letter (a-d) differ (P < 0.05).
[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Identified as vein steak only if *M. gluteus medius* present on both sides of steak.
[f] Table values do not include additional nine day postmortem aging due to shipment of product.

The interaction of USDA quality grade and aging period and its effect on retail yield and by-product percentages of top sirloin butts is shown in Table 17. Although not significant, gross cut loss and cooler shrink percentages increased with increased aging times for both Top Choice and Select top sirloin butts. This follows the same trend shown in the ribeye roll results. Also, the percentage of steaks from Top Choice top sirloin butts decreased as aging time increased.

The interaction of aging treatment and aging period of top sirloin butts (Table 18) had a significant impact on waste ($P = 0.0212$), cooler shrink ($P < 0.0001$), gross cut loss ($P < 0.0001$), and total saleable yield ($P = 0.0011$). Across all aging periods, dry-aged top sirloin butts displayed higher ($P < 0.05$) percentages of waste when compared to those that were wet-aged, with 28 d dry-aged being the highest overall. Regardless of aging period, dry-aged top sirloin butts were significantly higher for cooler shrink and gross cut loss overall when compared to wet-aged top butts. These results mimic the aging treatment x aging period presented for ribeye rolls (Table 14). Inversely, total saleable yield for wet-aged top sirloin butts was higher ($P = 0.0011$) when compared to those that were dry aged, whereas 14 and 21 d wet-aged top butts exhibited the highest percentage of total saleable yield. All wet-aged product for ribeye rolls, strip loins, and top sirloin butts resulted in higher percentages of total saleable yield when compared to their dry-aged counterparts, which is identical to Smith (2007).

Table 17
Least squares means ± SEM[a] of retail yields (%) for fabrication of top sirloin butts (n = 96) stratified by USDA quality grade x aging period[e]

Item	UPC[b]	Top Choice				Select				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Retail yield										
Top sirloin steaks	1422	64.9 ± 1.7	64.9 ± 1.7	56.6 ± 1.7	57.9 ± 1.7	68.2 ± 1.7	64.4 ± 1.9	61.7 ± 1.7	61.0 ± 1.7	0.4550
Beef for stew	1727	0.5 ± 0.6	0.0 ± 0.6	4.7 ± 0.6	0.0 ± 0.6	0.6 ± 0.6	0.0 ± 0.6	4.6 ± 0.6	0.2 ± 0.6	0.9959
Lean trimmings (90% lean)	1653	0.73 ± 0.30	0.80 ± 0.30	0.00 ± 0.30	0.70 ± 0.30	0.83 ± 0.30	0.02 ± 0.32	0.00 ± 0.30	0.65 ± 0.30	0.4687
Beef for stir fry		3.6 ± 0.6	4.8 ± 0.6	0.0 ± 0.6	4.8 ± 0.6	4.0 ± 0.6	4.0 ± 0.6	0.0 ± 0.6	5.3 ± 0.6	0.7342
Fat		16.0 ± 2.2	12.1 ± 2.2	18.5 ± 2.2	17.9 ± 2.2	11.2 ± 2.2	14.3 ± 2.4	13.8 ± 2.2	14.0 ± 2.2	0.3789
Waste (crust included)		8.8 ± 0.9	10.4 ± 0.9	12.7 ± 0.9	9.9 ± 0.9	9.1 ± 0.9	10.5 ± 1.0	10.9 ± 0.9	9.1 ± 0.9	0.6912
Bone		0.23 ± 0.06	0.05 ± 0.06	0.00 ± 0.06	0.00 ± 0.06	0.02 ± 0.06	0.04 ± 0.06	0.00 ± 0.06	0.00 ± 0.06	0.2535
Cooler shrink		5.1 ± 0.4	6.7 ± 0.4	7.5 ± 0.4	8.5 ± 0.4	6.0 ± 0.4	6.7 ± 0.4	8.7 ± 0.4	9.5 ± 0.4	0.4390
Purge		0.11c ± 0.03	0.18b ± 0.03	0.17bc ± 0.03	0.18bc ± 0.03	0.20b ± 0.03	0.11c ± 0.03	0.31a ± 0.03	0.22ab ± 0.03	0.0196
Fab cut loss[c]		0.11 ± 0.08	0.31 ± 0.08	0.16 ± 0.08	0.23 ± 0.08	0.14 ± 0.08	0.31 ± 0.08	0.21 ± 0.08	0.27 ± 0.08	0.9948
Gross cut loss[d]		5.2 ± 0.4	7.0 ± 0.4	7.6 ± 0.4	8.8 ± 0.4	6.1 ± 0.4	6.7 ± 0.4	8.9 ± 0.4	9.8 ± 0.4	0.2427
Total saleable yield		69.8 ± 1.5	70.4 ± 1.5	61.3 ± 1.5	63.4 ± 1.5	73.6 ± 1.5	68.4 ± 1.7	66.3 ± 1.5	67.1 ± 1.5	0.1300

Means within the same row lacking a common letter (a-c) differ (P < 0.05).
[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Table values do not include additional nine day postmortem aging due to shipment of product.

Table 18
Least squares means ± SEM[a] of retail yields (%) for fabrication of top sirloin butts (n = 96) stratified by aging treatment x aging period[e]

Item	UPC[b]	Dry aged				Wet aged				
		14 d	21 d	28 d	35 d	14 d	21 d	28 d	35 d	*P* > F
		%								
Retail yield										
Top sirloin steaks	1422	57.3 ± 1.1	54.1 ± 1.2	50.4 ± 1.1	48.7 ± 1.1	75.8 ± 1.1	75.0 ± 1.1	67.9 ± 1.1	70.2 ± 1.1	0.2516
Beef for stew	1727	0.36b ± 0.53	0.00b ± 0.53	1.23b ± 0.53	0.16b ± 0.53	0.72b ± 0.53	0.00b ± 0.53	8.02 ± 0.53	0.00b ± 0.53	<0.0001
Lean trimmings (90% lean)	1653	0.10 ± 0.31	0.07 ± 0.34	0.00 ± 0.31	0.09 ± 0.31	1.47 ± 0.31	0.76 ± 0.31	0.00 ± 0.31	1.26 ± 0.31	0.1352
Beef for stir fry		3.6b ± 0.6	2.4b ± 0.6	0.0c ± 0.6	3.0b ± 0.6	4.0b ± 0.6	6.4a ± 0.6	0.0c ± 0.6	7.1a ± 0.6	0.0007
Fat		11.3 ± 0.9	10.5 ± 1.0	11.8 ± 0.9	13.3 ± 0.9	15.9 ± 0.9	15.9 ± 0.9	20.5 ± 0.9	18.6 ± 0.9	0.1208
Waste (crust included)		17.9c± 0.9	20.9ab ± 1.0	23.6a ± 0.9	19.0bc ± 0.9	0.0d ± 0.9	0.0d ± 0.9	0.0d ± 0.9	0.0d ± 0.9	0.0212
Bone		0.07 ± 0.07	0.0 ± 0.07	0.0 ± 0.07	0.0 ± 0.07	0.18 ± 0.07	0.09 ± 0.07	0.0 ± 0.07	0.0 ± 0.07	0.7906
Cooler shrink		9.3c ± 0.4	11.9b ± 0.4	13.0b ± 0.4	15.6a ± 0.4	1.7e ± 0.4	1.5e ± 0.4	3.2d ± 0.4	2.4de ± 0.4	<0.0001
Purge		0.06e ± 0.04	0.08de ± 0.04	0.04e ± 0.04	0.08d ± 0.04	0.24bc ± 0.04	0.19cd ± 0.04	0.44a ± 0.04	0.32b ± 0.04	0.0070
Fab cut loss[c]		0.047 ± 0.069	0.291 ± 0.075	0.003 ± 0.069	0.088 ± 0.069	0.204 ± 0.069	0.351 ± 0.075	0.373 ± 0.069	0.417 ± 0.069	0.1194
Gross cut loss[d]		9.4c ± 0.4	12.0b ± 0.4	13.0b ± 0.4	15.7a ± 0.4	1.9e ± 0.4	1.8e ± 0.4	3.6d ± 0.4	2.8de ± 0.4	<0.0001
Total saleable yield		61.4d ± 0.7	56.6e ± 0.8	51.6f ± 0.7	52.0f ± 0.7	81.9a ± 0.7	82.2a ± 0.7	75.9c ± 0.7	78.6b ± 0.7	0.0011

Means within the same row lacking a common letter (a-f) differ (P < 0.05).
[a] SEM = Standard error of the least squares means.
[b] UPC = Universal product code.
[c] Cut loss calculated by comparing recovered weight to initial cut weight taken on specific fabrication day.
[d] Cut loss calculated by comparing recovered weight to weight recorded on the day product was received.
[e] Table values do not include additional nine day postmortem aging due to shipment of product.

Effects of aging treatment, aging period, and USDA quality grade on total cutting times of ribeye rolls, strip loins, and top sirloin butts are shown in Table 19. As expected, the dry-aged subprimals took a greater ($P < 0.0001$) total amount of time to process when compared to the wet-aged products. These results are supported through the research of Smith (2007). Dry aging will inevitably cause the surface tissue to dry out, creating what is referred to as waste or "crust." This excess time associated with processing dry-aged product must be expected when producing dry-aged product. Furthermore, aging period had a significant effect on the total cutting time for ribeye rolls and top sirloin butts. Fourteen and 21 d ribeye rolls had a greater ($P = 0.0005$) amount of processing time compared to 28 and 35 d product. These results contradict research of Smith (2007), which found 28 and 35 d short loins to have greater processing times than 14 or 21d short loins. In the present study, 28 d top sirloin butts required the shortest ($P = 0.0199$) amount of processing time compared to the other aging periods. One significant interaction, aging day x USDA quality grade, was found for total cutting time of strip loins and is shown in Figure 6. Fourteen day, Top Choice strip loins took the greatest ($P = 0.0021$) amount of time to process. 14 and 28 d, Select and 28 and 35 d Top Choice strip loins had the shortest ($P < 0.05$) total cutting time when compared to other aging day and quality grade combinations.

Table 19
Least squares means for total cutting time for fabrication of ribeye rolls, strip loins, and top sirloin butts stratified by aging treatment, aging period, and USDA quality grade

Main effects	Total cutting time (s)					
	Ribeye rolls	N	Strip loins	N	Top sirloin butts	N
Aging treatment						
Dry aged	384.1a	48	441.0a	48	266.7a	48
Wet aged	304.3b	48	372.6b	48	194.7b	48
P > F	<0.0001		<0.0001		<0.0001	
Aging period [b]						
14 d	369.3a	24	-	24	246.3a	24
21 d	371.1a	24	-	24	244.5a	24
28 d	307.4b	24	-	24	197.1b	24
35 d	329.0b	24	-	24	234.8a	24
P > F	0.0005		-		0.0199	
USDA quality grade						
Top Choice	346.5	48	-	48	231.9	48
Select	342.0	48	-	48	229.5	48
P > F	0.6994		-		0.8410	
RMSE[a]	32.88		39.82		41.91	

Means within the same column lacking a common letter (a-b) differ ($P < 0.05$).
[a] RMSE = Root Mean Square Error from Analysis of Variance.
[b] Table values do not include additional nine day postmortem aging due to shipment of product.

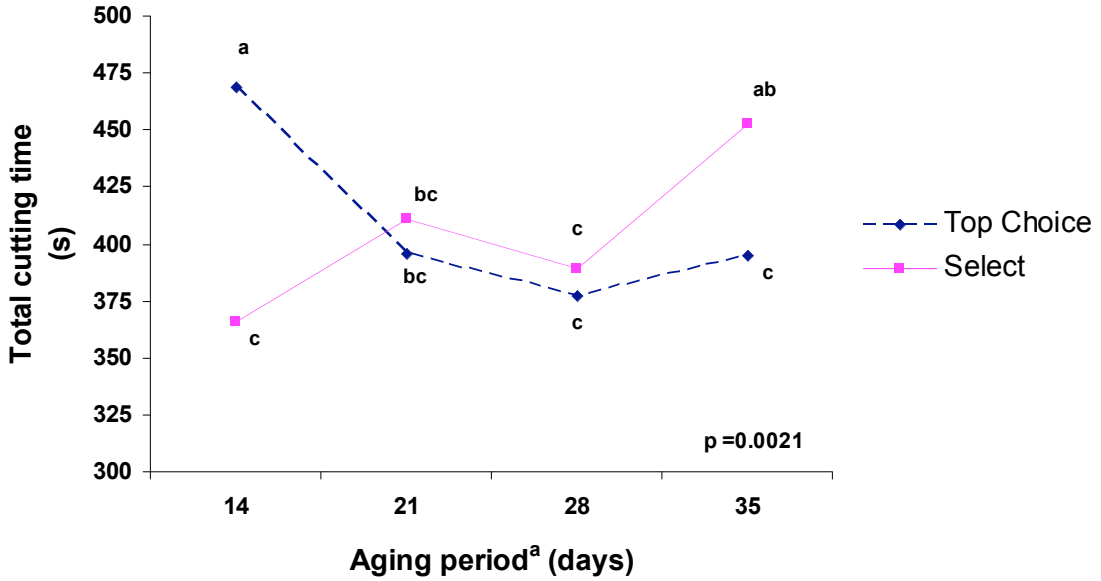

Fig. 6. Least squares means for total cutting time of strip loins stratified by aging period x USDA quality grade. Means lacking a common letter differ ($P < 0.05$).
[a] Table values do not include additional nine day postmortem aging due to shipment of product.

CHAPTER IV

CONCLUSIONS

Quality grade proved to have a substantial effect on consumer evaluation of various palatability characteristics of beef steaks, especially those steaks from the ribeye rolls and strip loins. Consumers could not detect any flavor differences between wet- and dry-aged steaks; however, both treatments had very high overall ratings. Therefore, the average consumer might be unsure of what palatability attributes are associated with dry-aged beef, as many of them were not sure if they had ever consumed dry-aged beef before. Also, this could indicate the flavor differences between wet- and dry-aged products are simply not present.

Retail cutting tests indicated that dry-aged products had lower total saleable yields and increased processing times when compared to wet-aged products. Even though this conclusion was expected, it is apparent now that there must be substantial price differentials present at the retail and foodservice levels in order to offset the losses incurred by dry aging, especially when there are very little palatability differences present. The question remains, however, will the increase in price for dry aged-product be acceptable to the majority of consumers purchasing beef at the retail level?

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APPENDIX

Yield and Shear Records

Project: Megan's Dry Aging **Date:** 5/23/07

Sample #							
TAMU Code							
RAW WEIGHT							
COOKED WEIGHT							
SHEAR							
KG / LBS							
1							
2							
3							
4							
5							
6							
7							

Place Label Here

Cutter: _____

Recorder: _____

In Bag Weight: _____

Bag Weight: _____

Purge Weight: _____

Initial Cut Weight (Out of bag) _____

Subprimal Ready to Cut Weight _____

Pre Cut Trimming (Crust) Weight _____

Pre Cut Trimming Bone Weight _____

Retail Cut	# of cuts	Weight of cuts
_____	(____)	_____
_____	(____)	_____
_____	(____)	_____
_____	(____)	_____
_____	(____)	_____

Time

Bag Opening _____

Waste Trimming _____

Trimming _____

Cutting _____

Total Time _____

Lean Trim Weight _____

Fat Trim Weight _____

Bone Dust Weight_____

Bone Weight _____

Waste Weight_____

Total Component Weight _____

% _____

SENSORY INFORMATION SHEET

The following document contains important information concerning participation of human subjects in research at Texas A&M University. There will be approximately 200 participants in this study. Please read the following information carefully.

- This study will take place between February 2007 and May 2007.
- The purpose and objectives of this study are as described below:

  To identify tenderness and flavors for dry aged beef.
- The benefit of participating in this study is the advancement of research in Meat Science and no risks are involved with participation in this study above the inherent risks associated with eating a meat product.
- Your role in this study is one of a consumer panelist and you will be tasting beef products that may be part of a scientific research project.
- Your participation in this study is confidential and your name will be entered as a code in data analysis to ensure confidentiality.
- Your participation in this study is completely voluntary and you may decide to discontinue participation at any time.
- The significant new findings during research that may relate to your health or willingness to participate in this study will be provided immediately upon discovery so that you may decide whether or not to continue participation in the study.
- The time you will spend participating in this study (Tasting samples and filling out evaluation forms) will be approximately 1 hour on behalf of you. You will be informed if additional participation time will be necessary.
- The Food and Drug Administration (FDA) may inspect any FDA sponsored research.
- All meat products have been inspected and passed by the USDA.
- Any added ingredients have been approved by the Food and Drug Administration (FDA) and do not include any known food allergens.

This research study has been reviewed and approved by the Institutional Review Board-Human Subjects in Research, Texas A&M University. For research related problems or questions regarding subjects' rights, the Institutional Review Board may be contacted through Ms. Melissa McIlhaney, IRB Coordinator, Office of the Vice President for Research, (979) 458-4067 e-mail: mcilhaney@tamu.edu.

Megan Laster, Graduate Research Assistant
Jeff W. Savell, Research Advisor
Rhonda K. Miller, Research Advisor
Texas A&M University Kleberg Rm. 348
College Station, TX 77843-2471 (979) 845-3935

PANELIST DEMOGRAPHIC INFORMATION

FILL OUT THE FOLLOWING INFORMATION BY PLACING AN X IN THE CORRECT BOX.

1. Please indicate your age by marking the appropriate blank:

___ Under 21 years _____ 30-39 years _____ 40-49 years

___ 22-29 years _____ 50-59 years _____ 60 years or older

2. Please indicate your income (combined income if both you and your spouse are employed) by marking the appropriate blank:

_____ Under $20,000 _____ $30,000 - $39,000 _____ $50,000 - $59,000

_____ $20,000 - $29,000 _____ $40,000 - $49,000 _____ $60,000 or more

3. Please indicate your household size, including yourself:

____ 1 _____ 3 _____ 5

__ _ 2 _____ 4 _____ 6 or more

4. Please indicate your current working status:

____ Not employed _____ Part-time

____ Full-time _____ Student

5. Please indicate your sex:

____ Male _____ Female

6. Please indicate your ethnic background:

_____ White _____ Black _____ Hispanic

_____ American Indian _____ Asian or Pacific Islander

Consumption Information

1. Please mark the number of times a week you consume meat.

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

2. Please mark the number of times a week you consume poultry.

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

3. Please mark the number of times a week you consume pork.

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

4. Please mark the number of times a week you consume fish.

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

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

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

6. Please mark 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)

2-sided directional difference test
Participant Number _____

Instructions

1. First taste the product on the left. Then taste the product on the right.

Indicate by placing a mark in the box of the sample that you prefer.

☐	☐
168	**362**

2. Please comment on the reasons for your choice:

_____
_____
_____
_____
_____

Sensory Ballot

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

Dislike Extremely — Like Extremely

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

Dislike Extremely — Like Extremely

3. Indicate by placing a mark in the box how you feel about the **INTENSITY** of the **BEEF FLAVOR**.

Extremely Bland or No Flavor — Extremely Flavorful or Intense

4. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** for the **TENDERNESS**.

Dislike Extremely — Like Extremely

5. Indicate by placing a mark in the box how you feel about the **LEVEL OF THE TENDERNESS**.

Extremely Tough — Extremely Tender

6. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **JUICINESS**.

Dislike Extremely — Like Extremely

7. Indicate by placing a mark in the box how you feel about the **LEVEL OF THE JUICINESS**.

Extremely Dry — Extremely Juicy

8. How likely would you be to **PURCHASE** this sample if it were available at a reasonable price in your area? Please circle one of the choices below.

____ Definitely would buy

____ Probably would buy

____ May or may not buy

____ Probably would not buy

____ Definitely would not buy

Exit Interview
Participant Number _____

1. On average, how many meals do you eat away from home (at restaurants) each month? (Place an X on one like below.)

_____ 15 meals or more
_____ 10-14 meals
_____ 4-9 meals
_____ 1-3 meals
_____ Never

2. Who in your household typically does the majority of the grocery shopping? (Place an X on one line below.)

_____ Self
_____ Spouse
_____ Other

3. When grocery shopping, where do you typically shop? (Place an X on one line below.)

____ Grocery chain (i.e., H.E.B., Albertsons, Kroger)
____ Small or specialty grocer (i.e., Readfield's, Farm Patch)
____ Discount or warehouse store (i.e., Sam's Club)
____ On-line/Web
____ Other: (Please describe: _____)

4. At what store do you most often purchase meat products? (Indicate a store or chain name on the line below.)

_____

5. Who is the main meal preparer in your home? (Place an X on one line below.)

____ Self
____ Spouse
____ Children
____ Other

6. How often does your family prepare and eat dinner meals at your home in an average month? (Place an X on one line below.)

____15 meals or more
____ 10-14 meals
____4-9 meals
____1-3 meals
____ Never

7. Are you familiar with the term "aging" in reference to beef?
   ____ Yes
   ____ No

8. Do you feel that aging of beef is a positive or negative term?
   ____ Positive
   ____ Negative

9. What does the term aging (in regards to aging beef) mean to you? (Mark all that apply.)

____ Improves juiciness	____ Decreases juiciness
____ Improves tenderness	____ Decreases tenderness
____ Improves meat value	____ Decreases meat value
____ Improves flavor	____ Decreases flavor
____ Improves overall eating satisfaction	____ Decreases overall eating satisfaction
____ All of the above	____ All of the above

   Other (indicate) _____

10. Have you ever eaten dry aged beef?
    ____ Yes
    ____ No
    ____ Not sure

11. What are your perceptions of dry aged beef?
    ____ Dry aged beef is better than other beef.
    ____ Dry aged beef is the same as any other beef.
    ____ Not sure.
    ____ Other (indicate) _____

12. How would you consider dry aging of beef in terms of meat/food safety?
    ____ Dry aged beef is safer.
    ____ Dry aged beef is less safe.
    ____ Dry aging does not change meat safety.
    ____ Not sure.

13. If dry aged beef was available at your preferred retail store, would you be willing to spend $1.00 more per pound of product?
    ____ Yes
    ____ No

14. On average, how long does it take to prepare a dinner meal in your home? (Place an X on one line below.)

____ More than 1 hour
____ 30 minutes to 1 hour
____ 15 - 30 minutes
____ Less than 15 minutes

15. Indicate your overall favorability for the following types of meat. (Place a number on each line below using range from 1 to 10, where 10 means VERY FAVORABLE and 1 means UNFAVORABLE.)

____ Chicken
____ Beef
____ Pork
____ Seafood

THANK YOU.

VITA

Name: Megan Ann Laster

Education: Texas A&M University
B.S., Animal Science
May 2006

Texas A&M University
M.S., Animal Science (Meat Science)
December 2007

Department Address: 2471 TAMU KLCT 348
College Station, TX 77843-2471