# A SURVEY OF POSTMORTEM AGING TIMES FOR BEEF STEAKS MARKETED IN THE RETAIL CHANNEL

A Thesis

by

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

MASTER OF SCIENCE

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August 2015

Major Subject: Animal Science

## ABSTRACT

This study was designed to determine the actual postfabrication storage time or aging time for beef rib/loin cuts sold at retail. Postmortem aging of beef is a commonly accepted practice in today's industry; however, not all members of the meat industry are utilizing this practice to its full advantage. In the surveyed retail stores, subprimals from the rib/loin regions were followed through the distribution channel to final retail package and into the meat case to measure true post-fabrication to consumer time to assess what proportion of beef was aged <14 d in the retail channel across six market regions in the southern United States. Subprimal aging time at the retail establishments surveyed averaged 26.3 d, with a range of 3 to 225 d. It was also found that 79.0% of the surveyed beef product had no production claims.

Where possible, scanning information from retailers was used to measure when products arrived and when they were utilized at the store. This information allowed for a more in-depth analysis of possible trends in retail handling across four market regions in the southern United States. Data were gathered through various software inventory-tracking systems and surveys were conducted of the back room of individual stores. Also, information on weekly online retail store advertised specials was tracked to gain insight into beef items that retailers are featuring. The majority of the aging time observed in this study took place from the packer to the retailer and not from the retailer to the consumer, which had 15.2% of boxed subprimals aged <14 d. The weekly beef feature items that were collected seemed to suggest that beef items are more heavily

featured around March-April and October-December when other meat items may be a more popular choice for the consumer.

# DEDICATION

I dedicate this thesis to Brian Cesari and my family, thank you for your unconditional love and support. It is because of your love and support I am where I am today. I love all of you more than you know.

ACKNOWLEDGEMENTS

Thank you to my committee members, Dr. Savell, Dr. Gehring, and Dr. Hale, for all their guidance throughout my research and allowing me to learn through the research process. Also, I thank Dr. Ashley Arnold for all her guidance and support during my research. I am incredibly grateful for the opportunity to know and work with each of you.

Thank you also to the Department of Animal Science and the store retailers that participated in this survey for making this research possible.

Finally, thank you to my family and friends for being so encouraging, loving, and supporting throughout this process.

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# 1. INTRODUCTION

Postmortem aging of beef is an important factor that may influence the palatability of a beef cut. According to Smith et al. (1978), postmortem aging of beef subprimals has been shown to have an effect on the tenderness of meat products. Adequate postmortem aging is necessary when developing the flavors desired for steaks and roasts. Aging can be defined as the length of time and temperature of storage following slaughter (Smith et al., 1978) to increase tenderness of the muscles in a carcass. The National Beef Tenderness Surveys (Morgan et al., 1991; Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013) have provided the beef industry with valuable reference points for measuring postmortem aging of beef cuts. These surveys provided information to the industry to assist with marketing decisions in the food service industry and retail markets.

Findings from The National Beef Tenderness Surveys (Morgan et al., 1991; Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013) have helped shape research needs and production and marketing decisions by the industry. In addition to the tenderness and palatability findings of these surveys, the opportunity to determine the average postmortem age (termed post-fabrication times in the surveys), was one of the most intriguing results and the surprise when individuals learned such a range of time between products produced and packaged and when they were offered to consumers through either the retail channel or food service channel (Guelker et al., 2013).

The first survey (Morgan et al., 1991) found that the average aging time was 17 days with a range of 3 to 90 days. Subsequent surveys found similar ranges. Beginning with Brooks et al. (2000), the survey started reporting the post-fabrication time information so that a new category, "< 14 days," was included as a way to measure the amount of subprimal product that would be considered not aged enough before it was cut and sold. According to Pearson and Young (2012), aging product usually occurred by holding or storing the product while endogenous enzymes hydrolyze some of the muscle proteins in order to improve tenderness and flavor. Aging meat would be an expensive endeavor due to storage costs and demand for beef products in the retail market.

The surprising information from the past three surveys was that the "best" results (lowest shear force values/highest palatability ratings) were found in the NBTS-2006 (Voges et al., 2007) where the percentage of subprimals with post-fabrication time of <14 days was the lowest of the three surveys. It was unclear why this aging survey was so different in this survey than the other surveys, but ensuring that beef is aged 14 days or more should be a priority for everyone in the beef marketing chain.

The challenge with measuring postmortem age in the backrooms of retail stores was that access to the backrooms of stores was often restricted. Without question, general trends could be obtained from this information, but what was truly needed was to be able to follow products with known ages from subprimal to retail cut in the case so that better approximation could be made of the actual time from slaughter (or at least fabrication date) to the time that consumers purchase the product.

Aging beef before consumption was a critical and necessary step in ensuring that the consumer would have a positive eating experience resulting in increased demand for beef. With beef prices at all-time highs, it was even more important that beef meets or exceeds consumer expectations. Lack of sufficient aging before consumption may place beef at a greater risk of failing to deliver on what the consumer desired. Managing postmortem aging may be a simple solution to increasing quality and enhancing beef's place as a high-quality and enjoyable product for the consumer. Anything that increases the demand for beef certainly helps everyone in the beef supply chain.

# 2. LITERATURE REVIEW

*Postmortem Age*

Postmortem aging time has been a topic of investigation for beef retail cuts for many years. Quantifying differences in palatability attributes by using sensory and mechanical methods has required much time and effort. Because meat was a multiple component system, any method to quantify tenderness and other palatability attributes would be differentiated into several components (Huff and Parrish, 1993). A study conducted by Huff and Parrish (1993) investigated attributes, such as animal age and sex on postmortem aging 3 to 28 days. For all ages and sexes of cattle, steaks aged 3 days postmortem had the least ($P < 0.05$) softness to tooth pressure and the most resistance to fiber fragmentation. Conversely, steaks aged 28 days were softer and easier to fragment than steaks from the other three aging periods (Huff and Parrish, 1993). As postmortem aging time increased, myofibrils became fragmented as the Z-disks became more degraded (Parrish et al., 1973). Animal age and postmortem aging time had more influence on tenderness attributes than did sex of the animal. More importantly, increased postmortem aging time improved myofibrillar tenderness attributes regardless of sex or age of the animal. This improved tenderness as postmortem aging time increased, which supported the concept of myofibrillar tenderness of beef steaks (Huff and Parrish, 1993).

Meat tenderness was the lowest at the time rigor mortis was fully developed and increased progressively during postmortem aging (Aberle et al., 2001). A number of studies unanimously recognized that meat-tenderizing process resulted from proteolysis of myofibrillar and associated structural proteins. In non-aged beef these proteins ensure inter-and intramyofibril linkage and attach myofibrils to sarcolemma by costameres. Proteolysis of these proteins caused weakening of the structures and thus tenderization (Laville et al., 2009). Guelker et al. (2013) found that the subprimal aging times at retail establishments averaged 20.5 days with a range of 1 to 358 days, whereas aging time at the food service level revealed an average time of 28.1 days with a range of 9 to 67 days.

Declining market share was a problem that confronted the beef industry over the past two decades. Although numerous factors may have contributed to this situation, recent consumer surveys have clearly indicated lack of consistency in product tenderness to be a major concern for most consumers. Postmortem aging appeared to be beneficial to all palatability attributes, except juiciness, which was not influenced by postmortem aging (Jeremiah et al., 1993). Initial and overall tenderness increased progressively and shear force values decreased progressively as postmortem aging was prolonged and intramuscular connective tissue became progressively less perceptible (Jeremiah and Gibson, 2003).

The National Beef Tenderness Surveys (Morgan et al., 1991; Brooks et al., 2000; Voges et al., 2007; Guelker et al., 2013) have provided the beef industry with valuable reference points for assessing the state of the industry with regards to postmortem aging of beef cuts. However, when postmortem age was observed it has yet to be determined the proportion of postmortem aging that occurred from the packer to the retail establishment and then the handling time from the retail establishment to when the consumer purchases the beef retail product. By determining the proportion of time the beef subprimals spend in transit between the packer and the retail establishment versus the amount of time the subprimals are handled by the retailer until purchased by the consumer the industry could focus education efforts and resources on aging of retail products before the product was purchased.

*Postmortem Aging Methods*

Dry aging and wet aging were the two methods of postmortem aging that could be used in today's industry. Both methods had advantages and disadvantages in the market place. The method used to age meat is dependent on the consumer expectations, combined with yield and economic value considerations. According to Parrish et al. (1991), dry-aged beef primals and subprimals (aging a cut "as is" under refrigeration) developed more desirable flavor and tenderness. However, dry aging has been known to result in a high percentage of shrink during cooler storage, demanded careful control of storage variables and required more storage space. Further more, vacuum packaging after dry aging did not impair the flavor attributes of dry-aged beef, the product could be repackaged after dry aging for storage, transport, and inventory control for the end user (Campbell et al., 2001).

In a study conducted by Stenström et al. (2013), it was found that 51% of consumers ($n$ = 61) did not know the difference between dry and vacuum aged beef and 69% of the consumers did not know if dry-aged beef was available in their local grocery store. Perhaps more information on the method of dry aging was needed to allow the consumer to be informed when making a purchasing decision. Dry aging of beef brought out pleasant flavors, and aging was recognized as a positive term. However, dry-aged meat was less available and considered a specialty, a value-added product, so it was more expensive (Stenström et al., 2013). Storage costs were an important factor when looking at the economic impact an aging method could have on the retail market. Tenderness and juiciness also improved during dry aging. The development of palatability attributes could be sufficient to offset the expense incurred during dry aging (Campbell et al., 2001).

Wet aging was defined as aging in a vacuum bag under refrigeration. Other processors indicated wet aging would produce acceptably tender and flavorful products in a shorter time without loss of yield and aging space (Parrish et al., 1991). In a study conducted by Parrish et al. (1991), dry aging and wet aging methods were evaluated for shrink, tenderness, and palatability. Loins and ribs that were dry-aged had more cooler shrink than the loins and ribs that were wet aged. No measurable purge was found in wet aged products. That was probably a result of proper handling and temperature control of the product (Parrish et al., 1991). On the other hand, trim loss of the dehydrated and discolored surfaces was about 5-10 times greater for dry-aged product than for wet-aged product. Parrish et al. (1991) reported weight loss for dry-aged strip loins were about 12%.

Differences in palatability attribute scores as affected by wet and dry aging treatments were slight. Steaks from wet aging, however, had higher scores ($P < 0.01$) for tenderness and overall palatability. Although tenderness scores were statistically higher, both aging treatments provided very palatable products (Parrish et al., 1991). Either method of aging, or any of the three quality grades could provide satisfactory products. Demand, cost efficiency, and preference in restaurants would probably dictate aging and/or product use (Parrish et al., 1991).

Postmortem aging of meat was probably the most widely used tenderizing process in the meat industry. Packers, purveyors, retailers and restaurateurs use postmortem aging periods of varying lengths-as short as a few days or as long as a month (Savell et al., 1981). Electrical stimulation is a postmortem treatment that can have an effect on tenderization. One of the most widely recognized results of carcass electrical stimulation is the acceleration of rate of postmortem pH decline (Aberle et al., 2001). Electrical stimulation also shortens the duration of rigor mortis. Violent contractions produced by stimuli utilized great quantities of ATP and depleted energy reserves in the muscle. In the absence of ATP, muscles quickly develops rigor mortis (Aberle et al., 2001).

Electrical stimulation would have more of an impact on tenderness than postmortem age, even for 2 wk, could achieve. Electrical stimulation would accelerate the postmortem aging in beef but the actual aging time reduction and extent of ultimate tenderization appeared to be affected by the inherent tenderness of the beef (Savell et al., 1981). Electrical stimulation has also been known to have a positive effect on tenderness for cattle that may have had a higher percentage of *Bos indicus* genetic influence, which had more calpastatin than *Bos taurus* influenced cattle. Electrical stimulation improves tenderness, makes marbling more visible, and shortens aging time (Aberle et al., 2001). Because electrical stimulation could accelerate the postmortem aging period, this had an economic impact on the industry because less time would be needed in postfabrication storage and product would be able to move at a quicker pace through the retail channel while still receiving the postmortem aging time benefit.

Watanabe et al. (2015) evaluated the effects of aging in beef with solid-phase micro extraction (SPME) and gas chromatography-mass spectrometry (GC-MS) and was able to identify seventy volatile substances, including non-aromatic, heterocyclic and homocyclic compounds. They suggested from the results of the study, the aging process may lead to an increase not only in the amount of compounds related to the taste of meat, but also in the quantity of odor active compounds (Watanabe et al., 2015). In this study samples, from the distal *M. biceps femoris* were taken from four fattened Japanese Short-horn steers, and the samples were vacuum packaged two days postmortem and were aged for a 2, 9, 16, 23, and 30 days postmortem at 4°C and then were stored at 20°C until analysis (Watanabe et al., 2015).

The samples then were cooked to 180°C and it was concluded that the Maillard Reaction affect on the aging of volatile compounds lead to a statistically significant increase of benzeneacetaldehyde and heterocyclic compounds including 2-formylfuran, pyrazine, 2,6-dimethylpyrazine, 2,3-dimethylpyrazine, 2-acetylthiazole, and 2-formyl-3-methylthiophene. These compounds were known to play an important role in the aroma of cooked meat and increased in the amount of precursor, amino acids, as well as hexoses and ribose during storage were reported previously, indicating that aging was important for not only the taste, but also for the aroma of cooked meat (Watanabe et al., 2015).

*Shelf-life*

A study conducted by Jennings et al. (1978) investigated the influence of fat thickness, marbling, and length of aging on beef palatability and shelf-life characteristics. This study aged strip loins from 60 Hereford and Hereford-Angus cross steers and heifers that were chosen to fit into four categories; >1.52 cm fat thickness or above, <1.02 cm fat thickness, >1.52 cm fat thickness or below and <1.02 cm fat thickness. One set of strip loins were aged under vacuum for 10 days at 2 C, while the matching strip loin was aged for 20 days. It was found that regardless of the fat thickness, the twenty day aged strip loins had lower shear force measurements. However, it was also found that the twenty-day aged strip loins had greater off-odor, more extensive fat discoloration and higher bacterial counts than the ten days of vacuum packaged aging (Jennings et al., 1978). Aging has been reported to influence meat color through metmyoglobin accumulation rate, metmyoglobin reduction activity, and oxygen consumption rate (Madhavi and Carpenter, 1993).

The shelf-life portion of this study was conducted after the 10- and 20-day vacuum packaged storage periods. A three-member panel evaluated the degree of vacuum of each strip loin prior to opening, degree of off odor, fat surface color and lean surface discoloration of the *longissimus* muscle. The length of the aging process was the only factor from analyses of variance of produce significant effects on shelf-life characteristics (Jennings et al., 1978).

Modified Atmosphere Packaging (MAP) has given new opportunities for extending the shelf-life of fresh beef and has changed distribution patterns since it was introduced more than 30 years ago. However, recent studies showed that the choice of modified atmosphere (MA) gas combinations also influenced eating quality as well as shelf-life and color. Meat packed in high $O_2$ (>21%) MA is affected negatively for palatability. The sensory properties (in terms of warmed-over favor (WOF), flavor desirability, overall palatability, tenderness and juiciness) were affected negatively during high $O_2$ MAP storage (Clausen et al., 2009). The main reason oxygen was applied to fresh meats was for the desired red color or “bloom” to be maintained for longer periods of time. The $CO_2$ also was known for antimicrobial effects on microbial growth.

Oxygen also had an affect on the oxidation of fatty acids, which could have an effect on flavor and shelf-life. Modified atmosphere packaging typically was comprised of 70-80% oxygen and 20-30% $CO_2$ (Clausen et al., 2009). In this study, it was found that high $O_2$ had a marked negative influence on several eating quality parameters. The effect of MAP on meat toughening in the study may have been at least partly caused by reduced proteolysis. Tenderness and juiciness in the cooked meat was reduced and the flavor appeared distinctly more intense with a warmed-over/oxidized taint, and in addition, a premature browning occurred. Thus the high oxygen MAP systems could not be recommended either to the meat industry or for the retail distribution of meat (Clausen et al., 2009).

Kim et al. (2010) evaluated the effects of HiOx-MAP (80% $O_2$, 20% $CO_2$) and vacuum packaging on lipid oxidation and color stability of beef steaks taken from the *longissimus lumborum, semimembranosus, and adductor* muscles. Packaging occurred after 24 hours postmortem had passed. These steaks were randomly assigned to a packaging method and then were displayed for nine days at 1°C. It was observed that the HiOx-MAP packaged samples showed a more rapid increase in lipid oxidation and a decrease in color stability (Kim et al., 2010). Both of these conditions were not favorable to beef concerning shelf-life. Also, it was noted that the *longissimus lumborum* seemed to have less lipid oxidation under the HiOx-MAP conditions than the *semimembranosus, and adductor* muscles. This may suggest that not all muscles were equally affected in the same environments. In contrast, steaks packaged in vacuum did not have a change in TBARS values during nine days of display (Kim et al., 2010). It would appear that the MAP packaging that was chosen could have an impact on the shelf-life of retail beef and possibly tenderness, but not all retail products may be affected to the same extent.

*Marketing*

The supply of tender beef was an important challenge for the beef industry. There are fewer cattle available in today's market due to several years of drought conditions from previous years. These drought conditions caused cattle to be harvested that may have been kept if there had been more desirable rainfall.

Knowledge about the profile of consumers who were more optimistic or more accurate in their tenderness evaluations was important for product development and beef marketing (Van Wezemael et al., 2014). The United States, genetic selection and management practices have collectively contributed to improvements in producing quality cattle for today's beef industry. One unintended consequence has been increased incidence of carcasses that were considered to be too heavy for the marketplace (West et al., 2011). The beef industry had to find new ways to maximize profits but also find a way to provide products that the consumer will purchase. Retailers adopted innovative cutting styles to effectively merchandise subprimals from heavy weight beef carcasses. The industry must account for decreased primary saleable yields and increased labor requirements through increased retail pricing (West et al., 2011) and with these increased costs the consumer's expectations of the eating experience may rise as well.

Also, to address these larger subprimals, the National Cattlemen's Beef Association, The Beef Checkoff and the Cattlemen's Beef Board created Beef Alternative Merchandising (BAM) funded research to find new ways to offer portion sizes for health-conscious consumers (Desimone et al., 2013). The methods utilized to process, package, distribute, and merchandise beef have changed considerably over the past two decades, with advances in more efficient and rapid chilling of carcasses, boxed beef distribution and merchandising and centralized preparation and packaging display-ready, retail cuts. The advancements in processing and packaging would substantially improve beef's competiveness in the marketplace (Jeremiah and Gibson, 2003).

Computer and information technology in the meat industry has advanced over the years, which has allowed data to be gathered on beef items and help in business decisions. A computer software program, CARDS (Computer Assisted Retail Decision Support), was developed so retailers could evaluate the price/value relationship of beef subprimals. The CARDS program continues to serve as a valuable reference to assist retailers in the process of making decisions regarding meat purchasing and merchandising (Voges et al., 2006). This technology would be a tool in assessing merchandising steaks and roasts, beef for stew, lean trimmings, etc. Because of this variety, processing times can be quite long, which would add to the labor requirements necessary to effectively market such cuts (Voges et al., 2006).

Tenderness was considered to be the single most important factor influencing consumers' perceptions of taste (Savell et al., 1987). Nguyen and Klaus (2013) conducted a study that explored the consumer perception of fairness towards retailers' marketing tactics. The study found three dimensions that were discussed; product dimension, interaction dimension and service dimension. Product dimension was defined as value for money and good prices, quality products and good reputation. The interaction dimension was defined as honesty and integrity, transparency and ethical behavior. The service dimension was defined as fair treatment, customer care and good services. Today, few people question whether meat should be aged; rather, the question was how long and by which method (Stenström et al., 2013). With dry-aged beef as a specialty item it would provide consumers the feeling of premium class and exclusivity (Stenström et al., 2013).

*Tenderness*

Eating satisfaction resulted from the interaction of tenderness, juiciness, and flavor. However, the problem of consumer dissatisfaction would be solved only when we solve the problem of unacceptable variation in meat tenderness (Koohmaraie, 1996). In a study conducted by Field et al. (1971) shear values for the *longissimus* and *biceps femoris* muscles decreased as aging time increased. However, not all beef cuts responded the same to postmortem aging. The decrease was smaller for the *biceps femoris* and this muscle did not change significantly in shear values between 7 and 21 days aging. It was evident that the *longissimus* benefited more from aging than does the *biceps femoris* (Field et al., 1971). When shear force was evaluated cores were taken from the cooked steaks after a set amount of time and the steaks had reached room temperature. Once the cores were taken from steaks the Warner-Bratzler machine was able to measure the amount of force it took to shear through the sample. The amount of connective tissue present in the muscle may have been a factor in the effectiveness of postmortem age of beef.

In the National Beef Tenderness Survey conducted in 1990, Morgan et al. (1991) found that the postmortem fabrication times averaged 17 days and ranged from 3 days to 90 days. According to Morgan et al. (1991), it appeared that the cuts from the chuck averaged the lowest in postmortem aging time, 15 days, compared to other primal cuts. This could have been influenced by the economy and the consumers' current preference at the time. In the National Beef Tenderness Survey – 2010, conducted by Guelker et al. (2013), the cold storage areas of the retail stores were surveyed to obtain box information to determine postmortem aging times. Subprimal postfabrication storage or aging times at retail establishments averaged 20.5 days, with a range of 1 to 358 days (Guelker et al., 2013).

Tenderness has been determined to be an important factor for consumers when making purchasing decisions about beef. Some factors that have been known to be associated with tenderness in beef such as marbling, subcutaneous fat thickness, catheptic enzymes, calcium dependent proteases and their inhibitor (Shackelford et al., 1991). Smith et al. (1978) reported that 11 or more days of postmortem aging would maximize tenderness of the majority of muscles from the chuck, rib, loin, and round of USDA Choice beef carcasses.

# 3. MATERIALS AND METHODS

*Postmortem Aging Time*

Stores from targeted regions in various parts of the U.S. were chosen for this beef postmortem aging survey to gather postfabrication storage time or aging time data on retail beef cuts. Members of the National Cattlemen's Beef Association retail marketing team provided assistance in identifying potential retail establishments to survey and initiated contact with the selected retailers. Once permission from the retail establishments was obtained, corporate retail representatives from each retail chain were asked to select individual stores to represent diversity within their market regions. Once these stores were identified the current store managers were notified about the survey and the dates that the surveys would be conducted in the region. In each stores, subprimals were followed from the rib/loin regions through the distribution to final retail package and into the case to measure post-fabrication to consumer time to better assess what proportion of beef aged (14 d or more) in the retail channel across six market regions in the southern United States.

Most of this survey involved store-cut product in addition, where possible, scanning information on market regions was used to measure when products arrived at the retail establishment and when they were utilized at the store. This information allowed for more in-depth analysis of possible trends in retail handling across four market regions in the southern United States. Data were gathered through various software inventory-tracking systems and surveys were conducted of the back room of individual stores. Also, information on weekly online retail store advertised specials was tracked to gain insight into beef items that retailers are featuring. These featured items were recorded weekly for each region.

The software-tracking systems observed were originally designed to track cases of beef products ordered by retailers for recalls and to meet Country of Origin Labeling (COOL) requirements. This software allowed retailers to locate recalled product in the stores and to see if the product had been purchased. These software-tracking systems could follow beef products from the point of packer distribution to the retail store and then the retailers would scan the box labels daily until the product had been merchandised to the consumer to be purchased.

*Beef Retail Features*

Data were recorded from each market in spreadsheets that were created in Microsoft Excel for Mac 2011 Version 14.48 (150116). The data sheets for postfabrication storage or aging time were formatted to record store number, store location, pack date, item identification, manufacturer identification, weight of product, label date, label claim, specialty program and product serial number in different columns. The spreadsheets for weekly-featured items were formatted to include the start date of the featured ad, end date of the featured ad, ad type, chain, store number, store location, cut name, bone in or boneless, grade, program, claim, and price per pound.

*Statistical Analysis*

Data were analyzed using SAS (SAS Institute Inc., Cary, NC). Descriptive statistics and frequency distributions were generated using the PROC MEANS and PROC FREQ procedures, respectively. Frequency distributions for marketing claims and weekly features were tested for significance ($P < 0.05$) using $\chi^2$ analysis. All other data were analyzed using PROC GLM where main effects and significant ($P < 0.05$) two-way interactions were included in the model. Data were analyzed to evaluate differences in post-fabrication aging and handling times between subprimal types and their respective quality grades. Least squares means were calculated; where ANOVA testing indicated significance, least squares means were separated using the PDIFF procedure and an $\alpha < 0.05$.

# 4. RESULTS AND DISCUSSION

*Postmortem Aging Time*

For this study six markets in the southern United States were surveyed for aging time of beef in the retail channel. Subprimal aging time at the retail establishments surveyed averaged 26.3 d, with a range of 3 to 225 d (Table 1). This average postmortem aging time was greater than the 20.5 d average postmortem aging time found by Guelker et al. (2013). The range of postmortem aging days found 3 to 225 d was smaller than the range 1 to 358 d found by Guelker et al. (2013). Voges et al. (2007) reported an average postmortem aging time of 22.6 d and the range of days was 3 to 83 d, which was lower than the currently observed average aging time. Brooks et al. (2000) reported an average aging time of 19 d and ranged from 2 to 61 d, and Morgan et al. (1991) reported the postmortem aging time averaged 17 d and ranged from 3 to 90 d. The average postmortem aging time observed by this study was greater than the averages observed in the past; however, the range of postmortem age days was still quite large.

Shortloins had the least amount (6.8%) of boxed subprimals aged for <14 d compared to ribeyes that had the highest amount (21.5%) of boxed subprimals aged for <14 d. When comparing all boxed subprimals from all the surveyed market regions in the southern United States 15.2% had been aged <14 d. This observed average was less than the average reported by Guelker et al. (2013), which was 37.5% of all boxed subprimals were aged <14 d, Voges et al. (2007) reported that 19.6% of boxed subprimals were aged <14 d and Brooks et al. (2000) reported that 34.1% of boxed subprimals were aged <14 d.

Subprimal aging times in regards to quality grade were reported in Table 2. USDA Prime, USDA Choice, USDA Select, and No Grade tenderloins showed that the Select (19.3 d) and No Grade (17.5 d) tenderloins had similar aging times, while the Prime tenderloins had the longest aging time of 26.0 d, with the a significant difference in aging time ($P = 0.0122$). It was observed that 24.0% of the USDA Prime tenderloins were aged <14 d and 19.3% of the USDA Choice tenderloins were aged <14 d. Aging times among USDA Prime, USDA Choice, USDA Select, and No Grade ribeyes varied significantly ($P < 0.0001$). USDA Prime ribeyes had 15.6% aged <14 d, USDA Choice ribeyes had 7.2% aged <14 d, USDA Select ribeyes had 35.9% < 14 d, and No Grade ribeyes had 28.7% aged <14 d. USDA Prime ribeyes were aged 22.9 d, USDA Choice ribeyes were aged 27.3 d, and USDA Select ribeyes were aged 18.2 d. The USDA Prime and USDA Choice strip loins were aged significantly longer than the USDA Select strip loins, however the No Grade strip loins had the highest mean aging time at 94.1 d. The USDA Prime strip loins had 5.6% aged < 14 d, USDA Choice had 5.7% aged < 14 d, USDA Select strip loins had 20.9% aged < 14 d.

The USDA Choice and No Grade shortloin aging time was significantly shorter than that seen for USDA Select shortloins ($P = 0.0078$). It was observed that 9.4% of the USDA Choice shortloins were aged <14 d, 1.4% of the USDA Select shortloins were aged <14 d, and 8.5% of the No Grade shortloins were aged <14 d. Aging times for USDA Prime, USDA Choice, and USDA Select top butts were significantly shorter than ungraded top butts top butts ($P < 0.0001$). USDA Prime top butts had 8.6% aged <14 d, USDA Choice had 7.5% aged < 14 d, USDA Select had 10.1% aged < 14 d, and No Grade had 2.7% aged < 14 d. This survey of postfabrication storage time demonstrated that ungraded tenderloins received the least amount of postmortem age at 17.5 d, while ungraded strip loins had the greatest amount of postmortem age at 94.1 d.

*Postmortem Handling Time from Packer to Retailer*

The least squares means aging time of beef retail cuts of the time period the subprimals are packed into boxes and then transported to the retail store was analyzed (Table 3) and the time period the beef retail cuts were handled by the retail stores until the product was purchased by the consumer was analyzed (Table 4). Starting with the handling time from packer to retailer, it was observed that USDA Prime tenderloins spent a significantly longer amount of time in this phase of transport than the USDA Choice and No Grade tenderloins ($P < 0.0001$). USDA Prime and USDA Choice ribeyes showed no significant difference in time spent between the packer and the retailer; however the USDA Select ribeyes did spend significantly less time in transit between the packer and the retailer than the USDA Prime and USDA Choice ribeye subprimals and the No Grade ribeyes spent the most time in this transit period ($P < 0.0001$). The USDA Prime and USDA Choice strip loins did show a significant difference in aging time between the packer and retailer ($P < 0.0001$) but the USDA Select strip loin aging time was comparable to the USDA Choice strip loin aging time. The No Grade strip loins had the longest time spent in transit from packer to retailer.

The USDA Select and No Grade shortloins showed no significant differences in postfabrication storage times from the packer to retailer (*P* < 0.0001). The USDA Select shortloins had 24.3 d and the No Grade shortloins had 24.1 d of postfabrication storage time. The USDA Choice, USDA Select, and No Grade top butts did show a significant amount of difference in aging time from the packer to retailer (*P* < 0.0001), the USDA No Grade top butts spent a longer time period (25.5 d) in this stage of transit than the USDA Choice top butts (15.3 d) and USDA Prime top butts (20.2 d) with the USDA Choice top butts spending the least amount of time in transit from packer to retailer. From this survey, it was observed that not all beef subprimals or quality grades spend equal amounts of time in transit from packer to retailer.

*Postmortem Handling Time from Retailer to Consumer*

The least squares means handling time period from the retail store to consumer purchase was analyzed (Table 4). There were significant differences between the USDA Prime tenderloins aging time of 3.1 d and USDA Choice tenderloins 5.1 d postfabrication storage time from retailer to consumer (*P* = 0.0056), however the No Grade tenderloin aging time was comparable to both USDA Prime and USDA Choice tenderloin aging times. When the USDA Prime ribeyes were compared to USDA Choice ribeyes and USDA Choice ribeyes were compared to USDA Select ribeyes there were no significant changes in the aging time (*P* = 0.4404). There was a significant change in aging time from retailer to consumer for USDA Prime strip loins (3.6 d), USDA Select (2.4 d), and No Grade strip loins (5.2 d) strip loins (*P* < 0.0001). USDA Select strip loins received the least amount of aging time at the retail store before purchased by the consumer. When shortloins were analyzed, it was observed that the USDA Choice shortloins (4.5 d) were not aged significantly longer than the USDA Select shortloins (6.0 d), but were aged longer than the No Grade shortloins (2.0 d). There was a significant difference in the aging time between the USDA Select shortloins and No Grade shortloins from the retailer to the consumer ($P = 0.0018$). There was a significant difference in aging time for the USDA Choice, and USDA Select top butts ($P < 0.0001$), but USDA Prime, USDA Choice and No Grade top butts showed no significant differences in aging time. USDA Choice and No Grade top butts received the most time handled by the retailer before purchased by the consumer while the USDA Select top butts received the least amount of handling by the retailer. From this survey it was observed that not all beef subprimals or quality grades receive the same amount of handling time from the retailer to consumer purchase.

*Production Claims*

The frequency of the ten observed production claims on retail beef products were analyzed in Fig. 1. In this survey, 2,853 cases were surveyed from six market regions in the southern United States to collect production claim data (chi-square = <0.0001). The claims that were observed included no claim, natural, grass-fed, antibiotic free, natural and antibiotic free, natural and Certified Tender, natural dry-aged, natural and antibiotic free and Certified Tender, Angus, and natural and antibiotic free and Angus.

Of the 2,853 cases surveyed, 2,255 cases from the rib and loin subprimals contained no production claims. The other nine production claims included natural, antibiotic free, Certified Tender, aging methods, and breed claims, which were represented by the other 598 cases. According to Umberger et al. (2009), there was an increasing area of differentiation among meat products in how they relate to source-of-origin and types of production methods that were used in raising the animals. Consumer preferences for natural and regionally produced beef are shown to be motivated by a combination of perception of personal beliefs and altruistic factors (Umberger et al., 2009).

According to the United States Department of Agriculture (2014), all fresh meat qualified as natural. Products labeled as natural are products containing no artificial ingredients or added colors and only minimally processed. Minimal processing was defined as the product was processed in a manner that did not fundamentally alter the product. Six of the marketing claims had additional characteristics added to the natural claim. These claims ranged from breed type of cattle, aging method used, and antibiotic use in the live animal.

*Retail Beef Features*

The frequency of beef retail items and middle meats being featured was analyzed (Fig. 2) by month over the course of a year. Over this time frame it was observed that of the 871 recorded feature items 427 (51.5%) of all beef featured items were middle meat products. There was a significant difference between the amount of total weekly beef features observed (chi-square < 0.0001) each month over the course of the survey. The months with the highest amount of weekly beef features were April (100 features) and October (105 features) and the months with the least amount of features were May (41 features) and July (38 features).

A possible scenario for the distribution of beef features throughout the year would be that the months that few beef features were observed was because it was during the height of the summer grilling season and beef retail items did not need to be featured to move efficiently through the retail supply chain. The time periods that did have high amounts of beef features were March and April, which falls around Easter when ham and lamb tend to be popular meat items as well as October, November and December when hams and turkeys are popular. Heavily featuring beef retail products during these months could be retailers offering an incentive to the consumer to purchase a beef product over a lamb, pork or turkey product.

There was also a significant difference in the observed weekly middle meat features (chi-square = 0.0003) that were featured each month. The months that featured the most middle meat items were October (51 features) and December (56 features) and there appeared to be less middle meats featured in May (25 features) and June (21 features). One possible conclusion for the increased amount of middle meat features, as a percentage of all beef features was that the summer was the height of the grilling season and middle meats were often popular grilling items. In was observed in July that 83.8% of all the beef features were middle meats features along with August (81.6%) and August (76.7%).

The frequency of weekly middle meats features for steaks and roasts by month were shown in Fig. 3 by month. Throughout the survey there was a significant difference in the amount of steaks features and the amount of roasts featured (chi-square = < 0.0001). This could be attributed to the seasonality of roast consumption, which tended to increase when the weather was cooler, which was seen in November (9 roast features) and December (16 roast features). Roast consumption also would appear to be not as prevalent during the height of the grilling season of May, June, July, and August when there was only one roast feature observed.

Fig. 4 was able to depict the number of features by month and the average postmortem aging time of the middle meats in that particular month. The postmortem aging time was then broken into time spent from the packer to the retailer and the retailer to consumer. It appeared that if the number of features increased so did the average postmortem aging time. This could be due to the fact that if a large product order was placed when a feature was planned the cases could have had different pack dates. Also some of the product may not have sold during the feature time period and the retailer kept the left over product in inventory.

# 5. CONCLUSION

In this study it was observed that the amount of postmortem aging time allowed in the retail beef supply chain was different among subprimals and quality grades. Subprimal aging time at the retail establishments surveyed averaged 26.3 d, with a range of 3 to 225 d. While the postmortem aging time observed had improved over past surveys, there was still 15.2% of boxed subprimals that were being aged <14 d and 79.0% of surveyed beef product had no production claims.

The majority of the postmortem aging time observed in this study took place from the packer to the retailer and not from the retailer to the consumer. It would appear that when the number of features increased then the average postmortem aging time increased during that month as well. The weekly beef feature items that were collected suggested that beef items are more heavily featured around March-April and October-December when other meat items may be a more popular choice for the consumer to purchase. Overall the meat industry appears to be utilizing postmortem aging more than in the past to improve beef retail products that are marketed to the consumer, but there is room for improvement.

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# APPENDIX

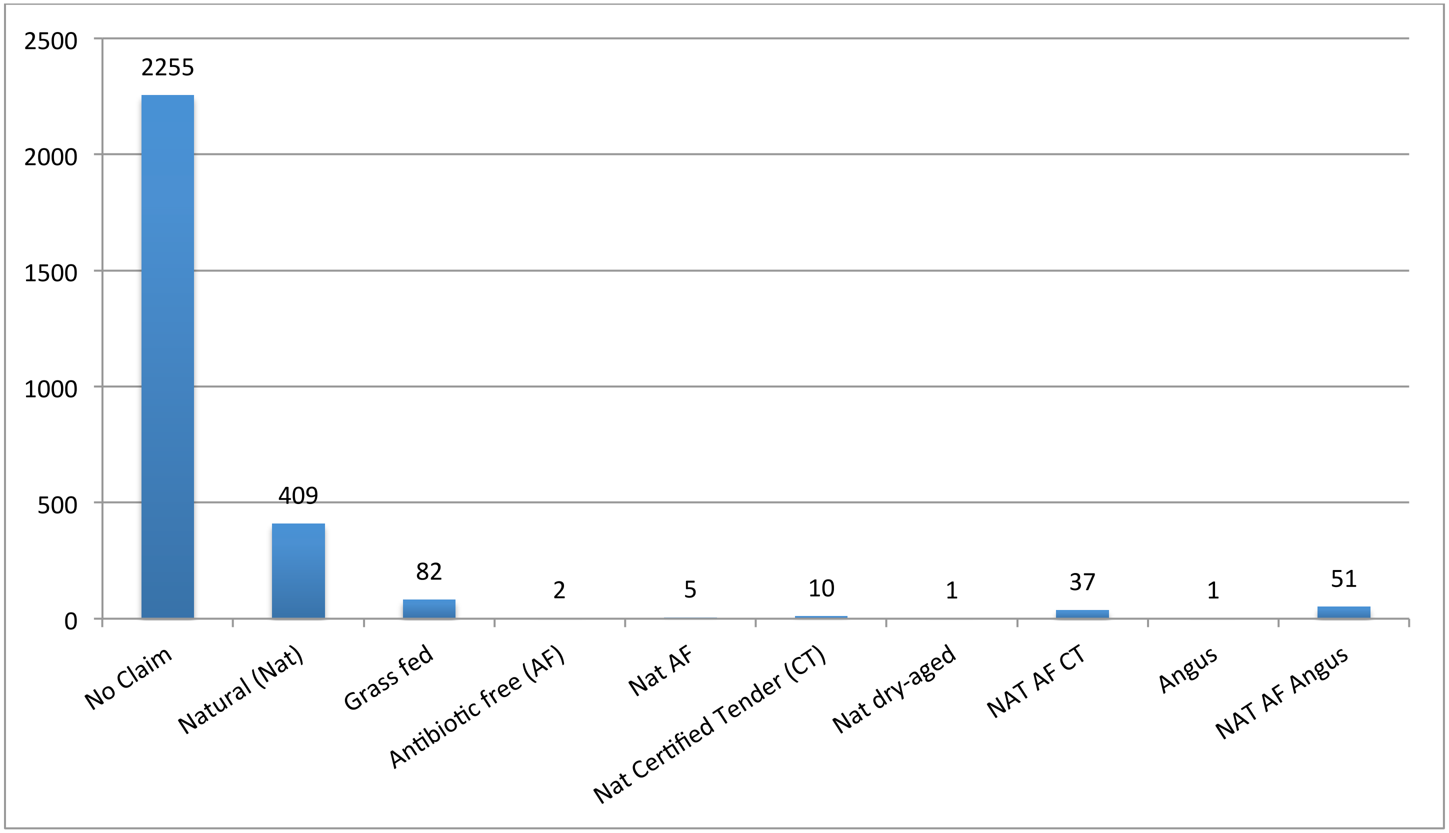


Fig. 1.

Frequency distribution of product cases ($n$ = 2,853) bearing production claims (chi-square = < 0.0001).

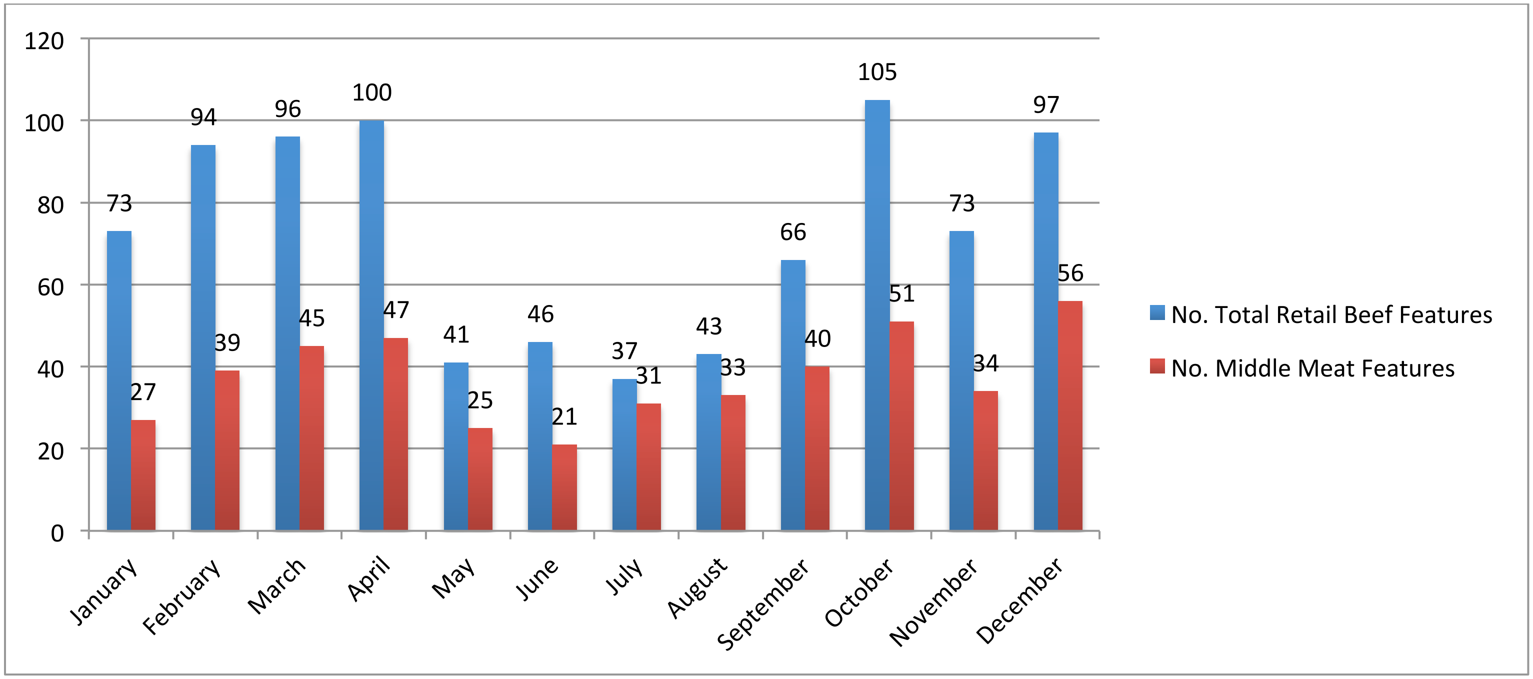


Fig. 2.

Frequency distribution of total weekly beef features (*n* = 871; chi-square = < 0.0001) and weekly middle meats features (*n* = 449; chi-square = 0.0003) presented by month. (Beef features from five major retail grocery chains were tracked weekly from July 2014 to June 2015).

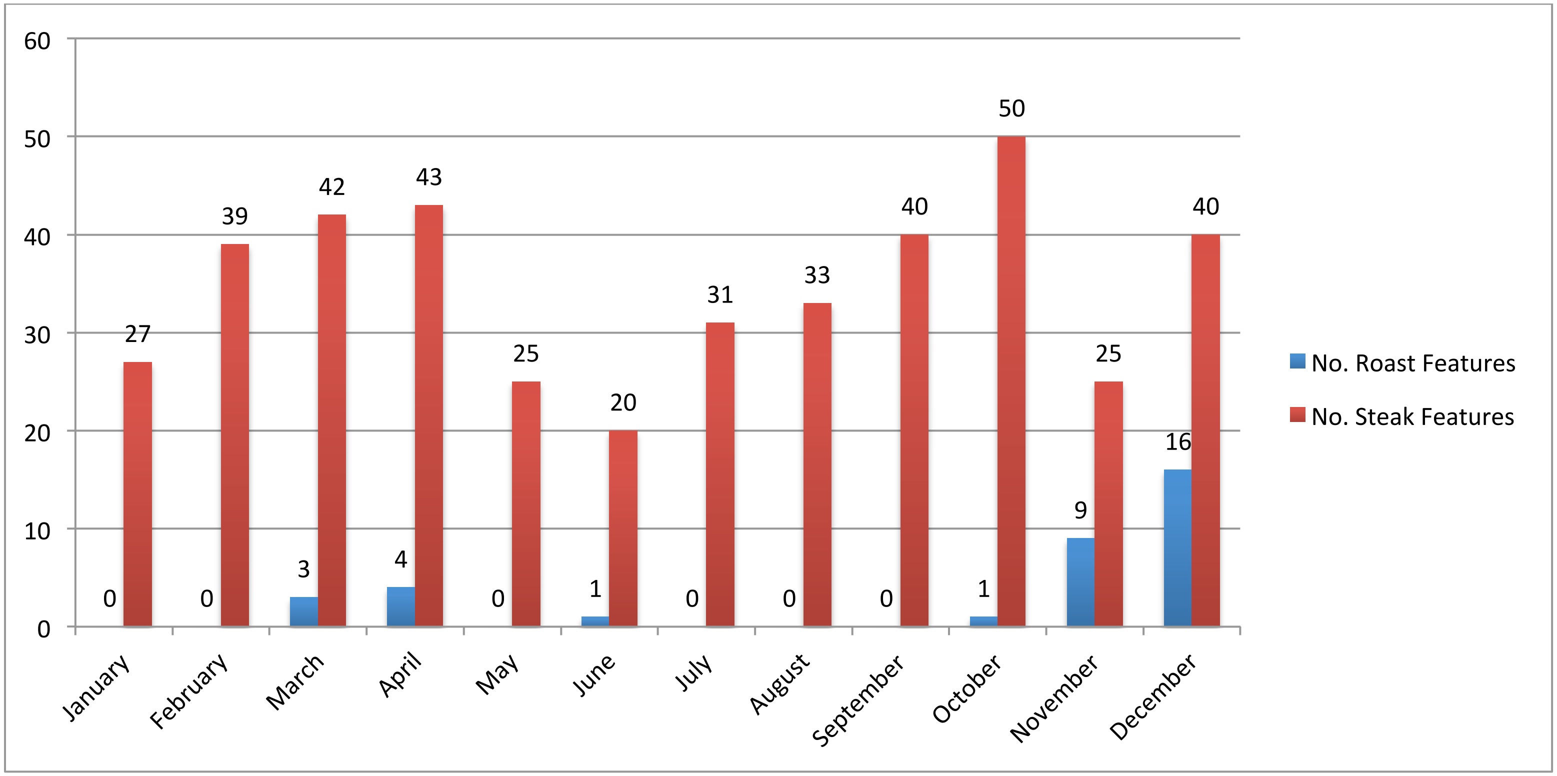


Fig. 3.

Frequency distribution of total weekly middle meats features for steaks (*n* = 415) and roasts (*n* = 34) presented by month (chi-square = < 0.0001). (Beef features from five major retail grocery chains were tracked weekly from July 2014 to June 2015)

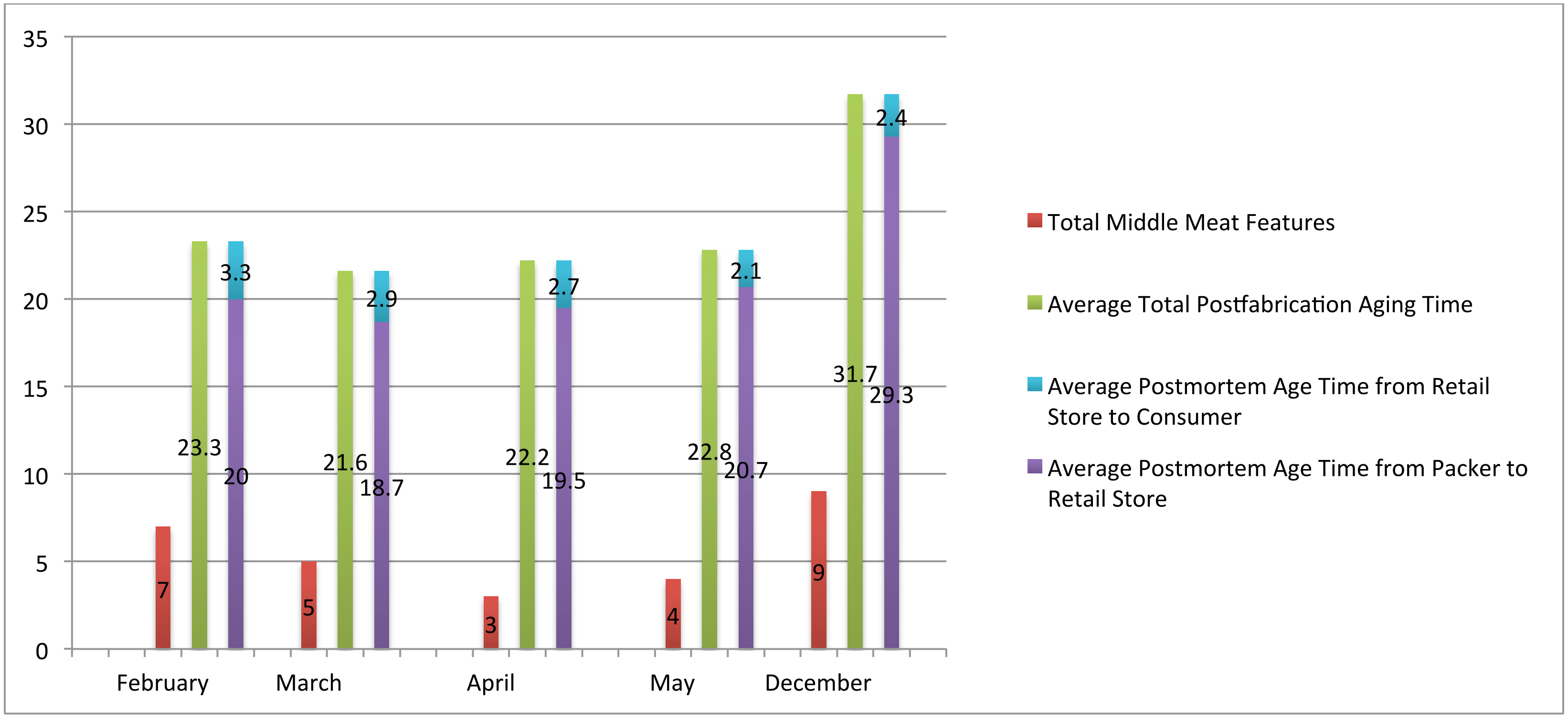


Fig. 4.

Depiction by month for total middle meats features, mean total postfabrication time (d), mean time (d) from packer to retail store, and mean time (d) in days from retail store to consumer.

Table 1.

Postfabrication storage or aging times[A] (days) for subprimals audited at retail establishments.

| Subprimal type | No. of cases | Days | | | | Age < 14 d, % |
|---|---|---|---|---|---|---|
| | | Mean | SD | Minimum | Maximum | |
| Tenderloin | 392 | 23.3 | 14.1 | 7.0 | 88.0 | 20.9 |
| Ribeye | 836 | 24.6 | 19.9 | 3.0 | 225.0 | 21.5 |
| Strip loin | 750 | 32.2 | 26.3 | 4.0 | 136.0 | 13.5 |
| Shortloin | 251 | 27.1 | 10.2 | 4.0 | 66.0 | 6.8 |
| Top butt | 623 | 22.8 | 8.1 | 8.0 | 65.0 | 8.7 |
| Overall | 2852 | 26.3 | 19.0 | 3.0 | 225.0 | 15.2 |

[A] Postfabrication aging/storage times were determined from six market regions in the southern United States.

Table 2.

Least squares means ± SEM[A] of postfabrication storage or aging times[B] (days) for subprimal type stratified USDA quality grade.

| | USDA Quality Grade | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subprimal type | *n* | Prime | Age < 14 d, % | *n* | Choice | Age < 14 d, % | *n* | Select | Age < 14 d, % | *n* | No Grade | Age < 14 d, % | *P* > F |
| Tenderloin | 167 | 26.0a ± 1.1 | 24.0 | 218 | 21.4b ± 1.0 | 19.3 | 3 | 19.3c ± 8.1 | 0.0 | 4 | 17.5c ± 7.0 | 0.0 | 0.0122 |
| Ribeye | 205 | 22.9c ± 1.3 | 15.6 | 236 | 27.3b ± 1.3 | 7.2 | 245 | 18.2d ± 1.2 | 35.9 | 150 | 33.3a ±1.6 | 28.7 | < 0.0001 |
| Strip loin | 107 | 28.7b ± 1.6 | 5.6 | 157 | 28.1b ± 1.3 | 5.7 | 412 | 23.6c ± 0.8 | 20.9 | 74 | 94.1a ± 1.9 | 0.0 | < 0.0001 |
| Shortloin | - | - | - | 106 | 25.6b ± 1.0 | 9.4 | 74 | 30.2a ± 1.2 | 1.4 | 71 | 26.1b ± 1.2 | 8.5 | 0.0078 |
| Top butt | 221 | 22.7b ± 0.5 | 8.6 | 107 | 23.4b ± 0.8 | 7.5 | 258 | 21.8b ± 0.5 | 10.1 | 37 | 29.0a ± 1.3 | 2.7 | < 0.0001 |

Means within a row lacking a common letter (a-d) differ ($P < 0.05$).

[A] SEM = Standard error of the least squares means.

[B] Postfabrication aging/storage times were determined from six market regions in the southern United States.

Table 3.

Least squares means ± SEM[A] of handling time[B] (days) from packer to retail store[C] for subprimal type stratified USDA quality grade.

| | USDA Quality Grade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subprimal type | *n* | Prime | *n* | Choice | *n* | Select | *n* | No Grade | *P* > F |
| Tenderloin | 156 | 23.5a ± 1.0 | 155 | 14.5b ± 1.0 | - | - | 4 | 12.8b ± 6.2 | < 0.0001 |
| Ribeye | 195 | 19.4b ± 1.4 | 163 | 22.7b ± 1.5 | 218 | 15.3c ± 1.3 | 150 | 30.1a ± 1.6 | < 0.0001 |
| Strip loin | 102 | 25.1b ± 1.6 | 90 | 21.7c ± 1.7 | 396 | 21.5c ± 0.8 | 74 | 88.9a ± 1.9 | < 0.0001 |
| Shortloin | - | - | 53 | 18.7b ± 1.0 | 66 | 24.3a ± 0.9 | 69 | 24.1a ± 0.9 | < 0.0001 |
| Top butt | 214 | 20.2b ± 0.5 | 46 | 15.3c ± 1.1 | 244 | 20.6b ± 0.5 | 37 | 25.5a ± 1.2 | < 0.0001 |

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

[A] SEM = Standard error of the least squares means.

[B] Handling times were determined from four market regions in the southern United States.

[C] Calculated as time (days) from pack date to entry in retail store inventory.

Table 4.

Least squares means ± SEM[A] of storage or aging time[B] (days) at the retail store[C] for subprimal type stratified USDA quality grade.

| | USDA Quality Grade | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Subprimal type | *n* | Prime | *n* | Choice | *n* | Select | *n* | No Grade | *P* > F |
| Tenderloin | 156 | 3.1b ± 0.4 | 155 | 5.1a ± 0.4 | - | - | 4 | 4.8ab ± 2.7 | 0.0056 |
| Ribeye | 195 | 3.4 ± 0.4 | 163 | 3.4 ± 0.4 | 218 | 2.7 ± 0.4 | 150 | 3.1 ± 0.4 | 0.4404 |
| Strip loin | 102 | 3.6b ± 0.5 | 90 | 3.1bc ± 0.5 | 396 | 2.4c ± 0.2 | 74 | 5.2a ± 0.5 | < 0.0001 |
| Shortloin | - | - | 53 | 4.5a ± 0.9 | 66 | 6.0a ± 0.8 | 69 | 2.0b ± 0.8 | 0.0018 |
| Top butt | 214 | 2.4a ± 0.2 | 46 | 3.4a ± 0.5 | 244 | 1.3b ± 0.2 | 37 | 3.4a ± 0.6 | < 0.0001 |

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

[A] SEM = Standard error of the least squares means.

[B] These times were determined from four market regions in the southern United States.

[C] Calculated as time (days) from entry in retail store inventory to subprimal cut date.