INFLUENCE OF CUT, COOKING METHOD, AND POST-MORTEM AGING ON BEEF

PALATABILITY

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Influence of cut, cooking method, and post-mortem aging on beef palatability

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University's regulations and meets the accepted standards for the degree of

DOCTOR OF PHILOSOPHY

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ABSTRACT

The objectives of these studies were to determine the effects of cut, cooking method, and postmortem aging on improving consumers' perception of beef. Consumers evaluated bottom round, top sirloin, ribeye, and a value cut samples for overall like, tenderness, juiciness, and flavor to understand how different cuts influence consumers' perception of beef characteristics. Consumers' rated the ribeye and value cut similar for overall like, tenderness, juiciness, and flavor. Bottom round steaks were rated the lowest for overall like and the toughest. Correlation and regression coefficients showed flavor was the largest influencing factor for overall like for the ribeye, value cut, and top sirloin. The value cut is comparable to the ribeye. Study two evaluated how different cooking methods (open-pan, oven bag, vacuum bag) influence the formation of warmed-over flavor (WOF) in reheated and fresh beef clod roasts (small, medium, large) utilizing a trained panel and thiobarbituric acid reactive substances (TBARS). Fresh vacuum bag and reheated open-pan roasts had higher cardboardy scores compared with fresh open-pan roasts. Brothy and fat flavors were higher in reheated roasts that were cooked in oven and vacuum bags. Lipid oxidation found fresh and reheated large and reheated medium roasts to have lower TBARS values. Presence of WOF can be prevented by cooking, storing, and reheating larger roasts in a cooking bag. Study three evaluated low marbled beef short and strip loins to determine the effect of post-mortem aging time (six aging periods) and type (wet and dry) on Warner-Bratzler shear force, slice shear force, and a trained panel. Slice shear force was not influenced by the aging parameters. As the days increased up to 35 d product was more tender, with days 35, 42, and 49 being similar. Panelists found similar results for tenderness up to 28 d of aging. Overall aged flavor was influenced by aging period, with days 42 and 49 having the numerically highest flavor scores, and dry boneless loins having more intense aged

flavor. Beefy flavor was not influenced by aging. Aging regardless of method improves

tenderness of low marbled loins, but neither method was able to improve beefy flavor.

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CHAPTER I. INTRODUCTION AND REVIEW OF LITERATURE

Introduction

There are three major attributes that determine beef palatability; tenderness, juiciness, and flavor (Voges et al., 2007). Of these three attributes, researchers have found that tenderness is what consumers consider to be the most important determinant of meat quality (Huffman et al., 1996). Dikeman (1987) reported that tenderness is the most important trait to palatability, and that further research should be conducted to understand the importance to the beef industry. Dikeman (1987) referred to the high cost of the *psoas major* muscle as an economic indicator of the importance of tenderness to higher cost valuation of tenderloin which is bland in flavor but consistently tender. Research focusing on meat quality and consumer acceptability has been reported for the past 70 years, which indicates that tenderness is not a new issue to the industry. In 1936, Mackintosh et al. stated that the desirability of a piece of meat is measured by the consumer based on the meat's juiciness, flavor, and tenderness, and of these three organoleptic properties, tenderness is the most important. Furthermore, Pearson (1966) found via consumer survey that tenderness was the most important attribute contributing to the acceptability of meat.

Many researchers have stated that the principal driver for beef demand is consumer satisfaction and many consumers are not satisfied with the quality, consistency, and/or tenderness of beef (Platter et al., 2005). Understanding consumers' perception of beef could reverse the decline in demand that the beef industry has experienced for several decades (Schroeder & Mark, 2000). The National Cattlemen's Beef Association (NCBA) has determined that improving quality and consistency with respect to tenderness is critical to improve demand of beef (Tatum et al., 1999).

Researchers have focused on beef tenderness and ways to improve it based on consumer demands. Even though tenderness has consistently been recognized as the most important palatability trait, flavor also has an influence on overall palatability. The complexity of beef flavor makes it difficult to identify influential components of desirable beef flavor. Tenderness has been the main concern for the industry, but the importance of flavor needs to be addressed in relation to consumer acceptability (Calkins & Hodgen, 2007). Miller et al. (1995) asked consumers "*Which factor in beef steaks eating quality is important to you?*" and found that 50% of consumers identified tenderness as the main factor while 40% listed flavor as the first emphasis in relation to beef quality. Killinger et al. (2004) found similar results with their in-home study in Chicago and San Francisco. Consumers in these cities cited the need for a flavorful product. It was found that consumers would not apply additional condiments to steaks if they knew it was going to be flavorful. Flavor has been shown to correlate with overall like similarly to tenderness (Neely et al., 1998).

Tenderness and flavor are influenced by many factors that can and cannot be controlled. Marbling, genetics, animal handling, processing, cooking methods, and specific cuts are a few examples of why these palatability traits are so complex. Some of these examples can be influenced to provide a desirable product for consumers. Marketing, education, and changing the way the product is processed and cooked can positively influence consumers' perception of beef in relation to tenderness and flavor acceptability.

Beef Tenderness

Consumers have indicated that tenderness is the most important beef palatability trait (Savell et al., 1987) The Beef Quality Audits of 1991, 1995, and 2000 all list tenderness as one of the top quality concerns for the industry that is also an area that needs improvement

(Carriquiry, 2004). Additionally, the National Beef Tenderness Survey revealed that consumers' perception of taste is influenced by tenderness (Morgan et al., 1991). It has been proven that consumers demand tender product and reject tough through willingness-to-pay research (Lusk et al., 1999). Consumers at a supermarket chain were permitted to return any steak they deemed undesirable. Over a 3-year period, $364,000 worth of steaks were returned with 78% of the consumers complaining about the tenderness of the meat (Morgan, 1992).

Researchers estimate physical tenderness by using the Warner-Bratzler Shear Force (WBSF) method guidelines by the AMSA (1995). Warner-Bratzler Shear Force measures the kilograms, pounds, or Newton of force that it takes to shear through a 1.0 cm core. Shackelford et al. (1991) stated that 4.6 kg is the threshold for tender beef. Sullivan and Calkins (2011) and Belew et al. (2003) also identified muscles with a WBSF value greater than 4.6 kg to be classified as tough. Researchers use WBSF in studies to determine if consumers can differentiate between tenderness levels. Boleman et al. (1997) conducted a consumer study to determine consumer perceptions of top loin steaks with known shear force values and how their buying trends were modified. The steaks were labeled either "Red", "White", or "Blue" and respectively placed into one of the following categories based on their shear force values: 1) 2.27 to 3.58 kg (tender); 2) 4.08 to 5.40 kg (intermediate); and 3) 5.90 to 7.21 kg (tough). Consumers rated each steak for tenderness, juiciness, flavor, and overall satisfaction. The "Red" steak was classified as tender based on WBSF values. Consumers rated this steak the highest in overall satisfaction and in tenderness. A difference was detected between each of the categories, showing that without a consumer knowing the tenderness classifications they can still differentiate between levels.

Influence of different cuts

Beef tenderness has had an influence on the cuts of beef that are marketed in the stores and restaurants. Middle cuts (rib and loin) are heavily marketed because of their satisfactory tenderness, whereas cuts from the chuck and round are typically fabricated into roasts or processed into a ground product (Belew et al., 2003). Demand for the tougher end cuts has decreased over the past decade as consumers selection has shifted to purchasing the middle cuts (Kukowski et al., 2005). The chuck and round represent 53% of the carcass, which allows an opportunity to increase carcass value by finding means to market certain cuts from the chuck and round (James & Calkins, 2008).

Consumers have shifted from making large roasts and want a convenient, easy, and fast product (Bagley et al., 2010). The lifestyle of Americans has changed with a growing number of women in the work force. Resurreccion (2003) reported that in the United States, three-fourths of women aged 25-54 are working compared to 20 years ago when about half were employed outside the home. This change in demographics has led to consumers possessing less time to plan and prepare meals. Households are purchasing fewer roasts and shifting towards more prepared products. The increase of working women is not the only influence on consumer changes. Society has become fast paced, causing consumers to plan at the last minute for dinners leading them to eating out more or purchase products that are pre-prepared (Resurreccion, 2003).

With this understanding, the NCBA via The Beef Checkoff funded Muscle Profiling research. Researchers at the University of Nebraska and University of Florida evaluated (profiled) 39 different muscles of the chuck and round to identify muscles that were underutilized (Johnson et al., 2003). Muscles classified as tender (WBSF < 3.9 kg) consisted of *psoas major* (tenderloin), *infraspinatus* (IF), *spinalis dorsi* (SPI), *serratus ventralis* (SV),

multifidus dorsi, *subscapularis*, and *terres major* (Calkins & Sullivan, 2007). Numerous studies have found similar results, which have led to the marketing of the IF as the flat iron steak. Consumers have found the IF to be comparable to *longissimus thoracis* (LT) steaks (Kukowski et al., 2004). The flat iron steak has been one of the more successful cuts added to the market. In 2006, more than 92 million pounds of flat iron steaks were sold (Calkins & Sullivan, 2007). This cut is classified as a value-cut because it adds underutilized value to the beef carcass.

The IF is not the only muscle that has been found to be acceptable by consumers and panelists. Kukowski et al. (2004) evaluated various muscles from the beef chuck and rib to determine consumer preference. Panelists rated the IF as the most tender muscle, but the *triceps brachii* (TB), *complexus* (COM), and SV were similar to the IF. Correlations coefficients for palatability attributes showed tenderness to have a greater impact on overall like than juiciness and flavor, indicating it can be a major component in consumer acceptability. Kukowski et al. (2004) concluded that the COM, SV, TB, and IF were suitable to be marketed as steaks as they rated equal or superior to the LT steaks. Belew et al. (2003) found similar results when conducting WBSF. They categorized muscles as very tender (< 3.2 kg), tender (3.2 kg $<$ WBSF < 3.9 kg), intermediate (3.9 kg $<$ WBSF < 4.6 kg), and tough (> 4.6 kg). The IF and SV were categorized as very tender and COM was categorized as tender.

In 2010 and 2011, the Beef Check-off funded its fourth National Beef Tenderness Survey to determine the progress of the industry compared to the past studies (NCBA, 2011). This was a nationwide study conducted in retail stores and with the foodservice industry. Ten retail beef cuts (top blade, boneless ribeye, bone-in ribeye, top loin, bone-in top loin, T-bone, porterhouse, top sirloin, top round, and bottom round) and three foodservice cuts (ribeye, top loin, and top sirloin) were evaluated using WBSF and consumer sensory panel. The top round and bottom

round were the toughest cuts, whereas the other cuts did not differ for WBSF evaluation. Even though the other cuts did not differ, the top blade (flat iron) numerically had the lowest WBSF score. Consumer panelists found the flat iron to be more tender than all of the other cuts. The flat iron rated the highest for tenderness like/dislike and tenderness level. These studies show that there are other muscles in the carcass that WBSF and consumers identify to be acceptable for tenderness. Historically these muscles are found in the grocery stores as roasts, but it has been shown that they can also be used as steaks to capture unrealized value.

Beef marbling

Beef carcasses are valued and separated based on the quality grade assigned by USDA graders. Many believe that quality grades are a way to determine the palatability of carcasses. Dikeman (1987) stated that marbling is related to palatability, but only 10-15 percent of the variation in palatability is attributed to marbling. Marbling and tenderness have a low correlation coefficient, meaning the amount of marbling is not a strong indicator of how tender a product will be. Killenger et al. (2004) examined consumer acceptance of strip loins that were similar in tenderness but differed in marbling level. Loins were separated into two groups "high marbled" (Modest/Moderate) and "low marbled" (Slight). Consumers evaluated both groups of steaks and found them to be similar in tenderness. High marbled steaks were juicier, more flavorful, and more desirable for overall like compared to low marbled steaks. An in-home study was also conducted, where consumers found the same results as the controlled environment experiment, the low and high marbled steaks were rated similarly for tenderness. Tenderness was controlled in this study, but it shows that marbling did not have an additional influence on consumer sensory evaluation of tenderness.

Kukowski et al. (2004) found marbling to have an effect on tenderness for the SV, IF, and *supraspinatus* (SS). Consumer panels rated USDA Choice chuck muscles more tender than USDA Select muscles. Nelson et al. (2004) found similar results when comparing Certified Angus Beef (CAB), USDA Choice, and USDA Select steaks from the round, loin, and chuck. Warner-Bratzler Shear Force scores for the loin showed that CAB steaks were the most tender followed by USDA Choice, with USDA Select being the least tender. Sensory panel results indicated similar results, where CAB steaks rated higher for tenderness compared to USDA Select. Quality grade had a greater influence on the middle cuts compared to the end cuts, specifically the round. George et al. (1999) conducted an audit in eight U.S. cities and found that USDA Select strip loin and top sirloin steaks to be the least tender and have the most variation in tenderness compared to USDA Prime and USDA Choice strip loin and top sirloin steaks. Select steaks were more prevalent in the marketplace where approximately 60% of the steaks were Select when all cities were combined.

The previous research shows that marbling may influence tenderness, but it is not the main characteristic. Belew et al. (2003) stated that post-mortem proteolysis, intramuscular fat or marbling, connective tissue, and the contractile state of muscle should all be considered as characteristics influencing palatability. Marbling becomes more of an influence on beef palatability when beef is cooked to higher endpoint temperatures (Dikeman, 1987).

Influence of cooking on beef tenderness

Cooking meat causes changes that can positively or negatively affect the eating experience for a consumer. Cooking method (grill, broil, fry, etc.) and endpoint temperatures are important to understand because they can vary for different cuts of meat. As mentioned previously, consumers are transitioning away from large roasts because they take longer to

prepare. Large roasts usually consist of multiple muscles and connective tissue, which requires slow cooking (Adhikari et al., 2004). Cooking these roasts too fast will not allow for the breakdown of connective tissue leading to a tough product. Consumers want a small, convenient product that does not require as much time, but provides a satisfactory eating experience (Bagley et al., 2010). Understanding consumers and what they do in-home is difficult compared to a controlled experimental environment. Bagley et al. (2010) recognized this challenge of in-home research, but state that it is critical to understand the different variables that are controlled by the consumer and evaluate their influence on acceptability.

Cooking methods for beef vary from grilling to pan-frying depending on consumer preference. Bagley et al. (2010) and Goodson et al. (2002) both found that consumers in their studies preferred to cook beef on a grill. Seventy-one percent of surveyed consumers in Bagley et al. (2010) preferred to cook on a grill compared to the oven, barbeque, pan-fry, pan-broil, and (or) braise/simmer. Cooking method preference can be influenced by geographic location. Goodson et al. (2002) provided consumers in Chicago and Philadelphia with paired clod steaks, a steak from Top Choice, Low Choice, High Select, and Low Select, and a questionnaire. Consumers were instructed to prepare steaks using their preferred method for this cut. Chicago and Philadelphia consumers used the grill as the predominant form of cooking, but the other methods varied based on location. Chicago consumers braised and broiled the steaks more than Philadelphia consumers. These various cooking methods are important to understand because they can explain different variations in tenderness. Philadelphia consumers fried their clod steaks more than Chicago consumers. The consumers in Chicago rated fried steaks the lowest in tenderness out of all of the cooking methods, whereas the Philadelphia consumers evaluated fried steaks the highest for tenderness. The level of tenderness for the grilled clod steaks did not differ

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from the other methods (broiled, braised, and fried) in Chicago, whereas tenderness of grilled clod steaks differed from fried steaks in Philadelphia.

Cooking method is important, but internal endpoint temperature (degree of doneness) also influences the palatability of meat. Goodson et al. (2002) found that when the clod steaks were cooked to a medium degree of doneness or less, they were rated higher for tenderness compared to steaks cooked medium-well degree of doneness or greater. Similarly, Lorenzen et al. (2005) found that when steaks were cooked to a lower temperature, sensory panelists evaluated steaks higher for tenderness. Steaks that were cooked to very-rare had the highest numerical sensory panel tenderness score. It was also found that WBSF values increased with increasing endpoint temperature.

Impacts on Flavor Characteristics

Meat flavor is a very complex trait that cannot be described in simple terms. Sensory panelists typically evaluate samples for tenderness, juiciness, and flavor. Flavor in a typical beef study usually refers to overall beef flavor. Beef flavor consists of multiple aromatics, basic senses, and aftertastes, which makes it difficult to identify these characteristics in a single word (Adhikari et al., 2011). Flavor is complex because it involves the reactions of aldehydes, ketones, alcohols, furans, and many other compounds (Calkins & Hodgen, 2007). These reactions are influenced by cooking methods, cooking temperatures, endpoint temperature, cut type, and other methods. Adhikari et al. (2011) recognized the complexity of beef flavor and developed a lexicon for beef. Their highly trained panel identified 38 different flavor and aroma characteristics. The most common descriptors found in almost all samples were beef identity, brown/roasted, bloody/serumy, metallic, fat-like, and the five basic tastes (bitter, salty, sour, sweet, and umami).

Tenderness is cited as being the most important palatability attribute followed by flavor. Goodson et al. (2002) and Neely et al. (1998) reported that flavor may be just as important to consumers as tenderness. In both studies flavor was highly correlated with overall like and Goodson et al. (2002) concluded that consumer satisfaction was driven by flavor. The authors also stated that tenderness was favorable in this study, which could have allowed for the consumers to focus their attention on flavor. Both studies show that flavor is important and research needs to be conducted to ensure consumer satisfaction.

Cut and cooking's influence on flavor

Beef flavor intensity of different beef cuts can vary based on the location on the carcass, how the cut is prepared, and cooked endpoint temperature. The National Beef Tenderness survey of 2006 found that consumers rated steaks from the rib and loin the highest for beef flavor and flavor like, whereas steaks from the round received the lowest scores (Voges et al. 2007). Lorenzen et al. (2003) found similar results with a trained sensory panel. Panelists' rated top loin and top sirloin steaks higher for the descriptive term "beefy" compared to top round steaks. Panelists' in Jeremiah et al. (2003) found that beef strip loin and eye of round steaks had the most bland beef flavor compared to the flavorful skirt, flat iron, and exterior cap steaks.

Within cuts, flavor can vary based on cooking method and endpoint temperature. Adhikari et al. (2004) cooked eight different chuck muscles using four different cooking methods and three different endpoint temperatures. They found that by grilling chuck muscles to a medium-rare degree of doneness increased the favorable roasted flavor of the meat. Beefy flavor was more prevalent when the chuck eye roll was grilled or convection-cooked to a medium-rare degree of doneness. Cooking to a higher degree of doneness (well-done) produced more roasted and beefy flavor, but did not statistically differ from steaks cooked to medium, medium-rare, or

rare (Lorenzen et al., 2005). There are so many variables that can influence the flavor of a product. Unlike tenderness, there is not an industry standard method to mechanically measure flavor. Flavor perception relies heavily on trained descriptive sensory panels, which allows for a large amount of variability as every palate is unique. This adds to the complexity of understanding flavor which makes it very difficult for industry to identify a standard by which to provide a uniform, acceptable product to the consumer.

Warmed-over flavor of beef

Flavor of fresh product is a concern to consumers, but with the expanding product line of precooked meats, other flavor concerns become prominent. Consumers spend less time planning a meal and want a product that is nutritious, flavorful, and quick to prepare. Food companies have realized this demand and market ready-to-eat microwavable or heat and serve products. This trend of preparing products, chilling, and reheating is also prevalent in the foodservice industry, especially hospitals, cafeterias, and restaurants (Robbins et al., 2003). All of these processes lead to quality deterioration and the formation of off-flavors. The formation of off-flavors is commonly referred to as warmed-over flavor (WOF). Tim and Watts (1958) were the first to recognize WOF as a flavor defect in cooked meat. Warmed-over flavor is described as stale, rancid, cardboardy, and painty (Thongwong et al., 1999). These off-flavors are typically noticeable in cooked meats that have been stored fresh for up to 48 hours or more, and then reheated (Brewer, 2006; Mielche & Bertelsen, 1994). The heating process causes disruptions to cell structure and inactivation of enzymes, which could lead to the development of WOF (Kanner, 1994). As meat is stored fresh flavor begins to disappear and WOF characteristics become more prevalent.

Warmed-over flavor is caused by oxidation of phospholipids. Phospholipids have a high level of unsaturation, which provides greater opportunity for oxidation (Farmer, 1994). Maintaining the quality of cooked meats can be accomplished by preventing/reducing the amount of lipid oxidation (Rojas & Brewer, 2007). Larger cuts of meat have a higher oxidative stability because of the availability of oxygen and temperature gradient, but many consumers do not want to deal with a large roast (Mielche & Bertelsen, 1994). Prevention of oxidation and development of WOF can also be accomplished through heating meat by roasting or grilling. Microwave cooking causes a rapid increase in WOF (Mielche & Bertelsen, 1994). Research is conflicted on the cook temperature and time that triggers WOF. Kingston et al. (1998) found that increasing the cook temperature leads to more oxidation and shorter cook times prevent the occurrence of lipid oxidation. Mielche and Bertelsen (1994) agree that increased heating temperature accelerates oxidation, but state improved oxidative stability of meat is achieved with longer cooking times. Consumers should also store cooked meat intact as slicing, storing, and reheating allows more oxidation to occur within the core regions of the roast. Exposing the interior (an area that has little exposure to oxygen) of whole muscle cuts leads to a greater chance of lipid oxidation (Brewer, 1998).

Limiting oxygen exposure to meat is crucial to preventing WOF. Vacuum-packaging and modified-atmosphere packaging have been effective in slowing lipid oxidation (Mielche & Bertelsen, 1994). Eliminating oxygen from packages can help limit the development of WOF (Kingston et al., 1998). Hwang et al. (1990) cooked beef loins to 70°C, sliced, and divided steaks into one of three treatments, vacuum, N_2/CO_2, and air. Samples were frozen for 11 weeks before a panel evaluated them for off-flavors. Vacuum and N_2/CO_2 samples had a more meaty flavor and less WOF. McDaniel et al. (1984) found similar results; panelists preferred cooked

roasts that were stored in vacuum-packaging before reheating. Development of WOF occurs

during the storage of cooked meats, not during the reheating process.

Importance of Beef Aging

Aging of beef is a process used by the industry to enhance palatability and provide a

satisfactory eating experience for the consumer. Aging meat increases tenderness and enhances

the development of numerous flavors (Campbell et al., 2001; Warren & Kastner, 1992). There

are two types of aging used in the industry, dry and wet. Meat that is wet-aged is vacuum-sealed

in an oxygen barrier bag and stored at temperatures above freezing (Smith et al., 2008). This

form of aging occurs during the transport and distribution of products and is currently the most

common form of aging. Dry aging is an intensive process that involves storing a carcass or

primal cuts in an open-air, humidity, and temperature controlled cooler for extended days (Sitz et

al., 2006). Wet-aging allows for an improvement of tenderness, but steaks tend to have stronger

sour and bloody/serumy flavor, whereas dry-aging helps to enhance the flavor. Beefy and

brown-roasted flavor is more prevalent with dry-aging (Warren & Kastner, 1992). Dry-aging

does not provide an advantage for tenderness and is not as economical viable as wet-aging due to

the weight loss caused by shrinkage and trimming of discolored lean (Warren & Kastner, 1992).

The amount of time product is aged varies based on specific company protocol, availability of

product, and research findings. Fourteen days is the recommended minimum time in order to

optimize tenderness, but not all products in the market are aged 14 days.

The 2010/2011 National Beef Tenderness Survey collected product from 12 different

cities across the United States (NCBA, 2011). Researchers recorded brand names, grades of

product available, and post-fabrication aging times in order to understand the types of products

available for consumers to purchase. Comparing results to the 2005/2006 survey, retail beef in

today's market is less uniform. The amount of time beef is aged in today's market ranges from 1 to 358 days compared to the 2005/2006 survey's range of 3 to 83 days. Furthermore, in 2005/2006 19.6% of subprimals were aged less than 14 days, this increased to 35.7% in 2010/2011. George et al. (1999) suggested the increase in tenderness variability could be attributed to the increase in number of steaks aged for less than 7 days. Average days aged also decreased in 2010/2011 from 22.6 days to 20.5 days. Proper aging of beef is crucial for consumer satisfaction. The large amount of variation in the market could explain why some consumers stop buying certain products.

Tenderness improvement

Post-mortem proteolysis of myofibrillar proteins has been shown to assist in the improvement of tenderness, but this process is variable depending on length and rate of aging (Koohmaraie & Geesink, 2006). The length of time a product is aged is important to allow the process of post-mortem proteolysis to occur. Brewer and Novakofski (2008) wet-aged beef loins sections for 0, 7, or 14 days to determine if consumers had the ability to differentiate the aging periods. Consumers' tenderness scores increased with aging; with a significant difference from 0 to 14 days. Consumers' ability to differentiate between the aging periods and the large variability of product in the market could explain why consumers can become dissatisfied with beef. Warner-Bratzler shear force values do improve as a product is aged for a longer period of time. Smith et al. (2008) aged steaks for 14, 21, 28, or 35 days and found that the steaks aged for 28 and 35 days had lower WBSF scores compared to the shorter aging periods.

Aging for extended periods of time allows for tenderness improvement, but it may also depend on the physical type of aging conducted. Wet-aging dominates the industry due to the efficiency of aging that occurs during distribution. However, research evaluating palatability

improvements due to dry-aging continues to be evaluated. Dikeman et al. (2013) evaluated wet-aging, dry-aging, and a special aging bag to determine the effects on sensory properties. Sensory panels found no effect of aging method on overall tenderness. Dry-aging or the aging bag (stimulates traditional dry-aging) did not have an advantage in improving tenderness. Sitz et al. (2006) and Warren and Kastner (1992) also concluded that aging (dry and wet) improved tenderness as both methods were able to produce a product that was similar in tenderness level. Wet-aging has been shown to receive higher consumer sensory scores and lower WBSF values. Laster et al. (2008) found that wet-aged ribeye steaks had lower WBSF values and higher consumer tenderness like ratings than dry-aged ribeyes. All of these studies indicate that regardless of aging method, beef should be aged for an extended period of time to improve tenderness.

Flavor development

Aging improves tenderness, but it also aids in the development of flavors and off-flavors. Wet-aging in a vacuum bag has been shown to have higher bloody/serumy and sour flavor, whereas dry-aging provides a full, robust aged beef flavor (Warren & Kastner, 1992). Flavor enhancement is the main reason for dry-aging of beef (Baird, 2008). Beef flavor and brown/roasted aromatics increase as the aging period increases. Steaks dry aged for up to 21 days have more intense levels of these attributes compared to steaks aged for 7 days (Campbell et al., 2001). Wet-aging for extended periods, up to 35 days, can result in unfavorable off-flavors. Yancey et al. (2005) found that metallic and sour flavors were prevalent in steaks aged 21 or 35 days compared to 7 or 14 days. Unlike wet-aging, dry-aging 14 to 35 days has been shown to be effective in producing favorable flavors unique to this aging method. Due to the uniqueness of this flavor and expense of dry-aging, 64.48% of consumers are not sure if they

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have ever eaten dry-aged beef (Smith et al., 2008). Dry-aged beef is typically found in upscale

hotels and restaurants. It may improve and enhance flavor, but due to the extensive process, wet-

aging will remain the prominent form of aging in the industry.

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CHAPTER II. CONSUMER EVALUATION OF PALATABILITY CHARACTERISTICS OF A BEEF VALUE-ADDED CUT COMPARED TO COMMON RETAIL CUTS

Abstract

The objectives of this study were to educate consumers about value-added beef cuts and evaluate their palatability responses of a value cut and three traditional cuts. Three hundred and twenty-two individuals participated in the beef value cut education seminar series presented by trained beef industry educators. Seminar participants evaluated tenderness, juiciness, flavor, and overall like of four samples, bottom round, top sirloin, ribeye, and a value cut (Delmonico or Denver) on a 9-point scale. The ribeye and value cut were found to be similar in all four attributes and differed from the top sirloin and bottom round. Correlations and regression analysis found that flavor was the largest influencing factor for overall like for the ribeye, value cut, and top sirloin. The value cut is comparable to the ribeye and can be a less expensive replacement.

Introduction

Tenderness, juiciness, and flavor are palatability attributes that are commonly used to describe beef quality (Voges et al., 2007). Dikeman (1987) showed that tenderness is the major determinant of beef quality followed by flavor. With this understanding, the beef industry has heavily marketed the middle cuts of beef (rib and loin) to meet the consumers demand for a tender, juicy, and flavorful product. This demand for the middle cuts of beef has led to less utilization of carcass end cuts (chuck and round; Kukowski et al., 2004). Beef chuck and round are traditionally marketed as underutilized low-end roasts and steaks because they are considered to be tougher than middle cuts (Bratcher et al., 2006; Paterson & Parrish, 1986). Retail cuts from

the chuck generally have lower sensory panelist tenderness and overall palatability ratings because muscle fibers run in multiple directions (Adhikari et al., 2004). The challenge to the beef industry is to capture the underutilized value of end cuts by appealing to the consumers demand for a palatable product that is convenient. Bagley et al. (2010) stated that today's consumer differs from the traditional cook who prepared large roasts. Consumers are now looking for cuts that are convenient and smaller without sacrificing favorable palatability attributes.

With this understanding, The Beef Checkoff funded a Muscle Profiling Study in the late 1990s to establish a database of palatability attributes of the individual muscles in the beef chuck and round (Von Seggern et al., 2005). This study brought attention to muscles in the chuck that had the potential to be a value-added cut. The Flat Iron (*infraspinatus*; IF) was the first successful value-added chuck cut. It was identified because it is the second most tender muscle in the beef carcass once the internal connective tissue seam is removed (Calkins & Sullivan, 2007; Von Seggern et al., 2005). The Muscle Profiling study also classified the *serratus ventralis* (SV) and *triceps brachii* (TB) muscles to possess palatability attributes suitable for retail steak fabrication (Bratcher et al., 2006; Calkins & Sullivan, 2007).

Based on the The Beef Checkoff Muscle Profiling study, new beef cuts have been introduced over the past 10 years (NCBA, 2012). These "next generation value cuts" include the Delmonico (chuck eye steak) and Denver cut. The Delmonico steak can consist of four different muscles, *longissimus dorsi* (LD), *spinalis dorsi* (SPI), *complexus* (COM), and *multifidus dorsi* (MUL), whereas the Denver cut is only the *serratus ventralis* (SV; Cattlemen's Beef Board, 2012). Kukowski et al. (2004) had consumers' rate muscles from the chuck for tenderness, juiciness, flavor, and overall like. They found that the COM, SV, IF, and TB rate equal or

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superior to *longissiumus thoracis* (ribeye; LT) steaks and thus were candidates for retail steaks. Paterson and Parrish (1986) found similar results, where the SV did not differ from the IF in tenderness. It is important to educate consumers about these cuts and allow them the opportunity to evaluate samples so the industry is aware of their perception of palatability attributes. The objectives of this study were to educate consumers about value-added cuts in the beef industry and to evaluate consumer assessment of palatability traits of three traditional retail cuts (bottom round, ribeye, and top sirloin) and a value-added cut (Delmonico or Denver cut).

Materials and Methods

Educational program

Four locations within North Dakota (northwest, southwest, south central and southeast) were selected to best represent the population. Meat science personnel travelled to the four sites to present information about beef palatability and how The Beef Checkoff research has worked to increase the value of beef carcasses. Those attending this educational program were consistent beef consumers either directly (cattle production) or indirectly (allied industry) affiliated with the beef industry. Attendees were presented with details about the new value-added cuts that were being introduced to foodservice and retail markets. This educational presentation was followed by beef sample consumption and evaluation.

Sample preparation

USDA Choice chuck rolls (IMPS 116), bottom rounds (IMPS 170), ribeye rolls (IMPS 112A), and top sirloins (IMPS 184) were purchased from a local meat processing facility and stored at the NDSU meat science laboratory. Chuck rolls were further processed into either a "Delmonico" (IMPS 116D) or "Denver" (IMPS 116G) steak and classified as the value cut (VC).

Steaks were cut (2.54-cm thick) from each roast, vacuum-packaged, and stored at 4°C before each site presentation.

Before cooking, all steaks were minimally seasoned with salt, black pepper, and granulated garlic mix. Steaks were cooked on a Weber® gas grill (Model E-310™, Weber-Stephen Products, Palatine, IL) set to a medium heat setting. Steak temperature was monitored with hand-held thermometers (HH801B, Omega Engineering Inc, Stamford, CT) and removed once a medium-rare (62-63°C) degree of doneness was reached. Steaks were allowed to rest approximately 10 minutes then cut into 2.54 x 2.54-cm cubes from the center of each steak. Consumers (n = 253) received the samples from warmed chafing dishes. An additional 69 consumers received the samples as a kabob. Kabob samples were served to each consumer as a plated meal where they were instructed how to consume based on where the samples were on the kabob skewer.

Consumer analysis

Procedures using human subjects for consumer analysis were approved by the North Dakota State University Institutional Review Board prior to initiation of the study. Consumers were not aware of the identity of each sample and presentation order was randomized to eliminate first order bias. Each sample was evaluated on a 9-point scale for tenderness, juiciness, flavor, and overall like (9 = extremely tender, juicy, flavorful, really like; 1 = extremely tough, dry, bland, and don't like). Once all ballots had been turned in, the cut identity was revealed to allow for the consumers to assess the relationship of the commonly used steak samples relative to the Delmonico and Denver value cuts.

Statistical analysis

Data were analyzed using ordinary least squares (PROC GLM, SAS Institute, Cary, NC). The statistical model for the palatability attributes included geographical location, cut, and the interaction of location by cut. Least square means were separated by using Probability of Difference. Significance was declared at $P < 0.05$. Correlation coefficients were generated utilizing MANOVA/printe in order to determine tenderness, juiciness, and flavor relationship with overall like. The PROC REG RSQUARE analysis was used to determine a prediction equation for overall like.

Results and Discussion

Consumer overall like ratings

Consumers in the southeast region rated almost all cuts higher for overall like compared to the other regions ($P < 0.0001$; Figure 2.1). The VC and ribeye (RE) were preferred over the top sirloin (TS) and bottom round (BR) in this region, with the RE having the highest overall like score. A location effect was expected because of the diverse demographics at each event, but northwest region consumers generated an interesting trend. These consumers ranked all of the cuts lower for overall like compared to other regions. Goodson et al. (2002) found a significant difference in overall like of clod steaks comparing two cities (Chicago and Philadelphia) which differed by cooking method. Chicago consumers had higher scores for grilling compared to Philadelphia. The findings of Goodson et al. (2002) underscore the diversity of consumers across the United States. The present study was conducted within the boundaries of one state, but there may be differences within the state which is evident in the significant interaction of location by cut.

Participants also found the main effect of cut to have an effect on overall like responses as shown in Table 2.1. The RE and VC did not differ in overall like, meaning the VC could be a less expensive replacement for the RE. Consumers in the study conducted by Kukowski et al. (2005) rated the *longissimus* as the highest for overall like and the SV as least acceptable. They concluded that the cooking method was not controlled because it was an in-home study, which may have influenced their scores for SV. Cooking method and degree of doneness was controlled in the present study in order to standardize eating experience for consumers participating in the study.

Figure 2.1. Effect of location and cut on consumers overall like response ($P < 0.001$).
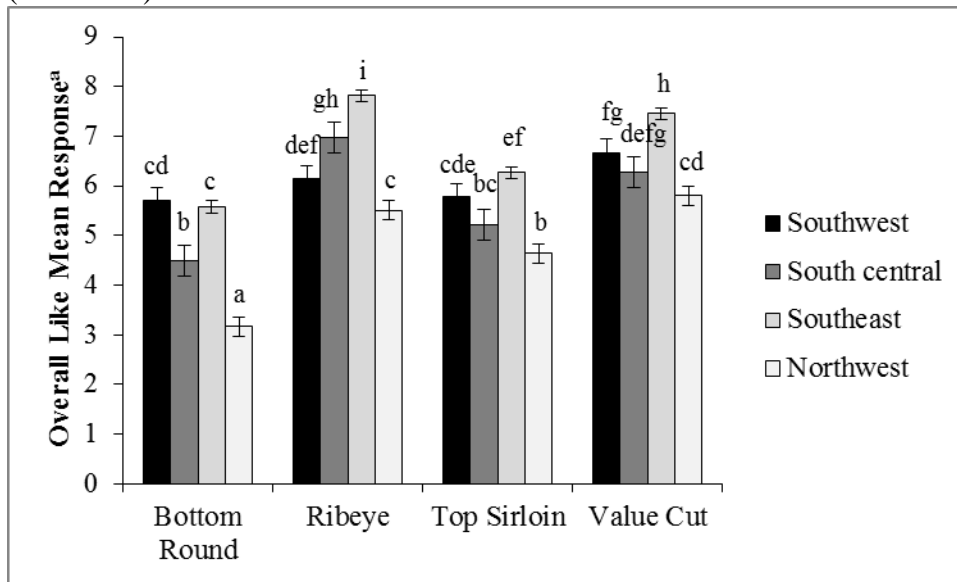
[a]9 = extremely tender, juicy, flavorful, and really like; 1 = extremely tough, dry, bland, and don't like. Least square means without a common letter differ ($P < 0.05$).

Tenderness ratings

Similar to overall like, tenderness was also significant ($P < 0.001$) for the interaction of location by cut, where the data followed the same trend as overall like (data not shown). As mentioned previously, location effect was expected but the focus of the research was on palatability of the different cuts. Consumers found the BR to be the toughest of the four cuts

(Table 2.1). This finding agrees with Calkins and Sullivan (2007) report on muscle tenderness classification revealing the *biceps femoris* (BIF; bottom round) to be classified in the tough group based on Warner-Bratzler shear force values (WBSF). The National Beef Tenderness Survey also found BR to have the highest WBSF values compared to the other retail cuts in the study (Voges et al., 2007). In Voges et al. (2007) survey, sensory panels' rated different retail cuts for palatability attributes. The BR, eye of round, and top round received the lowest sensory ratings for overall like and tenderness (Voges et al., 2007).

Table 2.1. Least square means of consumer panelist responses[1] for the various cuts.

	Tenderness	Juiciness	Flavor	Overall-like	n
Bottom Round	3.99[c]	4.92[b]	5.41[b]	4.74[c]	322
Ribeye	6.44[a]	6.22[a]	6.51[a]	6.61[a]	318
Top Sirloin	5.85[b]	5.10[b]	5.31[b]	5.47[b]	321
Value Cut	6.36[a]	6.53[a]	6.62[a]	6.55[a]	317
SEM	0.12	0.11	0.11	0.11	—

[a,b,c]Means within a column lacking a common superscript differ ($P < 0.05$).
[1] 9 = extremely tender, extremely juicy, extremely, flavorful, and really like; 1 = extremely tough, extremely dry, extremely bland, and don't like.

In the present study, it was expected that the RE would be rated the highest in tenderness, but the VC was rated similarly. Belew et al. (2003) classified the SV as very tender compared to the *gluteus medius* (sirloin) and *longissimus lumborum* (strip steak; LM) which were classified as tender. The VC in our research consisted of the SV, which was found to not significantly differ from the LT. Carmack et al. (1995) also found no difference in tenderness in the SV and LM.

Juiciness and flavor ratings

Similar to tenderness, the RE and VC did not differ in juiciness and flavor, but both differed from the TS and BR (Table 2.1). Adhikari et al. (2004) compared muscles of the chuck based on cooking methods and endpoint temperature. They found that grilling the chuck muscles to a medium-rare degree of doneness may be the best option because of improved juiciness and flavor. Grilling to a medium-rare degree of doneness is the same procedure we

followed in our study. That may be a reason why the VC had the numerically highest juiciness level. Hildrum et al. (2009) compared muscles from the chuck and round. They found the chuck muscles, specifically the IF, to be juicier. Carmack et al. (1995) found the SV to be juicier than all of the muscles compared in their study except for the IF.

In the present study, BR and TS differed from VC and RE for flavor, which conflicts with the findings of Carmack et al. (1995), where the BIF ranked highest in beef flavor and the IF, LM, and SV were low in beef flavor. The hindquarter cuts exhibited more beefy flavor in their study compared to the present study. The TS had the lowest beef flavor, but it was not on the bland side of the scale (less than 5). Kukowski et al. (2004) compared muscles from the chuck and rib and found the SV and COM to have higher flavor ratings compared to the LT. Even though not statistically different, the VC was rated higher than the RE for flavor.

Correlations and regression of palatability attributes

Partial correlation coefficients were calculated to show a relationship between overall like ratings and the other palatability attributes. Correlations were separated by cut to determine if each cut had different factors relating to overall like. For BR (Table 2.2), all three attributes strongly correlate with overall like equally. While a single attribute is not a determinant of overall like, it is interesting to note changes from one cut to another. The RE, TS, and VC overall like were strongly correlated with flavor compared to other attributes (Table 2.3, 2.4, and 2.5 respectively). Goodson et al. (2002) had similar results with the clod steaks in their study, where flavor desirability was more important than tenderness to the consumer.

Table 2.2. Bottom round correlation coefficients among consumer palatability responses[a].

	Overall-like	Tenderness	Juiciness
Tenderness	0.73		
Juiciness	0.74	0.66	
Flavor	0.75	0.59	0.70

[a]All correlations are $P < 0.0001$.

Table 2.3. Ribeye correlation coefficients among consumer palatability responses[a].

	Overall-like	Tenderness	Juiciness
Tenderness	0.68		
Juiciness	0.71	0.67	
Flavor	0.77	0.68	0.65

[a]All correlations are $P < 0.0001$.

Table 2.4. Top sirloin correlation coefficients among consumer palatability responses[a].

	Overall-like	Tenderness	Juiciness
Tenderness	0.71		
Juiciness	0.72	0.56	
Flavor	0.79	0.50	0.70

[a]All correlations are $P < 0.0001$.

Table 2.5. Value cut correlation coefficients among consumer palatability responses[a].

	Overall-like	Tenderness	Juiciness
Tenderness	0.66		
Juiciness	0.65	0.62	
Flavor	0.75	0.53	0.62

[a]All correlations are $P < 0.0001$.

Understanding these results led to an r-square regression analysis to determine how the variables interacted with one another to determine overall like. The analysis in Table 2.6 confirms the results found in the correlations. Tenderness, juiciness, and flavor variables were significant and were included in the model. The RE, TS, and VC overall like were driven by flavor followed by tenderness. The tenderness values of these cuts were acceptable, which may cause consumers to base more of their decision on flavor (just as seen in Goodson et al., 2002). The BR overall like was influenced by tenderness and flavor, leading one to believe that because

it was tough, tenderness was a larger factor in "like" score for this cut. A considerable amount of research has focused on the importance of tenderness, but flavor may be the driving determinant on cuts already deemed tender.

Table 2.6. Regression predicting overall like responses for each cut.

	Intercept	Tenderness	Juiciness	Flavor	R^2
Bottom Round	0.04	0.36	0.28	0.37	0.78
Ribeye	0.29	0.25	0.20	0.53	0.81
Top Sirloin	0.01	0.33	0.19	0.50	0.80
Value cut	0.34	0.30	0.15	0.50	0.73

Conclusions

The potential to increase the value of end cuts on a beef carcass is evident in the high overall like, tenderness, juiciness, and flavor responses of the value cut utilized in this present study. The value cut did not statistically differ from the ribeye, but was more flavorful and juicy. Grilling the steaks to a medium degree of doneness could have influenced the flavor and juicy responses in comparison with other studies that allowed consumers to cook cuts of meat to their own standards. Location did have an effect on consumer responses, but this is expected in studies when there is a diverse demographic background. The value cut, ribeye, and top sirloin were all found to be tender cuts which may have caused consumers to base their overall like scores on the flavor of the steak. The Denver or Delmonico cut could be a popular cut for the industry, but more consumer education is necessary. Using an education platform similar to our study would allow beef consumers to learn while sampling and thus establishing a higher order learning process that could lead to action. In this case, requesting value cuts from their local butcher which would ultimately drive more value up the beef market chain.

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CHAPTER III. EFFECTIVENESS OF OXYGEN BARRIER OVEN BAGS IN LOW TEMPERATURE COOKING ON REDUCTION OF WARMED-OVER FLAVOR IN BEEF ROASTS

Abstract

A 3 x 3 x 2 factorial was utilized to determine if roast size (small, medium, large), cooking method (open-pan, oven bag, vacuum bag), and heating process (fresh, reheated) prevented warmed-over flavor (WOF) in beef clod roasts. Fresh vacuum bag and reheated open-pan roasts had higher cardboardy flavor scores compared with fresh open-pan roast scores. Reheated roasts in oven and vacuum bags did not differ from fresh roasts for cardboardy flavor. Brothy and fat intensity was increased in reheated roasts in oven and vacuum bags compared with fresh roasts in oven and vacuum bags. Differences in TBARS were found in the interaction of heating process and roast size with the fresh and reheated large, and reheated medium roasts having the lowest values. To prevent WOF in reheated beef roasts, a larger size roast in a cooking bag is the most effective method.

Introduction

Consumer sensitivity to warmed-over flavor (WOF) in pre-cooked beef products is an important topic in the meat industry. Tims and Watts (1958) first recognized WOF as a flavor defect in cooked meat that had been refrigerated for 48 h or less before being reheated for consumption (Byrne et al., 2002; Kanner, 1994). This method of storage and cooking is commonly seen in hospitals, cafeterias, and restaurants where large cuts of meat are cooked and held at a constant temperature for a period of time before serving (Robbins et al., 2003). In addition to the products in the foodservice industry, companies are concerned with the incidence of WOF in ready-to-eat products commonly found in the retail market. Consumer demand for a

convenient meat product that has the same flavor profile as a product that is cooked fresh is increasing, but ready-to-eat meat products have been shown to be susceptible to WOF due to the product either being stored frozen or at a refrigerated temperature prior to purchase (Johnston et al., 2005; Thongwong et al., 1999; Yang et al., 2002). The development of WOF in beef after cooking and storing has become a draw-back for the marketing of ready-to-eat products (Hwang et al., 1990).

Warmed-over flavor develops due to oxidation of the polyunsaturated fatty acids in the phospholipids (Byrne et al., 2002). Oxidation can be triggered or accelerated by numerous factors including temperature, oxygen exposure, light, addition of catalysts, hematin compounds, and lipoxygenase (Antony et al., 2002). The primary cause of oxidation in meat is heating because the process of cooking disrupts the cellular structure as well as inactivates enzymes allowing for the release of oxygen from oxymyoglobin (Kanner, 1994; Rojas & Brewer, 2007). Rhee et al. (1996) found beef to be higher in total iron and heme iron than pork and chicken. As product is heated, it experiences an increase in lipid oxidation due to the denatured heme iron facilitating the oxidation (Brewer, 2006; Han et al., 1995).

Warmed-over flavor is commonly found in slow-cooked beef due to prolonged exposure to heating. Cooking temperature and time affects the extent of lipid oxidation (Kingston et al., 1998). Some studies have shown that slow cooking is better for stability (Mielche & Bertelsen, 1994), while others have reported that cooking to temperatures above 100°C inhibits oxidation (Bailey & Um, 1992). Maillard reaction products (MRP) work as antioxidants in meat once heating temperatures reach 90°C or higher (Han et al., 1995). Byrne et al. (2002) cooked chicken patties in a convection oven at 4 different temperatures to see if MRP inhibited lipid

oxidation once the products were stored and reheated. They found that MRP did not prevent

lipid oxidation and attribute this to the product being ground instead of a whole muscle roast.

Panelists have described meat samples to have stale, wet, cardboardy, painty, grassy, or

rancid flavors and aromas when testing for WOF development (Campo et al., 2006; Rojas &

Brewer, 2007). These off-flavors are not desirable for the consumer and will prevent them from

repeat buying of a product. Consumers today want a convenient product that tastes fresh from

the oven. Most research on minimizing WOF has utilized additives to ground product, but recent

consumer attitudes suggest that consumers prefer to purchase product that has minimal additives

(Johnston et al., 2005; Stapelfeldt et al., 1993). Nitrites, sodium tripolyphospate, honey, vitamin

E, and rosemary are a few examples of additives that have been shown to inhibit the

development of WOF in ground product (Johnston et al., 2005; Trout & Dale, 1990). Few

projects have focused on whole muscle roasts and how different cooking procedures and roast

size may prevent lipid oxidation and development of WOF. Therefore, the objective of this

study was to evaluate fresh cooked and reheated beef roasts of various sizes that were cooked by

three different methods to determine the most effective combination to prevent WOF.

Material and Methods

Treatment assignments

Beef clods (NAMPS 116) were purchased fresh from a local foodservice wholesale firm

and stored frozen at the North Dakota State University meat science laboratory. Roast size,

cooking method, and heating process were assigned into a 3 x 3 x 2 factorial. Roasts were

categorized as small (Sm), medium (M), and large (L; approximately 1.1, 2.2, and 7.3 kg,

respectively). Cooking methods utilized in this study were oven bags (OV; Reynolds Consumer

Products, Lake Forest, IL), vacuum bags (VB; Cryovac® Oven Ease Bag™, Cryovac Sealed Air

Corp., Duncan, SC) and open-pan roasting (OP). The VB were rated for 4 h of oven time and could not sustain the high volume of air movement produced by the convection oven, causing them to unseal. To prevent this, the sealed VB were placed in OV. Heating processes were freshly cooked (F) and reheated (RH).

Cooking

Prior to cooking, roasts were thawed at 4°C for a minimum of 24 h. Roasts were thoroughly rubbed with a salt, black pepper, and granulated garlic mix (10:1:0.4 by weight ratio). For L roasts, the rub allowance was based on approximately 2% of the roast weight. For smaller roasts having greater cut surface area relative to weight, proportionally lesser spice rub allowances (approximately 1.5% for the M roasts and 1.25% for the Sm roasts) were used. Both Sm and M roasts were placed in a convection oven (model ET-88; Vulcan-Hart, Baltimore, MD) set at 77°C until an internal temperature of 71°C was reached and then held at that temperature for 1 to 2 h. Temperature was monitored using an Omega handheld digital thermometer model HH801B (Omega Engineering Inc, Stamford, CT). The L roasts were cooked in the same oven set at 77°C and removed after 24 h of cooking. The roasts designated as RH were placed in refrigeration (4°C) and held for 72 h as cooked, in a bag or open. Open roasts were covered with foil during storage to prevent moisture loss. Roasts designated F were removed directly from the oven and prepared for sensory panel evaluation. After 72 h of refrigeration RH roasts were warmed to an internal temperature between 65°C and 77°C before being presented to the trained panel.

Sensory evaluation

Procedures using human subjects for sensory panel analysis were approved by the North Dakota State University Institutional Review Board prior to initiation of the study. A seven-

member trained sensory panel participated in six, 1-h training sessions to understand WOF flavor descriptors and to determine which descriptors to include on the ballot. A panel leader facilitated the training to insure consistent intensity ranking. The trained panel and panel leader formed an 8-point scale ballot that included the following flavor descriptors: cardboardy, painty, brothy, salt, bitter, fat, sweet, and other off-flavors (Table 3.1).

Table 3.1. Sensory panel descriptors for beef roasts.

Descriptor	Definition
Cardboardy	Flavor associated with slightly stale beef and wet cardboard
Painty	Flavor associated with rancid oil and fat
Brothy	Flavor associated with cooked beef broth
Fat	Flavor associated with cooked beef fat
Salt	Salt taste
Sweet	Sweet taste
Bitter	Bitter taste
Other off-flavors	Off-flavors that cannot be described by specified descriptors

Johnson and Civille, 1986; Campo et al., 2006.

Panelists were assigned to individual booths with red lighting to mask meat color. Each panel member was provided with unsalted crackers, ricotta cheese, and distilled water for palate cleansing. The panel sessions began with a warm-up sample to eliminate first-order bias. A total of ten, 1.27-cm samples were evaluated during each session, and each sample was labeled with a 3-digit random code. Panelists participated in 3 sessions each week over 3 wk.

Thiobarbituric acid reactive substances (TBARS)

Two, 3-g samples were taken from each roast during sensory panel sample preparation, wrapped in aluminum foil, placed on dry ice, transported to the laboratory, and stored at -80°C for up to 1 month. Immediately before analysis, samples were thawed, and an equal portion of each was finely minced and pooled. A 0.150-g subsample was homogenized in 1 mL of ice cold phosphate buffer [10 m*M* sodium phosphate, pH 7.0; 2% (wt/vol) sodium dodecyl sulfate] containing 10 µL of 100X butylated hydroxytoluene (included in the OxiSelect Kit, see below) using a Brinkmann Kinematica Polytron (Westbury, NY) homogenizer. The homogenate was

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centrifuged at 12,000 x g for 10 min at 4°C, and the supernatant was stored for up to 1 month at -80°C. Protein concentration in the supernatant was determined as outlined in the DC Protein Assay (Bio-Rad Laboratories, Hercules, CA) kit instruction manual. A 100-µL aliquot of the supernatant was analyzed for TBARS as described in the OxiSelect™ TBARS Assay Kit [MDA (malondialdehyde) Quantitation, STA-330; Cell Biolabs, Inc., San Diego, CA] product manual. Values are expressed as mg MDA/kg meat or µmole MDA/g protein extracted.

Statistical analysis

The data were analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary, NC). The model included cooking method, roast size, and heating process as fixed main effects. Random main effect consisted of day. All interactions were included in the initial model. Those interactions that were clearly non-significant ($P > 0.30$) were removed from the model. Significant differences ($P < 0.05$) in least squares means were separated using probability of difference.

Results and Discussion

Sensory panel evaluation of samples for WOF

Panelists evaluated roasts for the presence of WOF using the flavor descriptors of cardboardy and painty. Cooking method, roast size, and heating process did not have an effect on the development of painty flavor (Table 3.2). The reduction of beef flavor and the appearance of cardboardy were noticeable at 1 to 3 d of storage, followed by painty flavor which becomes prominent at 3 to 7 d of storage (Johnson & Civille, 1986). The reheated roasts in the present study were only stored for 3 d, which could explain why painty flavor scores for reheated roasts were not different from fresh roasts.

Table 3.2. *P*-values of main effects and interactions[1] of cooking method, roast size, and heating process on sensory panelist responses and on TBARS.

Treatment effect	Cardboardy	Painty	Brothy	Salt	Fat	Bitter	Sweet	TBARS
Cooking method	0.13	0.77	0.90	0.71	0.96	0.10	0.14	0.23
Roast size	0.10	0.73	0.25	0.07	0.49	0.01	0.27	0.01
Heating process	0.53	0.75	0.01	0.01	0.21	0.40	0.77	0.04
Cooking method x roast size	—	0.10	—	—	—	—	0.15	0.08
Cooking method x heating process	0.04	0.52	0.04	—	0.04	—	0.34	0.19
Roast size x heating process	—	0.22	—	0.01	—	—	0.16	0.01
Cooking method x roast size x heating process	—	0.15	—	—	—	—	0.16	0.16

[1]Dash indicates interactions removed from model, *P* > 0.30.

There was an interaction of cooking method x heating process (*P* = 0.04) for cardboardy flavor (Table 3.2). The roasts that were cooked in an OP and served F had lower cardboardy scores compared with those of VB-F and OP-RH (*P* = 0.04, Table 3.3). It was interesting that the VB-F roasts had the numerically highest cardboardy score of all combinations, but on an 8-point scale, all responses were considered low for overall intensity. Cooking and storing in bags may be crucial for the prevention of oxidation with evidence from Hwang et al. (1990) who reported that WOF develops during the storage period, not during reheating. Previous studies have only evaluated post-cooking storage in vacuum bags, not cooking and storage of whole roasts in the same vacuum bag. We found that cooking and storing in OV or VB may help minimize the appearance of WOF. The cardboardy scores of OV and VB roasts that were served RH did not differ from those of the F roasts. The cooking bags appeared to limit the development of WOF. Hwang et al. (1990) found that cooked, reheated roasts that are stored in vacuum or N_2/CO_2 packages have more beef flavor and less warmed-over, cardboardy flavor. This can be attributed to the minimal amount of oxygen in vacuum bags (Kingston et al., 1998). McDaniel et al. (1984) found similar results when looking at storing product for up to 21 d in

vacuum packaging and two gas packaging treatments. Sensory evaluation showed that roasts

stored in vacuum bags for 14 and 21 d were preferred over the gas treatments. Processing and

cooking parameters can positively or negatively affect the development of WOF (Robbins et al.,

2003).

Table 3.3. Effect of heating process x cooking method on sensory attributes[1].

	Fresh				Reheated				
	OP	OV	VB	SEM[2]	OP	OV	VB	SEM[3]	*P*-value[4]
Cardboardy	1.08[b]	1.27[ab]	2.17[a]	0.36	1.87[a]	1.48[ab]	1.60[ab]	0.24	0.04
Painty	1.61	1.57	1.80	0.36	1.85	1.51	1.39	0.21	0.52
Brothy	1.90[ab]	1.09[b]	1.39[b]	0.37	1.64[b]	2.29[a]	2.28[a]	0.23	0.04
Fat	1.62[ab]	0.82[b]	0.83[b]	0.49	1.00[b]	1.80[a]	1.97[a]	0.31	0.04

[1]Measured on a 1 to 8 scale with 1 being extremely bland and 8 extremely flavorful; Non-responses indicated by a 0.
[2]Fresh cooked roasts standard error of the means for open-pan (OP), n = 7; oven bag (OV), n = 7; and vacuum bag (VB), n = 7.
[3]Reheated roasts standard error of the means for open-pan (OP), n = 20; oven bag (OV), n = 26; and vacuum bag (VB), n = 21.
[4]*P- value* comparing interaction of heating process x cooking method.
[a,b]Means within a row with different superscripts are different ($P < 0.05$).

Sensory panel evaluation of other flavor descriptors

Reheated roasts in OV and VB had higher brothy scores compared with those of OV-F,

VB-F, and OP-RH ($P = 0.04$, Table 3.3). Robbins et al. (2003) found a decrease in beef/brothy

aroma when roasts were open-pan roasted and held hot for periods of 1 to 2 h in a roaster. The

higher brothy scores for reheated, bagged roasts in our study could be attributed to the fact that

these roasts were cooked and reheated in the same bag, which allowed for them to sit/heat in

juices from the first cooking step. This could also explain why fat sensory scores for reheated

OV and VB were higher than the F counterparts ($P = 0.04$, Table 3.3).

Panelists found Sm-RH roasts to be the saltiest compared with all other roasts ($P = 0.002$,

Figure 3.1). It is interesting that panelists were able to pick up salt flavor since they were served

the middle pieces, no edges, and the cutting board and knives were wiped off between each

sample. Each roast was rubbed evenly, but smaller roasts have a greater cut surface area which

could cause the higher salt score. The reheating of the roasts could have had the same

marinating effect on salt as brothy and fat.

Figure 3.1. Heating process and roast size effects on panelist salt score
($P = 0.01$)
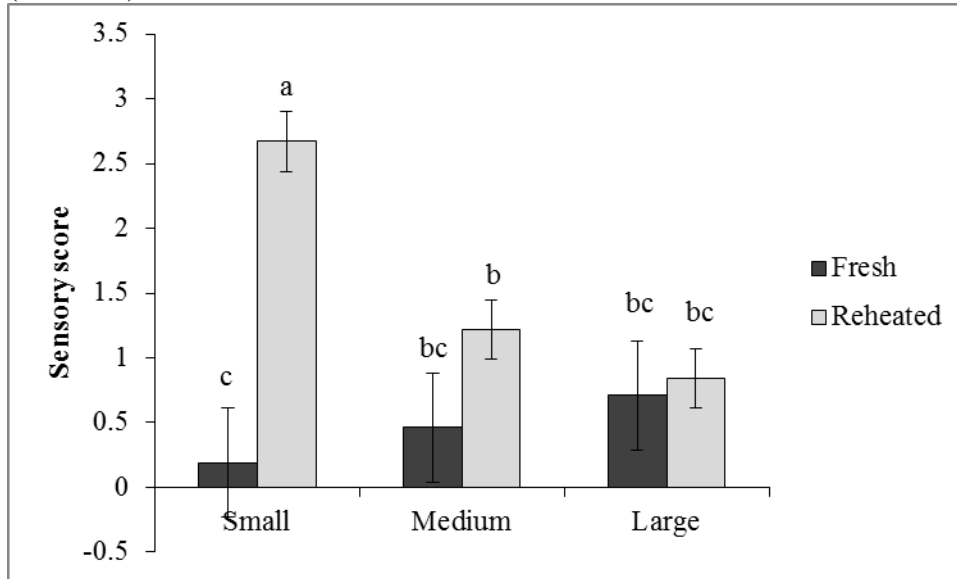
Sensory scale: 1 = extremely bland, 8 = extremely flavorful; non-responses
indicated by a 0. Means with different superscripts are different ($P < 0.05$).

Assessment of lipid oxidation by TBARS

Measures of TBARS were used to assess degree of lipid oxidation. There was an

interaction of heating process x roast size ($P = 0.01$) on TBARS (Table 3.2). Stratified across all

cooking methods, L-F, L-RH, and M-RH roasts had the lowest degree of lipid oxidation (Figure

3.2). Medium F and Sm-F roasts had the highest TBARS value and differed from the M-RH, L-

F, and L-RH roasts. This high value is unexplainable considering the RH roasts would be

expected to have higher TBARS. Panelists were unable to detect WOF for this interaction of

heating process and roast size. White et al. (1988) found that a consumer panel cannot detect off-

flavors of fresh prepared and precooked beef samples when TBARS values are 6.3 mg/kg meat

or lower. This could explain why panelist did not detect WOF for M-F roasts.

Figure 3.2. Heating process and roast size effects on TBARS ($P = 0.01$)
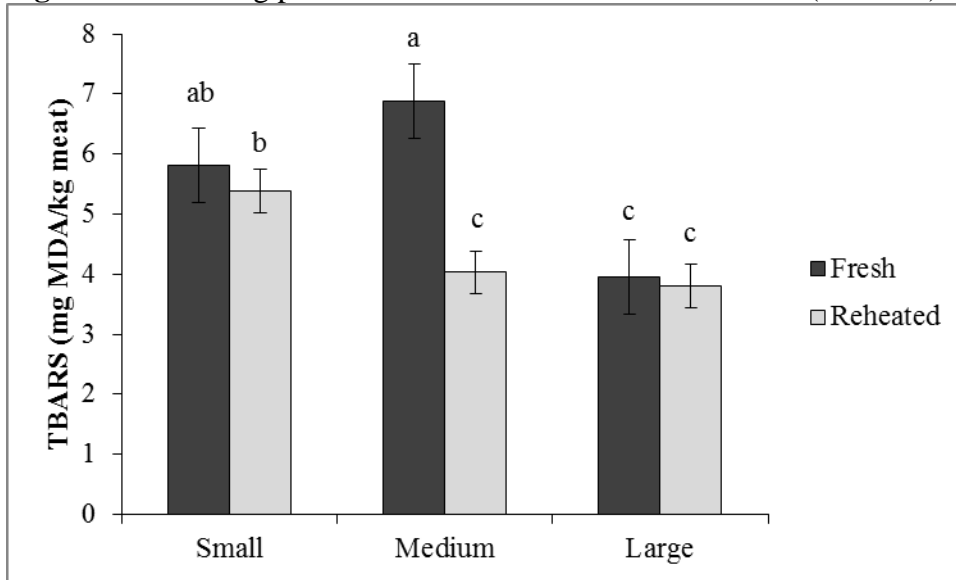
Means with different superscripts are different ($P < 0.05$).

The amount of oxidation was minimized with L-F, L-RH, and M-RH roasts. Smith et al. (1987) found that TBARS accumulate more slowly in ground chicken breasts when heated below 74°C, a temperature similar to the oven setting in our study. Minimal development of oxidation in our study may also be attributed to the roasts remaining whole during cooking, chilling, and reheating processes. Large OV, VB, and OP roasts tended to have lower TBARS values compared to Sm-OP, Sm-OV, M-OV, and M-VB ($P = 0.08$), with the L-OV having the numerically smallest value. Larger pieces of meat have a greater chance of being stable depending on the temperature and presence of oxygen (Mielche & Bertelsen, 1994). The oven bags could have helped to minimize the amount of oxidation in the L roasts.

Conclusions

Cooking, storing, and reheating beef clods at a low temperature in a cooking bag with or without vacuum lowers the presence of WOF. The average consumer would have access to OV; and the foodservice industry would be able to utilize VB. Roast size did not influence panelist WOF scores, but TBARS analyses found the L-RH and M-RH roasts to have less lipid oxidation.

Besides limiting the amount of oxidized flavor characteristics, the OV and VB may have allowed for an increase in the desirable flavor notes of brothy and fat. These flavor notes could have masked the oxidation flavors. Consumers or foodservice companies may be able to decrease the occurrence of WOF in reheated beef roasts by using oven bags and by selecting larger roasts.

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CHAPTER IV. EFFECTS OF POST-MORTEM AGING TIME AND TYPE OF AGING ON PALATABILITY OF LOW MARBLED BEEF LOINS

Abstract

The objective of this study was to evaluate the effect of post-mortem aging time and type (dry vs. wet) of aging on sensory panel flavor characteristics, tenderness, Warner-Braztler shear force (WBSF) and slice shear force (SSF) of beef loins with USDA marbling scores between Slight[50] to Small[50]. Ninety-six short loins (IMPS 174 PSO 2) and 96 strip loins (IMPS 180) were obtained from two processing facilities and randomly assigned to one of four treatment groups: dry bone-in (DBI), dry boneless (DBL), wet bone-in (WBI), and wet boneless (WBL). Loins were evaluated at seven day intervals beginning at 14 d post-mortem and continuing through day 49. Steaks (2.5-cm thick) were cut from each loin, vacuum packaged, and frozen until further evaluation. The effect of aging was assessed by WBSF, SSF, and a trained 8-member sensory panel. Panelists evaluated samples for tenderness, juiciness, overall aged flavor, beefy, bloody/serumy, brown-roasted, and sour on an 8-point scale (1 = extremely tough, dry, and bland; 8 = extremely tender, juicy, and flavorful; non-responses indicated by a 0). Data were analyzed using generalized least squares (PROC MIXED, SAS). The model included aging time, aging type, loin type, and quality grade as fixed main effects with the random main effect of kill date. Aging time and type did not influence SSF, juiciness, beefy flavor, and brown-roasted flavor. Length of aging affected WBSF with the product becoming more tender as the days increased ($P = 0.003$) up to 35 d, with days 35, 42, and 49 being similar. Bone-in steaks evaluated by WBSF also tended to be tougher than boneless ($P = 0.06$). Panelists found an improvement in tenderness when steaks reached 28 d of aging ($P = 0.0004$) compared to days 14 and 21. Dry-aged bone-in steaks were tougher than DBL ($P = 0.05$), but not different from WBL

49

and WBI. Overall aged flavor increased as the days of aging increased ($P = 0.02$). Days 42 and 49 had higher aged flavor compared to days 14 and 21. Aged flavor was also found to be highest for DBL ($P = 0.006$). Wet-aged steaks exhibited more bloody/serumy notes compared to dry-aged ($P = 0.05$). These data suggest that aging steaks up to 35 d improves tenderness of low-marbled loins. Dry aging strip loins for up to 49 d will increase the favorable aged flavor of the loins. Dry-aging did not have an advantage over wet-aging to improve beefy flavor.

Introduction

Consumers expect a product that is tender and has acceptable flavor, making it a vital reason to identify means to enhance these characteristics. It has been proven that consumers consider tenderness as the most important trait followed by flavor (Dikeman, 1987). Tenderness and flavor have been shown to improve by the established concept of aging (Brooks et al., 2000). There are two types of aging used in the industry, dry and wet, with wet being the most common practice due to economics (Campbell et al., 2001). Dry aging involves storing the product unpackaged in a refrigerated cooler with controlled temperature and humidity whereas wet aging is vacuum-sealed (anaerobic) and stored at refrigerated temperatures (Campbell et al., 2001). The 2010/2011 National Beef Tenderness Survey found that aging times vary in the industry with a range of 1 to 358 d, with close to half (44.2%) of the short loins evaluated aged for less than 14 d, which was suggested as the recommended minimum days for aging (NCBA, 2011).

Aging meat for a period of time improves tenderness and has also been shown to promote development of flavors associated with beef (Sitz et al., 2006). Wet-aged beef commonly has more bloody/serumy and sour flavor notes whereas dry-aged has beefy, brown-roasted, and overall aged flavor. The majority of research has reported up to 21 d of aging with very few studies that have passed 35 d. Sitz et al. (2006) wet-aged and dry-aged Certified Angus Beef

(CAB) loins for 37 d and found no difference in flavor between dry and wet. Warren and

Kastner (1992) found opposite results, where panelists found a more favorable beefy flavor score

for dry-aged samples compared to wet-aged. Campbell et al. (2001) also found an increase in

beef flavor along with overall aged flavor and brown roasted when aged up to 21 d.

Aging research has focused mainly on beef that is a higher quality grade, but according to

the Agricultural Marketing Service, over 30% of young beef carcasses graded USDA Select in

2011. According to George et al. (1999), there is a one in four chance of obtaining a tough steak

from a USDA Select grade carcass and a one in five chance for low choice. Flavor has also been

shown to be greater as the quality grade increases. Hodges et al. (1974) found that 15 days of

dry aging USDA Choice short loins gave a greater beef flavor intensity compared to USDA

Standard. Most studies on aging have focused on USDA grade Choice or higher, but in the eight

cities audited by George et al. (1999), 60% of the steaks in the retail market were USDA Select.

They suggested that research should focus on USDA Select and the lower one-third USDA

Choice grades because of their prevalence in the retail market. Also, there is very limited

scientific information regarding aging techniques within these quality grades or aging times over

40 days. The present study examined extended aging time and aging method (dry versus wet) on

bone-in and boneless, USDA Slight[50] to Small[50] marbling score, beef short loins to determine the

effects on beef palatability.

Materials and Methods

Loin collection

Ninety-six short loins (IMPS 174 PSO 2) and 96 strip loins (IMPS 180) were collected

from two commercial processing facilities over a five month period. The short loins and strip

loins were from carcasses that were selected by trained university personnel to have a USDA

marbling score between 350 (Slight^{50}) to 450 (Small^{50}) and maturity class A^{50} to A^{100}. Carcass

weight, ribeye area (REA), fat depth, marbling level, carcass maturity and initial Minolta color of

12th rib lean (L*, a*, b*, Minolta) were recorded at the plant (data not shown). Selected strip

loins and short loins were processed and sealed in oxygen barrier bags at the plant of origin and

transported to North Dakota State University to be immediately processed. Loins were weighed

and randomly assigned to one of four treatments, dry bone-in (DBI), dry boneless (DBL), wet

bone-in (WBI), and wet boneless (WBL). A split-plot design with dry versus wet cross

classified with boneless versus bone-in aging in a 2 x 2 factorial was utilized.

Aging conditions

Loins assigned to dry aging were removed from the vacuum bag, encased in a muslin

sock, and suspended from a rail in a refrigerated aging chamber. Temperature was held at 1$^{°}$C

and relative humidity was maintained at 65% during the aging period. An ultraviolet air

purifying system circulated air to prevent any surface microbial growth. Wet aged samples

remained in the sealed oxygen barrier bag and were placed in a large walk-in cooler that held a

temperature of 1°C. Wet-aged bone-in loins were placed on racks chine-bone down, whereas the

wet boneless loins were placed with the subcutaneous fat up. Bags were monitored weekly for

vacuum integrity and repackaged if the seal was broken.

Aging sample collection

Wet and dry aged loins designated for removal from the aging process on days 14, 21, 28,

35, 42, and 49 were removed from the aging chamber for further processing. An out-of-bag/sock

odor was determined by university personnel on a five-point scale with one being no off-odors

and five having an extreme off-odor. Loins were weighed to determine evaporative loss,

trimmed of subcutaneous and kidney fat (IMPS 174), and reweighed. Discolored or

objectionable tissue was trimmed and loins were stripped of the heavy connective tissue and reweighed to determine trim loss. A final odor score was assessed by the same evaluator on the whole loin using the same scale as the initial odor. Loins were cut into 2.54 cm steaks and weighed to determine the retail weight. The second, third, and fourth steak from the cranial end (*longissimus* dorsi) were removed for slice shear force (SSF), Warner-Bratzler shear force (WBSF), and trained sensory panel analysis, respectively. Minolta color was assessed on the sensory panel steak after a 20 minute bloom period. Steaks were labeled, individually vacuum-packaged, frozen, and stored until further analysis.

Tenderness analysis

Steaks designated for WBSF and SSF were thawed in a $4^{°}$C cooler for 24 hours prior to cooking on George Forman Lean Mean Grilling Machine^{TM} clamshell style grills to an internal temperature of $65^{°}$C. Temperatures were monitored internally in the center of each steak with a copper-constantan, Neoflon PFA insulated wire and temperatures were recorded using an Omega handheld digital thermometer model HH801B (Omega Engineering Inc, Stamford, CT). Final temperature was recorded once the steaks were removed from the grill and reached its peak temperature.

After cooking, WBSF steaks were weighed, overwrapped with polyvinyl chloride film, and allowed to cool to room temperature. A minimum of six 1.27 cm diameter cores were obtained from each steak parallel to the muscle fibers (AMSA, 1995). Cores were sheared on a WBSF machine (G-R Electrical Manufacturing Co., Manhattan, KS) perpendicular to the muscle fibers and recorded as kg of force. The mean of the six cores per steak was used for statistical analysis.

Slice shear force steaks were weighed and immediately processed for shearing. Using the sample sizing box, a 5-cm long section was obtained from the lateral end of the steak. The 5-cm section was placed in the sizing box, centered on the $45^{°}$ slots with the muscle fibers lined up with the angle, and cut using a double bladed knife. The 1 cm section was sheared perpendicular to the muscle fibers with a Warner-Bratzler shear machine with a slice shear force blade (G-R Electrical Manufacturing Co., Manhattan, KS) and recorded as kg of force according to Shackelford & Wheeler (2009).

Sensory analysis

Procedures using human subjects for sensory panel analysis were approved by the North Dakota State University Institutional Review Board prior to initiation of the study. An eight member trained sensory panel participated in orientation sessions where they evaluated samples similar to the test samples to identify descriptors for inclusion on the ballot. Panelists were trained for these descriptors based on references from the beef flavor lexicon (Adhikari et al., 2011). A panel leader facilitated the training to insure consistent intensity ranking. Panelists evaluated the samples for tenderness, juiciness, overall aged flavor, beefy, bloody/serumy, brown/roasted, and sour (Table 4.1) on an 8-point scale (1 = extremely tough, dry, and bland; 8 = extremely tender, juicy, and flavorful). Non-responses for flavor attributes were indicated by a 0. Prior to evaluation, steaks were thawed for 24 h at $4^{°}$C and cooked on a George Forman Lean Mean Grilling Machine^{TM}, clamshell style grill to an internal temperature of $70^{°}$C. Temperature was monitored using the same equipment as WBSF and SSF. Steaks were immediately cut into 1.27 x 2.54 cm cubes and individually presented to the panelists in plastic soufflé cups. Panelists were assigned to a partitioned booth with a red filtered light. Unsalted crackers, part-skim ricotta

cheese, and deionized water were provided for palate cleansing. Panelist evaluated nine samples

a day, three days a week, for a total experimental time of 21 days.

Table 4.1. Sensory definitions for beef strip and short loins aged wet and dry.

Flavor attribute	Definition
Overall aged flavor intensity	Full, blended and sustained cooked beef flavor that has fewer dominating individual flavor notes
Beef flavor intensity	Amount of beef flavor identity
Bloody/serumy	Aromatic associated with blood on cooked meat
Brown/roasted	A round, full, dark, caramelized aromatic associated with beef that has been cooked with dry heat
Sour	Taste factor associated with citric acid

Adhikari et al., 2011; Campbell et al., 2001; DeGeer et al., 2009.

Statistical analysis

Data were analyzed using generalized least squares (PROC MIXED, SAS Institute, Cary,

NC). The model included aging period, aging method, bone-in versus boneless, and quality

grade as fixed main effects. The random main effect consisted of kill date. All interactions were

included in the initial model. Those interactions that were clearly non-significant ($P > 0.30$)

were removed from the model. Significant differences ($P < 0.05$) in least squares means were

separated using probability of difference (PDIFF) in SAS. Linear, cubic, and quadratic contrasts

were evaluated for aging days.

Results and Discussion

WBSF and SSF analysis

Warner-Bratzler shear force decreased linearly ($P < 0.0001$) as the aging period increased

(Table 4.2). Day 42 numerically had the lowest WBSF value and differed from days 14, 21, and

28 ($P = 0.003$). Once the product reached 35 d the tenderness did not statistically improve.

Smith et al. (2008) also found that when steaks are aged for 28 and 35 d, the WBSF values are

lower than steaks aged for shorter periods. Aging, regardless of the type of aging, for a period of

time does decrease WBSF values (Brewer & Novakofski, 2008). Unlike WBSF, SSF was found

to not be affected by aging length ($P = 0.25$; Table 4.2), but it tended to linearly decrease ($P = 0.06$). Variation within the SSF observations was much higher (SEM = 0.97) than WBSF and sensory panel which may account for the lack of significance.

Table 4.2. Aging days influence on tenderness and juiciness.

	Aging Days						Day P - value	Linear P - value	SEM[1]
	14	21	28	35	42	49			
WBSF[2], kg	2.80[a]	2.58[ac]	2.48[c]	2.45[bc]	2.20[b]	2.28[bc]	0.003	0.0001	0.11
SSF[3], kg	14.14	13.77	11.82	11.79	11.56	12.43	0.25	0.06	0.97
Tenderness[4]	5.79[b]	5.90[b]	6.22[a]	6.21[a]	6.25[a]	6.43[a]	0.001	0.0001	0.12
Juiciness[4]	5.49	5.47	5.72	5.76	5.61	5.59	0.23	0.24	0.11
n	32	32	32	32	32	32	-	-	-

[1]Pooled standard error of the means.
[2]Warner-Bratzler Shear Force measurement.
[3]Slice shear force evaluation.
[4]Measured on a 1 to 8 scale with 1 being extremely tough, dry and 8 extremely tender, juicy.
[abc]Means within a row with different superscripts are different ($P < 0.05$).

Unlike aging period, the method (wet or dry) and loin type (bone-in or boneless) did not influence WBSF or SSF (Table 4.3). Wet-aged loins had similar WBSF and SSF values compared to dry-aged loins across all days ($P = 0.55$; 0.98, respectively). Aging of beef is important, but suppliers need to choose the type of aging that is going to be the most beneficial and economical. Typically, dry-aging is utilized for enhancing or intensifying flavors, it is not commonly used for a tenderness advantage (Baird, 2008). Laster et al. (2008) evaluated dry and wet-aged ribeyes, and found that the wet-aged loins were more tender than dry-aged loins. Results from the present study show that regardless of the aging method, tenderness will improve. Due to the more intensive and expensive process of dry-aging, wet-aging should be used if the only goal is to improve the tenderness of a product.

Table 4.3. Aging method and loin type influence on tenderness and juiciness.

	Aging Method			Loin Type			Method	Loin
	Wet	Dry	SEM[1]	Bone-in	Boneless	SEM[1]	P - value	P - value
WBSF[2], kg	2.49	2.44	0.07	2.57	2.36	0.07	0.55	0.06
SSF[3], kg	12.60	12.57	0.55	12.97	12.20	0.58	0.98	0.32
Tenderness[4]	6.14	6.12	0.09	6.07	6.19	0.09	0.83	0.16
Juiciness[4]	5.63	5.58	0.08	5.58	5.63	0.08	0.48	0.66
n	96	96	-	96	96	-	-	-

[1]Pooled standard error of the means.
[2]Warner-Bratzler Shear Force measurement.
[3]Slice shear force evaluation.
[4]Measured on a 1 to 8 scale with 1 being extremely tough, dry and 8 extremely tender, juicy.

Warner-Bratzler shear force analysis showed that bone-in loins tended to be tougher than boneless loins ($P = 0.06$; Table 4.3). The loin type (bone-in or boneless) did not influence SSF, but similar to the aging period, the level of variation was higher than other observations (SEM = 0.58). Numerically, bone-in loins had higher SSF values than boneless loins. DeGeer et al. (2009) found bone-in shell loins and boneless strip loins to not differ.

Quality grade (Low Choice and Select) also did not influence WBSF and SSF tenderness methods (data not shown in tabular form). Dikeman et al. (2013) evaluated USDA Choice and USDA Select steaks that were aged (dry, wet, and special aging bag) for 21 d. The quality grade and aging method did not have an influence on WBSF. Smith et al. (2008) found conflicting results; USDA Choice steaks in their study had lower WBSF values than USDA Select steaks. Quality grade may not have influenced WBSF and SSF scores in the present study because of the specific marbling range. Regardless of aging period, loin type, and aging method, the low marbled loins would be classified as very tender (WBSF < 3.2 kg) based on previous research (Belew et al., 2003).

Sensory panel tenderness and juiciness evaluation

Sensory panel evaluation of steaks found the same results as WBSF for tenderness, as the aging period increased the tenderness linearly improved ($P < 0.0001$; Table 4.2). Days 14 and 21 were tougher than days 28 - 49 ($P = 0.001$). Numerically, day 49 received the highest

tenderness rating, but did not significantly differ from days 28 - 42. According to these results, across both aging methods and loin type, the optimal aging period for low marbled loins is 28 d. Unlike the present study, George et al. (1999) found that post-fabrication aging time did not affect sensory panel tenderness for top loin steaks, obtained from a retail setting whereby the aging periods were described as ranges instead of specific days, which could have influenced sensory ratings. Unlike tenderness, juiciness was not influenced by the length of aging ($P =$ 0.23; Table 4.2). Sitz et al. (2006) found no juiciness differences whereas Campbell et al. (2001) reported that juiciness had a higher score with 21 d of aging.

Aging method and loin type did not influence sensory panel tenderness and juiciness scores (Table 4.3), but the interaction of aging method by loin type had an effect on tenderness ($P = 0.05$; Figure 4.1). Dry boneless loins were more tender than DBI loins, whereas WBL and WBI did not significantly differ from DBI and DBL. Sitz et al. (2006) showed that after 37 d of wet and dry-aging, panelists did not find any tenderness differences. Warren and Kastner (1992) dry and wet-aged strip loin steaks for 14 d and found that vacuum-aged and dry-aged samples were similar in tenderness scores. These studies utilized boneless product, the combination of loin type and aging method has more of an influence combined than each attribute individually.

Unlike WBSF, quality grade of the steaks influenced sensory panelists' perception of tenderness with Low Choice steaks rating more tender than Select steaks (data not shown in tabular form). These results are similar to Smith et al. (2008), USDA Choice steaks rated higher than USDA Select steaks for tenderness like and level of tenderness. Dikeman et al. (2013) showed that USDA Choice and USDA Select steaks do not have an effect on sensory panelists' tenderness evaluation. Similarly, Low Choice steaks tended to be juicier than Select steaks ($P =$ 0.07). Smith et al. (2008) found similar results with USDA Choice steaks rating higher for

juiciness like and level of juiciness compared to USDA Select steaks, unlike Dikeman et al.

(2013) who showed that juiciness was not influenced by quality grade.

Figure 4.1. Aging method and loin type effect on sensory panel tenderness score ($P = 0.05$).
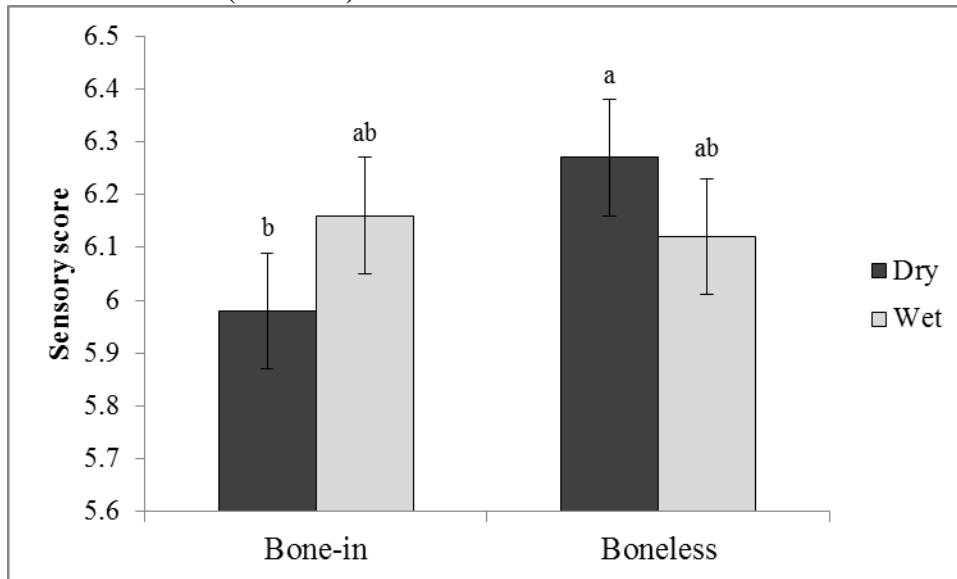
Sensory scale: 1 = extremely tough, 8 = extremely tender. Means with different superscripts are different ($P < 0.05$).

Sensory panel flavor analysis

Aging period influenced the development of overall aged flavor of the loins across aging method and loin type ($P = 0.02$). The amount of aged flavor increased linearly ($P = 0.001$) as the product aged for extended periods of time. Aged flavor numerically reached its peak at 42 d and dropped for 49 d (Table 4.4). Loins that were aged for 42 d had higher aged flavor compared to 14 and 21 d ($P = 0.02$). Aging the loins for 21 d increased the aged flavor; these samples did not differ from 28, 35, and 49 d. Aging for 14 or 21 d has been shown to increase dry-aged flavor compared to 7 d and no aging (Campbell et al., 2001). Overall aged flavor was the only flavor characteristic to be influenced by aging days. Unlike other studies, in the present study beefy flavor was not significant for days of aging. According to Smith et al. (2008), aging (wet or dry) can improve the beefy flavor when aged for 21d.

Table 4.4. Aging days influence on sensory panel flavor characteristics[1].

| | Aging Days | | | | | | Day | Linear | |
	14	21	28	35	42	49	P - value	P - value	SEM[2]
Aged flavor	1.33[a]	1.53[ac]	1.63[abc]	1.61[abc]	1.96[b]	1.85[bc]	0.02	0.001	0.14
Beefy	2.83	2.80	2.79	2.78	2.75	2.73	0.98	0.40	0.11
Bloody/Serumy	0.10	0.07	0.13	0.78	0.06	0.07	0.53	0.28	0.03
Brown/Roasted	1.10	0.94	0.80	0.98	1.18	1.05	0.13	0.36	0.10
Sour	0.10	0.12	0.14	0.10	0.15	0.12	0.82	0.54	0.03
n	32	32	32	32	32	32	-	-	-

[1]Measured on a 1 to 8 scale with 1 being extremely bland and 8 extremely flavorful; non-responses for flavor characteristics calculated as a 0 response.
[2]Pooled standard error of the means.
[abc]Means with different superscripts are different ($P < 0.05$).

Beefy flavor was not influenced by aging method and loin type (Table 4.5). It has been commonly reported that dry-aging of beef increases beefy flavor (Campbell et al., 2001; Warren & Kastner, 1992). These studies were conducted with loins that had a higher quality grade which could be attributed to an increase in beefy flavor. Hodges et al. (1974) reported that flavor from USDA Choice or higher product will improve with aging compared to lower quality grades. The loins in the present study were obtained from carcasses possessing a lower quality grade compared to previous research. That said, Sitz et al. (2006) used CAB and found no significant difference in flavor. Dikeman et al. (2013) also found USDA Select, dry-aged steaks to have a higher beef flavor intensity compared to vacuum and the special beef aging bag. Dikeman et al. (2013) did note that the difference between quality grades was small and may not be noticeable by consumers.

Table 4.5. Aging method and loin type influence on sensory panel flavor characteristics[1].

| | Aging Method | | | Loin Type | | | Method | Loin |
	Wet	Dry	SEM[2]	Bone-in	Boneless	SEM[2]	P - value	P - value
Aged flavor	1.44	1.87	0.08	1.50	1.81	0.08	0.0002	0.006
Beefy	2.82	2.74	0.07	2.75	2.81	0.07	0.44	0.47
Bloody/Serumy	0.12	0.05	0.02	0.08	0.09	0.02	0.05	0.93
Brown/Roasted	1.01	1.00	0.07	1.00	1.02	0.07	0.88	0.68
Sour	0.08	0.16	0.02	0.10	0.15	0.02	0.004	0.06
n	96	96	-	96	96	-	-	-

[1]Measured on a 1 to 8 scale with 1 being extremely bland and 8 extremely flavorful; non-responses for flavor characteristics calculated as a 0 response.
[2]Pooled standard error of the means.

Brown/roasted flavor is also associated with the dry-aging process. Aging method and loin type did not influence the amount of brown/roasted flavor (Table 4.5). This contradicts Campbell et al. (2001) who found steaks dry-aged for 14 or 21 d had higher brown/roasted flavor compared to the wet-aged control. Other flavors typically associated with aging are bloody/serumy and sour. Products that are wet-aged are typically described as being higher in these flavor characteristics. In the present study panelists found wet-aged loins to be higher in bloody/serumy flavor compared to dry-aged counterparts ($P = 0.05$; Table 4.5). Warren and Kastner (1992) found vacuum-aged samples to have a more intense bloody/serumy flavor than either dry-aged or unaged samples. Wet-aging is associated with sourer loins, but panelists found dry-aged loins to have more sour flavor compared to wet-aged loins ($P = 0.004$; Table 4.5). This contradicts previous research finding vacuum-samples usually are more sour than dry-aged loins (Warren & Kastner, 1992). Dry-aged samples were sourer than wet-aged samples, but the means for this flavor characteristic were extremely low on the 8-point scale, which may be due to a large amount of zero responses for the sour flavor.

Dry boneless loins were found to be significantly higher for overall aged flavor ($P = 0.007$; Figure 4.2). Dry bone-in, WBI, and WBL loins were not significantly different. Campbell et al. (2001) found that aged flavor of bone-in products had lower scores because of the reduced exposure to oxygen. Overall aged flavor has been shown to be higher for strip loins compared to shell loins because of the bone decreasing the amount of flavor development (DeGeer et al., 2009).

Figure 4.2. Aging method (dry vs. wet) and loin type (bone-in or boneless) effect on sensory ratings for overall aged flavor ($P = 0.007$).
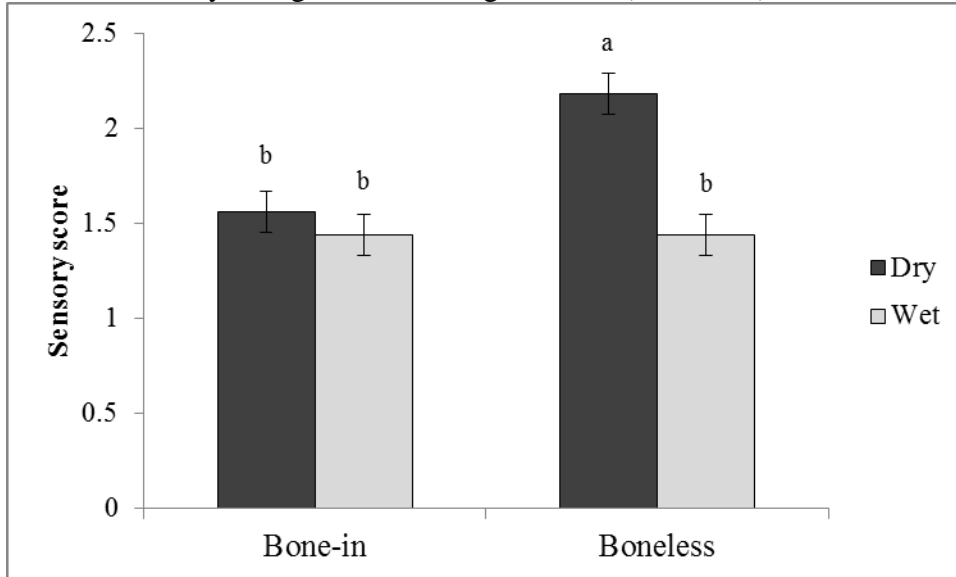

Sensory scale: 1 = extremely bland, 8 = extremely flavorful; non-responses for flavor characteristics calculated as a 0. Means with different superscripts are different ($P < 0.05$).

Odor analysis

Odor of the loins was evaluated to assess the olfactory appeal of the product after the aging process. As the product aged, the amount of initial (out of bag/sock) odor increased linearly ($P < 0.0001$) with 49 d aged product having the highest amount of initial odor stratified across aging method and loin type (Figure 4.3). Product was then trimmed of any objectionable lean and fat to make and a final odor was evaluated to determine if trimming decreased the initial odor. Final odor on day 14 differed from day 49 ($P = 0.04$) with the 49 d aging period having the highest final odor, but this did not differ from day 28 (Figure 4.3). It was also found that the type of aging influenced the odor of the loins. Dry aged loins had higher initial and final odor ($P < 0.0001$; $P = 0.0003$, respectively) than wet-aged loins (data not shown in tabular form). Trimming of the loins numerically decreased the presence of odor.

Figure 4.3. Aging period effect on initial odor ($P < 0.0001$) and final odor ($P = 0.04$).
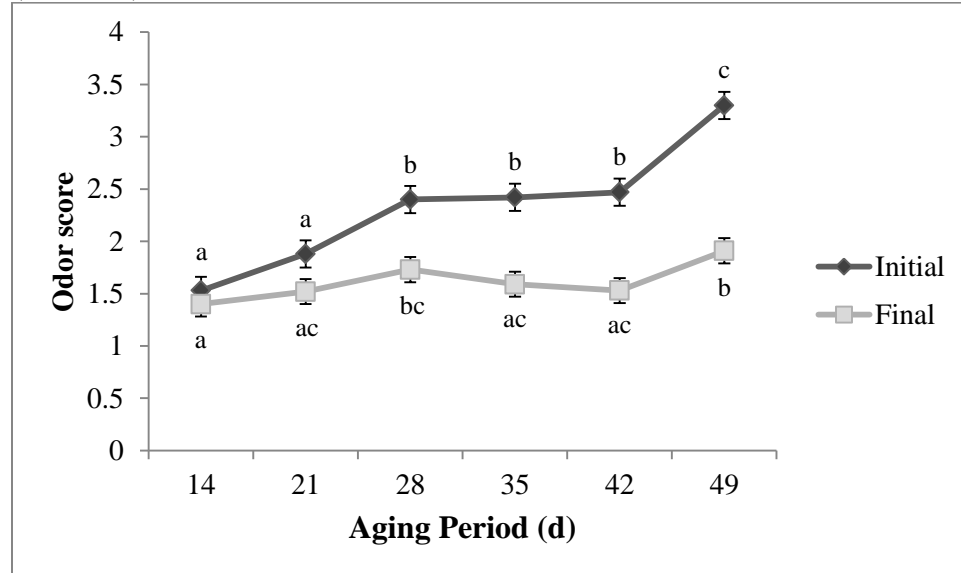
Odor scale: 1 = no off-odor, 5 = extreme off-odor. Means within each line with different superscripts differ ($P < 0.05$).

Conclusions

Dry-aging low marbled strip loins will increase the favorable aged flavor of the loins. Dry-aging does not have an advantage over wet-aging to improve the favorable beefy flavor. Both methods of aging produce tender product that would be acceptable to the consumer. Aging for extended periods of time, beyond 14 d, does improve the tenderness and helps to enhance the overall aged flavor. Wet-aging of these low marbled loins produces a tender product, but does not increase flavors that are commonly lacking in low marbled beef. Wet-aging is the most economical method over dry-aging. More research is necessary regarding methods to enhance flavor of low marbled loins to find ways to make them more desirable to the consumer.

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