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Evaluation of Extended Aging Type and Cooking Practices on Palatability of Beef Steaks

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Evaluation of Extended Aging Type and Cooking Practices on Palatability of Beef Steaks

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Abstract

Two studies were conducted to determine if sous vide was a viable way to improve palatability of various beef cuts, and to determine whether extended aging duration and the presence of a bone impacts the consumer ratings of beef short loins.

When evaluating the impact of sous vide cooking (**SVG**) on multiple beef muscles, there was a muscle × method interaction for overall liking ($P = 0.04$). The traditionally cooked (**TRAD**) *Longisimus lumborum* (**LL**) was rated the highest ($P < 0.05$). The Chuckeye steak (**CHE**) was rated next, both TRAD and SVG, with the traditional ranked higher, this was followed by the *Triceps brachii* (**TB**) also for both TRAD and SVG, however for the TB the SVG ranked higher ($P < 0.05$). The TRAD *Biceps femoris* (**BF**) rated the lowest ($P < 0.05$) of all of the muscles. Shear force did no differ between the cooking treatments ($P > 0.05$), or was there an interaction between muscle × method for shear force measurements ($P < 0.05$). The LL was rated the highest for tenderness ($P < 0.05$) while the BF was rated the lowest ($P < 0.05$).

The second study compared subprimals aged over three aging periods (21, 42 63 days), then split into bone-in or boneless steaks, there were no interactions observed within the consumer data ($P \geq 0.05$). BI steaks were rated higher ($P < 0.05$) for juiciness and overall liking by consumers, however BI and BL were rated similarly by consumers for tenderness and flavor ($P > 0.05$). When evaluated by consumers, aging did not have an effect on tenderness ($P \geq 0.392$), juiciness ($P \geq 0.890$), flavor ($P \geq 0.901$) or overall liking ($P \geq 0.518$). A greater percentage of BI steaks ($P<0.05$) were rated as premium quality than BL steaks. When analyzed objectively through Warner-Bratzler Shear Force (WBSF), there were no interactions between treatments ($P>0.05$). Bone-in steaks had higher WBSF values than BL steaks ($P < 0.05$). As aging time increased, WBSF values decreased ($P<0.05$). Steaks aged for 63 d had the lowest

shear force measurements ($P < 0.05$), while those aged for 21 d and 42 d were similar. BI steaks had less cook loss than BL steaks ($P < 0.05$). Steaks aged for 63 d exhibited greater cook loss ($P < 0.05$) than steaks aged for 21 d and 42 d, which were similar ($P > 0.05$).

Cooking method had a large impact on consumer ratings. Traditionally cooked steaks had higher ratings by consumers than sous vide steaks. Steaks from muscles used commonly by consumers had higher consumer ratings. Consumers found no differences between the different aging periods for tenderness, however as aging time increased, WBSF decreased as well, showing that extended aging may require further research to determine its viability.

The implications of this study are that BI product shows promise with greater juiciness and overall liking. Sous vide is still a valuable tool. It’s capable of cooking steaks consistently and with no ill effects on the quality of the steaks.

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Dedication

This thesis is dedicated to all of my family. My husband, James, my kids, Belle and Harley my parents, Jenny and Matt, my sisters Lauren, Rachel and Amara and finally, to my grandmother Gloria. Thank you all in helping me get to be where I am today.

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Literature Review

Palatability defined

Palatability is defined in research as the overall eating experience as it is related to tenderness, juiciness, and flavor (O'Quinn et al., 2018; Smith et al., 1986). In the past, tenderness was rated the most important palatability trait in beef (Smith et al., 2011; Savell et al., 1987). In a study completed by Miller et al. (2001) 78% of consumers would pay a higher price for beef if it was guaranteed to be a tender cut. Similarly, Boleman et al. (1997) separated steaks into 3 tenderness categories based on Warner-Bratzler shear force measurements (Red = 2.27 – 3.58 kg, White = 4.08 – 5.4 kg, and Blue = 5.90 – 7.21 kg) and found that when consumers were able to evaluate the steaks before purchasing that they were able to differentiate between the tenderness categories and purchased 2.27 – 3.58 kg steaks more often (94.6%) whereas 4.08 – 5.40 kg and 5.90 – 7.21 kg steaks were purchased only 3.6 and 1.8% of the time, respectively. Consumers were willing to pay a $1.10/kg premium for the 2.27 – 3.58 kg labeled steak. Killinger et al. (2004) documented that tenderness was the most correlated to overall acceptability (r = 0.87) followed by flavor (r = 0.78) and then by juiciness (r = 0.65) when consumers evaluated steaks from strip loins in their homes, however when tenderness was made to be similar, flavor became just as important as tenderness (r = 0.86, r = 0.85 respectively). Conversely, O'Quinn et al. (2012) found that the correlation between tenderness, juiciness and flavor in relation to overall acceptability was r = 0.76, 0.73, and 0.88, respectively.

More current research has shown that flavor has a greater impact on palatability than tenderness (O'Quinn et al., 2018). It was documented by O'Quinn et al. (2018) that tenderness accounted for 43.4% of palatability, flavor accounted for 49.4%, and juiciness accounted for

7.4% of palatability. O'Quinn et al. (2018) conducted evaluated 11 other studies across a wide range of treatments and over 1500 samples to show evidence of the above percentages and how they pertain to the palatability of beef. This study showed that the failure of tenderness, juiciness, or flavor to be acceptable led to a 7.2, 6.5, or 12.3 times increase, respectively, in the unacceptability of the steak as a whole.

It should be noted that each palatability trait is related to each other. For instance, a juicier steak will often be perceived as more tender, and a drier steak will often be perceived as less tender (Becker et al., 2016, Killinger et al., 2004, Miller et al., 2001). This is generally referred to as the halo effect (Corbin et al., 2015). The results from Corbin et al. (2015) could then be skewed and not as reliable due to the halo effect, but this point also shows the distinct correlation between the palatability traits. The summation of these papers shows that palatability is one of the key factors for consumers, and that consumer trends have shifted to favor flavor as the main trait as compared to tenderness in years past.

Cooking Methods

There are many cooking methods in existence including: roasting, frying, broiling, grilling, sous-vide, and many others. Yancey et al. (2010) covered a variety of cooking methods including clamshell grills (CLAM), forced-air convection oven (FAC), countertop griddles (GRID), gas-fired charbroiler (CHAR), and forced-air impingement oven (IMP). In the study, *Longissimus thoracis* steaks were used to evaluate the cooking methods. Yancey et al. (2010) observed although the CLAM had the fastest cook times and lowest cook losses, it was the least repeatable, and had highest shear force values (toughest), and the least cooked red color. The FAC produced the lowest shear force values, the reddest steaks, but had the longest cook time.

As covered by many others, shear force measurements also increased with increasing temperatures. (Yancey et al., 2016, 2010; Obuz et al., 2004, 2003) In 2016 conducted by Yancey et at. (2016) using the *Semimembranosus* and *Infraspinatus*, it was observed that the CLAM was again the shortest in cook time, but in contrast to the previous study, the CLAM was among the lowest shear force values. The conclusions from this study show that cookery method may not have a great effect on cooked color and tenderness, but the combination of muscle type and end-point temperature may have a greater relationship.

Vierck et al. (2020) used four dry heat cookery methods (clamshell grill (CLAM), salamander (SALA), charbroiler grill (CHAR), and convection oven (OVEN)) following sous-vide preparation on *Longissimus lumborum* steaks. It was determined that CLAM was one of the least preferred methods of cookery by consumers while SALA steaks were more preferred. CLAM grills were observed to be detrimental for flavor, though noted to be consistent, rapid and repeatable for research purposes. The main focus of this study was the different cooking methods, however there were no results indicating that the prior sous-vide preparations had any effect on consumers ratings of the different cooking methods.

Furthermore, several studies have shown the differences between sous-vide cooking and other cookery methods (James and Yang, 2012; Garcia-Segovia et al., 2006; Obuz et al., 2004, 2003). James and Yang (2012) used sous-vide, oven-roasting, and high-pressure processing (HPP) on beef *Semitendinosus* muscles and reported that HPP had the lowest shear force as well as low cook losses, however the industrial mechanisms of HPP do not allow it to be a common method for consumers. Sous-vide, however, is accessible to consumers, and according to James and Yang (2012), it resulted in similar cook losses and low Warner-Bratzler shear force measurements when compared to the other two cooking treatments. The oven-roasted samples resulted in the greatest cook-loss and highest shear force measurements when compared to the other two cookery methods.

The results from the above studies contrast what was found by Obuz et al. (2004) who looked at multiple muscle types including the *Longissimus lumborum* (LL), *Biceps femoris* (BF), and deep *Pectoralis* (DP), and used these muscles to compare water-bath cooking, which is very similar to sous vide cooking, and the electric belt grill. It was observed that the water-bath method produced higher Warner-Bratzler shear force values, higher cook-loss values, and had much longer cook-times than the belt grill for the LL and the DP. However, for both the BF and the DP, there were distinct temperature ranges where WBSF decreased significantly (40-60°C and 45-65°C, respectively). Obuz et al. (2003) had very similar findings, though only using the BF and the LL. The LL increased in WBSF values during water-bath cooking as compared to belt-grill cooking. Belt-grill cooking followed by water-bath holding and reheating resulted in decreased WBSF values for the BF. Obuz et al (2003) attributed the decrease in WBSF values to the collagen content of the BF.

Cooking Method Effect on Palatability

It has been well documented that cooking method has a great effect on the palatability of food products, though it is impossible to determine a "best" cooking method as each has advantages and disadvantages. The American Meat Science Association (AMSA) gives an overview of several types of cookery methods such as the clamshell grill, conveyor belt grill, open-hearth grill, oven roasting, microwave, impingent ovens, and other cooking methods (AMSA, 2015). The AMSA does not recommend certain cookery methods for meat such as the high-velocity, FAC, microwave oven, or convection-oven cookery due to the inconsistency of the cooking methods.

Yancey et al. (2016, 2010) evaluated multiple cooking methods including the FAC, CHAR, GRID, IMP, and CLAM and covers the *Longissimus thoracis*, *Semimembranosus and Infraspinatus.* It was determined by Yancey et al. (2016) that the cookery methods did not have an effect on the steaks, but rather that the end-point temperature had a greater impact with the results of the study. Yancey et al. (2010) found that there were differences between cooking methods, but that increasing the end point temperature was a consistent factor in differences in the *Longissimus.*

In a review of literature on the quality and energy evaluation in meat cooking done by Pathare and Roskilly (2016), the authors cover a number of cooking techniques that are popular in homes and industry. Oven-cooking, frying, sous vide, high pressure processing, and ohmic cooking are all explored in regards to palatability. Oven cooking is described as being a broadly used technique, but that it creates tougher, drier meat (Pathare and Roskilly, 2016). This occurs in different stages, with the first stage coming from the denaturation of myofibrillar proteins, then the shrinking of intramuscular collagen or gelatinization and then by a final shrinkage and dehydration of myofibrillar proteins (Pathare and Roskilly, 2016). Frying is another form described as being a high heat environment, which minimizes cooking time and weight loss of products and creates good Maillard reaction products (Pathare and Roskilly, 2016). Sous vide is described as a cooking technique which increases tenderness, juiciness, reduces cook losses, but generally increases cook times significantly due to the low temperature nature of the cooking method (Pathare and Roskilly, 2016). High pressure processing is described as an excellent way to inactivate microbial growth while still getting a tender product, however this type of cookery method is generally only used at the industry level due to the expense of the equipment (James and Yang, 2012).

Sepulveda et al. (2019) used CHAR, SAL, CLAM, and flat top gas grills (FLAT) on the quality grades of Prime, Top Upper 2/3 Choice, Low Choice, and Select. The study found that cooking method and quality grade had impacts on consumer ratings, with CHAR steaks being rated highest for flavor and for overall liking, FLAT steaks being rated low for juiciness and tenderness, and the CLAM being rated low for flavor (Sepulveda et al., 2019). The CHAR had longer cooking times, greater production of Maillard products, and more enzymatic breakdown of the steaks, which could indicate why consumers preferred the CHAR steaks over the other three treatments (Sepulveda et al., 2019).

Palatability of Different Muscles

There are many different muscles used across species by consumers for various occasions, cooking methods, and research. Beef researchers generally use the *Longissimus lumb orum* as it is commonly bought and used by consumers (Fabre et al., 2018; Yancey et al., 2010; Obuz et al., 2004, 2003; Shackelford et al., 1999a; Shackelford et al., 1999b). Other muscles used for tenderness measurement studies, are the *Semimembranosus*, *Biceps femoris*, and *Semitendinosus* (Fabre et al., 2018; Yancey et al., 2016; James et al., 2012; Obuz et al., 2003, 2004). Comparing these different muscles is very important due to the nature of the cuts of meat being used. For instance, Obuz et al. (2003) compared the *Biceps femoris* (BF) and *Longissimus lumborum* (LL) to determine the effects of cooking time, holding time and holding temperature on the two muscles. The study determined that due to the nature of the muscles, the BF had improved tenderness when compared to the LL, which had no tenderness improvement. This difference is attributed to the higher collagen content of the BF.

Nyquist et al. (2018) covered nine beef cuts (*Longissimus lumborum* (LL); *Longissimus thoracis*, *Complexus*, and *Spinalis dorsi* (LCS); *Infraspinatus* (IF); *Serratus ventralis* (SV); *Triceps brachii* (TB); *Tres major* (TM); *Adductor* (AD); *Semimembranosus* (SM); and *Biceps femoris* (BF)) throughout the chuck and the round and determined that chuck muscles were more likely to give a consumer a positive eating experience, while muscles from the round gave consumers a lower quality eating experience.

Meat tenderness is very closely related to its texture. This includes myofibrillar proteins, muscle cytoskeleton, intramuscular connective tissue, and intrafiber water content (Obuz et al., 2003). Girard et al. (2012) explains that the tenderness of the muscle as it relates to WBSF is affected by the age and breed of the animal the muscle comes from, along with the variation of muscle fiber composition, size, and sarcomere length. All of these things are related to postmortem handling of the animals including the ultimate pH, the aging temperatures, carcass position and suspension, and early postmortem glycolytic rates of the different muscles (Girard et al., 2012). Naqvi et al (2021) adds that tenderness of different muscles is affected by genetics, husbandry practices, feeding, transport, stunning and exsanguination methods, storage and cooking procedures. The author also indicates that the anatomical location and functionality of the muscle impacts the tenderness, and that this is affected by the age of the animal. Furthermore Naqvi et al. (2021) indicates that high temperature cooking resulted in increasing hardness, chewiness and cohesiveness for the BF and the Semitendinosus (ST). It was also shown that the higher cooking temperatures increases collagen solubility in both muscles during sous vide cooking (Naqui et al., 2021). Girard et al. (2012) indicates that as the age of an animal increases the connective tissue contribution to the higher shear force values increases due to the decrease in soluble collagen.

Chriki et al. (2012) used the Integrated and Functional Biology of Beef (BIF-Beef) data to identify different muscle characteristics and how they affect the tenderness of the muscle. Of the five muscles used (*Semitendinosus* (ST), *Semimembranosus* (SM), *Rectus abdominis* (RA), *Triceps brachii* (TB), *Longissimus thoracis* (LT)), the LT was used the most often in the current review. These muscles have a wide range of muscle fiber type, collagen content, and biochemical traits, and through cluster analysis it was shown that muscles with low collagen content, low muscle fiber-cross sectional area, and oxidative muscle type had better tenderness than those with opposing characteristics (Chriki et al., 2012). Muscles with high collagen content were found as less tender, and the muscles with the most soluble collagen content were rated as more tender (Chriki et al., 2012). The LT was rated the most tender for collagen content and had the lowest WBSF. Similarly, Lawrence et al. (2001) attributed the differences between the five muscles (*Biceps femoris, Deep pectoralis, Gluteus medius, Longissimus lumborum,* and *Semitendinosus)* in the study to the collagen content of the muscles. These muscles were chosen specifically for the differences in their characteristics to show the differences in tenderness across muscles, across cooking treatments. It was observed that the *Deep pectoralis* was the toughest of the muscles across all treatments. The *Biceps femoris* and the *Semitendinosus* were similar except when cooked at high temperatures, then the *Biceps femoris* was rated higher for toughness. This difference is attributed to the lack of time for collagen solubilization. The *Gluteus medius* was rated higher than the *Semitendinosus* except when cooked at high temperatures. This was again attributed to the collagen content. The *Longissimus lumborum* was rated the best and most repeatable of the muscles across all treatments.

Jeremiah et al. (2002) produced a comprehensive work covering 33 different muscles and muscle groups in beef. All muscles were roasted in a convection oven at 177°C to an internal temperature of 72°C and analyzed by trained panels for overall and initial tenderness, juiciness, amount of perceivable connective tissue, and flavor. The *Psoas major, Ilio-psoas*, *Longissimus thoracis*, and *Triceps brachii* (long head), and *infraspinatus* were all rated highly for tenderness. The tenderloin was rated the highest for overall tenderness, least amount of perceivable connective tissue, flavor desirability, and overall palatability. In contrast, the shank muscles were rated the lowest for initial and overall tenderness, the highest for perceivable connective tissue, lowest for flavor and overall palatability. According to this study, conducted in Canada, a 95% acceptance of beef is the overall goal. Unfortunately, according to the panel in this study, only four muscles (*Psoas major*, *Ilio-psoas*, *Teres major*, *Spinalis dorsi*) reached that goal in overall acceptability. For juiciness, 11 muscles/muscle groups (*Spinalis dorsi*, diaphragm, *Psoas major*, *Teres major, Tensor fasciae latae*, *Spinalis dorsi*, *Obliquus abdominus internus, Trapezius*, *Gracillis*, *Vastus lateralis*, and *Biceps femoris* were deemed to reach a 95% acceptance goal. Only seven muscles/muscle groups (*Teres major*, *Psoas major*, *Longissimus thoracis, Longissimus lumborum, Ilio-psoas, Spinalis dorsi, Teres major subscapularis)* reached a 95% acceptance goal for flavor. On the opposite spectrum, there were muscles/muscle groups that did not reach a 50% desirability rate from the panel. Overall palatability had 11 muscles/muscle groups (*Biceps femoris*, Neck, Diaphragm, *Obliquus abdominus internus, Adductor, Serratus ventralis, Trapezius*, Shank, *Latissimus dorsi*, *Semitendinosus, Deep pectoral, Superficial pectoral)* that did not reach a 50% acceptability. Jeremiah et al. (2002) addresses that the less desirable muscles may need different cooking methods to make them more desirable, contributes the slight differences between his study and others to the differences in cooking methods.

Sous vide history

Sous vide is a newer method of cooking that has been gaining a lot of popularity over the last several decades (Baldwin, 2011). The principle of sous vide is that a food item is vacuum sealed in a heat stable packaging and then cooked under controlled conditions (Dominguez-Hernandez et al., 2018; Baldwin, 2011; Creed, 1998; Schellekens, 1996). Sous vide was developed around the 1970s, though it has not truly become an object of scientific research until about the 1990s. George Pralus is credited with the discovery of the sous vide cooking method (Creed, 1998, SVAC). However, there were several other forms of sous vide in industry in existence at the time including Nacka in Sweden (Bjorkman and Delphin, 1966) and a company called A.G.S. in the United States (McGuckian, 1969). The vacuum packaging allows for less evaporative losses and prevents any kind of recontamination of the food product after cooking, thus extending the shelf life of the product (Baldwin, 2011). Furthermore, the precise heating allows for near perfect reproducibility, and greater control over the degree of doneness, making it ideal for catering and restaurants (Baldwin, 2011).

There have been many studies that have evaluated sous vide cooking, and a number of them focus on the tenderizing ability of this form of cookery (Biyikli et al., 2020; Park et al., 2020; Dominguez-Hernandez et al., 2018; Baldwin, 2011; Creed, 1998; Schellekens, 1996). In a review of present sous vide research, Dominguez-Hernandez et al (2018) covered numerous studies that all concluded that cooking using sous vide increased the overall tenderness of meats such as pork, beef and lamb. This tenderizing characteristic has also carried over into chicken and turkey, and has been labeled as an outstanding method of cookery for both products (Biyikli et al., 2020; Park et al., 2020). However, it is difficult to determine what the precise time and temperature combination is the best. For example, Park et al. (2020) used 60°C and 70°C with time combinations of 1, 2 and 3 hours on chicken breasts, with the ideal temperature being 60°C and ideal time being 2 and 3 hours as determined by consumer acceptability. Biyikli et al. (2020) sous vide turkey cutlets and used multiple temperature – time combinations (65, 70, 75 °C × 20, 40, 60 min) and determined that the main effect of temperature had the greatest impact. This study showed that the cooking yield, moisture and elasticity values decreased with increasing temperatures, while cooking loss, fat, pH, hardness, cohesiveness, gumminess, and chewiness values increased. Turkey cutlets cooked at lower temperatures for shorter amounts of time were rated higher by consumers in this study (Biyikli et al. 2020). Another study using beef *Semitendinosus* muscles used more temperature – time combinations (50, 55, 60, 65°C × 90, 150, 270, 390 min), with shear force decreases with increasing temperatures, and no effect of the extended times on the beef steaks (Vaudagna et al., 2002). Unfortunately, Vaudagna et al. (2002) does not give great detail to the differences in treatments, however, there is a decrease in WBSF values (about 0.3 kg $cm^{-2)}$ is noted from the graphs from 50°C to 60°C, with a slight increase in toughness at 65°C. As discussed, there is no set temperature – time combination that has been set as a standard in sous vide cooking. This makes the use of this method of cooking difficult in some respects as there is no set data even for the same cut of meat (Kurp et al., 2022).

Sous vide cooking

Sous-vide has been described as a way to increase tenderness, improve shelf-life, increase efficiency of cooking, and increase uniformity of products (Cho et al., 2021; Park et al., 2020; Mortensen et al., 2012 Baldwin, 2011). This method of cookery has been applied to not only chicken (Cho et al., 2021) but to beef (Mortensen et al., 2012) and even to vegetables (Zavadlav et al., 2020). However, in the case of meat, though tenderness and shelf life may be increased, the overall flavor and appearance acceptability is lower than traditionally cooked meats (Cho et al 2021; Baldwin, 2011). This is due to the “poached” appearance that cooking within a bag causes (Baldwin, 2011). Therefore, finishing service, including searing or saucing, is used to create a more desirable appearance and flavor. Searing increases the Maillard compounds present and therefore creates a more flavorful eating experience (Baldwin, 2011; Dominguez-Hernandez et al, 2018).

Though sous-vide has a much higher yields than traditional oven roasting, this cooking method still has significant cook losses that can contribute to negative palatability scores (Dominguez-Hernandez et al., 2018). Becker et al. (2016) found that tenderness and juiciness of pork meat were affected oppositely with lower temperatures having juicier meat, but not as tender, and higher temperatures having less juicy meat, but more tender. Therefore, a balance of the time and temperature must be obtained. Kurp et al. (2022) had similar results with pork loin slices. The study determined that the moisture content of the pork slices was highest at lower temperatures, and lowest at higher temperatures. Finally, beef *Semitendinosus* muscles, were cooked at very low temperatures for extended periods of time, and the ST produced juicier meat at lower time and temperature combinations, and more tender meat at much higher time and temperature combinations (Mortensen et al.,2012)

Shelf life is a very important aspect of sous-vide and is a main contributor to why the cookery method is so popular in industry (Baldwin, 2011). The main reason for this is the main principle of sous-vide cooking which is that the food must be vacuum sealed in heat-resistant packaging (Biyikli et al, 2020; Dominguez-Hernandez et al, 2018; Baldwin, 2011; Vaudagna, 2002). Vacuum sealing allows for pasteurization to occur during cooking, and prevents contamination following cooking. Mason et al. (1990) reported in a review of literature covering all cook - chill food products that the low oxygen environment along with the low pressure prevents microbial growth and thereby can extend shelf life by 5 to 21 days. It was also reported than these conditions help to prevent lipid oxidation and prevent off-flavors from becoming prevalent as the product reaches the end of its shelf life (Mason et al, 1990).

More currently, Diaz et al. (2008) discovered that even after 10 weeks of refrigerated cold storage, there was little to no microbiological issues with pork loins that had been subjected to sous-vide cooking. The flavor of the samples, however, were very unacceptable after 10 weeks due to the warmed-over flavor and rancid smell. The appearance acceptability declined sharply after 5 weeks and was unacceptable at 10 weeks (Diaz et al., 2008). Similarly, Rinaldi et al. (2014), using two different sous-vide methods (2 hr 100°C and 36hr 75°C) compared to a traditional boiled method (2hr 100°C), found that sous vide inactivated all pathogens to safe levels, though refrigerated storage was necessary due to *Clostridium botulinum* spores not being inactivated.

Collagen

One of the main components of meat palatability is collagen content. It is the main component of connective tissue in meat and is one of the main contributors to meat toughness (Du et al, 2013). Collagen is the most abundant structural proteins (Shoulders and Raines, 2009). As animals age, the crosslinks of collagen mature and become much more heat stable, making them harder to break (Nishimura, 2010). Du et al. (2013) explains that fibrogenesis is the generation of fibroblasts and the formation of connective tissue, and that fibrogenesis is very active at the fetal level of development. Collagen is the most abundant proteins in all animals, therefore it is extremely relevant to meat tenderness (Weston et al. 2002). Chriki et al. (2012) analyzed the BIF-Beef data-sets, and 5 chosen muscles (*Semitendinosus* (ST), *Semimembranosus* (SM), *Rectus abdominis* (RA), *Triceps brachii* (TB), and *Longissimus thoracis* (LT)), showed that collagen content was very relevant to the tenderness of the muscles. In this analysis, the muscles with the most collagen were the toughest, while those with less collagen were the least tough.

There are 28 types of collagen, but only types I, III, IV, V, VI, XII, XIV make up the collagen within animals (Nishmimura, 2010; Shoulders and Raines, 2009; Purslow, 2005). Types I and III are the major fibre-forming in the endomysium, perimysium, and epimysium (Purslow, 2005). Though collagen varies greatly between muscles, it is generally accepted that it makes up between 1-15% of the skeletal muscle dry matter (Nishmimura, 2010; Purslow, 2005; Bendall, 1967).

Interestingly, Jeremiah et al. (2002) examined 33 different muscles/muscle groups and found that those with high perceivable collagen content were also the least desirable overall, conversely the butt tender, tenderloin and rib-eye were perceived to have the least amount of collagen, and were the most desirable overall (Jeramiah, 2002). This can be attributed to the fact that collagen significantly affects tenderness, and that when one major palatability trait is lacking, the overall acceptability is lessened significantly (O'Quinn et al, 2018; Weston et al., 2002).

Cooking method has a large effect on collagen. James and Yang (2012) found that the connective tissue of the *Semitendinosus* was the most tender with high pressure processing. The gelatinization of the connective tissue was the highest with this treatment, followed closely by sous-vide cooking. Oven roasting had the highest Warner-Bratzler shear force values. Similarly, Vaudagna et al (2001) found that as temperature increased, the Warner-Bratzler values decreased, furthermore this study confirmed that the tenderization of meat occurs in 2 stages by showing an increase in toughness at about 40-50°C, and then a pattern of decreasing toughness until the lowest toughness, or highest tenderness, was reached between 60-64°C.

Purslow (2018) described this 2-step process with 3 forms of collagen. Collagen could start in the native (N) state, the unfolded (U) state, and the denatured (D) state. If going from N to U, this stage is reversible as it is the triple helix form going to an individual form of collagen. However, going from U to D is irreversible and occurs due to the individual form denatured random coils. These processes begin occurring at various temperatures depending on the rate of heating (Purslow, 2018). Further explanation of this 2-stage process is explained by Tornberg (2004) who states that the myofibrillar protein unfolding stage begins between 30 – 32°C, followed by protein-protein association between 36 – 40°C, and then the gelation stage between 45 – 50°C. Following this process, collagen begins to denature between 53 – 63°C. If the fibers are not stabilized as heating increases, they dissolve and form gelatin.

Sous-vide cooking has been linked to increased collagen solubilization (Ayub and Ahmad, 2019). Davey and Niederer (1977) found that prolonged cooking at low temperatures in a water bath would lead to increased tenderness and collagen solubility of young and old animals. They determined that cooking between 70 – 100°C would halve the Warner-Bratzler shear force values and is as effective as aging the meat.

More current work on the same subject led Naqvi et al. (2021) who worked with young and old animal steaks to determine whether sous-vide cooking could create similarly tender steaks from both. They used 3 different time × temperature combinations (1, 8, 18 h × 55, 65, 75°C), and half the steaks were aged for 13 days while the other half were not aged. They found that there was more heat soluble collagen in young animals than old, but with increased time and temperature the steaks from both young and old animals had lower Warner-Bratzler values believed to be from the solubilization of connective tissue in the steaks (Naqvi, 2021). Similarly, Dinardo et al. (1984) found that extended exposure to low temperatures increased the solubilization of collagen. The same temperature was used (60°C) with 3 different time treatments (0, 2, 4hr). These were compared against the conventional cooking method of 94°C in a conventional oven.

Extended Aging

Aging is a very well documented topic of research, but there is little research done on extended aging and the possible benefits. Most studies keep within a period of 3 to 4 weeks post-mortem (Colle et al., 2016; Lepper-Blilie et al., 2016; McCullough, 2013; Jeremiah and Gibson, 2003; Goll et al., 1964). Colle et al. (2016) aged *Biceps femoris* (BF) and *Semimembranosus* (SM) steaks 2, 14, 21, 42, and 63 days, and while the BF was unchanged objectively, the SM and BF were both perceived by consumers to be more tender as aging increased. The SM had higher acceptability and better juiciness. Despite the increase in tenderness, the shelf-life of product was greatly reduced. Lepper-Bilie et al. (2016) found that wet aged strip loins aged for 42 to 49 days had greater aged flavor, and increased in tenderness until about 21 d, but beyond that aging for longer periods of time did not affect other attributes.

Hernandez et al. (2022) took paired beef strip loins, halved them, and assigned them to aging periods and temperature treatments. After aging the steaks were cut, cooked, and analyzed by slice shear force. Steaks aged longer and at higher temperature possessed lower shear force values, however they also had higher microbial counts. It was also indicated that the traits of aging peaked at 42d of aging (Hernandez et al., 2022). Foraker et al. (2020) found similar results with regard to aging times, indicating that aging past 49d increased a sour and musty/earthy flavors while not improving the tenderness of the strip loins.

Bone-in vs Boneless

Recently, younger consumers seem to be drawn to bone-in cuts, and older consumers, who have experienced times with more bone-in products, have become more likely to choose bone-in products as well (Bass, 2018). The growing interest has found a gap in research where very few studies focus on bone-in vs boneless products. McCullough et al. (2013) found that bone-in products were overall more tender and that aging increased buttery/beef fat flavor and reduced metallic flavors at 7, 14, 21, and 28d of aging for the bone-in strip loin steaks as well as the bone-in ribeye steaks. Lepper-Blilie et al. (2016) found that there were few differences in regard to bone-in vs boneless product, but determined that bone-in product had greater WBSF values than boneless product.

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Chapter 2

THE VIABILITY OF SOUS VIDE TO IMPROVE THE PALATABILITY OF VARIOUS BEEF CUTS

ABSTRACT

The objective of this study was to determine if sous vide is a viable way to improve palatability of various beef cuts. Subprimals were selected from USDA Low Choice quality grade carcasses, wet aged at 2-4 °C in the absence of light to 21 d, then fabricated into 2.54 cm steaks representing the *Adductor* (**AD**), *Biceps femoris* (**BF**), chuckeye steak (*Longissimus thoracis, Complexus, and Spinalis dorsi*; **CHE**), *Longissimus lumborum* (**LL**), *Semimembranosus* (**SM**), *Serratus ventralis* (**SEV**), and *Triceps brachii* (**TB**). Steaks were randomly assigned in to one of two treatments, traditional grilling (**TRAD**) or sous vide cooking followed by finishing on a grill (**SVG**). A muscle × method interaction was found for overall liking with consumers ($P = 0.04$). The TRAD LL, TRAD CHE and SVG CHE were rated the highest ($P < 0.05$), this was followed by the TB also for both TRAD and SVG, however for the TB the SVG ranked higher ($P < 0.05$). The TRAD BF rated the lowest ($P < 0.05$) of all of the muscles. There were no effects on shear force between the cooking treatments ($P > 0.05$). There was no interaction between muscle × method for shear force measurements ($P = 0.859$). The LL had the lowest WBSF values ($P < 0.05$) while the BF had the highest ($P < 0.05$). The results of this study indicate that cooking method had a large impact on consumer ratings with TRAD cooking being preferred over SVG cooking. Overall, TRAD steaks had higher ratings than sous vide steaks. Muscle also had a large impact on consumer ratings. The data suggests that the steaks from muscles used more commonly by consumers had higher consumer ratings.

Key words: beef, consumers, cooking method, muscle, palatability, sous vide

INTRODUCTION

Consumers are often asked what the most important element in their beef eating experience is, and until more recently, tenderness was indicated first. Tenderness was the most important of these traits for a long time (Miller et al., 2001; Obuz et al., 2003, Naqvi et al., 2021), however advances within the industry have led to flavor becoming more important (O'Quinn et al., 2018). In addition to this, consumers have also begun to demand a very consistent, easy way to cook their steaks. This has opened many new avenues of cookery. Cooking methods such as ready-to-eat and sous vide have become increasingly popular as people are generally busier now than in the past, and these cooking forms allow for faster more efficient cooking (Biyikli, 2020).

Sous vide cooking was first introduced in the 1970s, but did not become very popular until the 1990s (Baldwin, 2012). Sous vide is French for "under vacuum" and is characterized as raw materials or raw materials with intermediate foods that are cooked under controlled conditions of temperature and time inside heat-stable vacuum sealed pouches (Schellekens, 1996). From that time on, sous vide has become vastly popular for its ability to produce a larger number of consistent, safe products at once, all while being very simple to use (Biyikli et al., 2020). Dominguez-Hernandez et al. (2018) gives a summary of over 15 studies, between the years of 1970 and 2016, that have evaluated sous vide cooking and their findings. There were clear results of more tender product as well as consensus of very uniform product. The increase in tenderness due to sous vide cooking is attributed to the degradation of collagen and myofibrillar proteins. Collagen gelatinization occurs between 58° - 64°C with extended holding times (Dominguez-Hernandez et al., 2018). Calkins et al. (2007) analyzed 39 different muscles from the round and chuck of the beef carcass and observed that muscles with more background toughness caused by connective tissue content were considered less tender. These were generally locomotive muscles. The 39 muscles were ranked for tenderness by WBSF and by consumers. Muscles such as the SEV and LL were rated more highly for tenderness by WBSF, whereas the AD, TB, and SM were rated much lower. The BF was rated the lowest of the muscles used in this study and was classified as tough. Consumers rated the LL and the SEV as tender, the AD and the SM as intermediate and the BF as tough.

Observing current research, there is no best time/temperature combination is for most food items, including steaks. Most current research focuses on a variety of time and temperature combinations to find the best grouping for a certain muscle (Mortenson et al, 2012; Vaudagna et al, 2002). Very few of these studies have more than 2 or 3 muscles, and most focus on muscles with already high tenderness ratings. There is little research on muscles with lower tenderness scores and how sous vide cooking affects their palatability. Therefore, the objective of this study was to compare traditional cooking and sous vide cooking of seven muscles ranging in tenderness scores to determine whether sous vide cooking would improve the palatability of the alternative steak cuts.

MATERIALS AND METHODS

Subprimal Collection and Steak Fabrication

Chuck rolls (Institutional Meat Purchase Specifications (IMPS) #116A; NAMP, 2010), chuck clods (IMPS #114; NAMP, 2010), chuck under blades (IMPS #116E; NAMP, 2010), beef inside rounds (IMPS #169; NAMP, 2010), outside rounds (IMPS #171B; NAMP, 2010), and strip loins (IMPS #175; NAMP, 2010) were obtained from USDA Low Choice quality grade (Small^{00}-Small^{100} marbling score) subprimals from a local retailer. Subprimals were wet aged at

2-4 °C in the absence of light for 35 d according to the pack date from the processor. Subprimals were then fabricated into 2.54 cm steaks representing the *Adductor* (**AD**), *Biceps femoris* (**BF**), chuckeye steak (*Longissimus thoracis, Complexus, and Spinalis dorsi*; **CHE**), *Longissimus lumborum* (**LL**), *Semimembranosus* (**SM**), *Serratus ventralis* (**SEV**), and *Triceps brachii* (**TB**). Steaks were randomly assigned within primals to one of two cooking treatments, traditional grilling (**TRAD**) or sous vide cooking followed by finishing on a grill (SVG), then vacuum packaged (PrimeSource Vacuum Pouches, Phoenix, AZ) and frozen at -20°C until further analysis.

Cooking Procedures

Traditional (TRAD) cooked steaks were thawed in a refrigerator overnight at 0 - 4°C, weighed to obtain a raw weight. Steaks were cooked on a clamshell (Cuisinart Griddler Deluxe, Stamford, CT) grill at 177°C until an internal temperature of 71°C was reached. Steaks were reweighed to determine cook loss.

Sous vide (SVG) cooked steaks were thawed in a refrigerator overnight at 0 – 4°C. A sous-vide water bath (APW Wyott Classic Insulated 12 × 27" Countertop Warmers X*Pert Series W-43Vi, Smithville, TN) was filled and the sous-vide water circulator (Immersion Circulator SmartVide 5, Evanston, IL) was set to 63.5°C. When the water bath reached temperature, steaks were weighed in the bag prior to submersion in the water bath. After cooking for 2 h, steaks were removed from the water bath, reweighed with the bag, then removed from the bag and cooked on a clamshell grill until an internal temperature of 71°C was reached. Steaks were reweighed for a final weight for cook loss.

Consumer Sensory Analysis

Steaks for consumer analysis were transported under refrigeration to Texas Tech University for consumer analysis.

For consumer sensory analysis, steaks were thawed as described previously, and the steaks designated for sous vide (SVG) were cooked in a circulating hot water bath at 63.5°C for approximately 2 h to medium-rare doneness (63°C). Immediately prior to serving these steaks were finished on a clamshell grill to a medium degree of doneness (71°C). Steaks designated for traditional grilling (TRAD) were cooked on a clamshell grill to a medium degree of doneness (71°C). Steaks were then all cut into steak thickness × 1 × 1 cm cubes and 2 cubes were served to each panelist. Untrained consumer panelists (*n* = 300) evaluated 7 samples for flavor, juiciness, tenderness, and overall liking on a 100-pt line scale using electronic tablets. Panelists were also asked to rate whether the steak was acceptable or unacceptable and assign quality levels to each sample.

Consumer panels were conducted using the methods previously administered at Texas Tech University (Corbin et al., 2015; Legako et al., 2015). Untrained consumer panelists (*n* = 300) were randomly recruited from the Lubbock, Texas area in groups of 20 for a total of 15 panel sessions. Panelists evaluated seven samples, for flavor, tenderness, juiciness, and overall liking on unstructured 100-point line scales using a digital ballot (Qualtrics, Provo, UT) on an electronic tablet (iPad, Apple, Inc., Cupertino, CA). Each scale was verbally anchored at each endpoint and midpoint (0 = extremely dislike/extremely tough/extremely dry; 50 = neither dislike nor like/neither tough nor tender/neither dry nor juicy; 100 = extremely like/extremely tender/extremely juicy). Additionally, each panelist was also asked to rate each trait as acceptable or unacceptable and designate each sample as unsatisfactory, everyday, better than everyday, or premium quality. Each ballot consisted of a demographics sheet, a purchasing motivators sheet, and eight sample ballots. During the panel, panelists were provided with water, apple juice, and unsalted crackers to serve as palate cleansers. Panelists were in their own individual booths.

Warner-Bratzler Shear Force

Following the cooking procedures outlined above, steaks were prepared and stored covered with plastic wrap in the refrigerator overnight at 2 – 4°C. The following day 6 1.27 cm cores were removed from each steak parallel to the muscle fiber according to the AMSA Sensory Guidelines (AMSA, 2015) and, using the Warner – Bratzler Shear Force machine (G-R Electric Manufacturing Co LLC, Manhattan, Kansas), samples were sheared once perpendicular to the muscle fibers with a v – shaped blade, kgf was determined for each of the steaks (AMSA, 2015).

Statistical analysis

Data were analyzed using SAS as a 2 × 7 factorial design of 15 replicates with cooking method, muscle, and their interaction serving as fixed effects and panel was incorporated into the model as a random effect. Acceptability data was analyzed as a binomial distribution. α was set as $P \leq 0.05$. The Kenward Rogers adjustment was used on all analyses.

RESULTS AND DISCUSSION

Consumer Demographics

Consumer demographic data is in Table 2.1. Of the 300 consumers who participated in the study, 54.7% were female and 45.3% were male. The majority of consumers were white/Caucasian (56.3%) who came from households of 2 people (27.7%). Most consumers were married (52.3%), between the ages of 20-29 years old (32%), with some college/technical school experience (34.7%), and a household income of less than $25,000 (23.7%).

When asked about their beef eating experiences, most consumers said that flavor was the most important palatability trait (46.3%), followed by tenderness (37.7%) and finally by juiciness (16.0%). The majority of consumers said they eat beef 1-5 times a week (72.7%) and prefer their steaks to a medium-rare degree of doneness (47.3%).

Consumers were also asked to rank their purchasing motivators for beef. These are shown in Table 2.2. They indicated that USDA grade, size/weight, and color were the top motivators ($P < 0.05$). These were followed with marbling, price, which were ranked similarly to size/weight and color ($P > 0.05$). Cut familiarity was ranked similar to marbling and price, as well as to eating satisfaction and nutrient content ($P > 0.05$). Nutrient content was rated similarly to welfare ($P > 0.05$), but was rated greater ($P < 0.05$) than antibiotic use, hormone use, packaging type and grass-fed claims, which were all rated similar ($P > 0.05$). Hormone use, packaging type, grass-fed claims, and natural/organic claims were all ranked similarly ($P > 0.05$). Brand and corn-fed claims were ranked the lowest ($P < 0.05$) along with natural/ organic claims, grass-fed claims, and packaging type, which were all rated similar ($P > 0.05$).

Consumer Sensory Analysis

There were no interactions for flavor, tenderness, juiciness ($P > 0.05$). There was muscle × method interaction for overall liking ($P = 0.04$, Table 2.3). The TRAD LL was rated the highest with the CHE, both TRAD and SVG ($P < 0.05$). This was followed by the TB also for both TRAD and SVG ($P < 0.05$). The TRAD SEV and TRAD AD muscles were ranked after these. Following those the SVG LL, SEV, and AD were ranked next. The TRAD SM rated lower ($P < 0.05$) than the SVG AD but higher than the SVG BF. The SEV, SM was ranked after the

SVG BF. However, the TRAD BF rated the lowest ($P < 0.05$) of all of the muscles for overall liking.

Consumers rated TRAD cooking higher than SVG cooking with regards to flavor ($P < 0.05$, Table 2.4). There were differences in regard to muscle as well for flavor ratings ($P < 0.05$). The TB, CHE and LL were rated the highest ($P < 0.05$) and were similar ($P > 0.05$). The SEV and AD were rated after the LL, but similarly ($P > 0.05$) to each other. The AD was rated similarly ($P > 0.05$) the SM, but the SM was rated lower than the SV ($P < 0.05$). The BF was rated the lowest of the muscles ($P < 0.05$), except the SEV and the SM ($P > 0.05$).

When asked about juiciness, consumers ranked TRAD over SVG ($P < 0.05$, Table 2.4). Differences were also found between the muscles ($P < 0.05$). The CHE was rated the highest for juiciness with the TB and the SEV ($P < 0.05$) and were rated similarly ($P > 0.05$) to each other. The LL was rated similar to the SEV and the TB ($P > 0.05$). Following the LL, the AD and the BF were rated next, followed by the SM which was rated similarly to the BF ($P > 0.05$), which was lower than all other muscles ($P < 0.05$).

There were differences found among the muscles for tenderness (Table 2.4). The CHE and the LL were rated the highest ($P < 0.05$). The TB was rated similarly to the LL ($P > 0.05$). The SEV and the AD were rated less than the TB and greater than the SM ($P < 0.05$), but were rated similarly to each other ($P > 0.05$). The BF was rated the least ($P < 0.05$) of the muscles, and was rated similarly to the SM ($P > 0.05$).

There were interactions between method × muscle for tenderness (P=0.018), juiciness (P=0.003), and overall acceptability (P=0.016, Table 2.5).

For overall acceptability (P=0.016), the TRAD LL was rated the highest with the SVG CHE, the TRAD CHE, and the SVG TB ($P < 0.05$), and all were ranked similar to each other (P

> 0.05). Both CHE and both TB muscles were rated similar to each other ($P > 0.05$). The TRAD CHE, SVG TB, TRAD TB, and TRAD SEV were rated similarly ($P > 0.05$). The SVG TB, TRAD TB, TRAD SEV, TRAD AD, and SVG LL were rated similarly ($P > 0.05$). The SVG SEV was rated similar to the TRAD SEV, TRAD AD, and SVG LL ($P > 0.05$). The SVG BF was rated similar to SVG SEV, the SVG AD, and the TRAD SM, but was also ranked with the lowest rated group, similar ($P > 0.05$) to the SVG AD, TRAD SM, SVG SM and the TRAD BF, which was ranked the lowest ($P < 0.05$).

There was an interaction for method × muscle for juiciness acceptability (Table 2.5). The CHE was rated the highest ($P < 0.05$) with the SVG being higher ($P < 0.05$) than the TRAD. These were ranked similarly to the SVG TB, the TRAD LL, the TRAD SEV and the TRAD TB ($P > 0.05$). The TRAD SEV, TRAD TB and the SVG SEV were rated similarly to each other ($P > 0.05$). The SVG SEV was rated similarly to the SVG LL and the TRAD AD ($P > 0.05$), but the SVG LL and the TRAD AD were not similar to the TRAD TB and TRAD SEV ($P < 0.05$). Both the SVG BF and the TRAD BF were rated next with the SVG being higher ($P < 0.05$) than the TRAD. These were ranked similar to the SVG LL and the TRAD AD ($P > 0.05$). The TRAD SM was ranked similar to both BF muscles ($P > 0.05$), and similar ($P > 0.05$) to the SVG AD, which was ranked similar to the TRAD BF ($P > 0.05$). The SVG AD and the SVG SM were ranked the lowest ($P < 0.05$). The LL and the SV were rated higher for TRAD cooking as compared to SVG cooking.

There was a muscle × method interaction for tenderness acceptability (Table 2.5). The SVG TB was rated the highest ($P < 0.05$) with the TRAD CHE, the TRAD LL, the SVG CHE, and the SVG LL. The TRAD TB was rated next and was rated similar to the SVG LL, the SVG CHE, and the TRAD LL ($P > 0.05$). The TRAD AD was rated similar to the TRAD TB and the

SVG LL ($P > 0.05$). The TRAD SEV and the SVG SEV were rated next, both were rated similarly to each other, to the TRAD AD, and to the SVG AD ($P > 0.05$). The TRAD SM was rated similarly to the SVG AD, the SVG SEV, and to the SVG BF ($P > 0.05$). The SVG SM and the TRAD BF were rated the lowest ($P < 0.05$) but were similar to the SVG BF ($P > 0.05$). There was a decrease in the percentage of steaks rated as acceptable for the TB, with the SVG TB being rated higher than the TRAD TB ($P < 0.05$).

Consumers found differences in both muscle and cooking method in regards to flavor acceptability (Table 2.6). TRAD cooked steaks were rated as acceptable more often than SVG steaks ($P < 0.05$). The TB muscle was rated the highest with ($P < 0.05$), and was rated similarly to the CHE and the LL ($P > 0.05$). These were followed by the AD which was rated similarly to the SEV and the SM ($P > 0.05$). The BF was rated the least among the muscles ($P < 0.05$), but was similar to the SEV and the SM ($P > 0.05$).

There were no interactions in eating quality for everyday quality (P=0.895) and premium quality (P=0.120, Table 2.8), but there was a method × method interaction for the unsatisfactory eating quality (Table 2.7). SVG cooked steaks were more likely ($P < 0.05$) to be rated as unsatisfactory than TRAD steaks.

While there is a vast amount of literature on cooking methods and the differences between many traditional cooking methods, there is very little literature with consumer data that shows differences between TRAD cooked steaks and SVG cooked steaks. The results of this study do confirm that consumers can tell the difference between the cooking methods and that TRAD steaks were preferred over SVG steaks.

The results of this study are fairly consistent with research on the differences in muscles. In comparison to Carmack et al. (1993), who ranked 12 different major muscles in regards to beef-flavor, tenderness, and juiciness, current results found the TB to be much higher in all traits. In current results the LL and the SEV were ranked highly for tenderness juiciness and flavor, in contrast the SEV and LL were rated low for flavor by Carmack et al. (1993). Calkins and Sullivan (2007) ranked muscles by tenderness by sensory panel and found that the LL was more tender than the TB and SEV, but agrees that these are underutilized muscles. The results of this study for the AD, SM and BF were very similar to Calkins and Sullivan (1993) with the BF being the lowest for tenderness by consumers. Nyquist et al. (2018) evaluated muscles from the chuck and round. It was observed that round muscles were generally not as well liked by consumers. The BF, SM, and AD had the lowest overall liking, tenderness, juiciness, and flavor scores, similar to the results of this study. It was also observed by the author that the SEV and the LL were rated highly by consumers. However, in contrast to the current study, Nyquist et al. (2018) observed that the SEV was more palatable than the LL, this study found that the SEV was only higher for juiciness, and the LL was greater in all other palatability traits, and it followed this trend across different quality grades (Prime, Choice, and Select).

Warner-Bratzler Shear Force

There were no interactions between muscle × method for Warner-Bratzler shear force measurements ($P = 0.397$, Table 2.9). No differences were observed in shear force in regards to cooking method ($P > 0.05$, Table 2.10).

There were differences between the muscles ($P < 0.05$, Table 2.9). The LL had the lowest WBSF ($P < 0.05$) while the BF had the highest values ($P < 0.05$). However, the SEV and SM were rated similarly ($P>0.05$) to the BF. The SM was rated similarly ($P > 0.05$) to the CHE. The CHE was rated similarly ($P>0.05$) to the AD and the TB. The AD was only rated similarly

(*P*>0.05) to the CHE and the TB. The TB was rated similarly (*P*>0.05) with the CHE, AD, and the LL. While the LL was rated similarly (*P*>0.05) only to the TB.

It is important to note that WBSF does not measure tenderness, but the kgf of force needed to shear through the muscle fibers. It is indicative of tenderness and can be used as a tool to quantify the consumer findings. The results for WBSF for this study show some differences when compared to previous research. Similar to Calkins and Sullivan (2007), the BF had the lowest WBSF, however the SEV had lower WBSF when compared to the consumer ratings as well as when compared with Calkins and Sullivan (2007). It is unclear what would have caused this distinction, however the SEV is not consistent for tenderness. In addition, the AD was ranked higher than expected and in accordance with the ranking by Calkins and Sullivan (2007), who had it ranked just above the BF and similar to the SM. Other muscles such as the SM, BF, and CHE, fell within similar ranges. Nyquist et al (2018) had similar results to the present study. The muscles of the round had the greatest WBSF values, with the SM being the greatest. Similarly, the present study found the LL to have the lowest WBSF values, but in contrast, the present study found the TB, AD, and SM to have lower WBSF values than the SEV. Nyquist et al (2018) did observe that the SEV had the most variation in fat percentage, which could explain for the variation in results. The distinctions between these muscles can be attributed to intramuscular connective tissue (IMCT) and more specifically within IMCT, collagen (Purslow, 2018). Furthermore, IMCT increases in toughness up from 50 – 60°C but then diminishes with higher temperatures (Purslow, 2018). In general, those muscles with higher collagen content had greater WBSF values.

Conclusions

The results of this study indicate that TRAD cooked steaks were generally preferred over SVG steaks by consumers. Overall, steaks that have been historically rated as tender, by consumers and objectively by WBSF, muscles outperformed muscles that have been rated as less tender, and SVG cooking did not have an effect on how well these muscles performed. However, SVG cooking has value in the number of steaks able to be cooked to a consistent temperature and not imparting any deleterious effects to steak palatability.

Table 2.1 Demographic characteristics of consumers (n=300) who participated in consumer sensory panels

Characteristic	Responses	Percentage of Consumers
Gender	Male	45.3
	Female	54.7
Household Size	1	12.0
	2	27.7
	3	16.3
	4	25.0
	5	11.7
	6	5.0
	>6	2.3
Marital Status	Married	52.3
	Single	47.7
Age	Under 20	5.0
	20-29	32.0
	30-39	20.3
	40-49	21.7
	50-59	11.3
	Over 60	9.7
Ethnic Origin	African-American	6.0
	White/Caucasian	56.3
	Hispanic	34.0
	Asian	0.3
	Other	0.0
	Mixed	2.0
	Native American	1.3
Annual Household Income	<$25,000	23.7
	$25,000-34,000	9.3
	$35,000-49,000	11.3
	$50,000-74,000	17.3
	$75,000-99,000	13.7
	$100,000-149,000	13.0
	$150,000-199,000	8.3
	>$199,000	3.3
Highest Education Level	Non-High School Graduate	6.0
	High School Graduate	18.0
	Some College/Technical School	34.7
	College Graduate	30.3
	Post-College Graduate	11.0
Beef Consumption Per Week	1 – 5	72.7
	6 – 10	20.0
	11 or more	7.0
Most Important Palatability Trait	Flavor	46.3
	Juiciness	16.0
	Tenderness	37.7
Degree of Doneness Preference	Very Rare	1.3
	Rare	4.7
	Medium-Rare	47.3
	Medium	21.3
	Medium-Well	17.0
	Well-Done	7.0
	Very Well Done	1.3

Table 2.2 Purchasing motivators[1] of consumers (n=300) who participated in consumer sensory panels

Trait	Importance
USDA Grade	70.33[a]
Size/Weight/Thickness	66.80[ab]
Color	66.05[ab]
Marbling	65.36[b]
Price	63.94[bcd]
Cut Familiarity	60.72[cde]
Eating Satisfaction Experience	59.79[ed]
Nutrient Content	56.00[ef]
Animal welfare	53.09[f]
Antibiotic Use	46.51[g]
Hormone Use	45.65[hg]
Packaging type	42.79[ghi]
Grass-fed	42.03ghi
Natural/Organic Claim	41.48[hi]
Brand	40.55[i]
Corn-fed	40.21[i]
SEM[1]	1.79
p-value	<0.0001

[1]Purchasing motivators: 0 = extremely unimportant, 100 = extremely unimportant

[2]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ

Table 2.3 Least squares means for the interaction of method × muscle for overall liking of consumer analysis[1] of seven beef muscles cooked sous-vide or traditional.

Treatment	Overall Liking
Sous vide[2]	
Adductor	47.77[de]
Biceps femoris	46.45[e]
Chuckeye Steak	66.73[a]
Longissimus lumborum	58.50[bc]
Semimembranosus	43.98[e]
Serratus ventralis	55.02[cd]
Triceps brachii	65.81[ab]
Traditional[3]	
Adductor	58.90[bc]
Biceps femoris	43.70[e]
Chuckeye Steak	67.65[a]
Longissimus lumborum	67.97[a]
Semimembranosus	47.59[e]
Serratus ventralis	58.95[bc]
Triceps brachii	61.79[abc]
SEM[4]	2.771
P-value	0.042

[1]1Sensory scores: 0 = extremely tough/dry/dislike flavor/dislike overall, 50 = neither dry nor juicy/neither tough nor tender, 100 = extremely juicy/tender/like flavor/like overall.

[2]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[3]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[4]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ.

Table 2.4 Least square means of consumer ratings of beef steaks from varying muscles cooked through two different methods.

Treatment	Flavor	Tenderness	Juiciness
Cooking method			
Sous vide[1]	53.60[b]	60.09	48.79[b]
Traditional[2]	56.74[a]	59.34	56.15[a]
SEM[3]	1.21	1.20	1.34
P-value	0.015	0.595	< 0.001
Muscle			
Adductor	53.68[bc]	44.65[c]	58.27[c]
Biceps femoris	48.48[d]	43.81[d]	43.71[cd]
Chuckeye	60.42[a]	64.61[a]	72.54[a]
Longissimus lumborum	59.46[a]	57.63[ab]	70.01[b]
Semimembranosus	49.18[cd]	37.86[d]	46.93[d]
Serratus ventralis	54.28[b]	58.50[c]	59.32[ab]
Triceps brachii	60.70[a]	60.26[b]	67.22[ab]
SEM[3]	1.89	2.32	2.69
P-value	< 0.001	< 0.001	< 0.001
Method × Muscle			
P-value	0.225	0.331	0.070

[1]Sensory scores: 0 = extremely tough/dry/dislike flavor/dislike overall, 50 = neither dry nor juicy/neither tough nor tender, 100 = extremely juicy/tender/like flavor/like overall.

[2]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[3]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[4]SEM(largest) of the least square means in the same main effect

[ab]Least squares means in the same main effect without a common superscript differ ($P < 0.05$).

Table 2.5. Interaction means for the interaction of method × muscle of the percentage of the seven muscles cooked sous-vide or traditional rated as acceptable for palatability traits

Treatment	Flavor Acceptability	Tenderness Acceptability	Juiciness Acceptability	Overall Acceptability
Sous vide[1]				
Adductor	73.29	75.22^{ef}	45.97^{fg}	68.26^{fg}
Biceps femoris	68.73	65.68^{fgh}	58.14^{de}	65.87^{fg}
Chuckeye Steak	83.80	92.29^{ab}	87.62^{a}	89.68^{ab}
Longissimus lumborum	75.69	89.67^{abc}	68.44^{cd}	79.09^{de}
Semimembranosus	65.58	63.97^{gh}	39.36^{g}	60.86^{g}
Serratus ventralis	73.13	76.30^{ef}	73.20^{bc}	73.28^{ef}
Triceps brachii	84.87	95.35^{a}	86.84^{a}	87.41^{abcd}
Traditional[2]				
Adductor	78.44	83.99^{cde}	68.08^{cd}	79.42^{de}
Biceps femoris	67.73	54.03^{h}	57.22^{def}	60.57^{g}
Chuckeye Steak	84.04	93.42^{a}	87.47^{a}	88.20^{abc}
Longissimus lumborum	89.02	92.40^{abc}	85.52^{a}	93.35^{a}
Semimembranosus	72.62	66.63^{fg}	53.53^{ef}	65.97^{fg}
Serratus ventralis	75.98	79.91^{de}	82.59^{ab}	81.02^{cde}
Triceps brachii	83.97	85.63^{bcd}	79.94^{ab}	84.08^{bcd}
SEM[3]	0.272	0.392	0.259	0.337
P-value	0.282	0.018	0.003	0.016

[1]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[2]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[3]SEM(largest) of the least square means in the same main effect

[ab]Least squares means in the same main effect without a common superscript differ ($P < 0.05$).

Table 2.6 Least squares means of percentage of seven different beef muscles cooked sous-vide or traditional rated as acceptable for flavor

Treatment	Flavor Acceptability
Cooking Method	
Sous-vide[1]	75.68[b]
Traditional[2]	79.70[a]
SEM[3]	0.105
P-value	0.036
Muscle	
Adductor	75.96[b]
Biceps femoris	68.23[c]
Chuckeye Steak	83.94[a]
Longissimus lumborum	83.40[a]
Semimembranosus	69.21[bc]
Serratus ventralis	74.58[bc]
Triceps brachii	84.43[a]
SEM[3]	0.177
P-value	<0.0001

[1]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[2]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[3]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ between main effects ($P < 0.05$)

Table 2.7 Interaction means for the interaction of method × muscle of the percentage of the seven muscles cooked sous-vide or traditional rated as unsatisfactory

Treatment	Unsatisfactory
Sous vide[1]	
Adductor	29.55[abc]
Biceps femoris	31.61[ab]
Chuckeye Steak	10.70[gh]
Longissimus lumborum	20.27[cde]
Semimembranosus	38.47[a]
Serratus ventralis	26.61[bcd]
Triceps brachii	9.60[gh]
Traditional[2]	
Adductor	17.66[defg]
Biceps femoris	33.95[ab]
Chuckeye Steak	13.65[efg]
Longissimus lumborum	6.27[h]
Semimembranosus	29.43[abc]
Serratus ventralis	19.11[def]
Triceps brachii	11.11[fgh]
SEM[3]	0.355
P-value	0.025

[1]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[2]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[3]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ.

Table 2.8 Least squares means of percentage of seven different beef muscles cooked sous-vide or traditional rated as a perceived quality level.

Treatment	Unsatisfactory	Everyday	Better than Everyday	Premium
Cooking Method				
Sous-vide[1]	22.00[a]	46.16	19.69	5.33[b]
Traditional[2]	16.89[b]	46.15	21.80	8.64[a]
SEM[3]	0.114	0.067	0.096	0.184
P-value	0.008	0.995	0.261	0.013
Muscle				
Adductor	23.07[b]	50.87[a]	18.66[cd]	4.87[bc]
Biceps femoris	32.77[a]	51.88[a]	12.77[de]	1.50[d]
Chuckeye Steak	12.10[c]	36.04[c]	35.88[a]	13.86[a]
Longissimus lumborum	11.53[c]	46.76[ab]	23.41[bc]	14.04[a]
Semimembranosus	33.80[a]	50.44[a]	9.85[e]	3.72[cd]
Serratus ventralis	22.64[b]	40.92[bc]	24.90[bc]	9.28[ab]
Triceps brachii	10.33[c]	46.62[ab]	28.66[ab]	12.04[a]
SEM[3]	0.213	0.123	0.201	0.470
P-value	< 0.0001	0.001	< 0.0001	< 0.0001

[1]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[2]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[3]SEM(largest) of the least square means in the same main effect

[ab]Least squares means in the same main effect (cooking method or quality grade) without a common superscript differ ($P < 0.05$)

Table 2.9 Least squares means of Warner Bratzler shear force measurements of different muscles (*n*=216)

Cooking method	Warner-Bratzler shear force, kgf
Sous vide[1]	3.34
Traditional [2]	3.42
SEM[3]	0.072
P-value	0.40
Muscle	
Adductor	3.21[c]
Biceps femoris	3.96[a]
Chuckeye Steak	3.26[bc]
Longissimus lumborum	2.77[d]
Semimembranosus	3.61[ab]
Serratus ventralis	3.79[ab]
Triceps brachii	3.03[cd]
SEM[3]	0.138
P-value	<0.001
Cooking method × Muscle	
SEM[3]	3.974
P-value	0.859

[1]Sous vide cooked steaks were cooked in a waterbath at 65.5°C then finished to 71°C on a clamshell grill

[2]Traditional cooked steaks were cooked to 71°C on a clamshell grill

[3]SEM(largest) of the least square means in the same main effect

[ab]Least square means within main effects without a common superscript differ ($P < 0.05$).

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Chapter 3

The Effects of Extended Aging on the Eating Quality of Bone-in and Boneless Short Loin

ABSTRACT

The objective of this study was to determine whether extended aging duration and the presence of the impacts the consumer ratings of beef short loins. Paired beef short loins (*n* = 40; IMPS #174) from the upper 2/3rd of the Choice grade (Modest^{00}-Moderate^{100} marbling score) were selected from a commercial processor and those designated for the boneless treatment were deboned into strip loins. Each subprimal was separated into thirds, and randomly assigned one of three aging periods: 21, 42, or 63 d. Following postmortem aging, all pieces were portioned into 2.54 cm steaks. Steaks were vacuum packaged and frozen at -20°C. Steaks were analyzed by consumer panels and for Warner-Bratzler shear force (**WBSF**) measurements. No interactions were observed within the consumer data. Bone in (**BI**) steaks were rated higher ($P < 0.05$) for juiciness and overall liking by consumers, but BI and boneless (**BL**) were rated similarly by consumers for tenderness and flavor ($P > 0.05$). When evaluated by consumers, aging did not have an effect on tenderness, juiciness, flavor or overall liking ($P > 0.05$). A greater percentage of BI steaks ($P<0.05$) were rated as premium quality than BL steaks. No interactions were found for WBSF measurments between treatments ($P<0.05$). Bone-in steaks were found to have higher WBSF values than BL steaks ($P<0.05$). Steaks aged for 63 d had the lowest shear force measurements, while those aged for 21 d and 42 d were rated similar. Bone-in steaks also had less cook loss than BL steaks ($P<0.05$). Steaks aged for 63 d exhibited greater cook loss ($P<0.05$) than steaks aged for 21 d and 42 d which were similar ($P>0.05$). The results of this study indicate that there is a promising future for bone-in products as it has been shown to be more tender objectively, juicier, and have better overall liking when compared to boneless

product. Consumers found no differences between the different aging periods for tenderness, however WBSF found that as aging time increased, tenderness increased as well, showing that extended aging may require further research to determine its viability.

Key words: beef, palatability, bone-in, boneless, consumers

INTRODUCTION

Meat counters in stores today have a large variety of cuts available to consumers. However, a large portion of those are boneless cuts with very little being bone-in product (Bass, 2018). Recently, younger consumers seem to be more willing to experiment with BI cuts, and in addition, older consumers, who have experienced times with more BI products, have become more likely to choose bone-in products as well (Bass, 2018). As of 2018, consumers would choose BI steaks with disregard of the price. Bass (2018) reported that a BI strip loins may be purchased at approximately $13.25 a pound, while a traditional BL strip loin costs $14.60 per pound. However, when steaks are produced of equal edible portions, 12 oz. meat weight, a boneless steak will cost $10.95 and the bone-in steak will cost $11.59 due to an extra 2 oz. of bone weight. As of 2018, consumers were more likely to choose to pay the extra for the BI steak.

Aging meat is a very well documented part of the beef industry. It is proven to increase tenderness, juiciness, and flavor by breaking down of proteins within the meat (Jeremiah and Gibson, 2003). Currently, the mean post-mortem aging period for beef is approximately 25.9 days to 31.5 days at foodservice institutions (NCBA, 2016). According the National Cattleman's Beef Association's (**NCBA**) Industry Guide for Beef Aging, most muscles, including the Longissimus dorsi, do not achieve ideal tenderness from postmortem aging until 23-30 d. Extended aging is defined as an aging period longer than industry average, typically to continually enhance and intensify flavor and tenderness (Colle et al., 2016).

This current market move towards bone – in product requires that the industry keep the same high standards for bone-in product as boneless product, and while there is immense data showing how aging affects meat, there is very little research showing the difference between bone-in and boneless meat products during the aging period. Current research, though limited, shows promise that bone-in product may increase the palatability of certain beef products (McCullough et al., 2013). In terms of objective flavor analysis, previous trained panel work has indicated beef aged bone-in produces greater aged flavor (Lepper-Blilie et al., 2016), greater beef flavor intensity, buttery/beef fat flavor, juiciness, and overall palatability (Jeremiah and Gibson, 2003; McCullough, 2013), in addition to reduced metallic off-flavors (McCullough, 2013). These flavor impacts may be caused by the influence of the bone during cooking.

However, these studies have been limited in the scope of aging, as previous studies primarily have evaluated aging periods within a window of approximately 3 to 4 weeks post-mortem (Goll et al., 1964; Jeremiah and Gibson, 2003; McCullough, 2013; Lepper-Blilie et al., 2016). McCullough (2013) observed increased buttery/beef fat flavor and reduced metallic flavors in at 7, 14, 21, and 28 d of aging in bone-in Longissimus lumborum steaks. The objective of this study was to evaluate the effects of extended aging beyond 21d on bone-in and boneless short loin steaks.

MATERIALS AND METHODS

Product collection and fabrication

Paired beef short loins (*n* = 20; IMPS #174) from the upper 2/3rd of the Choice grade, with A maturity carcasses (Modest^{00}-Moderate^{100} marbling score) were used in the study. Short loins were collected by Texas Tech University (TTU) research personnel at a commercial processing facility. During collection, the TTU research group recorded USDA marbling score, carcass lean and skeletal maturity, ribeye area, fat thickness, hot carcass weight, and the percentage of kidney, pelvic and heart fat. Following collection, short loins were transported under refrigeration (0°C - 4°C) to the UA Meat Science Laboratory for further fabrication. During fabrication, short loins designated for the boneless treatment were deboned into strip loins. Each subprimal was separated into thirds and was randomly assigned one of three aging periods: 21, 42, or 63 d. Following each postmortem aging period, all aged pieces were portioned into 2.54 cm steaks. Steaks were then vacuum packaged and frozen at -20°C until further analysis.

Cooking Procedures

Steaks were thawed overnight in a refrigerator at 0 – 4°C, and weighed prior to cooking to determine an initial raw weight. Steaks were cooked open-face on a clamshell grill (Cuisinart Griddler Deluxe, Stamford, CT) and turned every four minutes until an internal temperature of 71°C was reached. Steaks were reweighed to determine a final weight to determine cook loss.

Warner-Bratzler Shear Force

Following the cooking procedures described above, steaks (n = 210) were cooked, covered with plastic wrap, and put into refrigeration at 2- 4°C overnight. The following morning, the bones from the BI product was removed. Following the AMSA Sensory Guidelines (2015), six 1.27 cm cores were taken, parallel to the muscle fiber from each of the steaks and sheared once perpendicular to the muscle fibers using the v-shaped blade for the Warner-Bratzler shear force machine (G-R Electric Manufacturing Co LLC, Manhattan, Kansas). Peak kgf was recorded for each core and an average was calculated for each steak.

Consumer Sensory Analysis

Consumer sensory analysis was performed using methods previously used at TTU (Corbin et al., 2015; Legako et al., 2015; O'Quinn et al., 2012). Untrained consumer panelists (*n* = 100) were recruited as 20-member groups from the Lubbock, Texas area for eight total sessions. Each panelist was provided with an electronic ballot, napkin, plastic fork, toothpick, expectorant cup, and palate cleansers of water, apple juice and unsalted crackers. Ballots consisted of a demographic information sheet, purchasing motivators, and sample attribute evaluations. Panels were conducted using 100 point unstructured line scales on electronic tablets (iPad, Apple, Inc., Cupertino, CA) using electronic surveys (Qualtrics, Provo, UT). Scales were verbally anchored at each endpoint as juicy/tender/desirable or dry/tough/undesirable with a neutral term indicative of a midpoint. Additionally, each consumer was asked to rate each sample as acceptable or unacceptable for each trait evaluated and give each steak a perceived quality level of either unsatisfactory, every day, better than every day, or premium. Consumer panels were conducted as a completely randomized design with each panelist receiving one sample of each treatment (*n* = 6). Panelists evaluated each sample for flavor, juiciness, tenderness, and overall liking.

Steaks were prepared for analysis as described above. Following preparation, bone-in steaks were deboned, and all steaks were cut into steak thickness × 1 × 1 cm squares and 2 cubes were immediately served to consumers for analysis. Each steak was served to five randomly assigned panelists.

Statistical Analysis

Data were analyzed as a split-plot design using SAS, with bone-in vs boneless status serving as the whole-plot and aging time serving as the sub-plot. Our experimental unit was the steak. Aging type, period, and their interaction served as fixed effects and panel was incorporated into the model as a random effect and an average was taken of the 5 consumers. Acceptability data was analyzed as a binomial distribution. α was set as $P \leq 0.05$. The Kenward Rogers adjustment was used on all analyses.

RESULTS AND DISCUSSION

Carcass Characteristics

Carcasses used in this study were A maturity and had a marbling score of 580 (Table 3.1) The carcasses had an average preliminary yield grade (PYG) of 3.50, and adjusted PYG of 3.70. They had a ribeye area of 99.59 cm^3 and a kidney, pelvic, and heart fat percentage of 2.0.

Consumer Demographics

The demographic characteristics of the 100 consumers who participated in consumer panels are in Table 3.2. The majority of those that participated were white/Caucasian (57%) generally coming from households of 5 people (25%). There were more female participants (53%) than male participants (47%). Most of the consumers were married (52%), between the ages of 20 – 29 (31%), with household incomes between $75,000 – $99,000 (21%), and the majority of consumers also had some college/technical school experience (36%).

While eating steaks, a majority of the consumers said that flavor was the most important trait (49%). This was followed by tenderness (38%) and juiciness (13%). Most consumers indicated that they eat beef about 3 to 5 times a week (54%), and prefer a medium-rare degree of doneness (46%).

Consumers were also asked to rank their motivations for purchasing for beef (Table 3.3). They indicated that the size/weight, price, USDA grade, color and marbling were the top motivators ($P < 0.05$). These were followed by eating satisfaction, familiarity with the cut, nutrients, and welfare. Furthermore, hormone use, natural/organic claims, grass-fed, antibiotic use, packaging type, and brand were all rated higher ($P < 0.05$) than corn-fed which was ranked the least important of all the traits ($P < 0.05$).

Consumer Sensory Analysis

There were no interactions between bone × aging (Table 3.4) for consumer sensory traits. Therefore, the main effects were analyzed independently. In addition, consumers rated a similar percentage of steaks as acceptable for flavor, juiciness, tenderness and overall acceptability ($P > 0.05$, Table 3.5).

Consumers rated BI vs BL steaks similarly for both flavor ($P = 0.19$) and tenderness ($P = 0.09$, Table 3.4). We do see a slight tendency for tenderness though toward BI product. Differences were observed between BI vs BL for juiciness with BI being rated higher for juiciness than BL ($P < 0.05$), and differences were observed for overall liking with BI being rated higher than BL ($P < 0.05$). Aging times did not have an effect on tenderness, juiciness, flavor, or overall liking ($P > 0.05$, Table 3.4).

There were no interactions or main effects on the acceptability of the steaks. Over 80% of BI and BL steaks were rated as acceptable for flavor, tenderness and overall liking, while over 70% of consumers rated BI and BL steaks as acceptable for juiciness. These results are covered in Tables 3.5.

There were no interactions between bone × aging (Table 3.6) for consumer eating quality perceptions. There were no differences in eating quality with regard to BI vs BL for unsatisfactory (P=0.19), everyday ($P = 0.46$), or better than everyday ($P = 0.92$), however there were a greater percentage of BI steaks rated as premium quality compared to BI steaks. ($P < 0.05$). Aging period had no effect on the eating quality of the steaks ($P > 0.05$, Table 3.6).

The results of this study are slightly different than previous BI/BL research. McCullough et al. (2015) and Jeremiah and Gibson (2003) found BI to be more tender and juicier than BL. However, McCullough et al. (2013) had differences in flavor as well, though this likely because they used trained panels where the present study only conducted consumer sensory analysis. Similar to this study McCullough et al. (2013) also did not find any differences in aging periods between beef tenderloins, short loins, bone-in ribs, boneless strips, and boneless rib rolls, though aged for much shorter time periods of 7, 14, 21, and 28 days. Jeremiah and Gibson (2003) also found that BL steaks from beef ribs and short loins had more off flavors when aged for longer periods of time. It is likely that no off flavors were detected in the current study due to consumers not generally being trained to be able to taste for the specific off flavors. Our results from consumers help to understand whether the product is acceptable from the consumer point of view, and to see if the consumers can detect the differences between the treatments. If consumers can detect a difference, then this indicates that the treatments have an effect on the product.

Warner-Bratzler Shear Force

There were no interactions of aging type × aging period for shear force measurements (Table 3.7). Bone-in steaks had lower WBSF values than BL ($P < 0.05$; Table 3.7). There were also differences observed in aging times as well with 63 d aged steaks having the lowest WBSF values ($P < 0.05$), followed by 42 d and 21 d, having the highest WBSF values ($P < 0.05$).

The results of this current study fall in line with Jeremiah and Gibson (2003) who found that aging up to 28d resulted in lower shear force values. These results are different from McCullough et al. (2013), who aged a tenderloin, short loin, BI rib, BL strip loin and BL ribeye roll for 7, 14, 21 and 28 days and Lepper-Blilie et al. (2015) who aged strip loins and short loins for 14, 21, 28, 35, 42 and 49 days. Both studies found that WBSF was only affected by aging period and not by loin type (either BI or BL). In addition, McCullough et al (2013) stated that the trained panelists found BI steaks to be more tender than BL, this was not supported by WBSF data in that study, but McCullough et al. (2013) concluded that there was substance to the claims that BI was more tender.

Cook Loss

There were no interactions between aging type × aging period for cook loss in this study (P=0.930, Table 3.8). Bone-in steaks had less cook loss than BL steaks ($P < 0.05$; Table 3.8). Additionally, bone had an effect on cook loss (Table 3.8). 63 d aged steaks had the greatest cook loss ($P < 0.05$). Steaks aged to 42 d and 21 d were rated similarly to each other for cook loss ($P > 0.05$). Jeremiah and Gibson (2003) reported that BL strip loins had greater cooking losses than BI loins. Within that study, the product was aged up to 28 days as individual, retail-ready steaks, but did not attribute any additional cooking losses to aging.

Conclusions

The results of this study are promising for BI product, as it was juicier and had higher ranking for overall liking from a consumer perspective however, however it has greater WBSF. A slight tendency is seen for BI product from consumer tenderness ratings as well. Further aging resulted in lower WBSF values. More research is needed to confirm these results and could result in an industry shift toward BI product.

Table 3.1. Mean carcass characteristics (± standard deviation) of beef carcasses (*n* = 20).

Carcass Characteristics	Importance
Quality Attributes	
Lean maturity[1]	169.1 ± 19.87
Skeletal maturity[1]	163.2 ± 19.75
Marbling score[2]	580 ± 49.77
Yield attributes	
Preliminary yield grade	3.50 ± 0.52
Adjusted preliminary yield grade	3.70 ± 0.56
Ribeye area, cm^3	99.59 ± 7.86
Kidney, pelvic, and heart fat, %	2.0 ± 0.49

[1]100 = A, 200 = B.

[2] 500 = Modest, 600 = Moderate.

Table 3.2. Demographic characteristics of consumers (n = 100) who participated in consumer sensory panels

Characteristic	Responses	Percentage of Consumers
Gender	Male	47.0
	Female	53.0
Household Size	1	16.0
	2	18.0
	3	18.0
	4	14.0
	5	25.0
	6	7.0
	>6	0.0
Marital Status	Married	52.0
	Single	48.0
Age	Under 20	10.0
	20-29	31.0
	30-39	19.0
	40-49	19.0
	50-59	16.0
	Over 60	5.0
Ethnic Origin	African-American	0.0
	White/Caucasian	57.0
	Hispanic	34.0
	Asian	1.0
	Other	3.0
	Mixed	5.0
	Native American	0.0
Annual Household Income	<25,000	18.0
	25,000-34,000	12.0
	35,000-49,000	8.0
	50,000-74,000	14.0
	75,000-99,000	21.0
	100,000-149,000	17.0
	150,000-199,000	8.0
	>199,000	2.0
Highest Education Level	Non-High School Graduate	6.0
	High School Graduate	21.0
	Some College/Technical School	36.0
	College Graduate	27.0
	Post-College Graduate	10.0
Beef Consumption Per Week	1 – 5	68.0
	6 – 10	26.0
	11 or more	6.0
Most Important Palatability Trait	Flavor	49.0
	Juiciness	13.0
	Tenderness	38.0
Degree of Doneness Preference	Very Rare	1.0
	Rare	6.0
	Medium-Rare	46.0
	Medium	18.0
	Medium-Well	17.0
	Well-Done	8.0
	Very Well Done	4.0

Table 3.3. Purchasing motivators of consumers (*n*=100) who participated in consumer sensory panels

Trait	Importance
Size, Weight, Thickness	69.50[a]
Price	67.29[a]
USDA Grade	67.17[ab]
Color	66.93[ab]
Marbling level	64.10[abc]
Eating Satisfaction Experience	60.55[bc]
Cut Familiarity	60.15[bc]
Nutrient Content	57.97[cd]
Animal welfare	56.03[cde]
Hormones	50.25[def]
Natural/Organic claims	49.34[def]
Grass-fed	48.80[ef]
Antibiotic Use	48.05[ef]
Packaging type	43.95[f]
Brand	43.72[f]
Corn-fed	34.38[g]
SEM[1]	3.11
P-value	< 0.0001

[1]Purchasing motivators: 0 = extremely unimportant, 100 = extremely unimportant.

[2]SEM(largest) of the least square means in the same main effect.

[ab]Least square means without a common superscript differ.

Table 3.4. Least squares means of consumer sensory analysis of bone-in or boneless beef steaks aged for three different periods.

Treatment	Flavor	Tenderness	Juiciness	Overall Liking
Aging type				
Bone In	62.65	65.18	59.79[a]	64.73[a]
Boneless	60.37	61.79	53.41[b]	60.52[b]
SEM[1]	1.84	2.11	1.34	1.90
P-value	0.19	0.09	< 0.001	0.02
Aging period				
21 d	64.53	65.10	58.93	64.43
42 d	60.78	61.36	56.30	60.82
63 d	59.22	63.99	54.56	61.62
SEM[3]	2.13	2.50	2.63	2.24
P-value	0.078	0.397	0.421	0.155
Aging type × aging period				
SEM[3]	2.69	3.19	3.47	2.84
P-value	0.901	0.398	0.890	0.518

[1]Sensory scores: 0 = extremely tough/dry/dislike flavor/dislike overall, 50 = neither dry nor juicy/neither tough nor tender, 100 = extremely juicy/tender/like flavor/like overall

[2]Bone-in product had a skeletal attachment

[3]Boneless product had no skeletal attachment

[4]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ.

Table 3.5 Least squares means of percentage of bone-in or boneless beef steaks aged for three different periods rated as acceptable for palatability traits.

Treatment	Flavor Acceptability	Tenderness Acceptability	Juiciness Acceptability	Overall Acceptability
Aging type				
Bone In[1]	86.91	87.13	77.80	85.89
Boneless[2]	86.02	86.80	75.04	83.37
SEM[3]	0.204	0.176	0.172	0.188
P-value	0.755	0.905	0.439	0.402
Aging period				
21 d	89.96	85.59	77.30	87.35
42 d	83.88	82.55	75.27	83.16
63 d	84.85	89.00	76.74	83.17
SEM[3]	0.259	0.226	0.199	0.232
P-value	0.176	0.114	0.889	0.425
Aging type × period				
P-value	0.249	0.688	0.346	0.192

[1]Bone-in product had skeletal attachment
[2]Boneless product had no skeletal attachment
[3]SEM(largest) of the least square means in the same main effect
[ab]Least square means without a common superscript differ.

Table 3.6 Least squares means of percentage of bone-in or boneless beef steaks aged for three different periods rated as quality levels.

Treatment	Unsatisfactory	Everyday quality	Better than everyday quality	Premium quality
Aging type				
Bone In[1]	13.76	44.56	25.21	13.50[a]
Boneless[2]	17.76	47.64	25.57	6.79[b]
SEM[3]	0.177	0.131	0.180	0.265
P-value	0.191	0.460	0.921	0.011
Aging period				
21 d	13.49	44.62	28.20	10.78
42 d	17.88	45.34	25.58	7.47
63 d	19.97	48.34	22.59	11.03
SEM[3]	0.220	0.156	0.208	0.314
P-value	0.504	0.743	0.465	0.462
Aging type × period				
P-value	0.165	0.559	0.146	0.172

[1]Bone-in product had skeletal attachment

[2]Boneless product had no skeletal attachment

[3]SEM(largest) of the least square means in the same main effect

[ab]Least square means without a common superscript differ.

Table 3.7 Least squares means of Warner Bratzler shear force values for bone-in or boneless beef steaks aged for three different periods.

Treatment	
Bone Treatment	Warner-Bratzler shear force, kg
Bone – In[1]	3.60[a]
Boneless[2]	3.28[b]
SEM[1]	0.104
P-value	<0.0001
Aging period	
21 d	3.85[a]
48 d	3.36[b]
63 d	3.10[c]
SEM[3]	0.123
P-value	<0.0001
Aging type × period	
P-value	0.397

[1]Bone-in product had skeletal attachment
[2]Boneless product had no skeletal attachment
[3]SEM(largest) of the least square means in the same main effect
[ab]Least square means without a common superscript differ.

Table 3.8 Least squares means of cook loss for bone-in or boneless beef steaks aged for three different periods.

Treatment	
Bone Treatment	Cook loss, %
Bone – In[1]	18.57[b]
Boneless[2]	20.18[a]
SEM[3]	0.342
p-value	0.001
Aging period	
21 d	18.80[a]
48 d	19.00[a]
63 d	20.34[b]
SEM[3]	0.429
P-value	0.030
Aging type × period	
P-value	0.930

[1]Bone-in product had skeletal attachment
[2]Boneless product had no skeletal attachment
[3]SEM(largest) of the least square means in the same main effect
[ab]Least square means without a common superscript differ.

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Overall Conclusion

These studies both bring a lot of things to the industry. For the sous vide study, overall, steaks that have been historically rated as tender muscles outperformed muscles that have been rated as less tender, and SVG cooking did not have an effect on how well these muscles performed. However, SVG cooking has value in the number of steaks able to be cooked to a consistent temperature and not imparting any deleterious effects to steak palatability. In the extended aging study -the results of this study are promising for BI product. Following much of current research the current study found that BI product tends to be juicier and have a higher ranking for overall liking from a consumer perspective. However, for this study BI was ranked greater for tenderness through WBSF. More research is needed to confirm these results and could result in an industry shift toward BI product.