Effect of Cooking Method and Quality Grade on the Juiciness, Tenderness, and Flavor of Beef Strip Loin Steaks

by

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ABSTRACT

The objective of this study was to evaluate possible differences in consumer perception and objective evaluations of tenderness, juiciness, and flavor, in strip loin steaks cooked on different cooking methods. Consumer sensory analysis (n=288) and objective measures, including cooking loss, slice shear force (SSF), and pressed juice percentage (PJP) were performed to evaluate the effects of four different dry cooking methods [electric clamshell grill (CLAM), flat-top gas grill (FLAT), charbroiler gas grill (CHAR), and salamander gas broiler (SAL)] and four USDA quality grades [Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select)] on the palatability of beef strip loin steaks. To accomplish this, beef strip loins (IMPS # 180, NAMP, 2011), were collected from carcasses representing four USDA quality grades included: Prime, upper 2/3 Choice (Top Choice), lower 1/3 Choice (Low Choice), and Select (n = 12 / quality grade). After aging (21 d), strip loins were cut into 2.5-cm thick steaks and frozen (-20°C) prior to subsequent analyses. Proximal composition determination of pH, fat, moisture, and protein content were performed for each strip loin. Steaks for sensory and objective analyses were cooked on four different dry cooking methods targeting to a medium degree of doneness (70-72°C). No main effects or interactions influenced (P > 0.05) slice shear force (SSF) and press juiciness percentage (PJP). The cooking method with the lowest cooking loss was CLAM, (P > 0.05), whereas FLAT, SAL, and CHAR did not differ from each other. Cooking method and quality grade had an effect (P < 0.01) on tenderness, juiciness, flavor liking and overall liking when evaluated by consumer panel. Steaks cooked on CHAR had greater (P < 0.05) flavor liking and subsequently greater overall liking than any other cook method. FLAT steaks were scored lower for tenderness and juiciness than any other cook method ($P < 0.05$), whereas steaks cooked on CLAM had lower ($P < 0.05$) flavor liking scores than any other cook method, excluding FLAT. Overall acceptance was greater ($P < 0.05$) for steaks cooked on CHAR compared to all other cook methods, while steaks cooked on FLAT had lower ($P < 0.05$) overall acceptance, but FLAT were not different ($P > 0.05$) from CLAM. Related to quality grade, Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking ($P < 0.05$), but Prime did not differ from scores for Top choice. These results indicate that different dry cooking methods and USDA quality grade have an effect on beef consumer perception.

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CHAPTER I

INTRODUCTION

Cooking impacts basic traits related to consumer preferences such as flavor, tenderness, color and appearance (Domínguez et al., 2014; Lorenzen et al., 1999; Modzelewska-Kapituła et al., 2012; Pathare and Roskilly, 2016). Biochemical and physical changes occur during the heating process and these changes affect the microbiological quality and sensory characteristics (Barbera and Tassone, 2006; Boles and Swan, 2002; Pathare and Roskilly, 2016). Different cooking methods have several types of heat transfer and heat conditions influencing the tenderness, juiciness and flavor liking (Tornberg, 2005).

The tenderness in meat changes during cooking due to the transformation of connective tissue and myofibrillar proteins. When heating in the presence of water, collagen dissolves, while myofibrillar proteins denature, which causes increased tenderness (Bejerholm et al, 2014 and Bertram et al., 2004). Cooking induces structural changes like the transversal shrinkage of the fibers, which decreases the water-holding capacity and changes the water distribution of the meat (Tornberg, 2005). The cooking loss is strongly associated with fiber shrinkage (Bertram et al., 2004). It is reported that beef juiciness and cooking loss are negatively correlated, implying that a high cooking loss results in low juiciness (Tornberg, 2005; Toscas et al., 1999). During cooking, the core temperature of the meat increases from around 0°C up to as much as 85°C. The surface temperature of the meat can be very high (up to 300°C), depending on the cooking method (Tornberg, 2005).

The cooking method should be chosen according to the type of meat, the amount of connective tissue, and the shape and size of the sample (Bejerholm et al., 2014). Dry cooking methods, such as broiling, frying, and grilling are more suitable for meat from young animals with low collagen content (Maltin et al., 2003). Differences in heat transfer or thermal process can produce differences in fiber shrinkage; undesirable or increased changes in fiber shrinkage may be perceived by the consumers as an indicator of low quality meat (Barbera and Tassone, 2006).

Cooking meat using a clamshell grill has become common during university research and at institutions, serving as an alternative to the belt grill because it is faster, less expensive, and has acceptable repeatability (Mckenna et al., 2004a). Charbroiling has also become a popular method in the hotel and restaurant industry (Yancey et al., 2011). Lorenzen et al. (1999) and McKenna et al. (2004b) both found that consumers cook steaks on outdoor grill (charbroiling) over 40% of the time and use broiling and indoor grills over 13% of the time. Nevertheless, very little research has focused on the evaluation of possible differences of different dry cooking methods on beef palatability.

Increased marbling (intramuscular fat) level and USDA quality grade have been shown to be highly associated with beef eating quality (O'Quinn et al., 2012; Savell et al., 1978; Smith et al., 1982). Marbling has a very positive effect on the eating quality of some muscles, but it is only one of the many factors affecting eating quality. Other aspects such as cooking method (Lorenzen et al., 1999; McKenna et al., 2004b; Obuz et al., 2003), postmortem aging (Voges et al., 2007; Wheeler et al., 1999), muscle (Hunt et al., 2014; Modzelewska-Kapituła et al., 2012), and degree of doneness (Lorenzen et al., 1999; Lucherk et al., 2016) may also influence palatability.

The purpose of this study was to evaluate possible differences in consumer perception of palatability and objective measures of tenderness and juiciness of strip loin steaks representing four USDA quality grades cooked using four different dry cooking methods.

CHAPTER II

LITERATURE REVIEW

2.1 Beef palatability

The attributes that determine beef palatability are tenderness, juiciness, and flavor. Several Beef Consumer Satisfaction Studies have shown tenderness as major and contributing factor to consumers' perception of palatability (Kolle et al., 2004; Obuz et al., 2003; Savell et al., 1987; Smith et al., 1982; Voges et al., 2007). As a result, much industry research over the past 25 years has focused on tenderness improvement. Results of the most recent Beef Tenderness survey showed that over 95% of beef from the rib and loin in foodservice and at the retail level were classified as tender or very tender (Martinez et al., 2017). With such a large portion of the retail beef supply classified as tender, the importance of juiciness and flavor to the consumer eating experience is magnified. Numerous recent studies have evaluated the contribution and importance of flavor to beef palatability (Domínguez et al., 2014; Fruet et al., 2018; Kerth, 2016; Legako et al., 2015; Legako et al., 2016; Puangsombat et al., 2012). However, studies evaluating the contribution of juiciness to beef palatability are limited.

Several studies have shown that tenderness is a desirable quality; tender meat is softer, easier to chew, and generally more palatable than harder meat (Dikeman, 1987; Miller et al., 1995; Savell et al., 1987). Beef flavor is a combination of taste and aroma. Taste is a sensation related to the tongue, whereas aroma is a sensation of volatile compounds related to the epithelia of the nose (Cerny and Grosch, 1992; Donald, 1998). Juiciness has been attributed to the flow of juices from the actual meat and the moisture produced by saliva in the mouth during mastication (Gullett et al., 1984). Increased marbling (intramuscular fat) level and reduced animal age are highly associated with beef eating quality, and both characteristics are included in the USDA carcass classification system (USDA, 1997). Other factors also have an effect on beef palatability like postmortem proteolysis or aging (Mehaffey et al., 2009; Watanabe et al., 2015; Wheeler et al., 1999), muscle (Fabre et al., 2018; Hunt et al., 2014; Legako et al., 2015), degree of doneness (Lorenzen et al., 1999; Lucherk et al., 2016), and cooking method (Broncano et al., 2009; Jeremiah and Gibson, 2003; McKenna et al., 2004b; Obuz et al., 2003).

2.2 Changes in meat during heating

Cooking of meat products is essential to achieve a palatable and safe product (Tornberg, 2005). Biochemical and physical changes occur during the heating process and these changes affect the microbiological quality and sensory characteristics. Furthermore, the heating of meat results in better digestibility and, to some extent, in a change of the nutritive value (Barbera and Tassone, 2006; Boles and Swan, 2002). The cooking method should be chosen based on the type of meat, the amount of connective tissue, and the shape and size of the sample (Bejerholm et al., 2014). During cooking, the core temperature of the meat increases from around 0°C up to as much as 85°C. The surface temperature of the meat can be very high (up to 300°C), depending on the cooking method. The increase in temperature results in a tremendous change in both the structure and the water distribution in the meat. Water will be lost as a cooking loss, fat will melt and drip out, and the texture and flavor will change (Pathare and Roskilly, 2016). Bejerholm et al. (2014) describe that the cooking loss starts to develop around 40°C. In meat with low pH (below 5.4 for pork), cooking loss begins as low as 30°C. The rate of cooking loss is greatest between 50°C and 70°C, after which it decreases again (Figure 1). These changes in cooking loss can be explained by the changes in the meat structure. In a nuclear magnetic resonance study, a shift in the water populations was seen at 46°C; the water within the myofibrils diminished, but the water in the intermyofibrillar space increased (Bejerholm et al., 2014).

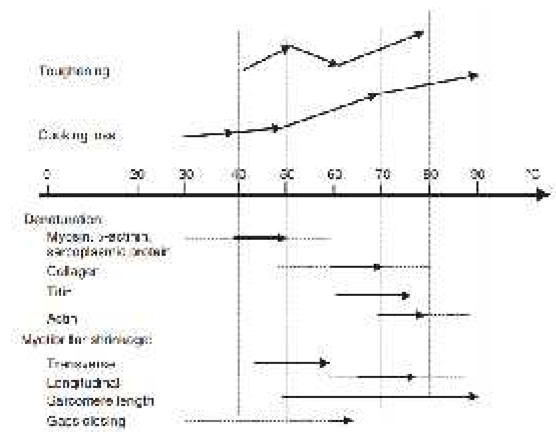

Figure 1. Changes in meat during heating (Laakkonen, 1973).

Tornberg (2005) described the consecutive changes in meat proteins during cooking in the following way: the sarcoplasmic proteins, including α-actinin and myosin, begin to denature in the temperature interval from 40 to 50°C, and a transverse shrinkage of the myofibrils begins at 45°C. This can explain the change in water distribution and the initiation of the cooking loss. In the temperature interval from 50 to 60°C, the rate of cooking loss is largest, sarcomere length decreases and collagen starts to denature. At 60°C, the gaps between the fibers are closed and a parallel shrinkage of the myofibrils begins. This might be due to water expulsion from the meat matrix with a high concentration of proteins. The decreasing sarcomere length and the shrinkage of the myofibrils continue with further heating, and it is not well understood why the rate of cooking loss decreases. Myoglobin begins to denature around 60°C. The denaturation of myoglobin is responsible for the change in color from a raw meat appearance to a cooked meat appearance. The maximum denaturation of myoglobin pigment occurs in the range 60–67°C. The heat-induced color change of the meat also depends on the oxidative status of the myoglobin before cooking (Tornberg, 2005).

Bejerholm et al. (2014) explained that in general, the denaturation of myosin and actin results in toughening of the meat. In a model system, the toughness of a whole muscle increases up to 50°C, followed by a decrease to approximately 60°C; however, when the temperature rises further , the meat becomes tougher again (Figure 1). The first rise in toughness can be explained by the denaturation of myosin. The decrease in toughness between 50 and 60°C is most likely due to a partial denaturation and shrinkage of the collagen fibers in the intramuscular connective tissue. From 60°C, the cytoskeletal protein titin begins to denature and later, at 70–80°C, actin also denatures, which can explain the second increase in toughening. At high temperatures, above 75°C, the collagen reaches a soluble gelatinized state. In muscles rich in connective tissue, softening of the texture is, therefore, seen at very high core temperatures. Collagen can also be solubilized at a lower temperature when given enough time and can be aided by moist heat cooking (Bejerholm et al., 2014).

Cooking methods use one or more ways to transfer heat (conduction, convection or radiation), which may result in the heterogeneous heat treatment of the product due to steep temperature gradients (Pathare and Roskilly, 2016: Tornberg, 2005;). The different cooking methods also use different media for heat transfer, such as dry heat methods (oven, roasting, broiling or pan frying), moist heating methods (boiling or braising), or microwave cooking (electromagnetic energy). Sometimes a combination of dry and moist heat methods are used (Bejerholm et al., 2014).

Bejerholm et al. (2014) explained that the rate of heating depends on the coefficient of conductivity in meat and the surface temperature of the meat. The surface temperature of meat is affected by the temperature of the heating source (e.g., oven temperature) as well as the air circulation and the relative humidity. Increasing air circulation improves heat conduction and increases the evaporation from the surface of the meat, whereas high humidity improves heat conduction but reduces evaporation. The heat absorbed in meat causes a temperature increase by heat conduction through meat from the surface to the center. The rate of temperature increase in meat is different at different depths of a meat cut (roast). Cooking to a certain core temperature in the center of roasts produces meat with layers of different degrees of doneness, depending on the heating method and temperature. A low heating temperature (<100°C) yields a more homogeneous appearance and less distinct layers of doneness compared with traditional oven roasting at 160–200°C (Bejerholm et al., 2014).

2.3 Cooking methods used for cooking meat

Different cooking methods have different cooking conditions (Jeremiah and Gibson, 2003). Three main factors differ among the various cooking techniques: the temperature at the surface of the meat, the temperature profile throughout the meat, and the method of heat transfer e.g. contact, air, water, steam, or microwaves (Pathare and Roskilly, 2016). Cooking meat often involves more than one type of heat transfer. Below, there is a compilation of characteristics of different cooking methods and their influences on the product.

- Oven roasting: Jeremiah and Gibson (2003) described the cooking condition during oven roasting. Most of the heat is transmitted to meat by normal or forced air convection (high-velocity air) in a closed oven, often preheated. Large meat pieces are placed on a rack in a roasting pan for even circulation of heat around meat. Oven roasting can apply the temperature in two different ways: a constant oven cooking temperature at approximately 150–160°C or roasting at a high temperature of up to 250°C followed by a lower temperature of approximately 150°C until the required core temperature is obtained. High temperatures can cause a high surface dehydration. Reduction in dehydration can be accomplished by forced air convection or the use of air/steam mixtures. High cooking temperatures enhance color and flavor and lessen the cooking times: however, these high cooking temperatures diminish meat tenderness and juiciness. On the other hand, low temperature and high relative humidity build the heat transfer and meat juiciness yet diminish flavor and color development (Pathare and Roskilly, 2016). Likewise, dry heat cookery produced meat with a lower apparent degree of doneness, and moist heat cookery in an oven film bag or slow cooker, required less time and produced products which appeared more well done than oven roasting (Jeremiah and Gibson, 2003).

- Pan-Broiling/Pan-frying: Bejerholm et al. (2014) make a general description of this two cooking methods, pan broiling and pan frying are methods by which usually small, thin cuts, such as chops, steaks, or patties, are cooked by direct heat conduction. Meat is placed in a preheated, uncovered frying pan and cooked with or without added fat. The meat should be turned frequently. In broiling, most of the heat is transmitted by conduction (by the contact) between the pan and the meat, whereas, in frying, there is conduction and convection. Moreover, more heat could be transferred between the oil and the meat due to the change from natural convection to forced convection because of turbulence in the oil (Bejerholm et al., 2014). Frying is a complex process due to coupled heat and mass transfer between meat and frying medium. Simultaneous heat and mass transfer of oil and air promote a number of chemical changes, such as moisture loss, oil uptake, crust formation, gelatinization of starch, aromatization, protein denaturation and color change via Maillard reactions, hydrolysis or oxidation, and oil polymerization. (USDA 2008).This is a method commonly used by consumers, but that quick method is not recommended for meat with high connective tissue content because the tenderizing effect of converting collagen into gelatin cannot be accomplished (Pathare and Roskilly, 2016).

- Braising/Casseroling: These are moist cooking methods that are mainly used for meat with a high content of connective tissue where maximum tenderization is required. The meat is often pre-browned and then placed in a covered pan to which some liquid, often a small amount of water, is added. The meat is cooked slowly in the moist atmosphere, and the maximum temperature reached is not higher than 100°C (Bejerholm et al., 2014).

- Microwave cooking: Jouquand et al. (2015) described this method as faster than other conventional methods with energy consumption that is often lower. The catering industry and households use microwave ovens mainly for defrosting and for reheating prepared products. The principle of microwave cooking is the conversion of electromagnetic energy into thermal energy within the meat. During cooking, microwave energy is absorbed by rotation of water molecules and translation of ionic components in meat; the water content and the dissolved ion content are, therefore, important factors. However, it is important to mention some drawbacks that occur during microwave cooking, like non-uniformity of heating (that creates uneven temperatures in the product), lack of browning (attributed to the low formation of Maillard reaction products owing to the relatively low meat surface temperature and the low temperature of the surrounding air) and undesired textural changes. This method is not recommended for meat with a high content of connective tissue because the tenderizing effect of converting collagen into gelatin is not achievable within the short cooking time (Jouquand et al., 2015).

Sous Vide Cooking: This method was introduced in the 1970s. It is defined as the method of heating raw meat packed inside a vacuum pouch in a water bath at a low temperature (Botinestean et al., 2016). The lower temperature minimizes the temperature gradient and reduces the damage to heat sensitive proteins and compounds. It also reduces cooking loss and preserves the juiciness. The low temperature in sous vide cooking has a positive effect on meat tenderness and also results in a controlled and uniform doneness of the meat, and the extended cooking time increases collagen solubility (Pathare and Roskilly, 2016).

2.4 Effects of cooking methods on beef palatability characteristics

Several studies have examined the effects of different cooking methods and/or cooking conditions on meat palatability characteristics (Chiavaro et al., 2009; Chumngoen et al., 2018; García-Segovia et al., 2007; James and Calkins, 2008; Jeremiah and Gibson, 2003; Lawrence et al., 2001; Lorenzen et al., 1999; McKenna et al., 2004; Modzelewska-Kapituła et al., 2012; Mora et al., 2011; Obuz et al., 2003; Trevisan et al., 2016; Vittadini et al., 2005; Wyrwisz et al., 2012; Yusnaini et al., 2015). Nevertheless, a clear summary or comparison about the effect of all cooking method on consumer palatability was not found, probably due to the great number of cooking methods and cooking condition that are used around the word. The general effect of cooking on consumer quality trails and results from some cooking methods comparison are presented above.

Cooking methods effect on tenderness

Changes in the texture of meat during cooking are due to heat-induced structural changes combined with the enzymatic breakdown of proteins (Lawrie, 1998). Cooking conditions as time/temperature on the heating source and the core temperature have an effect on tenderness, but the magnitude of those effects depend on the composition of meat (Modzelewska-Kapituła et al., 2012). The *biceps femoris* (BF, outer hind leg muscle) has a high content of connective tissue. It benefits more in tenderness when heated slowly than the *longissimus dorsi*, which is low in connective tissue (Jeremiah and Gibson, 2003).

Effect of cooking method on consumer tenderness perception has been reported by Lorenzen et al. (1999), who evaluated five different cooking methods, in four cities of the USA, cooked at different degrees of doneness. For Low-Choice steaks, the higher score was presented by the indoor grill, no presenting statistical differences with the pan-fry steaks, and this bout presented statistical differences with the outdoor grill and broiled steaks. For Low-Select steaks the higher score were obtained by the pan-fry steaks, presenting no statistical differences with the outdoor grill, but presenting statistical differences with the broiled and indoor grilled steaks. No statistical differences in tenderness evaluation were detected between cooking method for Top-Choice and High-Select steaks. Jeremiah and Gibson, (2003) evaluated the influence two different oven cooking procedures (low-temperature dry heat vs moist heat with a dry heat finish) on beef round muscles with a 6-member trained sensory panel. Higher overall tenderness score was obtained by the eye of round cooked in low temperature and dry heat oven compared to the moist heat with a dry finish (5.39 vs 5.00 respectively). However, no significant difference for initial tenderness or overall tenderness score were observed for the other four muscles. Chumngoen et al. (2018) also evaluate the effect of water cooking (moist) and oven cooking (dry) on quality characteristics of chicken. Descriptive sensory analysis revealed that water cooking meat exhibited a significantly lower initial hardness and chewdown hardness. Conversely, no effect of cooking method on tenderness evaluated with trained panel, also have been reported by other researchers; James and Calkins (2008) evaluated the effect of two different cooking speeds; fast (grill at 249-260°C) and slow cooking (grill at 149-160°C) and two different holding times (0 and 1 hour at 65°C) on the tenderness from seven beef muscles (*teres major, vastus intermedius, vastus medialis infraspinatus, triceps brachii, rectus femoris, and vastus lateralis*). Statistical differences in tenderness evaluation between muscles were found, but statistical differences were not found in the bout, between the two cooking speeds needier between the two holding times.

Differences in objective tenderness were reported by several authors. McKenna et al. (2003) evaluated the effect of the clamshell grill at high temperature vs electric broiler on WBSF and the repeatability of this measures of beef muscles strip loins. Electric broiler presented lower values for WBSF compared to the clamshell (4.60 vs 4.84 kg). However clamshell presented higher repeatability compared to the electric broiler (0.86 vs 0.41). As a conclusion, these authors suggest that clamshell cookers provide a highly repeatable, rapid cooking method that fits within the budgets of most institutions conducting meat tenderness research. Lawrence et al. (2001) evaluated five muscles from USDA select carcasses cooked on an electric belt grill at three temperatures (93, 117, and 163°C), in a forced-air convection oven and on an electric broiler. Neither *longissimus lumborum* nor *semitendinosus* WBSF values differed among the five cooking treatments. When evaluating the other muscles, the cooking method had an effect but differences were not consistent across methods. For *biceps femoris,* there was a higher value of WBSF for samples from the belt grill cooked at 163°C whereas the values from the other four cooking methods did not differ. For *deep pectoralis,* the higher values of WBSF was presented by the samples cooked on the electric broiler, the second higher value was presented by samples cooked on the belt grill cooked at 163°C, and the other cooking methods did not differ. For the *gluteus medius* the higher values of WBSF was presented by the samples cooked in the forced air convection oven and the values from the other four cooking methods did not differ. Belt grill cooking resulted in the highest shear force repeatability (R=0.70 to 0.89) for the *longissimus lumborum*. Wyrwisz et al.

(2012) evaluated the effect of three different cooking methods on the quality characteristics of five different beef muscles for l*ongissimus lumborum*, grilling had the lowest WBSF (18 N), compared to frying or roasting at 180ºC (WBSF of 31 N and 29 N, respectively). Similar trends were observed for the *psoas major*. Additionally, there were statistical differences between the three cooking methods when the muscle was the *semitendinosus*, with WBSF values of 24 N, 28 N, 40 N for grilling, frying, and roasting, respectively. Obuz et al. (2003) evaluated water bath cooking vs belt grill in addition to different holding times and holding temperatures on WBSF of beef *longissimus lumborum* and *bicep femoris*. These researchers reported lower WBSF for the *longissimus lumborum* cooked on the belt grill; however, they also reported that *bicep femoris* tenderness improved with increased holding time after cooking due to its higher collagen content. Yancey et al., 2011 also evaluate the effect of five different cooking methods (convection oven, impigment oven, electric griddles, char-grill, and clamshell) at three different end point temperatures on cooking quality characteristics of select beef ribeye rolls steaks. There was no cooking method by en point temperature interaction for WBSF. Convection oven presented the lower WBSF values, been no statistical different from the impingement oven but presenting statistical difference with the char-grill, electric griddles and clamshell. Electric griddles presented the highest WBSF repeatability at medium degree of doneness (R=0.75). Modzelewska-kapitula et al. (2012) evaluate the effect of two cooking conditions; dry air (180°) and steam(120°C) and three final internal temperature (75, 85, 95 °C), using beef *infraspinatus* and *semimembranosus* muscles. *Infraspinatus* muscle significantly reduces the WBSF at the steam oven when the final internal temperature change from 75 to 95°C (47.7 to 29.4 N).

No statistical change in WBSF for the three temperatures was observed in the dry air oven. For the *semimembranosus*, increased toughness was observed when the temperature change at the dry air oven from 75 to 95°C (43.4 to 66.7 N) whereas no statistical differences in WBSF was observed for samples from the steam oven.

No statistical differences in objective tenderness also have been reported by several authors; Garcia-Segovia et al. (2007) evaluated the effect of three cooking treatment (atmospheric pressure, sous-vide, and cook-vide), at three temperatures (60, 70 and 80°C), at cooking times of 15, 30, 45 and 60 min, on mechanical properties of beef *pectoralis* muscle. No statistical differences for WBSF were observed between the different cooking methods and the different holding times. However, the increase in toughness was observed when cooking temperature increase from 60 to 80°C. Shackelford et al. (1999) evaluated four cooking condition, represented by two different speeds on a belt grill; very rapid (260°C and cook time: 4.3 min) and rapid (163°C and cook time: 5.7 min), combined with two resting times; hot (2 minutes after cooking) and cold (24 h after coking stored at 4°C) on slice shear force (SSF) values of beef ribeye roll steaks. No statistical differences in SSF were observed between the four combinations cooking speed and resting time with mean values from 16.3 to 17.3 kg. Vittadini et al. (2005) evaluate the effect of three different cooking methods (natural convection, forced convection, and forced convection/steam combined), on physical properties of cooked pork *longissimus dorsi*. No statistical difference in WBSF was observed for pork samples from the 3 different cooking methods with mean values from 116.2 to 125.1 N.

Cooking method effect on flavor

Meat aroma develops from the interactions of non-volatile precursors, including free amino acids, peptides, reducing sugars, vitamins, nucleotides and unsaturated fatty acids, during cooking (Cerny and Grosch, 1992; Donald, 1998; Farmer and Patterson, 1991). Amino acids and reducing sugars react when heated above 110 ºC; this thermally induced reaction is called the Maillard reaction and is important in developing meat flavor (Bejerholm et al., 2014; Farmer and Patterson, 1991). The Maillard reaction is influenced by the method of heat transfer. Dry heat methods, especially panfrying, increase the amount of Maillard reaction and moist heat methods prevent the reactions from taking place (Shahidi et al., 2014). Dry heat cooking methods such as frying and grilling may increase Maillard reaction products by 10 times compared to broiling (Trevisan et al., 2016). A similar effect is achieved using roasting bags when cooking meat in an oven. In addition to the Maillard reaction, lipid degradation products are responsible for developing meat flavor during heating. The lipid degradation reactions take place at a much lower temperature than the Maillard reaction and the flavoring compounds can, therefore, be produced not only on the surface of meat but throughout the meat (Bejerholm et al., 2014). Lipid-derived flavor compounds are very important for the meaty flavor and are said to be responsible for the species-specific flavor (Bejerholm et al., 2014). One adverse effect resulting from thermal treatment is lipid oxidation, a major reason for the deterioration of meat, giving undesirable odors, rancidity, texture modification, and loss of essential fatty acids or toxic compound production. When different cooking methods were compared, roasting, which uses high temperatures for a long time, produced increased lipid oxidation compared to other methods (Domínguez et al., 2014). In a study made by Lorenzen et al. (1999) they evaluated the consumer's flavor perception of steaks from different quality grades cooked with different cooking methods. For Low-Choice steaks, the higher score was presented by the indoor grill, no presenting statistical differences with the pan-fry steaks, however, indoor grill presented statistical differences with the outdoor grill and broiled steaks. For High-Select steaks from the outdoor grill and the pan-fry obtained the higher scores and this two were statistically differed from the broiler and indoor grill. For Low-Select steaks the higher score was obtained by the pan-fry steaks, presenting no statistical differences with the outdoor and indoor grill but presenting statistical differences with the broiled. No statistical differences in flavor scores were detected between cooking method for Top-Choice steaks. Nevertheless, no differences in flavor using a trained panel also have been reported. Jeremiah and Gibson, (2003) evaluated the influence two different oven cooking procedures (low temperature dry heat vs moist heat with a dry heat finish) on beef round muscles with a 6-member trained sensory panel. For flavor intensity, flavor desirability, and overall palatability, there were no statistical differences between the dry heat and moist heat for the other five muscles. James and Calkins (2008) evaluated the effect of two different cooking speeds; fast (grill at 249-260°C) and slow cooking (grill at 149-160°C) and two different holding times (0 and 1 hour at 65°C) on the flavor from seven beef muscles. Statistical differences in flavor evaluation between muscles were found, but statistical differences for liver-like, metallic, oxidized, rancid, and fatty flavors were not found comparing the two cooking speeds and holding times.

Cooking method effect on juiciness

Cooking induces structural changes, which decreases the water-holding capacity of the meat (Offer, 1984). Cooking procedure and raw meat quality have an effect on the juiciness of the meat. However, the only reliable and consistent measure of juiciness is accomplished using sensory methods (Winger and Hagyard, 1994). The complexity of juiciness also causes difficulties in performing objective measurements (Pathare and Roskilly, 2016). The core temperature greatly affects the juiciness of the meat. An increase in the core temperature reduces the juiciness. Low oven temperature will produce juicier meat contrasted with meat cooked at a higher oven temperature with the same core temperature (Bejerholm et al., 2014). In beef cooking, juiciness and cooking loss are negatively correlated, implying that a higher cooking loss results in lower juiciness (Tornberg, 2005; Toscas et al., 1999). Effect of different cooking methods on juiciness has been evaluated by several authors. Lorenzen et al. (1999) evaluated the consumer's perception of strip lion steaks cooked with different cooking methods, from different quality grades, cooked at three different degrees of doneness. For the medium degree of doneness, indoor grill obtained the lower juiciness scores. No statistical differences for juiciness perception at the medium degree of doneness were detected for the pan fry, outdoor grill, and broil. Modzelewska-Kapitula et al. (2012) reported differences in juiciness, evaluated for a trained panel, of two different beef muscles cooked using two different oven steam conditions. For beef *semimembranosus* muscle, higher values of juiciness were reported for the steam cooking condition compared to the dry air condition; in this study, no differences in juiciness for *infraspinatus* muscle was reported. James and Calkins (2008) evaluated the effect of two different cooking speeds;

fast (grill at 249-260°C) and slow cooking (grill at 149-160°C) and two different holding times (0 and 1 hour at 65°C) on the juiciness evaluated by trained panel for seven beef muscles. The higher score for juiciness was obtained by the combination fast speed of cooking and zero hours of holding time, no presenting statistical difference with the slow speed and zero holding time. These bout, were different with the juiciness score for slow cooking and one-hour holding and the lower score was obtained by the fast cooking and one-hour holding time.

On the other hand, no statistical differences in juiciness also have been reported. Jeremiah and Gibson, (2003) evaluated the influence two different oven cooking procedures (low-temperature dry heat vs moist heat with a dry heat finish) on beef round muscles with a 6-member trained sensory panel. No significant difference in juiciness score was detected for all the five beef round muscles evaluated.

Cooking method effect on cooking loss

Meat cooking losses are usually between 20 – 40 % (Aaslyng et al., 2003; Davey and Gilbert, 1974; García-Segovia et al., 2007; Martens et al., 1982). The cooking loss is strongly associated with fiber shrinkage (Bertram et al., 2004). The review made by Tornberg (2005), summarizes the structural changes during cooking than may affect cooking loss and juiciness. When the transverse shrinkage of the fiber axis occurs, mainly at 40–60°C, this widens the gap already present at rigor between the fibers and their surrounding endomysium. At 60–70°C, the connective tissue network and the muscle fibers cooperatively shrink longitudinally, the extent of shrinkage increasing with temperature. This shrinkage causes the great water loss that is obtained during cooking (Tornberg, 2005). In general, cooking loss increases as core temperature increases, but the actual amount of cooking loss also depends on the cooking method and the amount of connective tissue in meat (Bejerholm et al., 2014). Cooking methods with a very short cooking time, such as panfrying, result in a lower cooking loss than conventional oven cooking methods at the same core temperature (Tornberg, 2005). The correlation between cooking time and cooking loss is not linear, as the cooking loss is determined by a combination of cooking time and heating rate. Low-temperature cooking results in lower cooking loss compared with cooking at conventional temperatures (Bejerholm et al., 2014).

Differences in cooking loss evaluating different cooking methods have been reported by several authors. In a paper published by McKenna et al. (2003) evaluated the effect of the clamshell grill at three different temperatures and the electric broiler on cooking loss of beef strip loin steaks. The higher cooking loss was presented by the electric broiler (30.3%), and the lower cooking losses were presented by the clam shell at low and medium temperature (20.7 and 21.1%). Vittadini et al., (2005), *longissimus dorsi* pork samples were cooked using different oven conditions. Cooking loss was similar between the natural convection oven (26.0%) and the forced convection oven (26.2), but those two oven methods had a lower cooking loss than the forced convection/steam combined oven (30.0%). James and Calkins (2008) evaluated the effect of two different cooking speeds; fast (grill at 249-260°C) and slow cooking (grill at 149-160°C) and two different holding times (0 and 1 hour at 65°C) on seven beef muscles. Fast cooking presented statistically lower cooking loss compared to the slow cooking speed, at the same time zero hours holding time present lower cooking loss compared to one hour holding time. Lawrence et al. (2001) evaluated five muscles from

USDA select carcasses cooked on an electric belt grill at three temperatures (93, 117, and 163°C), in a forced-air convection oven, and on an electric broiler. Belt grill at 93° presented the lower cooking loss for all the five muscles. The electric broiler presented the higher cooking losses for *biceps femoris* and *deep pectoralis*. For *longissimus lumborum*, *gluteus medius,* and *semitendinosus* muscles, electric broiler also presented the higher cooking losses, but this values did not statistically differ from the forced air convection cooking losses. Modzelewska-kapitula et al. (2012) evaluate the effect of two cooking conditions: dry air (180°) and steam (120°C) and three final internal temperature (75, 85, 95 °C), using beef *infraspinatus* and *semimembranosus* muscles. The higher cooking loss was obtained using the dry air and 95 °C as final temperature. The lower cooking losses were obtained for the dry air and steam at 75°C.

On the other hand, Yancey et al., 2011 also evaluate the effect of five different cooking methods (convection oven, impingement oven, electric griddles, char-grill, and clamshell) at three different end point temperatures on cooking loss. There were no statistical differences in cooking loss related to the five cooking methods evaluated with values from 26.2 to 32.6%. García-Segovia et al. (2007), evaluate the effect of three different temperatures (60°, 70°, 80°C), combined with 3 different sous-vide condition on beef cooking loss. For 15 minutes cooking, samples presented cooking losses from 10 % to 28% (60° and 80°C, respectively). For 1 hour of cooking samples presented cooking losses from 21 % to 36% (60° and 80°C, respectively). There was no statistical difference in cooking loss related to the different sous-vide conditions.

2.5 Quality grades effects on beef palatability

Increased marbling (intramuscular fat) level and USDA quality grade have repeatedly been shown to have a positive effect on beef tenderness, juiciness, flavor, and overall palatability, all associated with increased beef eating quality. The “Window of Acceptability” presented in Figure 2, illustrates the role of increased intramuscular fat on pork, lamb, and beef palatability (Savell and Cross 1988). Marbling has a very positive effect on the eating quality of some muscles, but it is only one of the many factors affecting eating quality. All factors that interact to determine eating quality need to be managed together. However, where all else is equal, increased marbling score will improve eating quality (Hunt et al., 2014; Killinger, 2004; Kolle et al., 2004; Lorenzen et al., 1999; Lucherk et al., 2016; Smith et al., 1985; Wheeler et al., 1999;).

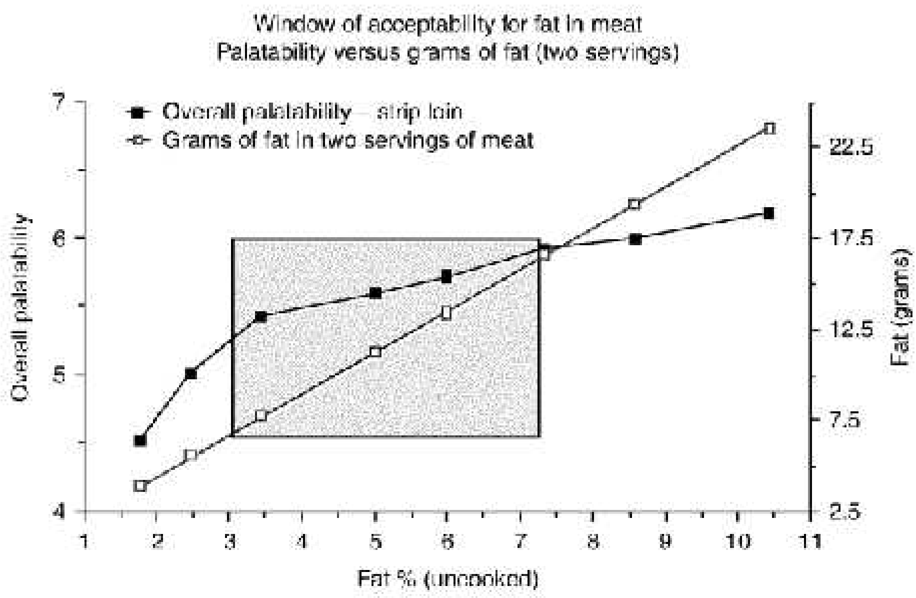

Figure 2. The window of acceptability to show the relationship between grams of fat and meat palatability. Source: Savell and Cross (1998)

Increased marbling level has a positive effect on beef tenderness, juiciness, flavor, and overall palatability (Savell et al., 1987; Smith et al., 1985). Tenderness has been cited as the most important factor affecting beef palatability (Savell et al., 1987; Smith et al., 1982; Voges et al., 2007). However, additional studies have shown that when tenderness reaches an acceptable level, the flavor becomes the next most important driver of beef eating satisfaction (Corbin et al., 2015; Killinger et al., 2004; Legako et al., 2015).

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CHAPTER III

EFFECTS OF COOKING METHOD AND QUALITY GRADE ON THE PALATABILITY OF BEEF STRIP LOIN STEAKS

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Abstract

Consumer sensory analysis (n=288) and objective measures, including cooking loss, slice shear force (SSF), and pressed juice percentage (PJP) were performed to evaluate the effects of four different dry cooking methods [electric clamshell grill (CLAM), flat-top gas grill (FLAT), charbroiler gas grill (CHAR), and salamander gas broiler (SAL)] and four USDA quality grades [Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select)] on the palatability of beef strip loin steaks. No main effects or interactions influenced ($P > 0.05$) slice shear force (SSF) and press juiciness percentage (PJP). The cooking method with the lowest cooking loss was CLAM, ($P > 0.05$), whereas FLAT, SAL, and CHAR did not differ from each other. Cooking method and quality grade had an effect ($P < 0.01$) on tenderness, juiciness, flavor liking and overall liking when evaluated by the consumer panel. Steaks cooked on CHAR had greater ($P < 0.05$) flavor liking and subsequently greater overall liking than any other cook method. FLAT steaks were scored lower for tenderness and juiciness than any other cook method ($P < 0.05$), whereas steaks cooked on CLAM had lower ($P < 0.05$) flavor liking scores than any other cook method, excluding FLAT. Overall acceptance was greater ($P < 0.05$) for steaks cooked on CHAR compared to all other cook methods, while steaks cooked on FLAT had lower ($P < 0.05$) overall acceptance, but FLAT were not different ($P > 0.05$) from CLAM. Related to quality grade, Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking ($P < 0.05$), but Prime did not differ from scores for Top choice. These results indicate that different dry cooking methods and USDA quality grade have an effect on beef consumer perception.

Keywords: Cooking methods, consumer, USDA quality grade.

Introduction

Cooking impacts basic traits related to consumer preferences such as flavor, tenderness, color, and appearance (Domínguez et al., 2015; Juárez et al., 2010; Lorenzen et al., 1999; Modzelewska-Kapituła et al., 2012; Pathare and Roskilly, 2016). Biochemical and physical changes occur during the heating process and these changes affect the microbiological quality and sensory characteristics (Boles and Swan, 2002; Barbera and Tassone, 2006; Pathare and Roskilly, 2016). The tenderness in meat changes during cooking due to the transformation of connective tissue and myofibrillar proteins. Cooking induces structural changes like the transversal shrinkage of the fibers, which decreases the water-holding capacity and changes the water distribution of the meat (Tornberg, 2005). The cooking loss is strongly associated with fiber shrinkage (Bertram et al., 2004). It is reported that beef juiciness and cooking loss are negatively correlated, implying that a high cooking loss results in low juiciness (Tornberg, 2005; Toscas et al., 1999;). Different cooking methods have several types of heat transfer and heat conditions influencing the tenderness, juiciness, and flavor, resulting in a variable cooking loss in meat (Tornberg, 2005). Differences in heat transfer or thermal process can produce differences in fiber shrinkage; undesirable or increased changes in fiber shrinkage may be perceived by the consumers as an indicator of low-quality meat (Barbera and Tassone, 2006).

Cooking meat using a clamshell grill has become common during university research and at institutions, serving as an alternative to the belt grill because it is faster, less expensive, and has acceptable repeatability (McKenna et al., 2004a). Charbroiling has also become a popular method in the hotel and restaurant industry (Yancey et al., 2011). Lorenzen et al. (1999) and McKenna et al. (2004b) both found that consumers cook steaks on outdoor grill (charbroiling) over 40% of the time and use broiling and indoor grills over 13% of the time. Nevertheless, very little research has focused on the evaluation of possible differences between different grilling methods on beef palatability.

Increased marbling (intramuscular fat) level and USDA quality grade have been shown to be highly associated with beef eating quality (O'Quinn et al., 2012; Savell and Cross., 1988; Smith et al., 1985). Quality grade is assigned based on marbling and maturity of a beef carcass (USDA, 1997). However, other aspects such as cooking method (Lorenzen et al., 1999; McKenna et al., 2004b; Obuz et al., 2003), postmortem aging (Voges et al ., 2007; Wheeler et al., 1999), muscle (Hunt et al., 2014; Modzelewska-Kapituła et al., 2012), and degree of doneness (Lorenzen et al., 1999; Lucherk et al., 2016) may also influence palatability.

The purpose of this study was to evaluate possible differences in consumer perception of palatability and objective measures of tenderness and juiciness of strip loin steaks representing four USDA quality grades cooked using one of four different dry cooking methods.

Materials and Methods

Strip Collection and Fabrication

Beef strip loins (IMPS # 180, NAMP, 2011), were collected from carcasses representing four USDA quality grades [Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select; n = 12 / quality grade)] by Texas Tech University (TTU) personnel. Strip loins were selected, identified, and transported to TTU. All strip loins were aged at 0 – 4 ^{o}C under vacuum until 21 d postmortem. Each strip loin was fabricated into 2.54 cm thick steaks and were numbered from 0 to 12 based on anatomical position. The anterior most steak (steak 0) was designated to compositional analysis. Each strip loin was cut into steaks following the example in Figure 3.1. Every three adjacent steaks (steaks 1-3, 4-6, 7-9, 10-12) were grouped and assigned randomly to one of the four cooking methods. Within each group of three steaks, the first two anterior-most steaks were designated to consumer assessment and the remaining steak was designated to slice shear force, pressed juiciness percentage, and volatile analysis (not reported here). All steaks were vacuum packaged individually, labeled, and stored frozen (-20oC) until subsequent analysis.

Compositional analysis

Proximate analysis of raw steaks was conducted by an AOAC official method (Anderson, 2007) using a near infrared spectrophotometer (FoodScan, FOSS NIRSystems, Inc., Laurel, MD). Prior to analysis, steaks were thawed for 24 h at 4°C. All exterior muscles, heavy connective tissue, and external fat were removed leaving only the muscle of interest. Samples were cubed, then placed in a grinder and ground through a 4-mm plate three times. A petri dish disc was filled with approximately 80 grams of sample, leveled with a plastic spatula, and was placed into the FOSS FoodScan machine to obtain percentages of fat, moisture, and protein for each sample.

pH Determination

Ten grams of ground sample, remaining from the compositional analysis described above, were placed in a 150 ml beaker and 90 ml of distilled water were added. The mixture was agitated 30 sec at 300 RPM with a magnetic stirrer. Homogenized samples were placed in a 150-mL beaker with a filter cone (#140) to allow the water to diffuse to the center of the cone. An electrode connected to an OAKTON MS-PH01 pH meter was placed in the center of the cone to measure the pH of the dilution and the value was recorded. The pH of each sample was determined as the average of 3 samples.

Approximate Cooking Times

Approximate cooking times were established for each cooking method using steaks from strip loins unrelated to the trial, but representing the range in quality grade (Select to Prime). Previously frozen 2.54-cm steaks were thawed at 2 – 4°C for 24-30 h and cooked using the four cooking methods, until achieving a medium degree of doneness (70-72°C). The objective of this step was to determine the length of time and necessary interventions, such as flipping, required to cook steaks using each method to establish a cooking schedule for objective and consumer analysis. The cooking devices were turned-on 30 min prior to cooking and were set to maintain a surface temperature of 200 - 220°C, which was monitored using a surface thermometer (Omega® RDXL4SD). The initial and final temperature were recorded with a digital Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT). The time to reach 68°C was recorded for each steak. The steaks were placed on a tray until reaching the final peak temperature and the temperature was recorded for each steak.

Cooking Procedure

Steaks were thawed at 2 – 4°C for 24-30 h. Following thawing, the steaks were trimmed, then initial core temperature and the raw weight were recorded. Steaks were cooked on one of four cooking methods: electric clamshell grill (CLAM; Cuisinart Griddler Deluxe, Model GR-150, East Windsor, NJ), flat top gas grill (FLAT; Imperial IR-6-GT36), Charbroiler gas grill (CHAR; Imperial IRB-36 Charbroiler), or Salamander gas broiler (SAL; CPG-SB-36). Steaks were cooked using one of four methods, following the devised cooking schedule from the previous step. The steaks were flipped at 6:30 and 7:30 min of cooking on SAL and FLAT, respectively (established time for reaching 35°C), the steaks on CHAR were flipped every 3 min, to prevent burning from fat dripping on the flame source, and the steaks on CLAM were not flipped because the double heating surface. The steaks were removed from each cooking device at the internal core temperature of 68-70°C and then pleased on a tray until reaching the final peak temperature, which was monitored with a digital Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT).

Cooking Loss and Slice Shear Force (SSF)

Objective tenderness was evaluated by SSF as described by Wheeler et al. (1999). In brief, steaks designated to SSF and PJP were cooked as described before. Steaks were weighed on a digital scale (Model AY1501; Sartorius, Göttingen, Germany), with a 0.1g sensitivity, prior to cooking; upon completion of cooking, steaks were reweighed to obtain a cooked weight. Cooking loss was determined as the difference between the steak's raw weight and cooked weight divided by the raw weight. The temperature was monitored using a digital Thermapen thermometer (Model Mk4, ThermoWorks, American Fork, UT).

After final temperature and weight were recorded, a 1-cm slice was removed from the lateral end of each steak to provide a square surface, and a second parallel cut was made 5 cm from the initial cut. Following this step, a 1-cm by 5-cm slice was obtained parallel to the muscle fiber orientation by slicing at a 45º angle with a double-bladed knife. Each slice was sheared perpendicular to the muscle fiber orientation using a Unit Force Analyzer (Nextech® DFS 500N) with a crosshead speed of 500mm/min.

Pressed Juice Percentage (PJP)

Objective juiciness was evaluated using the methods described by Lucherk et al. (2016). Immediately following shear force testing, an additional 1-cm thick, steak-width slice was removed immediately adjacent to the SSF sample and cut into three 1-cm samples, parallel to the muscle fiber orientation. Two sheets of filter paper (VWR Filter Paper 415, 12.5 cm, VWR International, Radnor, PA) previously stored in a desiccator were weighed for each 1-cm samples. Then, each of the three samples was weighed in two sheets of filter paper and compressed (Model 5542, Instron, Canton, MA) for 30 s at 8-kg pressure. After compression, the sample was removed from the two filter papers and the filter papers were re-weighed. The percentage moisture lost during compression was quantified as pressed juice percentage (PJP).

Consumer Sensory Analysis

Panelists (n = 288) were recruited from the Lubbock, TX area and were provided with an iPad with an electronic ballot, plastic fork, toothpick, napkin, expectorant cup, a cup of water, and palate cleansers (unsalted crackers and diluted apple juice) to use between samples. Each ballot contained an information sheet, demographic questionnaire, and eight sample ballots. Before starting each panel, panelists received verbal instructions about the ballot and use of the palate cleansers. Steaks were cooked as previously described, and at least twelve cubes (1.3-cm × 1.3-cm × steak thickness) were cut from each steak so that two pieces were served immediately to each predetermined consumer. Consumers received and scored eight samples representing various combinations of cooking methods and quality grades in a predetermined order. Every cooking method × quality grade combination was compared an equal number of times within each panel session. Attributes for each sample were ranked on an electronic ballot with a 100-point continuous-line scales for juiciness, tenderness, flavor liking, and overall liking. The zero-point anchors were labeled as not juicy, not tender, dislike flavor extremely, and dislike overall extremely; the 100-point anchors were labeled as very juicy, very tender, like flavor extremely, and like overall extremely. Also, each consumer rated each sample as either acceptable or unacceptable for each palatability trait.

Statistical analysis

Composition and pH were analyzed using the GLIMMIX procedure of SAS (Version 9.4; SAS Inst. Inc., Cary, NC), with quality grade as a fixed effect. Data gathered from objective measures (cooking loss, SSF, and PJP) and consumer data (tenderness, juiciness, flavor liking, and overall linking) were analyzed as split-plot design with USDA quality grade as a whole plot factor, the strip loin as the whole plot unit, and cooking method as a subplot factor. Data were analyzed using the GLIMMIX or MIXED procedures of SAS, with fixed effects of cooking method, quality grade, and their interaction. Acceptability data for each palatability trait were analyzed with a binomial model. Final peak temperature was included as a covariate for cooking loss and consumer evaluation of tenderness and juiciness ($P \leq 0.05$), the cooking day was included into the model as a block (random effect) for cooling loss, SSF, and PJP. Consumer nested within testing night was included as random effects for sensory attributes. Treatment least squares means were separated with the PDIFF option of SAS using a significance level of $P \leq 0.05$. Denominator degrees of freedom were calculated using the Kenward-Roger approximation. The PROC FREQ of SAS was used to summarize consumer demographic information.

Results and Discussion

Proximate analysis

Results for the proximate and pH analysis of the four quality grades are displayed in Table 3.1. USDA Quality grade influenced fat, moisture, and protein percentage ($P < 0.01$). Prime had the greatest fat percentage, followed by Top Choice, Low Choice, and Select, with a significant difference in fat percentage between each grade. As a result, Select had greater moisture percentage than any other quality grade, again with a significant decrease in moisture from Select to Prime ($P < 0.05$). Select and Low Choice had greater ($P < 0.05$) protein percentage than Top Choice or Prime, which were similar ($P > 0.05$). These results are similar to fat percentages reported previously for each respective USDA quality grade (Corbin et al., 2015; Lucherk et al., 2016; O'Quinn et al., 2012).

Quality grade also influenced pH ($P < 0.05$). Select had a greater ($P < 0.05$) pH than Low Choice and Prime but did not differ from Top Choice. Although statistical differences were detected, all values were within acceptable range (5.5-5.6). Jeremiah et al. (1991) described normal final pH between 5.4 and 5.8.

Cooking times and temperatures

Cooking times and final peak temperatures were recorded for steaks from the four cooking methods during cooking for SSF and are shown in Table 3.2. The fastest and least variable cooking method was CLAM, where the principal heat transfer method is conduction, from the bottom and the top due to the double heating surface. Conversely, CHAR took the longest to reach the desired degree of doneness and was also the most variable.

Cooking Loss, PJP, and SSF

Table 3.3 displays the effects of quality grade and cooking method for cooking loss, PJP, and SSF. No quality grade × cooking method interactions were detected ($P \geq 0.40$). Cooking method influenced ($P < 0.01$) cooking loss, but did not impact SSF or PJP ($P \geq 0.19$). CLAM had lower ($P < 0.05$) cooking loss than FLAT, SAL, and CHAR, which did not differ from each other ($P > 0.05$). The lower cooking loss of CLAM could be related to the shorter cooking times compared to the other methods. It has been previously reported that cooking methods with a shorter cooking time result in a lower cooking loss (Barbera and Tassone, 2006; Tornberg, 2005). However, the correlation between cooking time and cooking loss is not linear, as the cooking loss is determined by a combination of cooking time and heating rate (Bejerholm et al., 2014). Since heating rate also influences cooking loss, that could explain why no differences were observed between the other three cooking methods, and all had a higher cooking loss than CLAM because of differences related to the type of heat transfer for the other cooking methods. These results for cooking loss are in accordance with Lucherk et al. (2016), who reported cooking losses between 15.7% and 19.7% for strip loin steaks from different quality grades cooked on a clamshell grill. On the other hand, the results for cooking loss in this study are lower than losses reported by Alfaia et al. (2010) using grilling (32.6%), broiling (39.9%), and microwaving (42.7%); however, researchers cubed the samples into 5×5 cm^2 squares with 2.5-cm thickness before cooking.

Pressed juiciness percentage was not influenced by quality grade, cook method, or their interaction ($P \geq 0.19$). These results are slightly lower than the averages presented by Lucherk et al. (2016) for strip loin steaks from four different quality grades cooked to three different degrees of doneness, with values from 21.4% to 22.7%. However, the magnitude in variation in PJP between treatments is similar to the variability found by Lucherk et al. (2016).

Slice shear force was not influenced by quality grade, cook method, or their interaction ($P \geq 0.15$). Researchers have previously shown similarity in shear between various cook methods, such as García-Segovia et al. (2007) when evaluating different sous-vide conditions, Shackelford et al. (1999), who evaluating two different speeds on a belt grill, and Vittadini et al. (2005) and Yusnaini et al. (2015), who evaluating different oven cooking conditions. On the other hand differences in shear force when evaluating different cooking methods have been reported by other authors (Chumngoen et al., 2018; Lawrence et al., 2001; Modzelewska-Kapituła et al., 2012; Mora et al., 2011; Obuz et al., 2003; Wyrwisz et al., 2012; Yancey et al., 2011).

Previous researchers have reported that quality grade had an effect on SSF, such as Lucherk et al. (2016) who found differences in SSF values ranging from 9.5 kg to 13.4 kg for Prime to Select steaks, respectively. Martinez et al. (2017) also reported the effect of quality grade on Warner-Bratzler shear force with lower values for Prime steaks with 2.51 kg, but in the same study, they did not report differences between Top choice, Low choice, and Select.

Demographic profile and beef consumption habits of consumers

Consumer participant demographic information is presented as Table 3.4. The panel was composed of approximately half females. The majority of panelists (52.4%) came from the 22–29 and 30–39 age groups. Most participants were employed full-time (79.5%) or were students (12.2%). Household size of participants was primarily four, two, and one member. Caucasian/white was the primary ethnic group followed by Hispanic. Households' incomes among participants were primarily in the range of $20,000 to $50,000, which was near twice as many participants than any other income bracket. These consumer demographics were proportionally similar to previous research conducted in Lubbock, Texas (Corbin et al., 2015; O'Quinn et al., 2012; Legako et al., 2016). Previously, Lubbock was considered to have consumers with beef preferences similar to multiple geographic areas of the U.S. (Mehaffey et al., 2009). The beef consumption habits of consumer participants are presented in Table 3.5. Nearly 75% of the consumers eat beef weekly (1-6 times per week). Consumers commonly identified flavor as the most important palatability trait (48%), while only 11% identified juiciness as the most important palatability trait and 41% identified tenderness as the most important. Finally, the preferred cooking levels were Medium, Medium Rare, or Medium Well Done.

Consumer panel evaluation

Consumer sensory scores are shown in Table 3.6, displaying the effects of cooking method and USDA quality grade on consumer scores of tenderness, juiciness, flavor liking, and overall liking. There were no interactions between the cooking method and quality grade for any of the palatability attributes ($P > 0.05$). For all traits, both cooking method and quality grade influenced consumer scores ($P < 0.01$). FLAT steaks were scored lower for tenderness and juiciness than any other cook method ($P < 0.05$). Steaks cooked on CHAR had greater ($P < 0.05$) flavor liking and consequently greater overall liking than any other cook method. Steaks cooked on CLAM had lower ($P < 0.05$) flavor liking scores than any other cook method, except FLAT. Despite being less tender and juicy, steaks cooked on FLAT were scored lower for overall liking than all other cook methods, except CLAM.

One possible reason that consumers in this experiment rated CHAR steaks with better scores could be related to the longer cooking time. Several authors have suggested that cooking methods that use low temperatures and long cooking time may induce changes in the texture of meat, due to heat-induced structural changes combined with the enzymatic breakdown of proteins (Bejerholm et al., 2014; Pathare and Roskilly, 2016). Also, the longer cooking time can enhance the formation of flavor compounds due to Maillard reaction, lipid degradation, and other flavor compounds formation pathways (Corbin et al., 2015; Legako et al., 2015; Shahidi et al., 2014).

Lorenzen et al. (1999) reported differences in consumer perception of five different cooking methods in four cities of USA. Those authors found a significant interaction between cooking methods and USDA quality grade and between cooking method and city. Samples were scored using a scale ranging from 23 (as extremely tender) to 1 (not at all tender). Top loin steaks cooked at medium degree of doneness were rated with 19.1, 19.0 18.8, and 18.3 for pan fry, outdoor grill, broil, and indoor grill, respectively. For juiciness, the interaction between cooking method and USDA quality grade was not found; the juicier scores were received by pan-frying and the outdoor grill. Lorenzen et al. (1999) also reported higher flavor desirability ratings for outdoor grilling and pan-frying, while indoor grilling provided the least desirable beef flavor.

In the present study, Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking ($P < 0.05$). However, Top Choice did not differ from Prime or Low Choice for tenderness, juiciness, or overall liking (*P* > 0.05). Consumers scored Prime and Top Choice similarly and greater (*P* < 0.05) than Low Choice and Select, which were also similar (*P* > 0.05), for flavor liking.

Increased marbling (intramuscular fat) level has been reported to be highly associated with beef eating quality (Smith et al., 1985; Savell and Cross, 1988). A significant effect of USDA quality grade over consumer rating for tenderness, juiciness, flavor, and overall liking have been also found by several authors, reporting the higher consumer perception scores connected whit high marbled samples (Corbin et al., 2015; Lorenzen et al., 1999; Lucherk et al., 2016; McKenna et al., 2004).

Table 3.7 displays the percentage of beef strip loin steaks considered acceptable for tenderness, juiciness, flavor liking, and overall liking as influenced by cooking method and USDA quality grade. There were no interactions between the cooking method and quality grade for the acceptability of any of the palatability traits (*P* > 0.05). Cooking method influenced (*P* < 0.01) juiciness, flavor and overall acceptability, but did not influence tenderness acceptability (*P* = 0.22). A lower (*P* < 0.05) percentage of consumers indicated steaks cooked on FLAT were acceptable for juiciness compared to the other cook methods. A greater (*P* < 0.05) proportion of consumers believed flavor was acceptable for steaks cooked using CHAR compared to CLAM or FLAT, but CHAR did not differ from SAL for flavor acceptability (*P* > 0.05). Overall acceptance was greater (*P* < 0.05) for steaks cooked on CHAR compared to all other cook methods, while steaks cooked on FLAT had lower (*P* < 0.05) overall acceptance than any other cook method. Quality grade influenced consumer acceptance of all four traits (*P* ≤ 0.04). Prime and Top Choice had similar and greater (*P* < 0.05) acceptability for all traits compared to Low Choice and Select, which were also similar (*P* > 0.05); however, a similar ($P > 0.05$) percentage of consumers indicated that Top Choice and Low Choice were acceptable for juiciness, flavor liking, and overall liking.

Consumers in this experiment may have rated CHAR steaks more acceptable for overall liking due to the longer cooking time that may have induced changes in the texture of meat (Bejerholm et al., 2014; Pathare and Roskilly, 2016) and altered the formation of flavor compounds (Corbin et al., 2015; Legako et al., 2015; Shahidi et al., 2014). The results for acceptance due quality grade are in accordance with other authors than have reported increasing acceptability as USDA quality grade increased (Corbin et al., 2015; Lucherk et al., 2016; O'Quinn et al., 2012). Comparable results from other authors for acceptance due cooking methods were not found.

Correlations

The correlation coefficients quantifying the relationships between fat content, objective evaluations, and consumer palatability ratings are shown in Table 3.8. Fat was negatively correlated with objective measures of tenderness and juiciness ($P < 0.05$) and positively related ($P < 0.01$) with tenderness, juiciness, flavor liking and overall liking (r = 0.14, 0.14, 0.11, 0.13 respectively). These results are similar to those reported by Legako et al. (2015). On the other hand, in the results reported by Corbin et al. (2015), they found a high correlation between fat content and consumer evaluations. Pressed juiciness percentage was not related to any objective or subjective measure of palatability ($P > 0.05$). Cooking loss negatively correlated with consumer evaluations for tenderness, juiciness, flavor liking, and overall liking (-0.10, -0.19, -0.06, and -0.09 respectively; $P < 0.01$). Within the consumers eating quality traits, flavor liking was most strongly correlated to overall liking (r = 0.88; $P < 0.01$), followed by tenderness (r = 0.76, $P <$

0.01) and juiciness (r = 0.75, $P < 0.01$). Tenderness and juiciness scores were also strongly related (r = 0.74; $P < 0.01$) to each other. The similar high correlation for consumer quality traits was found by other authors as well (Corbin et al., 2015; Legako et al., 2015; Lucherk et al., 2016).

Conclusions

The purpose of this study was to evaluate possible differences in consumer perception of four different USDA quality grades and four dry cooking methods frequently used to cook beef steaks. CLAM is frequently used by universities and institutions for research, whereas CHAR, FLAT, and SAL are frequently used in the home and in restaurants. Consumers in this study were able to detect differences in tenderness and juiciness between CLAM and FLAT, consumers also detected differences in flavor between CLAM, CHAR, and SAL. Finally, consumers detected differences in overall acceptability between CHAR and CLAM. Furthermore, Prime samples had greater scores than Low Choice and Select for tenderness, juiciness, flavor liking, and overall liking, but Prime did not differ from Top choice. CLAM had the lowest cooking loss but the cooking method did not affect slice shear force and press juice percentage. Overall, results showed that different dry cooking methods and different USDA quality grade have an effect on beef consumer perception.

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Table 3.1. Least squares means for pH and proximate composition from strip loins representing four different quality grades[1] (n=12 strips per quality grade).

Trait	Prime	Top choice	Low choice	Select	SEM[2]	*P*-value
pH	5.52^{b}	5.55^{ab}	5.53^{b}	5.58^{a}	0.02	0.05
Fat, %	10.6^{a}	9.0^{b}	5.6^{c}	3.6^{d}	0.34	<0.01
Protein %	23.1^{b}	23.4^{b}	24.2^{a}	24.5^{a}	0.21	<0.01
Moisture %	65.8^{d}	66.9^{c}	69.4^{b}	70.9^{a}	0.42	<0.01

[a,b,c] Within a row, means without a common superscript differ ($P < 0.05$).

[1] Prime, Top (upper 2/3) Choice, Low (lower 1/3) Choice, and Select)

[2] SE (largest) of the least square means.

Table 3.2. Averages and standard deviations for removing time, initial, and peak core temperature for strip loin steaks from four different quality grades, cooked on four different cooking methods.

Cooking method	Flipping time	Removing time	Initial temperature	Peak temperature
Cuisinart	-	8:43 ± 1:42	3.9 ± 2.2	72.1 ± 3.6
Flat gas	7:30	16:16 ± 3:29	4.1 ± 1.9	71.7 ± 2.9
Char broiler gas	every 3 min	18:50 ± 3:48	3.8 ± 1.8	71.0 ± 2.0
Salamander gas	6:30	13:50 ± 2:32	4.0 ± 2.0	72.5 ± 3.0

n = 48 steaks per cooking method/12 per quality grade.

Table 3.3. Cooking loss, press juiciness percentage (PJP), and slice shear force (SSF) from steaks representing four different quality grades cooked on four different cooking methods (n=192).

	Cooking loss (%)	PJP (%)	SSF (kg)
Cooking methods			
Clamshell grill	20.5[a]	15.9	12.90
Flat gas	24.7[b]	14.5	13.06
Char broiler	26.0[b]	14.9	13.29
Salamander	25.8[b]	15.8	12.35
SEM[1]	1.0	0.7	0.57
Quality grades			
Prime	24.9	14.5	12.57
Top Choice	24.8	15.0	12.57
Low Choice	23.6	15.5	12.56
Select	23.7	16.1	13.91
SEM	1.1	0.8	0.70
P-values			
Cooking method	<0.01	0.19	0.40
Quality grade	0.34	0.21	0.15
Method × Quality grade	0.40	0.55	0.58

[a,b] Within a column, least squares means without a common superscript differ ($P < 0.05$) due to cooking method effect

[x,y,z] Within a column, least squares means without a common superscript differ ($P < 0.05$) due to quality grade effect

[1] SE (largest) of the least square means.

Table 3.4. Demographic characteristics for all consumers[1] (n=288)

Trait	Consumers %
Age	
< 20 y	6.9
20-29 y	21.9
30-39 y	30.6
40-49 y	16.7
50-59 y	15.3
≥ 60 y	8.7
Gender	
Male	45.5
Female	54.5
Occupation	
Tradesperson	14.2
Professional	28.8
Administration	18.8
Sales & Service	12.2
Laborer	5.6
Student	12.2
Currently Not Employed/Retired	8.0
Household Size	
1 person	17.7
2 people	20.8
3 people	14.9
4 people	23.9
5 people or more	22.6
Income Level	
< $20,000/year	15.9
$20,000-50,000/year	33.3
$50,001-75,000/year	14.6
$75,001-100,000/year	16.3
> $100,000/year	19.8
Education Level	
Non-high school graduate	2.4
High school graduate	26.4
Some college/technical school	27.1
College graduate	29.2
Post graduate	14.9
Cultural Heritage	
African-American	9.7
Asian	1.0
Caucasian/White	46.2
Hispanic	40.3
Other	2.8

[1] Location: Lubbock, Texas

Table 3.5. Beef consumption habits for consumers[1] (n=288)

Trait	Consumers %
How often do you eat Beef?	
Never eat	0.7
1-3 times a week	41.7
4-6 times a week	33.7
7-9 times a week	12.2
10 or more	11.8
Most important palatability trait when eating beef	
Flavor	47.9
Juiciness	11.5
Tenderness	40.6
Preferred cooking level	
Blue	0.4
Rare	2.1
Medium Rare	29.9
Medium	31.6
Medium Well Done	23.6
Well Done	12.5

[1]Location: Lubbock, TX

Table 3.6. The effects of cooking method and quality grade on the least squares mean for consumer (n = 288) sensory scores[1] for palatability traits.

Treatments	Tenderness	Juiciness	Flavor Liking	Overall Liking
Cook Methods				
Clamshell	63.6^{a}	62.5^{a}	59.1^{c}	61.5^{bc}
Flat top gas	60.6^{b}	55.6^{b}	61.1^{bc}	60.2^{c}
Char broiler	65.7^{a}	64.8^{a}	68.0^{a}	67.9^{a}
Salamander	65.6^{a}	63.7^{a}	62.5^{b}	63.9^{b}
SEM[2]	1.8	1.5	1.3	1.2
Quality grades				
Prime	67.7^{x}	66.1^{x}	65.8^{x}	67.8^{x}
Top Choice	66.4^{xy}	63.6^{xy}	64.7^{x}	65.0^{xy}
Low Choice	62.5^{yz}	59.5^{yz}	60.3^{y}	61.2^{yz}
Select	58.7^{z}	57.4^{z}	59.9^{y}	59.6^{z}
SEM	1.5	2.6	2.0	2.3
P-values				
Cook method	<0.01	<0.01	<0.01	<0.01
Quality grade	<0.01	<0.01	<0.01	<0.01
Method × Quality grade	0.74	0.63	0.41	0.50

[a,b,c] Within a column, least squares means without a common superscript differ ($P < 0.05$) due to cooking method effect.
[x,y,z] Within a column, least squares means without a common superscript differ ($P < 0.05$) due to quality grade effect.
[1] Sensory scores: 0 = not tender/juicy, dislike flavor/overall extremely; 100=very tender/juicy, like flavor/overall extremely.
[1] SE (largest) of the least square means.

Table 3.7. Least square means for the percentage of beef strip steaks considered acceptable for tenderness, juiciness, flavor and overall liking by consumers (n = 288).

Treatments	Tenderness	Juiciness	Flavor Liking	Overall Liking
Cook Methods				
Clamshell	86.3	85.9[a]	83.8[b]	86.2[bc]
Flat top gas	85.9	79.2[b]	86.2[b]	83.9[c]
Char broiler	89.1	87.7[a]	90.5[a]	90.5[a]
Salamander	88.9	85.8[a]	87.6[ab]	86.9[b]
SEM[1]	0.3	0.2	0.2	0.2
Quality grades				
Prime	91.7[x]	89.3[x]	90.2[x]	91.1[x]
Top Choice	90.7[x]	85.7[xy]	88.2[xy]	88.5[xy]
Low Choice	84.2[y]	81.5[y]	85.5[y]	83.8[y]
Select	81.6[y]	82.0[y]	84.1[y]	83.3[y]
SEM	0.3	0.3	0.2	0.3
P-values				
Cooking method	0.22	<0.01	<0.01	0.01
Quality grade	<0.01	0.04	0.03	0.02
Method*Quality grade	0.90	0.99	0.75	0.88

[a,b,c] Within a column, least squares means without a common superscript differ (P < 0.05) due to cooking method effect.
[x,y,z] Within a column, least squares means without a common superscript differ (P < 0.05) due to quality grade effect.
[1] SE (largest) of the least square means.

Table 3.8. Pearson correlation coefficients quantifying relationships between fat, objective evaluation and consumer palatability ratings

Trait	Fat	SSF[1]	PJP[2]	Cooking loss	Tenderness	Juiciness	Flavor Liking
SSF	-0.15*						
PJP	-0.14*	-0.04					
Cooking loss	-0.03	-0.01	-0.04				
Tenderness	0.14**	-0.09**	-0.02	-0.10**			
Juiciness	0.14**	-0.10**	-0.02	-0.19**	0.74**		
Flavor Liking	0.11**	-0.04*	0.00	-0.06**	0.68**	0.66**	
Overall Liking	0.13**	-0.07	-0.01	-0.09**	0.76**	0.75**	0.88**

[1] Slice shear force

[2] Pressed juiciness percentage

** Correlation coefficient differs from 0 ($P < 0.01$)

* Correlation coefficient differs from 0 ($P < 0.05$)

0

Cooking method		Cuisinart (1)			Flat Gas (2)			Char Broiler (3)			Salamander (4)			
Steak number	0	1	2	3	4	5	6	7	8	9	10	11	12	
Steak Destination	FOSS, pH	Consumer (1)	Consumer (2)	Volatiles-SSF-PJP (3)	Consumer (1)	Consumer (2)	Volatiles-SSF-PJP (3)	Consumer (1)	Consumer (2)	Volatiles-SSF-PJP (3)	Consumer (1)	Consumer (2)	Volatiles-SSF-PJP (3)	Extra

Figure 3.1. Example of one strip loin steak fabrication, cooking method assignment, and steak destination assignment.