THESIS

DISCOVERING CONSUMER PREFERENCES FOR STEAK THICKNESS AND COMMON FOOD SERVICE COOKERY METHODS FOR BEEF STRIP LOIN STEAKS

Submitted by

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ABSTRACT

DISCOVERING CONSUMER PREFERENCES FOR STEAK THICKNESS AND COMMON FOOD SERVICE COOKERY METHODS FOR BEEF STRIP LOIN STEAKS

The objective of this study was to quantify consumer preferences for steak thickness and cookery method. Paired strip loins from 38 carcasses with Small marbling scores were obtained from a commercial packing facility. Each strip loin was cut into 2 sections (4 sections per carcass) and each section was randomly assigned to 1 of 4 cookery methods (COOK): 1) grill (GRILL); 2) grill mark then finish in a steam oven (MARK+FINISH); 3) par cook in a steam oven then mark on a grill (PAR+MARK); 4) broil (BROIL). Each section was vacuum-sealed and aged at 2^{o}C for 21 days before being frozen. After freezing, three sets of paired steaks were cut from each section representing three steak thickness treatments (THICK): 1) 1.9-cm; 2) 2.5-cm; 3) 3.8-cm. For each cookery method and steak thickness combination pair, a single steak was designated for evaluation by a consumer panel while the other steak was assigned to objective testing for measures of tenderness, cook loss, and visual appearance. Known beef consumers (N = 307) evaluated each of the 12 treatment combinations of thickness and cookery method for tenderness, juiciness, flavor desirability and overall desirability using a 15-cm unstructured line scale. A significant COOK x THICK interaction ($P < 0.05$) affected consumer panel ratings for tenderness, juiciness, and overall desirability. As a main effect, COOK influenced ($P = 0.0005$) consumer ratings for flavor desirability; however, inconsistencies between the present and previous studies suggest that consumer-rated flavor desirability may have been affected more heavily by tenderness, and juiciness in what is termed a “halo effect” than by actual differences in flavor due to cookery method. The BROIL, 1.9-cm thick steaks

were more desirable than 2.5 and 3.8-cm BROIL steaks as rated by consumers for overall desirability, tenderness, and juiciness, and were more tender as evaluated using WBSF and SSF ($P < 0.5$). The GRILL method was among the most highly rated for consumer overall desirability, and no significant difference was found existed between THICK treatments. Consumer overall desirability ratings, consumer tenderness ratings and SSF values for the PAR+MARK cookery method had, more desirable values for 3.8-cm thick steaks compared to 1.9 and 2.5-cm thick steaks. The MARK+COOK method was rated the highest for consumer overall desirability, tenderness, juiciness, and had the lowest SSF and WBSF values ($P < 0.5$). The MARK+COOK method was the most likely to offer consumers a desirable eating experience at steak thicknesses of 2.5 and 3.8-cm thick. The PAR+MARK method was more likely to result in a more positive eating experience as steaks were cut thicker (3.8-cm) as demonstrated by consumer ratings for overall desirability. The GRILL method had the least amount of variation in consumer ratings for overall desirability between steak thicknesses for positive eating experience. Cookery method and steak thickness should be chosen in the correct combination in order to deliver consumers with a positive eating experience in food service industry.

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CHAPTER 1

INTRODUCTION

The population of cattle produced in the United States is incredibly diverse. The population includes cattle bred specifically for different purposes such as meat, breeding, and milk production. In addition, beef cattle are also bred to be better adapted to environmental differences, another source of variation in the cattle population. In the 2005 National Beef Quality Audit, a goal to specifically target "weights that maximize profits without creating conflicts with consumer preference" was outlined (Smith et al., 2006). Extreme genetic diversity within the domestic beef supply is one of the greatest challenges when trying to deliver a consistent product to consumers in all sectors of the industry.

Another important source of inconsistency is the industry's heavy reliance on carcass weight as the primary driver of gross dollar value. The trend toward heavier cattle reaching packing facilities can be attributed in part to the shrinking cattle herd. The National Beef Quality Audit allows for the tracking of national averages in hot carcass weight (HCW) and ribeye area (REA) measurements. When comparing the National Beef Quality Audit of 1991 to that of 2011, HCW increased by 29 kg, and REA increased by 5.4 cm^2 (Lorenzen et al., 1993; Moore et al., 2012). This increase in HCW has served to increase the efficiency and sustainability of beef production by increasing the amount of beef produced while maintaining a smaller national cow herd size (NCBA, 2014).

However, increased HCW has provided additional consistency challenges for the retail and food service sectors of the meat industry. There has been a concentrated effort to find innovative fabrication techniques to mitigate the severity of these consistency issues. Improvements in sorting and marketing of beef products is one way to combat the irregularity and inconsistency challenges created by such a variety in hot carcass weights (Dunn et al., 2000). These changes in the cattle production system have prompted the industry (National Cattlemen's Beef Association) to concede to alternative cutting and merchandizing options (Beef Alternative Merchandising). These alternative options advocate reducing portion sizes by halving subprimals and cutting thicker steaks that are smaller in diameter and resemble the size and shape of a filet steak. The retail and food service industries are either transitioning toward thinner cut steaks to maintain portion sizes from larger subprimal cuts, or are cutting thicker steaks using this alternative fabrication method. Beef Alternative Merchandising cutting methods may have more opportunity in the food service sector rather than the retail case (Sweeter et al., 2005; Dunn et al., 2000). These alternative fabrication methods come with their own set of challenges for the retail and food service sectors of the industry. For instance, they require very skilled labor, and result in yield loss due to additional trimming of the cuts.

There is no published evidence that steak thickness alone (disregarding degree of doneness and cooking method) contributes to tenderness, juiciness, or overall desirability of steaks. However, many consumers and experts speculate that steak thickness contributes to each of these attributes. Scientific evidence was needed to justify steak cutting strategies and preparation methods moving forward in order to deliver a consistent, positive eating experience for consumers.

Food service operators and restaurateurs utilize a variety of preparation methods for beef steaks, each of which employ different methods of heat transfer, which can affect steak sensory attributes including tenderness, juiciness, flavor, and internal and external appearance. In the food service industry, the decision determining steak cookery method is based upon the volume of steaks being prepared, kitchen space availability, equipment availability, style of serving (e.g.

buffet, plated, carving stations, etc.), and the preference of the head chef or kitchen manager. The 2011 National Beef Quality Audit stated that eating satisfaction is prioritized second only to food safety in the industry sectors of packers, food service establishments, and retailers (Igo et al., 2013). Steak preparation decisions then should be made by weighing which cooking method will deliver the most positive eating experience for the consumer.

The majority, over 96%, of beef in the food service and retail industry is classified as tender or very tender based on WBSF values reported in the 2006 National Beef Tenderness Survey (Voges et al., 2007). Once tenderness is no longer a negative eating factor, consumers turn to flavor to make decisions about overall like (Platter et al., 2003). It may be that the vast majority of consumers prefer a single preparation method over all of the others, or it may be true that no one group can agree on a preferred preparation method for steaks. Food service cookery methods have not been studied in great detail to increase understanding of their effects on the consumer's eating experience. In order to create steak cooking guidelines for the food service industry, more information was necessary to understand the differences created through the modification of steak thickness and cookery method.

The objectives of this study were:

- To determine the influence of steak thickness and common food service preparation method on the beef sensory experience perceived by invested beef consumers
- To establish WBSF, Slice Shear Force (SSF) values, and cookloss percentages for steaks of varying thicknesses and resulting from common food service cooking methods
- To obtain objective indicators of external and internal cooked steak appearance.

- To establish recommendations for steak thicknesses and cooking methods for beef loin steaks cooked in food service applications.

CHAPTER 2

REVIEW OF LITERATURE

Consumer Preferences in Thickness and Portion Size

Regular beef consumers individually prefer steaks cut to a thickness that offers them the best eating experience. Leick et al. (2011) reported that 26.9% of consumer participants rated steak thickness as their most important criteria when buying ribeye steaks. When buying top loin steaks, 32.12% stated that steak thickness was the most important factor considered before purchase (Leick et al., 2011). When consumers were asked to evaluate ribeye steaks of varying ribeye areas (REA) and constant weights for purchase, steaks that were thinner (from heavier carcasses) were chosen 26.7% of the time. Ribeye steaks from the smallest REA category were chosen least frequently, presumed by investigators as being less preferred due to small surface area and increased steak thickness (Leick et al., 2011).

Consumers had more variable selection preferences for top loin steaks. A portion of consumers preferred thicker steaks while a portion preferred thinner steaks (Leick et al., 2011). Sweeter et al. (2005) cut ribeye rolls from carcasses varying in REA into steaks of constant thickness, and also halved steaks to mimic the Beef Alternative Merchandising cutting method, and asked consumers to identify which steak they preferred. Sweeter et al. (2005) concluded that consumers preferred “large” steaks, cut from carcasses with a greater REA, compared with those originating from “average” sized carcasses. Consumers also were only willing to buy steaks cut in half if they were discounted by US$1.01/kg (Sweeter et al., 2005). Regardless of whether steaks were cut to a constant thickness or weight, consumers more frequently selected ribeye steaks from subprimals that had a larger REA (Dunn et al., 2000; Sweeter et al., 2005; Leick et al., 2011). Bass et al. (2009) tested whether REA influenced the acceptability of portion cut steaks from carcasses with various REAs and did not find a relationship between ribeye area and the acceptability of portion cut steaks from other muscles in the beef carcass.

In the retail sector, there has been no identified REA range that is more appropriate than another. Although thickness does impact a consumer's steak preference, research has shown that there is no one thickness that is consistently preferred over another (Leick et al., 2012). Since no REA range was preferred over another, it appears that that there is a buyer for every size of steak in the retail case (Sweeter et al., 2005). Consumers emphasized color, marbling level, and thickness more than they do price when buying steaks (Leick et al., 2012).

In the food service industry, Dunn et al. (2000) determined that the optimum REA range for portion cut steaks was between 77- and 97-cm^2. Steaks cut from carcasses with a REA of 77- to 97-cm^2 were observed to have optimum cooking times and tenderness ratings. These steaks offer the most desirable experience for both the food service restaurant preparing the steak as well as the consumer eating the product (Dunn et al., 2000). Steak thickness was the primary factor in determining variability of cooking time of steaks. In order to deliver a consistent product to customers, uniformly sized products should be ordered by the food service restaurant in order to minimize variability in thickness and portion size. There is a smaller margin for error for thinner steaks when cooked to specified end point temperatures and some food service cooks may not be able to consistently deliver the customer specified degree of doneness (Dunn et al., 2000). Selecting for a consistently sized product should limit variations in cooking time and inconsistencies in degree of doneness, as well as ensure that consumers are not recieving a compromised eating experience (Dunn et al., 2000).

Consumer Preferences in Cookery Method

Among many other factors, degree of doneness and cookery method are two consumer-controlled factors that affect eating satisfaction when preparing beef steaks in the household (Lorenzen et al., 1999; Neely et al.,1999; Savell et al., 1999). Cookery method has the opportunity to affect all sensory traits including tenderness, juiciness, and flavor (Goodson et al., 2002). Thus, the way consumers choose to prepare steaks of any kind in home greatly influences their chances of either having a positive or negative eating experience (Goodson et al., 2002). Similarly, the way that a food service restaurant chooses to prepare steaks can also greatly influence the probability of a consumer having a great eating experience.

Many Beef Customer Satisfaction surveys have been completed over the years to determine the consumers' choices and preferred cookery method for steaks in their own kitchens. The consensus from these surveys is that the preferred cookery method is inconsistent and regional. Consumers from different regions of the United States had variable preferences in both degree of doneness and cookery method (Savell et al., 1999; Lorenzen et al., 1999; Neeley et al., 1999). Therefore, few conclusions can be drawn about consumers preferences in cookery method based on previous research.

Beef Tenderness

Tenderness is the most influential factor in determining consumer acceptability of overall eating experience of steaks and beef products (Szczesniak and Jorgenson, 1965; Koohmaraie, 1996; Platter et al., 2003; Huffman et al., 1996). Miller et al. (2001) conducted research to determine a "threshold level" for acceptability of tenderness as determined by consumers by correlating shear force values with consumer acceptability. A threshold level for WBSF of <3.0, 3.0 to 4.3, and >4.9 kg resulted in 100, 93, and 25%, respectively, consumer satisfaction ratings for beef top loin steaks (Miller et al., 2001). Shackelford et al. (1991) reported that WBSF values of 4.6 and 3.9kg would hve a 50% and 68% chance, respectively, to be rated “slightly tender” by consumers.

Boleman et al. (1997) utilized the WBSF threshold level of 4.6 kg established by Shackelford et al. (1991) in a poll of consumers in order to determine their perceptions of top loin steaks of various, but known, shear force values. When consumers were not informed of shear force values, they only selected steaks from the “tender” category 55.3% of the time. However, when consumers were informed of shear force tenderness values, consumers purchased steaks from the “tender” group 94.6% of the time (Boleman et al., 1997). Consumers believe that tenderness is important to their eating experience and are willing to pay more for a product that is of guaranteed tenderness levels (Miller et al., 2001; Platter et al., 2003). It is important for all sectors of the beef industry (packer, retailer, and food service) to manage beef products correctly in order to maximize tenderness and increase the probability that the consumer will have a positive eating experience. Before beef products reach the food service restaurant or retail counter, production of tender beef products should be addressed through genetic selection, nutrition, animal health, and postmortem aging.

Marbling. Much research has been conducted in order to explain the effects of intramuscular fat on tenderness, juiciness, and flavor of beef products. Studies have described low to moderate, positive relationships between marbling and beef sensory traits (Briskey and Brey, 1964; Jeremiah et al., 1970; Smith et al., 2008). Intramuscular fat is less dense than protein and serves to dilute connective tissue and muscle fibers (Lawrie, 1966; Jeremiah et al., 1970; Smith et al., 1973). One property of samples that have a greater amount of intramuscular fat include reduced resistance needed to disrupt myofibrils. This creates a more tender meat product because less force is needed to chew or fragment the product (Smith et al., 1973). Bratcher et al. (2005) reported significant tenderness differences in the *Infraspinatus, Triceps brachii* **–** lateral and long head, *Serratus ventralis, Complexus, Splenius, Rhomboideus, Vastus lateralis, and Rectus femoris* from USDA Select versus premium Choice carcasses. The lubrication theory suggests that samples that readily release fat, or maintain juiciness for a more sustained amount of chewing have a higher perceived tenderness. Briskey and Kauffman (1971) suggested that steaks with greater lubrication due to increased marbling maintained quality attributes more sufficiently when exposed to extreme cooking methods or when cooked to a more severe degree of doneness.

Postmortem Aging. Aging has been the most influential postmortem practice used to improve beef tenderness (Smith et al., 1978; Calkins and Seideman, 1998; Tatum et al., 1999). Previous studies have found that beef tenderness increased each day post slaughter, and over 80% of the aging response occurred within 6 days post mortem (Smith et al., 1978; Calkins and Seideman, 1998). Muscle aging time in the industry has averaged approximately 20 days, but aging periods have been found to range from 2 to 91 days (George et al., 1999).

Tenderness increases with postmortem aging due, partially, to enzymatic proteolysis and loss of structural integrity of myofibrillar and stromal proteins. Destruction of myofibrillar proteins causes disruption in sarcomere integrity (Koohmaraie, 1996). This destruction in sarcomere integrity improves tenderness, and is one of the primary causes of the aging response (Goll et al., 1983; Koohmaraie, 1996). Cytoskeletal proteins are highly susceptible to proteolysis and enzymatic degradation during the aging period (Wang and Ramirez-Mitchell, 1983; Bandman and Zdanis, 1988). The cytoskeletal proteins that are targeted by these degradation enzymes to increase tenderness during postmortem aging are Titin and Nebulin. Titin and

Nebulin are largely responsible for structure of the muscle fiber and are degraded within 7 to 14 days postmortem. Lack of these structural proteins cause detachment of contractile proteins from the Z-disk (Huff-Lonergan et al., 1995). Nishimura et al. (1998) found that structural weakening of the perimysium and endomysium was most evident at 14 days of aging. This weakening of connective tissue has been attributed to the catheptic enzymes, elastase and plasmin (Greaser, 1997). Initial tenderness improvements postmortem can be attributed to the myofibrillar changes, and the more gradual tenderness increases that are seen later in the aging process can be attributed to connective tissue degradation (Feidt et al., 1996; Greaser et al., 1998; Nishimura et al., 1998).

Cookery Method. Many factors are very influential to the innate tenderness of beef products, yet beef product tenderness is also influenced by product handling at the food service or retail level. The factors that influence tenderness at the food service and retail level include preparation techniques, cookery method, and degree of doneness (Hedrick et al., 1968; Savell, et al., 1987, 1989; Pohlman et al., 1997). Many research studies have evaluated different cookery methods in order to determine their effects on WBSF and SSF. Identifying how a cookery method changes the internal properties of steaks has been important to develop a “gold standard” cookery method for WBSF and SSF assessment. Although scientists can agree that cookery methods influence tenderness, scientists have not yet completed studies to determine the influence that food service cookery method has on the consumer’s eating experience.

Cookery method has been studied in order to determine its effect on tenderness during the SSF and WBSF processes. Hedrick et al. (1968) compared the methods of deep fat frying and broiling of steaks to find that steaks that were deep fat fried had higher WBSF values. Other, more recent studies have studied more novel cookery methods such as clamshell grills, convection ovens, electric grills, and more (Lawrence et al., 2001; Kerth et al., 2003; McKenna et al., 2003; Bowers et al., 2011; Yancey et al., 2011; Callahan et al., 2013). For instance, Lawrence et al. (2001) reported that a forced air convection oven and electric broiler had lower WBSF values than did a belt grill. Also, Yancey et al. (2011) reported that the convection oven had lower WBSF values than did a clamshell style grill. Discrepancies between WBSF and SSF values for each cookery method studied have also been witnessed. In one research study, steaks cooked using a clamshell grill had the highest WBSF values, while steaks cooked with a conveyor convection, or a grill had the highest SSF values (Callahan et al., 2013). Although much research has been conducted, there have been no consistent conclusions drawn regarding which dry heat cookery methods have the greatest impact on the tenderness of steaks. There are many factors influencing the effect of a cookery method on steak tenderness, and no two modes of heating create the same results in beef products. This inconsistency in cookery method and heat transfer makes comparing cookery methods utilized in these various studies difficult.

When studying the differences between dry and moist heat cookery methods, Kolle et al. (2004) found that beef cooked utilizing a moist heat cookery methods had lower WBSF values for the *M. adductor*, *M. rectus femoris*, and *M. semitendinosus* than did steaks from the same muscles cooked using a dry heat cookery method. Bowers et al. (2012) studied the effects of cooking type, moist or dry, on beef roasts. No significant difference was found between the two cookery methods except in WBSF values when roasts were cooked to an end point temperature of 76.7^{o}C. The moist heat cookery method was found to have a tenderizing effect on the roasts when measured by WBSF when cooked to an end point temperature of 76.7^{o}C. It is important to note that tenderness differences due to cookery method are dependent upon many attributes within each muscle. Muscles from different parts of a carcass, with different intrinsic characteristics, should not be expected to perform the same as the *Longissimus* muscle using any cookery method.

Sarcomere Length and Collagen Solubility. Heating, or cooking, of meat always causes a reduction in sarcomere length, which is responsible for increasing toughness of steaks during the cooking process. However, many studies have shown that the extent of sarcomere shortening during the cooking process was dependent on the sarcomere length in the raw state as affected by postmortem changes and proteolysis (King et al., 2003; Hegarty and Allen, 1975; Locker and Danes, 1975; and Wheeler and Koohmaraie, 1999). Palka (2003), when studying the beef *Semitendinosis* muscle, found that sarcomere length decreased continuously as end point temperature increased. However, muscle fiber diameter was only affected until 50-60^{o}C had been reached, and there were no decreases in fiber diameter at higher temperatures (Palka, 2003). Furthermore, differences in sarcomere length are negatively correlated to cook loss percentages (Palka, 2003). As sarcomeres shrink, their water holding capacity decreases as well. Higher cook losses, combined with shortening sarcomeres, compound to decrease tenderness of cooked steaks.

Parrish et al. (1973) discussed the collagen solubility point of meat to be 60^{o}C. Bertola et al. (1994) reported that collagen in a sample was completely solubilized at an end point temperature of 66^{o}C after 5 minutes. In order to impact tenderness and reduce background toughness, this threshold should be met in order to solubilize collagen during the cooking process. Thin steaks that cook very rapidly may not reach 66^{o}C and be held there for 5 minutes due to their extremely fast cooking times. This decreases perceived tenderness ratings in samples from thin cut, rapidly cooked steaks (Dunn et al., 2000). Cooking thinner steaks at a lower temperature for a longer period of time may be useful to increase tenderness by allowing collagen to solubilize to the maximum of its potential.

Obuz et al. (2004) found that because the collagen content of the *Longissimus lumborum* was so low, the effect of cooking the steaks past the solubilizing point of collagen is overridden by the shortening and toughening of the myofibrillar proteins. The length of sarcomeres likely has a greater effect on *Longissimus* tenderness than does collagen amount or collagen solubility due to the small amount of collagen in the *Longissimus* muscle (Obuz et al., 2004).

Cooking Yield

An area of interest when studying cookery method has been cooked yield and cook loss percentages. The amount of time it takes to cook steaks utilizing any given cookery method greatly impacts the final yield of the research steaks (Callahan et al., 2013; Dunn et al., 2000). Callahan et al. (2013) discovered that the cookery method that took the shortest time also had the highest cooked product yields. Conversely, the cookery method that took the greatest amount of time had the greatest amount of cook loss, and the lowest cooked product yield (Callahan et al., 2013). Cook yield tests conducted on portion cut steaks found that thicker steaks had a greater amount of cook loss than did thinner steaks. This difference was attributed to a longer cooking time associated with cooking thick steaks all the way through to a desired degree of doneness (Dunn et al., 2000).

Yancey et al. (2011), while cooking to a common degree of doneness, found no differences in cooking loss percentages among the cookery methods of forced air convection, charbroiler, impingement oven, clamshell grill, or electric countertop griddles. Berry (1993) reported no differences in cook loss when comparing an electric broiler and broiler grill. Conversely, broiled steaks were found to have higher cook losses than those that were cooked on a grill or in an oven (Kerth et al., 2003). Similarly, steaks cooked on a clamshell grill had less cooking loss than those cooked on an electric broiler (McKenna et al., 2003). The effect of cookery method on cooked product yield is inconsistent from study to study, and may depend more on the method of heat transfer as well as the temperature setting of the oven/grill/broiler.

Research has reported that steaks that are seared, or form an outer shell of dehydrated material, tend to loose less water through the evaporation process, especially when cooked to higher end point temperatures (Wheeler et al., 1998; Kerth et al., 2003; Bowers et al., 2012). Searing of steaks is largely dependent on a conduction method of heat transfer as well as temperature of cooking, and amount of moisture present in the cooking environment (Kerth et al., 2003). This effect should be taken into consideration when comparing results of cooking yield due to cookery method, particularly when different heat transfer types are employed.

Cooking Time and Rate

In the food service industry, increased carcass weights and REAs pose a challenge when portion cutting, preparing, and cooking steaks. In portion cut steaks, thickness accounts for the majority of variation in cooking time (Dunn et al., 2000). Steaks from larger ribeyes, when portion cut, are thinner and have a greater amount of surface area, offering a faster cooking time. In contrast, steaks cut from smaller ribeyes are thicker, have less surface area, and will take a greater amount of time to cook. Cooking time is also directly related to efficiency of heat transfer, and oven temperature (Yancey et al., 2011). Cross et al. (1976) found that oven temperature has a large impact on the percent of moisture that is evaporated from steaks. Cookery methods employing a conduction style of heat transfer are found to increase the rate of cooking when compared to convection style cookery methods such as convection ovens, or electric broilers (Kerth et al., 2003; Lawrence et al., 2001; Yancey et al., 2011). Cooking yield was also affected by type of cookery method (dry or moist heat cookery). Steaks that were broiled, dry heat cookery method, had lower retained cooked product yield than steaks that were roasted, moist heat cookery method (Renk et al., 1985).

Although steak thickness has been found to impact cooking time, cooking rate of steaks does not differ from one thickness to another, and depends instead on heat transfer efficiency, and temperature of the heating unit (Dunn et al., 2000). Berry (1993) noted differences when comparing within steak tenderness uniformity, when steaks were cooked at different rates of speed. Tenderness uniformity increased with rapidly cooked steaks, while tenderness uniformity decreased in steaks cooked at slower rates. A sizeable tenderness gradient existed in steaks that were cooked at slower rates (Berry, 1993). Steak thickness has been found to be negatively correlated with shear force values, while surface area of steaks has been reported to be positively correlated (Dunn et al, 2000). Rate of cooking also influences cooked product yield. Steaks that were cooked at faster rates often are seen to have higher cooking loss values than do slower cooking methods (King et al., 2003; Cross et al., 1976; Lawrence et al., 2001).

Juiciness

Juiciness of steaks can be attributed to many factors, including: pH of the meat, water-holding capacity, intramuscular lipid content, and end point temperature to which the meat was cooked. Juiciness perception depends upon both initial juiciness due to fluid release as well as sustained juiciness through the chewing process (Weir, 1960). Initial juiciness is described as the first wetness that is perceived during the first few seconds of chewing. Sustained juiciness relies on the stimulation and release of saliva by the fat that is within the sample (Bratzler, 1971).

Wheeler et al. (1998) reported higher sensory panel juiciness ratings for steaks cooked on a belt grill rather than cooked utilizing an electric broiler. These juiciness scores were attributed to the higher value for cook loss for steaks cooked with an electric broiler. Furthermore, the evaporative portion of a steak's cook loss contributes to lower juiciness ratings as seen in trained sensory panels (Cross et al., 1976). Cookery method has not been found to influence lipid retention in steaks and roasts (Renk et al., 1985).

Flavor

The term flavor is extremely hard to define, and there are many factors that influence a product's flavor. Flavor is an attribute that employs three sensory systems, much more than simply taste on the tongue, and has a vast array of descriptive terms. Flavor is taste on the tongue and soft pallet, volatiles stimulating the olfactory nerve, and sensations in the mouth and airways. Furthermore, texture, visual appearance, and other sensory factors may contribute to a consumer's opinion of a sample's flavor.

An animal's diet plays an important role in flavor of beef products. Differing diets can cause very small differences in a ruminating animal's fatty acid profile, but above all, differences in diets impact the amount of intramuscular fat an animal deposits. Hiner (1956) and McBee and Wiles (1967) reported that as intramuscular fat increases, flavor also increases in a direct, linear relationship. Although many have published that beef flavor increases with beef fat content, Melton (1990) found that differences in flavor due to feeding practices were confounding. Beef flavor is complex and incredibly subjective, and it can be concluded that even if flavor differs, no one beef flavor can be described as being more desirable than another.

Two main reactions, the Maillard reaction and the thermal oxidation of fatty acids, influence beef flavor development during the cooking process. Different cookery methods impart different flavors due to variations in heat transfer type, rate of cooking, moisture content, and temperature of the cooking meat product (Rhee, 1989). These differences in cookery methods govern the possible reactions that can take place, and ultimately determine the end flavor of the cooked meat, as well as the intensity of the flavor of the cooked product (Rhee, 1989). Mottram (1996) explained differences in volatile compounds due to the Maillard reaction in the cooking process. Roast flavors are generally attributed to heterocyclic amines such as pyrazines, thizoles, and oxazoles, whereas a broiled meat emits a greater amount of aliphatic thiols, sulfides, and disulfides. Each of these volatile compounds impacts flavor and aroma in a unique ways, and explain the flavor preferences that consumers have in relation to cookery method (Mottram, 1996).

Lorenzen et al. (1999) reported differences in beef flavor ratings due to cookery method in a study that polled consumers from many cities across the United States. Consumer flavor ratings for the different cookery methods were inconsistent from city to city suggesting regional flavor preferences (Lorenzen et al., 1999). Furthermore, excessive crust formation, created from high-heat, conduction cookery methods, may inhibit a consumer's ability to evaluate the steak objectively (Wheeler et al., 1998).

It has also been noted that cooking rate and holding time may also have an influence on the potency of the beef off flavors (Calkins and Hodgen, 2007). Slower cooking times and longer holding times may allow for off odors to dissipate and lessen in intensity (Calkins and Hodgen, 2007).

Ribeye area has also been found to influence beef flavor intensity. Steaks from smaller ribeye areas have been found to possess a more intense beef flavor, while steaks that are cut from larger ribeye areas generally have a weaker beef flavor. Much of this flavor variation is likely due to intrinsic factors that change due to muscle fiber type (myoglobin concentration, concentration of polar lipids, and glycolytic storage). However, animals with small ribeyes generally yield portion cut steaks that are thicker. Thickness may play a role in flavor differences between ribeye areas. Steaks that are cut thicker also have longer cooking times, which allows for a greater amount of time for flavor development (Dunn et al., 2000).

Color

In order to objectively measure color differences in meat, two devices have been used: a colorimeter and a spectrophotometer. A colorimeter is used to detect and measure small color differences in samples that have nearly the same color. It uses a combination of illuminant and observer to measure CIE L* (lightness), a* (redness), and b* (yellowness) values. Spectrophotometers are more complex instruments that offer many combination settings.

Degree of doneness is the most influential factor determining internal color of cooked steaks. However, cookery method and steak thickness also influence internal and external appearance of steaks. A slower rate of heating will produce a less well-done internal appearance than a faster heating system (Berry, 1993). Furthermore, one study found that internal color for steaks cooked through forced-air convection, charbroiler, and impingement oven had more red internal appearances as measured by CIE a* while countertop griddles as well as clamshell grills had less red internal color on the red, CIE a*, scale (Yancey et al., 2011). A steam combination oven was compared to a forced air convection oven, and internal steak color measurements were obtained. The convection oven had higher, more red, internal CIE a* measurements (Bowers et al., 2012). Thinner steaks also have a higher visual degree of doneness score than thicker cut steaks (Dunn et al., 2000).

Bowers et al. (2012) reported that when using a steam combination oven rather than a forced air convection oven, roasts had a lighter, more tan appearance with a greater amount of moisture at the surface of the product. The product that was cooked in the convection oven had a hard shell and was darker in color, with a drier outward appearance (Bowers et al., 2012). Although roasts had differences in external appearances, there was no difference in external lean darkness (CIE L*) values measured on the external lean portion of the roast (Bowers et al., 2012). Cookery methods utilizing a high moisture environment showed less browning effects. Also, cookery methods using a conduction method of heat transfer have a greater chance of creating dark, or charred external appearances due to direct contact of steak surfaces with the heat source.

CHAPTER 3

MATERIALS AND METHODS

Institutional Animal Care and Use Committee approval was not required for this study as samples were obtained from federally inspected harvest facilities.

Product Collection and Sample Preparation

USDA Low Choice beef carcasses (n = 38) were selected from a commercial processing facility. Collection of samples was completed in three product collection periods that coincided with three consumer panel periods. Carcasses with a Small degree of marbling and no large visible defects in the loin primal were identified and tracked to fabrication, where paired strip loins (IMPS 180) were collected from each carcass. Once collected, strip loins were transported in coolers to the Colorado State University Meat Laboratory. Each strip loin was cut into 2, 18-cm sections (4 sections per carcass). Sections were created by cutting 18-cm sections beginning at the anterior of the strip loin, perpendicular to muscle fiber orientation. Once cut, sections were randomly assigned to one of four cooking methods (COOK): 1) grilled, using a radiant-heat, open-hearth gas grill (GRILL); 2) initially grill marked on a radiant-heat, open-hearth, gas grill and brought to final temperature in a steam oven (MARK+FINISH); 3) initially par cooked (warmed to a determined internal temperature) in a steam oven and grill marked on a radiant-heat, open-hearth, gas grill (PAR+MARK); 4) broiled in a commercial broiler (BROIL). Sections were vacuum-sealed and wet-aged (2°C) for 21 days before being frozen (-20^{0}C). Once frozen, each section was cut using a band saw (Model 400, AEW-Thurne, AEW Engineering Co. LTD., Norwhich, UK) into 3 pairs of steaks (6 steaks) representing 3 steak thickness treatments (THICK): 1) 1.9-cm; 2) 2.5-cm; 3) 3.8-cm. Steak THICK treatment location was randomized within each section. Within each pair, a single steak from was randomly designated for consumer panels. The other paired steak was designated for objective measurements of tenderness, cook loss, and internal and external color. All 12 COOK x THICK treatment combinations were represented within each pair of strip loins, so that comparisons were made within animal.

Cookery Method Standard Operating Procedures

Standard operating procedures (SOPs) were outlined for each cookery method to ensure consistent cooking practices through consumer sampling at three different locations. The SOPs were also utilized during the cooking process for steaks destined for shear force, and color measurements. The target end point temperature for all steaks was a medium rare degree of doneness, 63^{o}C. Steaks were cooked to a medium rare (63^{o}C) degree of doneness to more closely represent endpoint steak temperatures in food service applications.

For the GRILL cookery method, an open-hearth, radiant-heat, gas heated grill was set at a medium or high heat, with the target temperature for the hottest portion of the grill of 343^{o}C, as measured by an infrared thermometer (InfraPro® 35639-00, Oakton Instruments, Vernon Hills, IL). Steaks were grill marked at the hottest portion of the grill, on both sides in a cross hatch pattern (45^{o} rotation from grill grates) allowing one minute of contact time with the grill per hatch. Once grill marked, the steaks were flipped every 2 minutes. Steak temperature was measured in the geometrical center of each steak using a probe thermometer (SPLASH-PROOF SUPER-FAST® THERMAPEN®, ThermoWorks, Lindon, UT).

In the MARK+COOK method, the hottest portion (343^{o}C) of the open hearth, gas heated grill, was used to grill mark the steaks. Steaks were grill marked in a crosshatch pattern (45^{o} rotation from grill grates) on both sides, allowing one minute per hatch. Once steaks were grill marked, they were positioned on a wire mesh rack over a baking pan and placed in a steam oven

(Model SCC WE 61 E; Rational, Landsberg am Lech, Germany). The steam oven settings were; 66°C and 100% relative humidity. Steaks were allowed to rise in temperature until they reached the target end point temperature of 63°C, then immediately removed from the oven. Steak temperature was monitored in the geometric center of the steak using the oven core temperature probe (Model SCC WE 61 E; Rational, Landsberg am Lech, Germany).

A steam oven set at 66°C and 100% relative humidity (Model SCC WE 61 E; Rational, Landsberg am Lech, Germany) was utilized first for the PAR+MARK cookery method. Steaks were positioned on a wire mesh rack over a baking pan and placed in the oven. Steaks were heated to a designated temperature that was dependent on steak thickness. The temperatures at which the steaks were pulled from the oven were 33, 53, and 59°C for 1.9-, 2.5- and 3.8-cm thick steaks, respectively. Steak temperature was monitored using the oven core temperature probe (Model SCC WE 61 E; Rational, Landsberg am Lech, Germany). The temperature at which the steaks were pulled from the oven was designed so that the steaks could be grill marked in a cross hatch pattern (45° from grill grates) on both sides, allowing for one minute per hatch, and ultimately reach the target end point temperature of 63°C. Endpoint temperature was measured in the geometric center of each steak using a probe thermometer (SPLASH-PROOF SUPER-FAST® THERMAPEN®, ThermoWorks, Lindon, UT).

Finally, steaks designated to the BROIL treatment were cooked using a commercial, salamander style broiler was used on the highest setting available. Internal temperature of the broilers used varied from 260°C to 371°C. Variation was due to functionality and working state of the broilers at each location. Steaks were placed in 16oz ceramic rarebits before being placed into the broiler. Steaks were turned over half way through the cooking process. Steaks were turned at 3, 5, and 7 minutes for 1.9-, 2.5-, and 3.8-cm thick steaks, respectively. Once turned, steaks were allowed to cook the remainder of the way until they reached the optimum pulling temperature for their thickness. Temperatures designated for pulling were 57, 54, and 51ºC for steak thicknesses 1.9-, 2.5-, and 3.8-cm, respectively. Steaks were pulled from the broiler, removed from the rarebit, and the internal temperature was allowed to peak to the target temperature of 63ºC. Endpoint temperature was measured in the geometric center of each steak using a probe thermometer (SPLASH-PROOF SUPER-FAST® THERMAPEN®, ThermoWorks, Lindon, UT).

Shear Force Determinations

The paired steaks that were destined for shear force determinations were removed from freezer storage and allowed to thaw at 2ºC for 48 h before cooking. Steaks were cooked to a target end point temperature of 63ºC using the SOPs outlined above for each cooking method. Weight measurements were taken before and after cooking to estimate cook loss. Within 3 min of being removed from the grill/broiler/oven, a 1-cm by 5-cm slice was cut from the lateral end of each steak, parallel to muscle fiber orientation, in order to perform Slice Shear Force (SSF). Each slice was sheared once with a flat, blunt end blade using an Instron Universal Testing Machine (Model 4443, Instron Corporation, Norwood, MA) at a crosshead speed of 500 mm/min. Following SSF the steaks were allowed to cool to room temperature and 3 to 8, 1.27-cm diameter cores from the distal and medial ends of the steak were obtained, parallel to muscle fiber orientation for WBSF determinations. Each core was sheared once perpendicular to the muscle fiber orientation, using an Instron Universal Testing Machine (Model 4443, Instron Corporation, Norwood, MA) at a crosshead speed of 200 mm/min. Peak load measurements were recorded and averaged to obtain a single WBSF value for each steak.

Consumer Sensory Panel

A total of 6 untrained consumer panels were held in conjunction with 3 different National Cattlemen's Beef Association meetings. Consumers with a high affinity for eating and enjoying steak were targeted for this study. This consumer group was targeted as they are more likely to order steak in a food service establishment and have more discriminating palates for steak palatability traits. Steaks for consumer panels were removed from freezer storage and thawed for 48 h at 2^{o}C. Steaks were cooked using the SOPs previously outlined for each cookery method.

A total of 307 consumers participated in the sensory panels. Consumers were asked to complete a short demographic survey before participating in the sensory panel. The form used to record demographic information is included in Appendix 2. Consumer participants also were provided unsalted saltine crackers, apple juice, and water to cleanse their palates between each sample. Before participating in the panel, consumers were provided with instructions regarding cleansing their palate and how to appropriately mark their responses for each sample on the supplied ballet (Appendix 2).

In each panel session, consumers were assigned to groups of 6 to 14 individuals and asked to sample 12 steaks, one of each COOK x THICK treatment combination, all originating from the same carcass. Within carcass comparisons of all treatment combinations allowed for more accurate comparison of treatment differences. Panelists rated steaks for the traits of; tenderness, juiciness, flavor desirability and overall desirability, and consumer responses were recorded using a 15-cm unstructured line scale. The ballots included anchor descriptions at 0 and 15 cm of: 0 – very tough, very dry, very undesirable; and 15 – very tender, very juicy, and very desirable.

Internal and External Appearance

A colorimeter (Miniscan Model 4500s, Hunter Associates Laboratory, Reston, VA) was used to collect CIE L* a* b* measurements on the exterior and interior of each steak. Three measurement of CIE L* a* b* were obtained from different locations within or on the outer surface of the steak to gather an average for each sample. Exterior measurements were taken between char marks created by grill marking the steaks.

Subjective measurements of degree of doneness, percent surface char (percent of the surface of the steak that was blackened), and internal and external steak appearance were recorded. Visual degree of doneness was evaluated and recoded using a 5-point hedonic scale based on published photographic standards published in the 7th edition of the Meat Buyers Guide (2011). The scale for degree of doneness was as follows: 1-rare, 2-medium rare, 3-medium, 4-medium well, and 5-well done. Internal steak appearance was recorded using an 8-point hedonic scale (1-purple, 2-red, 3-reddish-pink, 4-pink, 5-pinkish-grey, 6-light brown, 7-medium brown, and 8-dark brown). External steak appearance was evaluated in between char marks created by grill marking the steaks. Measurements were recorded using an 8-point hedonic scale (1-light grey, 2-grey, 3-greyish-brown, 4-light brown, 5-brown, 6-dark brown, 7-brownish-black, 8-black). Percent surface char was measured by visually evaluating the percent of the steak that was charred or blackened on one side of the steak. Estimates were recorded as percentages of total surface area.

Statistical Methods

Using the mixed procedure of SAS (SAS Inst. Inc., Cary, NC), data were analyzed using a split plot design. Within this design, the whole plot factor was cookery method, and the sub plot factor was steak thickness. Also, the random effect of animal was used as a block. A covariate of off temperature was used when running results of SSF and WBSF values. Denominator degrees of freedom were calculated using the Kenward-Roger approximation (Kenward and Roger, 1997). Treatment least squares means were separated using the PDIFF option at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Consumer Panel Participants

Consumer demographic attributes, eating preferences, and consumption frequencies, are reported in Table 1 as a percentage of the total sample population by category. Because participants were not chosen to represent population demographics, some demographics were more heavily represented than others. For instance, approximately 48% of participants were over the age of 50, and 41% of participants reportedly earned a yearly income of greater than 100,000 dollars. Even though some demographic categories were more heavily represented than others, gender was fairly equal, with 50.7% of polled consumers being men and 49.3% being female.

The majority (60.6%) of consumers recorded that they preferred steaks that were cooked Medium Rare, followed by Medium (30.5%), Medium Well (5%), Rare (3.2%) and few participants preferred steaks cooked Well Done (0.7%). Thicker steaks, 2.5-cm and 3.8-cm, were preferred 59.1% and 34.2% of the time, respectively. Steaks cut at 1.9-cm were only reported to be preferred 6.8% of the time by participant. On average, participants consumed beef products approximately 6 times per week, and consumed beef products in a food service setting approximately 6 times per month. It was not asked to differentiate between beef steaks and beef as an ingredient eaten at food service establishments, so these estimations include all beef eaten in food service.

Tenderness and Cook Loss

A COOK x THICK interaction was observed for Slice Shear Force (*P* = 0.0006), Warner-Bratzler shear force (*P* = 0.0003) and consumer rated tenderness (*P* = 0.0003). Least squares means for Slice Shear Force, Warner-Bratzler shear force, and consumer rated tenderness can be found in Tables 2 and 3.

Steaks of all thicknesses cooked using the MARK+COOK method were among the most tender ($P < 0.05$) based on SSF, WBSF, and consumer perceived tenderness. The MARK+COOK method utilized a moist heat cookery method for the majority of the cooking time. Steaks in the MARK+COOK treatment were grill marked for 4 minutes in order to place crosshatch grill marks on both sides of the steak, then were placed in a steam oven for the remainder of the cooking time. Cooking times are reported in Table 2. Steaks cooked by the MARK+COOK method were more tender than those cooked utilizing a dry heat cookery method only (GRILL or BROIL) at 2.5- and 3.8-cm thick ($P < 0.05$). These results agreed with the findings of Kolle et al. (2004), where some steaks of the round were more tender when cooked using a moist heat cookery method. Additionally, roasts that were cooked to an end point temperature of 76.7^{o}C in a steam oven exhibited a lower WBSF value than those that were cooked in a convection oven (Kolle et al., 2004). Although roasts were cooked to a much higher degree of doneness in the results by Kolle et al. (2004), the use of a steam oven to increase tenderness is consistent with results of this study.

Tenderness is related to cooking loss (Callahan et al., 2013; Lawrence et al., 2001; Yancey et al., 2011). A COOK x THICK interaction was observed for cook loss ($P < 0.0001$). Least squares means for cook loss are reported in Table 2. The relationship between cook loss and tenderness was, in part, attributed to the bulk density effect. The bulk density effect states that steaks with higher cooking losses have a greater amount of myofibrillar protein and connective tissue per unit to be sheared (Lawrence et al., 2001). The MARK+COOK cookery method had the lowest cook loss values for all thicknesses ($P < 0.05$), with the exception of the 1.9-cm thick BROIL steaks, which also had among the most tender ratings for SSF and consumer perceived tenderness. The suggestion that a moist heat cookery method decreases cook loss, and increases tenderness was consistent with the work of Kolle et al. (2004) and Bowers et al. (2012) who found that moist heat cookery methods were associated with lower cook loss percentages, and more tender WBSF measurements. Lower cook loss percentages was reported to cause an increase in perceived tenderness when steaks are evaluated using a taste panels. Briskey and Kauffman (1971) attributed these changes in perceived tenderness to be a function of the lubrication effect.

Steaks that were 1.9-cm thick and part of the BROIL treatment were more tender than 2.5- or 3.8-cm thick BROIL steaks for the measurements of WBSF, and consumer perceived tenderness ($P < 0.05$). Additionally, 1.9-cm thick BROIL steaks had lower SSF values than 3.8-cm thick BROIL steaks ($P < 0.05$). Steaks in the BROIL treatment generated increased cook loss percentages as thickness increased ($P < 0.05$). This increase in cook loss percentages can be attributed to the increased time it took to cook thicker steaks (Table 3). Greater cook losses associated with steaks that cooked longer agreed with the findings of Callahan et al. (2013). Furthermore, thicker cut steaks were found to have greater cook loss percentages and lower values for WBSF by Dunn et al. (2000), which was consistent with the differences seen in the BROIL treatment in the present study. Steaks 3.8-cm thick from the BROIL treatment had the greatest percentage of cook loss compared to all other treatment combinations, and had among the highest values for SSF and WBSF ($P = 0.05$). The current results agree with Kerth et al.

(2003) who reported that broiled steaks had the highest cook loss percentages when compared to steaks cooked on the grill or in the oven (Kerth et al., 2003).

Steaks differing in thickness and cooked via the GRILL method did not differ in SSF or panel tenderness ($P > 0.05$). However, GRILL 1.9-cm thick steaks were more tender than 2.5-cm thick steaks when measured using WBSF ($P < 0.05$). Differences in WBSF values for GRILL steaks of varying thicknesses was 0.18kg of force and was considered to be of little practical consequence. Cook loss for GRILL steaks was lower for 1.9-cm thick steaks when compared to both 2.5-cm thick steaks and 3.8-cm thick steaks, which explained the small tenderness difference seen between 1.9-cm thick and 2.5- and 3.8-cm thick steaks ($P < 0.05$). Once again, the difference in cook loss for the various thicknesses is small and not likely to be of practical consequence.

Least squares means for cooking times are reported in Table 2. The COOK x THICK interaction was significant for cooking time ($P < 0.0001$). For GRILL steaks, there was an increase in cooking time as thickness increased. Callahan et al. (2013) stated that steaks cooked for longer cooking times will have higher cook loss percentages and greater SSF and WBSF measurements. High heat, conduction style cookery methods (GRILL) sears the exterior of the steak surface, allowing little escape of moisture during the cooking process once the product surface is initially seared. Thus, the effects of cooking time on tenderness and cook loss are lessened or eliminated (Kerth et al., 2003). Although thicker steaks were cooked for a longer period of time than thinner steaks, there was no statistically significant tenderness differences between THICK treatments as measured by SSF.

Within the THICK treatments, cooking loss percentage did not differ for the PAR+MARK cooking method ($P > 0.05$). Results of the present study were inconsistent with those of Kerth et al. (2003). Previous research cites searing as the reason for consistent cooked product yields, however, in the PAR+MARK treatment, there was no searing of the exterior of the steak before heating to reduce, or keep cook loss constant for all steak thicknesses. Although cook loss was consistent for all thickness treatments, 3.8-cm thick, PAR+MARK steaks were perceived to be more tender than 2.5- and 1.9-cm thick PAR+MARK steaks as rated by consumers ($P < 0.05$). PAR+MARK, 1.9-cm thick steaks were tougher than PAR+MARK 3.8-cm thick steaks for WBSF and SSF ($P < 0.05$). PAR+MARK steaks of all thicknesses had similar values for cook loss, yet differed ($P < 0.05$) in WBSF, SSF, and consumer perceived tenderness values. In previous studies, cook loss has been marked as an influencer of tenderness. In the current study, cook loss percentage can be identified as an influencer in some tenderness differences, while in other treatments, it did not influence consumer perceived or measured tenderness (Dunn et al., 2000; Callahan et al., 2013). .

PAR + MARK, 1.9-cm thick steaks were tougher than those that were cut thicker (2.5- and 3.8-cm) agreeing with Dunn et al. (2000), who also reported that steaks that were thicker were more tender than those that were cut thinner. Dunn et al. (2000) did not employ a moist heat cookery method to par cook the steaks and also cooked all steaks to a medium degree of doneness (70^{o}C). Steaks cooked using the PAR + MARK method differed ($P < 0.05$) in cooking time as thickness increased. PAR+MARK steaks were likely tenderized through the cooking process due to high humidity in the cooking environment, and slow cooking times. Thicker, 3.8-cm thick steaks had the greatest opportunity for collagen to solubilize during the cooking process due to the extended time it took to heat the steaks to 63^{o}C in the steam oven.

Juiciness

Least squares means for consumer rated juiciness are reported in Table 3. There was a COOK x THICK interaction for consumer rated juiciness (P = 0.0023). For the cookery methods of GRILL, MARK + COOK, and PAR + MARK, there were no differences in consumer perceived juiciness among 1.9-, 2.5-, and 3.8-cm thick steaks (P > 0.05). Perceived juiciness as rated by consumers only varied due to steak thickness within the BROIL treatment (P < 0.05). The BROIL cookery method was the only tested dry-heat cookery method that did not directly use conduction of heat through metal that would sear the outer surface of the steak. The results of the present study are consistent with the findings of Wheeler et al. (1998) who reported that steaks cooked in an electric broiler had lower juiciness ratings than those cooked on a belt grill.

Cross et al. (1976) reported that increased cook loss can result in reduced panel juiciness ratings due to the evaporative moisture that dissipates from the steak during cooking. Steaks within the BROIL treatment that were 3.8-cm thick exhibited the greatest amount of cook loss, while also having the lowest consumer perceived juiciness value. Juiciness as perceived by consumers is influence by the type of heat transfer as well as rate of cooking, and highest percentage of cooked product loss. Searing of the outer surface of the steak helped to keep internal steak moisture from evaporating when utilizing the GRILL and MARK + COOK method. The MARK+COOK method had the highest consumer perceived juiciness ratings. Searing of the outer surface, as well as the utilization of a steam oven to reduce cook loss is superior to other cookery methods at increasing consumer rated juiciness (Cross et al., 1976; Wheeler et al., 1998; Kerth et al., 2003; Bowers et al., 2012).

Flavor Desirability

Flavor desirability as perceived by consumers was not affected by steak thickness (*P* = 0.2128). Dunn et al. (2000) reported that increased cooking times to allow for a greater amount of time for flavor development. Following this theory, thicker steaks should have had a more developed flavor profile as they were exposed to each cooking method for greater periods of time. Flavor desirability as perceived by consumers during the present study did not agree with the findings of previous studies that evaluated the effect of steak thickness and cooking time on flavor development.

Consumer ratings for flavor desirabilty were affected by cooking method ($P < 0.0001$). The MARK + COOK and GRILL methods had more desirable flavor ($P <0.05$), as indicated by consumer ratings for flavor desirability, than did PAR+MARK and BROIL methods (Table 3). MARK + COOK steaks were among the slowest to cook at a thickness of 1.9-cm and the slowest to cook for 2.5- and 3.8-cm thick steaks ($P < 0.05$). Grilled steaks required the least amount of time to cook for 2.5- and 3.8-cm thick steaks, and among the least amount of time to cook for the 1.9-cm thick steaks ($P <0.05$). The MARK+COOK and GRILL methods did not differ ($P > 0.05$) in consumer ratings for flavor desirability. Rate of cooking in this study did not affect consumer rated flavor desirability.

Flavor has been attributed to taste, texture, sensations in the mouth and airways, and color and appearance of samples. In the present study, there was no evidence that flavor desirability was affected by heat transfer type, steak thickness, cook loss, or percentage of exterior charring. It is likely that the differences in consumer rated flavor desirability in the current study were due to the phenomena called the “halo effect.” The “halo effect” can be observed in taste panel data when one palatability trait influences the panelist’s opinion of another trait (Meilgaard et al., 2007). This conclusion was further supported by high correlation coefficients between consumer ratings for flavor desirability and consumer ratings for tenderness (r = 0.7, P = 0.0001), consumer ratings for juiciness (r = 0.77, P = 0.0001), and consumer ratings for overall desirability (r = 0.95, P = 0.0001).

Overall Desirability

A COOK x THICK interaction was observed for consumer rated overall desirability (P = 0.0065). Least squares means for consumer rated overall desirability are reported in Table 9. The MARK+COOK method had the highest values for consumer rated overall desirability for steaks that were 2.5- and 3.8-cm thick (P <0.05). As steak thickness increased, the MARK+COOK method showed an increase in consumer rated overall desirability (P < 0.05). PAR+MARK, 3.8-cm thick steaks were rated higher than PAR+MARK, 1.9- and 2.5-cm for consumer perceived overall desirability PAR+MARK (P <0.05). Steaks that were 1.9-cm thick had the lowest consumer overall desirability ratings, and PAR+MARK 2.5-cm thick steaks had among the lowest ratings for consumer overall desirability (P <0.05). GRILL steaks of varying thicknesses had no differences in consumer rated overall desirability (P > 0.05). BROIL, 1.9-cm thick steaks had higher ratings for consumer overall desirability than BROIL, 2.5- and 3.8-cm thick steaks (P <0.05). BROIL, 2.5- and 3.8-cm thick steaks were rated the lowest for consumer overall desirability (P <0.05). Likewise, broiled steaks were rated the lowest for overall like when compared to grill, panfry and any other in home cookery method as studied by Lorenzen et al. (1999).

Overall desirability ratings closely followed results of consumer rated tenderness and juiciness in the current study. It is apparent that all palatability factors impacted consumer overall desirability. Consumer overall desirability being affected by tenderness, juiciness, and flavor desirability is further confirmed by correlation coefficients for overall desirability as related to consumer perceived tenderness (r = 0.82, $P < 0.001$), juiciness (r = 0.87, $P < 0.001$), and flavor desirability (r = 0.95, $P < 0.001$).

Internal Color

Internal steak color has been shown to be most greatly affected by the degree of doneness to which the steak is cooked. When all steaks are cooked to a constant degree of doneness, cookery method and steak thickness have the opportunity to influence internal steak color. Least squares means for degree of doneness measurements are reported in Table 4. Steak thickness was not found to have an effect on degree of doneness ratings ($P = 0.4806$). This conclusion does not agree with the previous study by Dunn et al. (2000). Previous research reported that thicker steaks had a more rare visual degree of doneness. Internal color assessment as assessed visually and scored using an 8 point hedonic scale were also used to measure internal color. The COOK x THICK interaction was not significant ($P = 0.1726$) however, steak thickness ($P = 0.0294$) affected visually assessed internal color (Table 11). Visually assed internal color was more pink, or more rare, for thicker steaks and thinner steaks had a more pinkish-grey, or well done visual appearance. Furthermore, internal CIE a* values are also significantly affected by steak thickness (Table 12). CIE a* measurements of steaks cut at 3.8-cm thick were more red than those of 2.5-cm thick, which were more red than 1.9-cm thick steaks. The results of visual color assessment and CIE a* measurements from the present study were more closely related to the findings of Berry (1993) and Dunn et al. (2000), and concluded that steak thickness does impact internal steak redness, and thicker steaks have a more red internal appearance than thinner steaks.

Cooking method was determined to affect degree of doneness ratings ($P = 0.0194$) as well as internal visual steak appearance ($P = 0.0331$) and internal CIE a* values ($P < 0.0001$).

Steaks cooked using the MARK+COOK method had the lowest, or most rare, degree of doneness ratings and visual internal steak appearance ratings, and the BROIL method had the highest, or most well done, degree of doneness and internal steak appearance ratings ($P < 0.05$). Berry (1993) discussed that steaks that have a slower rate of heating produce a less well done visual degree of doneness rating. The MARK+COOK method had one of the slowest cooking rates as indicated by the amount of time taken to cook the steaks. However, GRILL steaks in the present study, which have the most rapid cooking rate, do not have the most well done visual degree of doneness score. In the current study, there is no indication that rate of cooking influences internal degree of doneness ratings, and internal steak appearance measurements.

The GRILL and MARK+COOK methods had the most red internal color as measured by CIE a* values, while the PAR+MARK and BROIL methods had the least red internal color as measured by CIE a* values ($P < 0.05$). Yancey et al. (2011) reported that internal color for steaks cooked through forced-air convection, charbroiler, and impingement oven had more red internal appearances as measured by CIE a*, whereas countertop griddles as well as clamshell grills had less red internal color on the red, CIE a*, scale. Results of the present study do not follow the same trend due to discrepancies in heat transfer type as related to internal redness measurements. Results of the present study somewhat agree with the work of Bowers et al. (2012), who found that roasts cooked in a steam oven had more red CIE a* measurements than those cooked in a forced air convection oven.

Values for degree of doneness, internal appearance, and internal CIE a* values minimally different, but the results for each measurement align with the other measurement values, indicating that COOK and THICK do influence internal appearance of steaks.

External Appearance

The COOK x THICK interaction for percent of external char ($P < 0.0001$) and visual ratings for external color ($P < 0.0001$) were significant. Least squares means for percent of external char are reported in Table 5. Steaks of the GRILL treatment had the greatest amount of external char for each steak thickness category. Also, GRILL steaks increased in percentage of external char as thickness increased ($P < 0.05$). Least squares means for visual external color ratings are reported in Table 5. Steaks of the GRILL treatment were the darkest in visually rated external color at all thicknesses ($P < 0.05$), and darkened in visual color ratings as the steaks became thicker ($P < 0.5$). GRILL steaks contacted a conduction method of heat transfer for a greater amount of time than any other cookery method. This direct contact with the heat source not only increases percent of external charring, but also has an effect on external color, as the steaks were in contact with a higher temperature for the entirety of the cooking process.

Steaks that were cooked using the BROIL method had the lowest values for percent of external charring at all thicknesses ($P < 0.5$). The BROIL cookery method utilized a convection style method of heat transfer, so there was little to no opportunity for external charring. BROIL, 3.8-cm thick steaks did have a higher percentage of external charring than did the BROIL, 1.9- and 2.5-cm thick steaks ($P < 0.5$). BROIL steaks also increased in visual external color ratings as they became thicker ($P < 0.5$). Steaks cut at 1.9-cm thick were rated as a “light brown,” and steaks cut at 3.8-cm thick were rated as “brown.” A greater amount of charring as well as darker visual color ratings for thicker, BROIL steaks can be attributed to the greater amount of cooking time for steaks cut to 2.5- and 3.8-cm thick (Table 2).

The MARK+COOK cookery method did not differ in percent surface char for the 3 thickness treatments ($P > 0.5$). Percent of surface charr was held constant due to the timed crosshatching protocol of 1 minute per hatch. The MARK+COOK method had the lowest, or lightest, external color measurements as rated by visual assessments ($P < 0.5$). MARK+COOK steaks at all thicknesses were described as being greyish brown in external appearance. The MARK+COOK method employed a moist heat cookery method, with a great amount of steam being generated in the oven which contributed to the MARK+COOK treatment being more grey in color. The present study is consistent with work completed by Bowers et al. (2012); roasts cooked using a steam oven rather than a forced air convection oven had a more tan, lighter, more moist external appearance.

Treatment main effect of thickness ($P < 0.0001$) and cookery method ($P < 0.0001$) were significant for external CIE L* values. Least squares means for external CIE L* measurements are reported in Table 5. GRILL steaks exhibited the lowest, most black, values for CIE L* measurement ($P < 0.5$), consistent with the dark exterior color seen in visual assessments. CIE L* values also suggested that as steaks increased in thickness, 1.9- to 2.5- to 3.8-cm thick, they also become darker, or more black.

Conclusions and Recommendations

Results of this study indicate that there was an interaction between cookery method and steak thickness that plays an integral role in consumer acceptability of steaks. Cookery methods impact SSF, WBSF, consumer rated tenderness, consumer rated juiciness, cook loss, flavor, and overall consumer rated desirability as well as internal and external color of steaks. The impact, positive or negative, of a cookery method on palatability measures of steaks was increased as steaks became thicker. Steaks that are cut thicker allow a greater amount of time for a cookery method to impart flavor, color, and tenderness characteristics. Cookery method decisions made in the food service industry should aim to create a cookery method and thickness combination that has the greatest opportunity to deliver the consumer a great eating experience. Final recommendations for cookery method and thickness combination are reported in Table 6.

Table 1. Consumer panelist demographic information.

Item	Category	Percentage of Response
Gender	Male	50.7
	Female	49.3
Age, yr	<18	0.3
	18-34	31.4
	35-50	20.2
	>50	48.0
Marital status	Single	23.0
	Married	71.6
	Divorced	4.3
	Widowed	1.1
Total household income, $/yr	<25,000	10.0
	25 to 34,999	3.8
	35 to 49,999	9.2
	50 to 74,999	15.3
	75,000 to 100,000	20.7
	>100,000	41.0
Ethnic background	Caucasian	96.47
	African-American	0.0
	Hispanic	0.7
	Native American	1.8
	Asian	0.7
	Other	0.4
Degree of doneness preferred	Rare	3.2
	Medium Rare	60.6
	Medium	30.5
	Medium Well	5.0
	Well Done	0.7
Thickness preferred	1.9-cm	6.8
	2.5-cm	59.1
	3.8-cm	34.2
		Average Response
Average times beef consumed per week		5.8
Average times beef consumed in a restaurant per month		6.3

Table 2. Least squares means for slice shear force (SSF, kg), Warner Bratzler shear force (WBSF, kg), cook loss (% of initial/green weight remaining), and cook time (minutes) for four cookery method and three steak thickness treatments.[5]

	SSF[1]			
Thickness	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	16.36^{a}	15.16^{a}	18.33^{by}	15.54^{ax}
2.5-cm	17.41^{bc}	14.18^{a}	17.65^{cxy}	16.31^{bx}
3.8-cm	16.65^{b}	14.85^{a}	16.82^{bx}	17.67^{by}
	WBSF[2]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	2.81^{abx}	2.66^{a}	3.08^{cy}	2.91^{bcx}
2.5-cm	2.99^{bcy}	2.64^{a}	2.87^{bx}	3.14^{cy}
3.8-cm	2.94^{bxy}	2.66^{a}	2.78^{abx}	3.20^{cy}
	Cook Loss[3]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	77.92^{bx}	81.76^{ay}	78.62^{b}	80.43^{ax}
2.5-cm	76.14^{cy}	83.43^{ax}	78.64^{b}	77.36^{bcy}
3.8-cm	75.80^{cy}	84.01^{ax}	79.58^{b}	73.36^{dz}
	Cook Time[4]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	6.75^{ax}	15.43^{bx}	8.94^{ax}	13.27^{bx}
2.5-cm	11.39^{ay}	31.19^{cy}	19.55^{by}	18.17^{by}
3.8-cm	21.19^{az}	56.88^{dz}	44.16^{cz}	26.26^{bz}

[1]Cookery method by steak thickness interaction for SSF was significant ($P = 0.0006$).
[2]Cookery method by steak thickness interaction for WBSF was significant ($P = 0.0003$).
[3]Cookery method by steak thickness interaction for cook loss was significant ($P < 0.0001$).
[4]Cookery method by steak thickness interaction for cook time was significant ($P < 0.0001$).
[5]Cookery methods: open hearth grill (GRILL); grill mark, then finish in a steam oven (MARK+COOK); par cook in a steam oven, then grill mark (PAR+MARK); salamander style broiler (BROIL).
[a-d]Values that do not share a common superscript in row differ ($P < 0.05$).
[x-z]Values that do not share a common superscript in column differ ($P < 0.05$).

Table 3. Least squares means for consumer panel responses for tenderness, juiciness, flavor desirability, and overall desirability for four cookery method and three steak thickness treatments.[5,6]

	Tenderness[1]			
Thickness	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	8.6[a]	9.0[ay]	7.6[by]	8.8[ax]
2.5-cm	8.1[b]	9.4[axy]	7.6[by]	7.6[by]
3.8-cm	8.2[bc]	9.9[ax]	8.5[bx]	7.8[cy]
	Juiciness[2]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	7.8[ab]	8.3[a]	7.2[b]	8.2[ax]
2.5-cm	7.5[b]	8.6[a]	7.1[b]	7.1[by]
3.8-cm	7.5[b]	8.6[a]	7.2[b]	6.5[cy]
	Flavor Desirability[3]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
	7.7[a]	8.1[a]	7.2[b]	7.0[b]
	Overall Desirability[4]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	7.7[ab]	8.0[ay]	7.0[by]	7.6[abx]
2.5-cm	7.5[b]	8.6[axy]	6.8[cy]	6.9[bcy]
3.8-cm	7.6[b]	8.8[ax]	7.7[bx]	6.8[cy]

[1]Cookery method by steak thickness interaction for consumer rated tenderness was significant ($P = 0.0003$).
[2]Cookery method by steak thickness interaction for consumer rated juiciness was significant ($P = 0.0023$).
[3]Main effect of cooking method for consumer rated flavor desirability was significant ($P < 0.0001$).
[4]Cookery method by steak thickness interaction for consumer rated overall desirability was significant ($P = 0.0065$).
[5]Sensory panel scales (15cm continuous line scale); tenderness (0 = very tough, 15 = very tender), juiciness (0 = very dry, 15 = very juicy), flavor desirability (0 = very undesirable, 15 = very desirable), and overall desirability (0 = very undesirable, 15 = very desirable).
[6]Cookery methods: open hearth grill (GRILL); grill mark, then finish in a steam oven (MARK+COOK); par cook in a steam oven, then grill mark (PAR+MARK); salamander style broiler (BROIL).
[a-d]Values that do not share a common superscript in row differ ($P < 0.05$).
[x-z]Values that do not share a common superscript in column differ ($P < 0.05$).

Table 4. Least squares means for degree of doneness scores (subjectively evaluated using a 5-point hedonic scale comparing to published photographic standards; 1 = rare to 5 = well done [Meat Buyers Guide, 2011]), internal color (subjectively evaluated using an 8-point hedonic scale; 1 = purple to 8 = dark brown), and internal CIE a* values (objectively measured using a colorimeter [Miniscan Model 4500s, Hunter Associates Laboratory, Reston, VA]).

	Cookery Method[6]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
Degree of Doneness[1]	2.72^{ab}	2.64^{a}	2.75^{ab}	2.85^{b}
Internal Color[2]	4.65^{ab}	4.56^{a}	4.66^{ab}	4.77^{b}
Internal a*[3]	10.89^{a}	10.91^{a}	9.73^{b}	9.63^{b}

	Thickness		
	1.9-cm	2.5-cm	3.8-cm
Internal Color[4]	4.73^{b}	4.67^{ab}	4.57^{a}
Internal a*[5]	9.04^{c}	10.25^{b}	11.59^{a}

[1]Main effect of cookery method for degree of doneness measurement significant ($P < 0.0001$).
[2]Main effect of cookery method for internal color measurement significant ($P = 0.0331$).
[3]Main effect of cookery method for internal a* measurement significant ($P = 0.0001$).
[4]Main effect of steak thickness for internal color measurement significant ($P = 0.0294$).
[5]Main effect of steak thickness for internal a* measurement significant ($P < 0.0001$).
[6]Cookery methods: open hearth grill (GRILL); grill mark, then finish in a steam oven (MARK+COOK); par cook in a steam oven, then grill mark (PAR+MARK); salamander style broiler (BROIL).
[a,b]Values that do not share a common superscript differ ($P < 0.05$).

Table 5. Least squares means for external surface char (subjectively measured as a percentage of overall steak surface area), external color (subjectively measured using an 8-point hedonic scale; 1 = light grey to 8 = black), and external CIE L* measurements (objectively measured using a colorimeter [Miniscan Model 4500s, Hunter Associates Laboratory, Reston, VA]).[5]

	External Surface Char[1]			
Thickness	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	51.64^{cx}	41.37^{b}	37.69^{bx}	1.06^{ax}
2.5-cm	63.09^{cy}	41.67^{b}	47.03^{by}	2.48^{ax}
3.8-cm	76.00^{cz}	45.85^{b}	49.66^{by}	17.30^{ay}
	External Color[2]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	4.86^{cx}	3.65^{ay}	4.20^{bx}	4.15^{bx}
2.5-cm	5.26^{cy}	3.34^{ax}	4.39^{bx}	4.55^{by}
3.8-cm	5.99^{cz}	3.63^{ax}	4.97^{by}	5.28^{bz}
	External L*[3]			
	GRILL	MARK+COOK	PAR+MARK	BROIL
	29.59^{c}	34.80^{a}	33.46^{ab}	32.49^{b}
	1.9-cm	2.5-cm	3.8-cm	
	35.37^{a}	32.65^{b}	29.72^{c}	

[1]Cookery method by steak thickness interaction for percent external surface char was significant ($P < 0.0001$).
[2]Cookery method by steak thickness interaction for external color measurement was significant ($P < 0.0001$).
[3]Main effect of cooking method for external L* value was significant ($P < 0.0001$).
[4]Main effect of steak thickness for external L* value was significant ($P < 0.0001$).
[5]Cookery methods: open hearth grill (GRILL); grill mark, then finish in a steam oven (MARK+COOK); par cook in a steam oven, then grill mark (PAR+MARK); salamander style broiler (BROIL).
[a-d]Values that do not share a common superscript in row differ ($P < 0.05$).
[x-z]Values that do not share a common superscript in column differ ($P < 0.05$).

Table 6. Final food service recommendations, based on consumer rated overall desirability, for steak thickness and cookery method combinations.

	Cookery Method[2]			
Thickness	GRILL	MARK+COOK	PAR+MARK	BROIL
1.9-cm	o	+	-	o
2.5-cm	o	+	-	-
3.8-cm	o	+	o	-

+ - Consumer overall desirability ratings > 8.0.

O – Consumer overall desirability rating 7.0 to 8.0.

- - Consumer overall desirability ratings < 7.0.

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Appendix A

Shear force day data sheet for internal and external color measurements.

NCBA Steak Thickness and Cookery Method 1
Dani Shubert
Cook Date____________________________

Sample Time_______________
Sample #_______________

External MiniScan Values	Internal MiniScan Values	Degree of Doneness
L* M______SD_______	L* M______SD_______	Rare
A* M______SD_______	A* M______SD_______	Medium Rare
B* M______SD_______	B* M______SD_______	Medium
		Medium Well
% Surface Char _____________		Well Done

Internal Color

1	2	3	4	5	6	7	8
Purple	Red	Reddish pink	Pink	Pinkish grey	Light brown	Medium brown	Dark brown

External Color

1	2	3	4	5	6	7	8
Light grey	Grey	Greyish brown	Light brown	Brown	Dark brown	Brownish black	Black

Appendix B

Consumer panel demographic form and consumer response ballot.

Panelist # 1 - About Yourself

Please Circle the answer that best describes you, or fill in the blank with your best response

Gender	**Marital Status**	**Age**	**Ethnic Origin**	**Annual Household Income**
Male	Single	Under 18	African-American	Under $25,000
Female	Married	18 - 34	Asian	$25,000 - $34,999
	Divorced	35 - 50	Caucasian/White	$35,000 - $49,999
	Widowed	Over 50	Hispanic	$50,000 - $74,999
			Native American	$75,000 to $100,000
			Other	more than $100,000

On Average, how many times per week do you consume beef? ____________________

On average, how many beef meals do you eat in a restaurant per month? __________________

How do you prefer your steaks to be cooked? Rare Medium Rare Medium Medium Well Well Done

How thick do you prefer your steaks to be cut? .75 inch 1 inch 1.5 inches

Sample ID: _______1__________ **(lines not to scale)**

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable

Sample ID: _______2_________

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable

Sample ID: _______3________

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable

Sample ID: _______4_________ **(lines not to scale)**

Tenderness: |———|

Very Tough Very Tender

Juiciness: |———|

Very Dry Very Juicy

Flavor Desirability: |———|

Very Undesirable Very Desirable

Overall Desirability: |———|

Very Undesirable Very Desirable

Sample ID: _______5_________

Tenderness: |———|

Very Tough Very Tender

Juiciness: |———|

Very Dry Very Juicy

Flavor Desirability: |———|

Very Undesirable Very Desirable

Overall Desirability: |———|

Very Undesirable Very Desirable

Sample ID: _______6_________

Tenderness: |———|

Very Tough Very Tender

Juiciness: |———|

Very Dry Very Juicy

Flavor Desirability: |———|

Very Undesirable Very Desirable

Overall Desirability: |———|

Very Undesirable Very Desirable

Sample ID: _______7_________ **(lines not to scale)**

Tenderness: |——————————————|

Very Tough Very Tender

Juiciness: |——————————————|

Very Dry Very Juicy

Flavor Desirability: |——————————————|

Very Undesirable Very Desirable

Overall Desirability: |——————————————|

Very Undesirable Very Desirable

Sample ID: _______**8**________

Tenderness: |——————————————|

Very Tough Very Tender

Juiciness: |——————————————|

Very Dry Very Juicy

Flavor Desirability: |——————————————|

Very Undesirable Very Desirable

Overall Desirability: |——————————————|

Very Undesirable Very Desirable

Sample ID: _______9_________

Tenderness: |——————————————|

Very Tough Very Tender

Juiciness: |——————————————|

Very Dry Very Juicy

Flavor Desirability: |——————————————|

Very Undesirable Very Desirable

Overall Desirability: |——————————————|

Very Undesirable Very Desirable

Sample ID: _______10________ **(lines not to scale)**

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable

Sample ID: _______11_________

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable

Sample ID: _______12_________

Tenderness: |————————————————————|

Very Tough Very Tender

Juiciness: |————————————————————|

Very Dry Very Juicy

Flavor Desirability: |————————————————————|

Very Undesirable Very Desirable

Overall Desirability: |————————————————————|

Very Undesirable Very Desirable