Evaluation of the beef marbling insurance theory

by

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Abstract

The objectives of this study were to evaluate the extent marbling compensates for reduced beef palatability at elevated degrees of doneness and to determine the relationship of residual moisture and fat in cooked steaks to beef palatability, specifically beef juiciness. Paired strip loins (IMPS # 180) were collected to equally represent five quality treatments [Prime, Top Choice (modest and moderate marbling), Low Choice, Select, and Select Enhanced (110% of raw weight)]. Steaks were grouped into sets of three consecutively cut steaks and randomly assigned a degree of doneness (DOD): very-rare (VR; 55°C), rare (R; 60°C), medium-rare (MR; 63°C), medium (M; 71°C), well-done (WD; 77°C), or very well-done (VWD; 82°C). Samples were subjected to consumer and trained sensory evaluation, Warner-Braztler shear force (WBSF), slice shear force (SSF), pressed juice percentage (PJP) evaluation, and raw and cooked proximate analysis. There were no ($P > 0.05$) interactions for consumer sensory ratings, indicating increased DOD had the same negative impact regardless of marbling level. There was a quality treatment × DOD interaction ($P < 0.05$) for percentage of steaks rated acceptable by consumers for juiciness. Increased marbling extended the point in which steaks became unacceptable for juiciness. Similarly, there was a quality treatment × DOD interaction ($P < 0.05$) for trained juiciness ratings. When cooked to MR and lower, Prime was only rated 8 to 18% higher ($P < 0.05$) than Select for trained juiciness ratings but was rated 38 to 123% higher ($P < 0.05$) than Select when cooked to M and higher. Besides cook loss, combined cooked moisture and fat percentage was more highly associated ($P < 0.01$) to consumer juiciness ($r = 0.69$) and trained initial ($r = 0.84$) and sustained ($r = 0.85$) juiciness ratings than all other objective evaluations. For regression analysis, cooked moisture and fat percentages, alone, were poor indicators of consumer and trained juiciness ratings. However, when combined, the regression

equations explained 45, 74, and 69% of the variation in consumer, trained initial, and trained sustained juiciness ratings, respectively. These results indicate that increased marbling levels only offer “insurance” for juiciness of steaks that are cooked at high degrees of doneness, but not for other palatability traits. Additionally, cooked residual moisture and fat percentages when combined are a good indicator of sensory juiciness ratings.

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Dedication

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Chapter 1 - Literature Review

History of beef degree of doneness

Degree of doneness (DOD) refers to the internal cooked color and the associated final internal temperature a cut of meat was cooked to. There are six DOD's that are primarily used by consumers and research: very-rare (VR), rare (R), medium-rare (MR), medium (M), well-done (WD), and very well-done (VWD). In an attempt to more accurately define these DOD, the National Livestock and Meat Board (NLSMB), in conjunction with Texas A&M University, developed the first Beef Steak Color Guide for research and extension use in 1979. This beef steak color guide was one of the first references to assign cooked temperatures to photographs of cross-sectional cut surfaces of steaks, representing each degree of doneness. According to this first guide, VR was approximately 55°C, with every increase in 5°C increments corresponding to the next DOD, ending with VWD at 80°C (National Livestock and Meat Board, 1979). It is unclear whether the designated temperatures were referencing the final internal temperature of the steak, accounting for post-cook temperature rise, or if the temperatures indicated were the "pull-off" temperature from the cooking surface. Additionally, there is some uncertainty on how the temperatures were determined for each DOD. However, communications with Dr. Gary Smith and Dr. Russell Cross, both of whom were involved with the development of this first guide, indicated that the temperatures were decided upon by an expert panel of both academics as well as industry members following visual appraisal of steaks cooked to varying end-point temperatures (Smith, 2018), though additional details were not provided.

In 1978, the American Meat Science Association (AMSA) published their first Guidelines for Cookery and Sensory Evaluation of Meat and recommended contacting Texas A&M regarding their ongoing work on the color guide development for NLSMB (American

Meat Science Association, 1978). The AMSA included their own beef steak color guide in their updated Sensory Guidelines in 1995 (American Meat Science Association, 1995) and this reference was adopted as the official guide for National Cattleman's Beef Association (NCBA) and the Agricultural Research Service (ARS) following its publication. The temperatures mostly matched the Texas A&M and NLSMB color guide, except MR was identified as cooked to a final internal temperature of 63°C as opposed to the original 65°C (American Meat Science Association, 1995). The authors gave no clear indication as to why MR was changed to 63, and not kept at 65°C nor did they discuss this change within the document. In the most recent sensory guidelines published by the AMSA, no beef steak color guide was included as more recent research has shown that internal cooked color does not always reflect the associated internal temperature, and thus the sensory guidelines recommend only using temperatures, and not internal cooked color, to reference doneness (American Meat Science Association, 2015). However, NCBA continues to publish the Beef Steak Color Guide, and has updated the photographs for each DOD while keeping the temperatures the same with every update (National Cattleman's Beef Association, 2016).

The Beef Steak Color Guide is mainly used for research purposes, as current foodservice industry reports cooking steaks to temperatures much lower than those reported in by the guides. For example, on their website, Certified Angus Beef (CAB) reports 52°C correlating to R, and only going up to 71°C for WD (Certified Angus Beef, 2018). Also, one of the executive chefs at Longhorn Steakhouse stated R is a steak cooked to 48.9°C, and MR is 54.4°C (Longhorn Steakhouse, 2015). It is not clear if those temperatures are the temperatures when the cut of meat is to be pulled off the cooking surface, or if they are related to the final internal temperature, accounting for a post-cook temperature rise. Furthermore, an article posted by the Food Network suggests R, MR, M, and WD to be pulled off at 52, 54, 57, 60, and 68°C respectively, with a three minute rest period (Food Network Kitchen, 2017), likely allowing for these steaks to rise to a final peak temperature close to the temperatures presented on the Beef Steak Color Guide. What's Cooking America has posted online an internal core temperature of 26 to 38°C classified as VR, and only going up to 71°C for WD (Stradley, 2016). Moreover, Chicago Steak Company indicates VR is 46°C, going up to 71°C for WD (Steak University, 2018). The temperature that correlates to R on the Beef Steak Color Guide equates to M here, and the website does indicate to pull steaks off the grill about 5°F before the desired temperature. This indicates the Beef Steak Color Guide is not a standard currently used across foodservice. Having no standardized guidelines brings into question the accuracy of reported temperatures, as well as the consistency in which foodservice is able to meet consumer expectations. Previous research has shown consumers will tend to be more critical when receiving cuts of beef that have been overcooked, rather than undercooked (Cox et al., 1997). Thus, it is plausible that foodservice maintains lower temperatures for each DOD in an effort to minimize the risk associated with overcooking of steaks

In the AMSA Sensory Guidelines, it is recommended to account for a post-cook temperature rise, depending on the cooking method. Cookery methods with more direct heat that primarily use conduction, create a greater post-temperature rise than convection methods, such as ovens (AMSA, 2015).

Based on a Food Safety Survey conducted by the Food and Drug Administration (FDA), 33% of consumers indicated they did not own a food thermometer and therefore temperature was not used as a way to determine doneness of meat products (Food and Drug Administration, 2010). In one report by the Food Safety and Inspection Service of the USDA, focus groups were conducted to understand cooking and food safety practices of consumers. The report indicated most of the consumers used a visual method as a way to determine the doneness of cooked meat. In the same report, consumers indicated internal cooked color was a safe alternative to determine doneness of meat (Koeppl, 1998). These reports indicate that though temperatures are recommended to achieve specific DOD, most consumers still rely upon visual evaluation for ultimate DOD determination.

Palatability defined

Multiple studies have found moderate to high correlations for overall liking to tenderness (r = 0.75 – 0.92), juiciness (r = 0.70 – 0.93), and flavor (r = 0.81 – 0.96; Parrish et al., 1973; Behrends et al., 2005; Hunt et al., 2014; Corbin et al., 2015; Legako et al., 2015; McKillip et al., 2017). Historically, tenderness has been cited as the most important palatability trait (Savell et al., 1987; Miller et al., 1995). Current research presents flavor as the most important contributing factor to overall beef palatability. A study from the mid 1990's indicated 51% of consumers reported tenderness to be the most important trait when eating beef (Huffman et al., 1996). However, in the same study, after regression analyses was conducted, flavor accounted for most of the variation in overall palatability with a reported R^2 of 0.67 (Huffman et al., 1996). In a more recent study, 69% of consumers indicated tenderness to be the most important palatability trait, yet flavor was more correlated (r = 0.86 compared to r = 0.75) to overall like (Hunt et al., 2014). Similarly, Lucherk et al., 2016 fed consumers their preferred DOD (rare, medium, and well-done), and rare consumers identified flavor (50.0%) to be the most important palatability trait, while medium and well-done consumers identified tenderness (50.6 and 48.8% respectively) as the most important trait. In the same study, all palatability traits were correlated to overall liking, with the highest correlation seen with flavor liking (flavor liking: r = 0.95;

tenderness: $r = 0.89$; and juiciness: $r = 0.81$; Lucherk et al., 2016). Furthermore, in a study conducted by Corbin et al. (2015), consumers identified flavor (50.8%) as the most important palatability trait when consuming beef, with all three traits being highly correlated to consumer overall liking (flavor: $r = 0.96$; tenderness: $r = 0.92$; and juiciness: $r = 0.93$). O'Quinn et al. (2018) developed a palatability model using 11 consumer studies conducted over a six year time frame that all used similar procedures to determine the contribution of tenderness, juiciness, and flavor to the overall beef eating experience. Flavor was found to contribute the most (49.4%), followed closely by tenderness (43.4%), with juiciness contributing the least (7.4%) to a consumers' overall eating experience, with the model in total accounting for more than 99% in variation of consumer overall liking scores (O'Quinn et al., 2018).

Raw and cooked fat and moistures for longissimus muscle

There have been several studies evaluating the raw intramuscular fat and moisture composition in the longissimus muscle. Intramuscular fat percentage increases as degree of marbling, or USDA quality grade increases (Campion et al., 1975; Savell et al., 1986; O'Quinn et al., 2012; Emerson et al., 2013; Hunt et al., 2014; Corbin et al., 2015; Legako et al., 2015). Studies have shown Prime contains the greatest amount of intramuscular fat (8 to 14%), followed by Upper Two-thirds Choice (6 to 10%), Low Choice (4 to 5%), Select (2 to 4%), with Standard containing the least amount of fat (1 to 2%; Campion et al., 1975; Savell et al., 1986; O'Quinn et al., 2012; Emerson et al., 2013; Hunt et al., 2014; Corbin et al., 2015; Legako et al., 2015). In contrast, as degree of marbling or USDA quality grade increases, moisture percentage decreases. Prime contains the least amount of moisture (60 to 69%), followed by Upper Two-thirds Choice (66 to 71%), Low Choice (69 to 72%), and Select (71 to 73%), with Standard containing the greatest percentage of moisture (72 to 74%; Campion et al., 1975; Savell et al., 1986; O'Quinn et al., 2012; Emerson et al., 2013; Hunt et al., 2014; Corbin et al., 2015; Legako et al., 2015).

Very little research has evaluated the cooked intramuscular fat and moisture percentage at various degrees of doneness of longissimus muscle steaks; and the limited published literature has produced inconsistent findings. In an early study, carcasses from various marbling degrees were either categorized as "high-marbled" (9.4% fat) or "low-marbled" (5.8% fat) and longissimus muscle steaks produced from the carcasses were broiled to three endpoint temperatures (60, 71, and 82°C; Gilpin et al., 1965). Regardless of marbling treatment, steaks broiled to 60°C contained less fat than 71 and 82°C. For "high-marbled" and "low marbled" steaks, fat percentage increased 1.8 and 1.5% receptively when cooked from 60 to 80°C (Gilpin et al., 1965). Moisture decreased 3.5 and 3.7% for "high-marbled" and "low-marbled" steaks respectively as temperatures increased from 60 to 71°C, and decreased 6.3 to 5.7% when cooked from 60 to 80°C (Gilpin et al., 1965). Parrish et al. (1973), evaluated the longissimus muscle from three marbling degrees [moderately abundant (10.7% fat), modest (8.6% fat), and slight (4.5% fat)] broiled to three DOD (60, 70, 80°C) and reported a moisture decrease and fat percentage increase within marbling degree when samples were cooked from 60 to 80°C. For moderately abundant, modest, and slight marbling levels, moisture content decreased 4.9, 5.3, and 4.4% respectively when cooked from 60 to 80°C, with fat percent increasing 2.3, 1.0 and 0.5% respectively for marbling treatment when cooked from 60 to 80°C (Parrish et al., 1973). Akinwunmi et al. (1993) evaluated the longissimus muscle from two marbling degrees (modest and slight), trimmed to two fat trim levels (2 - mm and 6 - mm), and broiled to three endpoint temperatures (60, 71, and 77°C) and did not observe an interaction between marbling treatment and endpoint temperature. As endpoint temperature increased from 60 to 71°C, moisture decreased by 1.4%, and increased to 3.4% when cooked to 77°C. Fat content did not differ among DOD. External fat was not removed before chemical analyses, and could potentially affect the variation in numbers, or lack thereof, in the fat and moisture percentages. Moreover, the studies mentioned above used the Soxhlet extraction procedure as their fat determination method. Similar to Akinwunmi et al. (1993), Smith et al. (2011) did not observe an interaction between marbling treatment and DOD when longissimus muscle from three USDA quality grades (Prime, Choice, and Select) were cooked to four DOD (63, 71, 77, and 80°C). Differing from the previous studies, steaks were cooked on a clamshell style grill, and not broiled as well used a modified Folch et al. (1957) procedure for their fat determination method. As samples were cooked from 63 to 77°C, a 2.5% reduction in moisture was reported, and increased to 3.5% when cooked to 80°C. No differences were seen among DOD for fat percentage (9.6 - 10% fat), but all were higher than the average raw fat percentage (7.3%) when quality grade fat percentages were averaged for each DOD (Smith et al., 2011).

More recent studies have evaluated the intramuscular fat (IMF) and moisture percentage and their relationship to beef palatability. Legako et al. (2015) evaluated four different muscles (longissimus lumborum, psoas major, semimembranosus, and gluteus medius) across five different quality treatments (Prime, Top Choice, Low Choice, Select, and Standard), and reported when pooled across muscles, IMF to be poorly correlated to consumer tenderness (r = 0.22), juiciness (r = 0.29), flavor (r = 0.27), and overall liking (r = 0.27). Moreover, moisture percentage was lowly and negatively correlated to consumer tenderness (r = -0.16), juiciness (r = -0.24), flavor (r = -0.23), and overall liking (r = -0.23). Similarly, Hunt et al. (2014) evaluated four muscles, three of the same four mentioned above, with the fourth being the serratus ventralis, replacing the psoas major, across two quality treatments (Top Choice and Select) and reported poor correlations for tenderness (*r* = 0.32), juiciness (*r* = 0.29), flavor (*r* = 0.37), and overall liking (*r* = 0.42) when IMF was pooled across muscles. However, IMF was not correlated to consumer traits for the semimembranosus, with the highest correlations found for the longissimus muscle (*r* = 0.29 – 0.42), followed by the serratus ventralis (*r* = 0.20 – 0.26), though both were still poorly correlated. Furthermore, moisture percentage had similar correlations to IMF when pooled, but were negatively associated with tenderness (*r* = -0.35), juiciness (*r* = -0.21), flavor (*r* = -0.37), and overall liking (*r* = -0.26; Hunt et al., 2014). Similar with muscle trends for IMF, moisture percentage correlations were not significant for the semimembranosus, and were the highest for the longissimus muscle (*r* = -0.27 to -0.41; Hunt et al., 2014). Lucherk et al. (2017) reported IMF having a correlation of *r* = 0.37 for consumer juiciness and *r* = 0.24 for consumer overall liking when evaluating the longissimus muscle across seven quality treatments (Prime, Top Choice, Low Choice, Select, Standard, High Enhanced Select, and Low Enhanced Select). Moisture percentage was only significantly correlated to consumer juiciness ratings, (*r* = -0.23), and not overall liking. Corbin et al. (2015) found IMF to be moderately to highly correlated to consumer tenderness (*r* = 0.79), juiciness (*r* = 0.88), flavor (*r* = 0.74), and overall like (*r* = 0.79). In this study though, a wider range of marbling treatments were used, ranging from Australian Wagyu containing 26.6% IMF to Standard that averaged 1.9% IMF. Moreover, moisture percentage was moderately to highly negatively correlated to consumer tenderness (*r* = -0.81), juiciness (*r* = -0.89), flavor (*r* = 0.76), and overall like (*r* = 0.80) as well.

The effect of DOD on beef palatability within same quality grade

Minimum research has been conducted looking at the effect of DOD on beef palatability while holding the quality grade, or amount of marbling constant. Moreover, research evaluating all six DOD within the same study is very limited.

Research has shown an increase in final internal temperature results in an increase in cooking loss (Cross et al., 1976; Milligan et al., 1997; Wheeler et al., 1999; Lorenzen et al., 2005; Gomes et al., 2014; Yancey et al., 2016). Wheeler et al. (1999) cooked longissimus muscle from USDA Select carcasses to three final internal temperatures (60, 70, and 80°C) using a belt grill and documented a 10% increase in cooking loss from 60 to 80°C. Similarly, Cross et al. (1976) found an 8% increase in cooking loss when the longissimus muscle was cooked from 60 to 80°C using an industrial oven, but doubled (16%) when cooked to 90°C. In that study, marbling was not held constant (Cross et al., 1976). When cooked on an open hearth broiler, a 15.4% increase in cooking loss was seen between steaks cooked to 60°C and 82°C for Upper Two-thirds Choice longissimus muscle steaks (Lorenzen et al., 2005). Standard inside round roasts cooked in a halo heat convection oven resulted in a 16.1% increase in cooking loss from 60°C to 80°C (Milligan et al., 1997). In that study, half of the roasts were injected at 5% with a $CaCl_2$ solution and the other half were not, so the reported values were pooled to get cook loss means. Gomes et al. (2014) found an interaction between cooking method and endpoint temperature when cooking the longissimus muscle to three final endpoint temperatures (65, 71, and 77°C) using either a conventional electric oven or electric counter top griddles. An increase in cooking loss was seen at each increase in final endpoint temperature, with 77°C having the highest cooking loss with each cookery method. No difference was seen at each endpoint temperature between cooking methods, except at 77°C, where griddles had a lower cook loss than oven samples (Gomes et al., 2014). Samples were reported to have the same degree of marbling, but it was not stated what degree that was. However, Yancey et al. (2016) only found an interaction for cook loss between cooking method and endpoint temperature for Select semimembranosus, and not for Select infraspinatus steaks, when evaluating five cookery methods (forced-air convection oven, forced-air impingement oven, open-hearth char broiler, electric countertop griddle, and electric clamshell griddle) and three endpoint temperatures (65.5, 71.1 and 76.6°C). Similar to Gomes et al. (2014), regardless of cooking method, an increase in cooking loss was reported with every increase in endpoint temperature for the semimembranosus muscle, but when cooked to 71.1°C on the electric counter top griddle, steaks had similar cook loss to those cooked to 65.5°C in the impingement oven (Yancey et al., 2016). In another study, the effects of same five cookery methods with the same three endpoint temperatures were evaluated on USDA Select longissimus muscle steaks, and it was reported that no difference was found among cooking methods for cook loss, with percentages ranging from 26.2 to 31.5% (Yancey et al., 2011). In that study, the main effect of endpoint temperature was significant, with steaks cooked to 76.6°C having 9% more cook loss than those cooked to 65.5°C, with no difference between 65.5 and 71.1°C (Yancey et al., 2011). The reported cooking losses ranged 26.2 to 35.2% for the longissimus muscle across DOD.

Multiple reports have demonstrated increases in endpoint and final internal temperatures negatively impact the palatability traits of juiciness and tenderness. Lorenzen et al., 2005 cooked the longissimus muscle from the same quality grade (Average Choice) to six final endpoint temperatures (55, 60, 63, 71, 77, 82°C) on an open hearth broiler. When fed under red lighting, consumer ratings for liking of tenderness and juiciness decreased as endpoint temperature increased, but no difference occurred for overall and flavor liking. For both consumer tenderness and juiciness, steaks cooked to 55, 60, and 63°C did not differ in ratings, but decreased 9.6 and 16.4% respectively when cooked from 55 to 71°C, and further decreased 21.9 and 30.5% respectively when cooked to 82°C (Lorenzen et al., 2005). Similarly, Gomes et al. (2014) served consumers the longissimus muscle cooked on two different cookery methods (counter top griddle and conventional electric oven) to three endpoint temperatures (65, 71, 77°C) and reported the highest acceptance for tenderness and juiciness at 65°C, and a higher overall impression when compared to 77°C when cooked on the griddle, with no difference between final endpoint temperatures for consumer flavor (Gomes et al., 2014). However, in the same study, when samples were cooked in an electric conventional oven, there was no difference for juiciness and tenderness between steaks cooked to 65 or 71°C, and no difference for overall impression for all endpoint temperatures. As previously mentioned, marbling degree was held constant but not reported at which degree.

In contrast, Schmidt et al. (2002) reported consumers found no differences in overall liking for USDA Choice, top sirloin steaks across DOD between R (63°C) and WD (77°C). This study evaluated the effect of using thermometers or the touch method to determine DOD on consumer sensory evaluation. In the study, each consumer was fed one whole steak, from their preferred DOD, with the DOD being determined by either a thermometer or the "touch" method (Schmidt et al., 2002). When using the thermometer, pulling steaks at 54, 60, 63, 71, 74, 77, and 82°C correlated to VR, R, MR, M, medium-well (MW), WD and VWD, but the final internal temperatures were most likely higher due to post-cook temperature rise. Consumers rated steaks cooked to MR higher for overall like, compared to those cooked to VR and VWD. Moreover, for juiciness like, consumers rated MR juicier than VWD, and more tender than WD and VWD, with all other DOD being intermediate (Schmidt et al., 2002). Finally, when cooked to VWD, flavor like was rated lower than MR, M, and WD samples, with all other DOD being intermediate (Schmidt et al., 2002). Lack of differences between DOD could be due to the study design in which consumers were fed one steak at their preferred DOD in a restaurant setting, and with unequal representation across DOD ordered. Out of the 210 consumers fed, only 9 ordered VR, 7 ordered MW, and 11 ordered VWD, with the majority (67) ordering MR (Schmidt et al., 2002).

Similarly, another study evaluated the effect of consumers ordering their preferred DOD in a restaurant setting (Cox et al., 1997). Over 3,000 consumers who ordered beef steak menu items at nine restaurants were surveyed for their assessment of the DOD and the palatability of the product. However, temperatures correlating to DOD was not held constant and was at the discretion of the chefs at the restaurant, as well as the cooking practices and cookery method. Furthermore, cut was additionally not held constant, but the majority (78%) of the consumers ordered a cut from the rump (Cox et al., 1997). Similar to the previous study, consumers ordered and received a whole meal, only eating and being surveyed over a single steak. Cox et al. (1997) reported no differences among DOD (R, MR, M, MW, and WD) for overall satisfaction, tenderness, and flavor liking. When the consumer received the steak at the correct ordered DOD, less than 5% of the steaks were rated very poor or poor for overall satisfaction, but was increased to 26% when deemed undercooked, and to 39% when overcooked (Cox et al., 1997). Thus, being served the correct DOD seemed to impact consumers overall eating satisfaction more, but meaningful comparisons are hard to make because consumers were only fed a single steak serving at their preferred DOD. So the basis of eating quality would more likely be influenced by being served the correct DOD or not.

Furthermore, the effect of increased DOD negatively impacts trained sensory palatability ratings. Cross et al. (1976) evaluated the longissimus muscle cooked on an industrial electric oven at three oven temperatures (121, 177, and 232°C) and pulled off at four temperatures (60, 70, 80, 90°C) and reported when served under red lights, trained panel tenderness, juiciness, and flavor acceptability scores decreased as temperature increased. Panelists rated 60°C highest for overall tenderness, juiciness, and flavor acceptability (Cross et al., 1976). A decrease in juiciness scores occurred for each increase in pull off temperature, with 90°C having the lowest juiciness scores. Similarly, Milligan et al. (1997) found injected USDA Standard $CaCl_2$ inside round roasts to be rated the highest by trained panelists for juiciness, initial tenderness, and overall mouth feel when pulled from the oven at 60°C, compared to 70 and 80°C. Roasts pulled at 70°C were rated higher than 80°C for initial and sustained juiciness, but was not different for tenderness and overall mouthfeel (Milligan et al., 1997).

Lastly, DOD has a positive linear relationship with shear force values. Wheeler et al. (1998) reported an increase in final internal temperature resulted in increased Warner-Braztler Shear Force (WBSF) values. In the study, subprimals (ribeye roll) were put into one of five tenderness categories (1 = < 3.5 kg; 2 = 3.51 to 4.5 kg; 3 = 4.51 to 5.5 kg; 4 = 5.51 to 6.5 kg; 5 = >6.5 kg) based upon a 3-d postmortem WBSF value of a steak produced from the subprimal, when cooked to 70°C. Additional steaks produced from the subprimals were then cooked to two endpoint temperatures (60 and 80°C) and WBSF was determined. An interaction between tenderness class and endpoint temperature was seen. Regardless of tenderness class, shear force increased from 60 to 80°C. However, when classified in the most tender tenderness class (1), a 55.7% increase in shear value was reported when cooked from 60 to 80°C, but this difference increased to 66.4% when steaks were classified in the toughest (5) tenderness class.

Moreover, when the longissimus muscle steaks were pulled from an open hearth broiler at six final internal temperatures (55, 60, 63, 71, 77, 82), no differences were reported in WBSF value among DOD of samples cooked from 55°C to 71°C, but were lower than samples cooked to 77 and 82°C (Lorenzen et al., 2005). Shear force values increased by 26% as temperature was increased from 55°C to 77°C, and 40% from 55°C when cooked to 82°C (Lorenzen et al., 2005).

Shear values only increased 14% when cooked from 71°C to 77°C, and 26% when cooked to 81°C (Lorenzen et al., 2005).

Yancey et al. (2011) evaluated the longissimus muscle using five cookery methods (forced-air convection oven, forced-air impingement oven, open-hearth char broiler, electric countertop griddle and electric clamshell griddle), cooked to three final endpoint temperatures (65.5, 71.1, 76.6°C). When end point temperature increased from 65.5 to 71.1 and 76.6°C, a 7% and 27% increase in WBSF was reported, with a 19% increase when increased from 71.1 to 76.6°C (Yancey et al., 2011). Yancey et al. (2016) conducted the same study but evaluated the semimembranosus and infraspinatus. The results differed than those of Yancey et al. (2011), in that for the infraspinatus, there was no difference in WBSF values among the three DOD, however, the impingement oven produced the toughest samples compared to all other cookery methods (Yancey et al., 2016). For the semimembranosus, the effect of increased cooking temperature on WBSF values was dependent on the cookery method. There was no difference in WBSF among the three DOD when the semimembranosus steaks were cooked on the char broiler, but when cooked in the forced-air convection oven and char broiler, endpoint temperatures of 65.5 and 71.1°C produced more tender steaks than when cooked to 76.6°C (Yancey et al., 2016). When cooked in the impingement oven, samples cooked to 76.7°C were intermediate to steaks cooked to 65.5 and 71.1, however on the clamshell, when cooked to 65.5°C, samples were more tender than the other two endpoint temperatures (Yancey et al., 2016). In contrast, Milligan et al. (1997) pulled $CaCl_2$ injected inside round roasts from a convection oven at three temperatures (60, 70, 80°C) and found no difference in shear values among DOD, most likely due to the pooled average of control and enhanced samples. When evaluating the longissimus muscle cooked on two different cookery methods (counter top griddle and conventional electric oven) at three endpoint temperatures (65, 71, 77°C). Gomes et al. (2014) found no difference between steaks cooked to 65°C and 71°C, but reported a 35% increase in WBSF values when longissimus muscle samples were cooked from 65 to 77°C.

Marbling effects on palatability traits within same DOD

Beef quality grade standards are set by the Agricultural Marketing Service of the United States Department of Agriculture (USDA, 2014). Beef quality grades are currently used in the industry to help to predict the palatability of beef after cooking. The grades are determined by the degree of marbling that is present in the ribeye cut surface between the 12th and 13th ribs.

Marbling has been shown to be moderately to lowly correlated to consumer and trained palatability (Campion et al., 1975; Emerson et al., 2013). Campion et al. (1975) found marbling to be lowly correlated to trained sensory panel scores for tenderness, juiciness, and flavor (r = 0.28, 0.31, 0.20, respectively). However, Emerson et al. (2013) reported much stronger correlations and found marbling to be moderately correlated to trained sensory tenderness, juiciness, and overall liking (r = 0.63, 0.67, 0.78, respectively).

Research commonly finds that consumers rank palatability traits higher among steaks with higher degrees of marbling. Legako et al. (2015) evaluated four different muscles (longissimus lumborum, psoas major, semimembranosus, and gluteus medius) across five different quality treatments (Prime, Top Choice, Low Choice, Select, and Standard) and found the effect of quality treatment to be dependent on muscle for all consumer palatability traits except tenderness. For the psoas major, no difference occurred across quality treatments for overall like and flavor liking, with only Low Choice being rated drier than all other quality treatments within the muscle (Legako et al., 2015). For overall liking and flavor of the semimembranosus, Select was rated 35 and 24% higher respectively, than Low Choice, with all other quality treatments being intermediate (Legako et al., 2015). Only for juiciness were Prime and Top Choice semimembranosus steaks rated 29 and 28% higher, respectively, than Standard. For the gluteus medius, Top Choice was rated 26, 22, and 26.6% higher than Standard for overall like, flavor liking, and juiciness, respectively, and 22 and 27% higher than Select for flavor liking and juiciness, respectively, with all other treatments being intermediate. For the longissimus muscle, Prime was rated 20.7 and 24.8% higher than Select and Standard for overall liking and Prime, Top Choice, and Low Choice and were rated 28, 12, and 23% higher for flavor liking than Standard. For longissimus juiciness scores, Prime was rated 20.6 and 22% higher than Select and Standard, respectively, with all other quality grades being intermediate (Legako et al., 2015). The impact of increased marbling was the greatest for the gluteus medius, followed by the longissimus, with no added benefit in the psoas, and the opposite effect for overall and flavor liking for the semimembranosus. There were no differences among quality treatments for consumer ratings of tenderness. The authors attributed this to the greater intramuscular fat percentage range (12%) within the longissimus muscle than the psoas major (5.2%), semimembranosus (4.9%), and gluteus medius (5.5%). Similarly, Hunt et al. (2014) evaluated four muscles (longissimus lumborum, gluteus medius, serratus ventralis, semimembranosus) across two quality grades (Top Choice, Select) and found the impact of increased marbling to be dependent on muscle for consumer juiciness, flavor, and overall liking. Similar to the previous study, for the semimembranosus, there was no added benefit in increased quality grade, for all sensory traits, but for all other muscles, Top Choice was rated higher by consumers for juiciness, flavor, and overall liking than Select. Increased marbling benefitted the longissimus the most, by having a range of 17 to 26% increase in consumer ratings for juiciness, flavor, and overall liking, while the gluteus medius only saw a 13-14%, and the serratus ventralis a 10-15% increase in consumer ratings when increasing quality grade from Select to Top Choice (Hunt et al., 2014). Additionally, Corbin et al. (2015) evaluated the longissimus muscle across various fat levels ranging from Australian Waygu (26.6%) to Standard (1.9%) and reported an increase in consumer sensory ratings for all traits, including overall liking (Australian Waygu = American Waygu = Prime > High Choice = Top Choice Holstein = Low Choice > Select Holstein = Select ≥ Standard ≥ Grass-finished), juiciness (Australian Waygu = American Waygu > Prime > High Choice = Top Choice Holstein = Low Choice > Grass-finished = Select Holstein ≥ Select ≥ Standard), and flavor liking (American Waygu = Australian Waygu = Prime ≥ Low Choice ≥ High Choice = Top Choice Holstein > Select Holstein = Select = Standard > Grass-finished) and tenderness, even though attempts were made to only include tender samples among the treatments. For tenderness, American Waygu, Australian Waygu, and Prime were all rated similar and higher than all other quality treatments, except American Waygu and Prime were similar to Low Choice (Corbin et al., 2015). Standard was rated tougher than all other quality treatments, except was similar to Select and grass-finished steaks. Moreover, both Waygu treatments and Prime had the highest percentage of steaks rated as premium quality by consumers, with Select and Standard having the highest percent of steaks rated as unsatisfactory. O'Quinn et al. (2012) also evaluated longissimus steaks across various intramuscular fat percentages, and reported consumer tenderness, juiciness, flavor, and overall liking scores decreased as marbling decreased. Prime was rated 20, 21, 14, and 19% higher than Low Choice, 36, 21, 22, 27% higher than Select, and 21, 26, 28, and 26% higher than Standard for tenderness, juiciness, flavor, and overall liking, respectively. Also, Prime was similar to High Choice across all palatability traits and was rated higher than Waygu for flavor and overall liking, with Standard only being rated lower than Select for tenderness (O’Quinn et al., 2012). Killinger et al.

(2004) evaluated the longissimus across three marbling degrees (moderate/modest, small, and slight), with moderate and modest marbling considered to be "high-marbled" and small and slight marbling considered "low-marbled" and reported consumers ratings for juiciness, flavor, and overall acceptability were higher for "high-marbled" steaks, than "low-marbled" as marbling increased. O'Quinn et al. (2018) used 11 studies conducted over a six year time frame to evaluate the effect of increased quality grades (Prime, Premium Choice, Low Choice, Select and Standard) on the percentage of longissimus steaks rated acceptable by consumers for all palatability traits. All studies used similar cooking methods, and same yes/no acceptability questions. When combing the data of all 11 studies, Prime had the highest percentage of steaks rated acceptable for tenderness, juiciness and overall liking while only having a similar percentage to Premium Choice for flavor. Premium Choice had a similar percentage of steaks rated acceptable to Low Choice for all traits, except overall liking and had a higher percentage than Select and Standard across all traits. Select only had a higher percentage of steaks rated acceptable for juiciness.

The results of studies using trained sensory panel evaluations are consistent with those that have used untrained consumers. Dolezal et al. (1982) evaluated 8 marbling degrees (8 = modest and higher; 7 = small; 6 = slight plus; 5 = slight average; 4 = slight minus; 3 = traces average and traces plus; 2 = practically devoid plus and traces minus; 1 = practically devoid average and lower) as determined by the USDA in 1975. Trained sensory panelists rated marbling category 1, 2, 3, and 4 samples lower for juiciness and overall desirability, when compared to marbling category 8 (Dolezal et al., 1982). Marbling category 7, 6, and 5 were similar to 8 for tenderness, flavor, and overall palatability as well. In an earlier study, Campion et al. (1975) evaluated the effect of five USDA Quality Grades (Prime, Top Choice, Low Choice, Select, and Standard) and determined trained sensory panel tenderness, flavor, and juiciness were positively correlated with marbling (*r* = 0.28, *r* = 0.20 *r* = 0.31, respectively), although the correlations were low. Miller et al. (1997) assessed the longissimus muscle from two quality grades (Choice and Select) using trained sensory panelists and found Choice samples rated higher for juiciness, tenderness, and flavor and overall mouthfeel. Similarly, Acheson et al. (2014) examined three marbling degrees (modest, small, and slight) of the longissimus muscle, and three carcass maturity levels (A, B, and C) and reported trained sensory panelists ratings for tenderness, juiciness, and buttery beef fat flavor increased with each increase in degree of marbling. There was no interaction between marbling degree and carcass maturity as well as no difference between sensory traits across maturities.

Increased marbling generally results in a decrease in shear force measurements. In the study conducted by Dolezal et al. (1982), marbling categories 1 and 3 were similar to 2, 4, 5, and 6, but were tougher than category 7 and 8, when aged 14-16 days. Moreover, Acheson et al. (2014) evaluated three marbling degrees (modest, small, and slight) of the longissimus muscle, and found an increase in WBSF as marbling degree increased (Slight > Small > Modest), but found no difference in SSF for small and modest marbling when aged 14 days. Similarly, Igo et al. (2015) collected top loin steaks across three quality grades (Prime, Choice, and Select) from 20 supermarkets and found WBSF to decrease as quality grade increased (Prime < Choice < Select), but, similar to the Acheson et al. (2014) paper, found no difference among SSF values. In contrast, when aged 14 days, Milligan et al. (1997) found no difference between quality grade of longissimus muscle samples when evaluating two quality grades (Low Choice and Select) collected from two processing facilities in different states (Texas and Kansas). However, when aged 7 days, Choice samples from Kansas had higher shear values than those from Texas, and

Select samples from both states (Milligan et al., 1997). When aged 21 days, regardless of muscle (gluteus medius, longissimus lumborum, semimembranosus, serratus ventralis), Top Choice samples possessed lower WBSF values than Select samples (Hunt et al., 2014). Additionally, Emerson et al. (2013) aged the longissimus muscle 14 days, and found as marbling degree increased from traces to moderately abundant, WBSF decreased at each decrease in marbling degree, except with moderate being similar to modest and slightly abundant. However, fewer differences were found across marbling degrees for SSF, with no differences occurring among modest, moderate, slightly abundant, and moderately abundant marbling.

DOD and marbling combined effect on beef palatability

One theory proposes that increased marbling can counteract the negative effect of increased cooking temperatures. This theory is known as the insurance theory, and states marbling acts as "insurance," to keep an acceptable eating experience as degree of doneness increases (Smith and Carpenter, 1974). Many studies have evaluated the effect of varying marbling levels cooked to various DOD on beef palatability. However, most of these studies are limited to two or three marbling levels and limited degrees of doneness and provide conflicting evidence in support of this theory. Few, if any, studies have evaluated all six DOD's across more than three marbling levels.

In one of the earliest studies evaluating marbling and DOD, no interaction was observed between marbling degree and DOD, when the longissimus dorsi from three marbling degrees (slight, modest, moderately abundant) were pulled off a broiler at three temperatures (60, 70, and 80°C), and served to trained panelists under red lighting (Parrish et al., 1973). This study found no difference among marbling degrees for tenderness, juiciness, flavor, and overall like. When cooked to 60°C, steaks had the highest ratings for all sensory traits, and decreased with each increase in endpoint temperature. This was one of the first studies to report increased marbling did not compensate for the negative impacts of increased DOD. Similar to the study above, Vote et al. (2000) observed no interaction when the longissimus muscle from two quality grades (Choice and Select) was cooked to two final endpoint temperatures (66 and 77°C) and served to trained sensory panelists. Choice was rated more tender than Select samples, and samples cooked to 66°C were rated more juicy as well as tender than those cooked to 77°C (Vote et al., 2000). Thus, the negative impact of increased endpoint temperature was consistent across both quality grades. However, only two quality grades were used in the study, and thus lacked significant variation of marbling to likely find an effect. Similarly, Akinwunmi et al., 1993 found no evidence of the insurance theory for trained sensory panelist scores when cooking the longissimus muscle from two marbling degrees (modest and slight) to three DOD (60, 71, and 77°C). In fact, similar to the previous study, no differences were observed between the two marbling degrees for all sensory traits evaluated at all three DOD. Additionally, no differences were found for flavor among the three DOD, but 60, and 71°C samples were rated more tender, and 60°C samples juicier than 77°C. McKillip et al. (2017) cooked the longissimus to three DOD (R = 60°C, M = 71°C, VWD = 82°C) from three quality grades (Prime, Low Choice, Select), and evaluated the effect on trained and consumer sensory ratings. There was no interaction between quality grade and DOD for all consumer sensory attributes, failing to support the insurance theory. Prime was similar to Low Choice for all sensory traits, with Low Select being rated the toughest and the driest, but was similar to Low Choice for flavor and overall liking (McKillip et al., 2017). Moreover, steaks got drier, tougher and were rated lower for overall like by consumers as DOD increase (R > M > VWD; McKillip et al., 2017). However, an interaction between quality grade and DOD was found only for trained initial juiciness ratings. When cooked to R, Prime samples were rated 14.7% higher than Select, and this difference increased to 34.8% when cooked to Medium, and further increased to 80% at VWD, indicating increased marbling helped to counteract the negative impact of increased endpoint temperature for initial juiciness. Moreover, Lucherk et al. (2016) found no interaction between quality grade (Prime, Top Choice, Low Choice, Select, and Standard) and DOD (R = 60°C; M = 71°C; WD = 77°C) of the longissimus muscle for all consumer sensory ratings and the percentage of samples rated acceptable. In that study, the consumers were fed their preferred DOD under white lighting. There was a quality grade × DOD interaction for trained sensory initial and sustained juiciness ratings, where Prime was rated 18.8% and 25.8% higher for initial and sustained juiciness, respectively, when cooked to R, 51.0% and 68.1% at M, and increased further to 54.1% and 64.9% at WD than Select. Thus, the consumer data failed to support the insurance theory, with trained juiciness ratings providing some evidence of increased marbling lessening the negative impact of increased DOD. O'Quinn et al. (2015) also fed consumers their preferred DOD of psoas major steaks, as determined by expert chefs using a color guide, from three quality grades (Choice, High Select, Select). The authors found no quality grade × DOD interaction for all traits evaluated. For the psoas major, there were no differences in quality grade for all palatability traits, and no difference among DOD for overall like and favor, however, increased DOD resulted in lower consumer juiciness scores.

Many studies have evaluated the effect of DOD and marbling of multiple muscles using consumers at-home. Lorenzen et al. (1999) evaluated the Longissimus muscle from three quality grades (Top Choice, Low Choice, High Select, Low Select) cooked to multiple endpoint temperatures, at the discretion of the consumer, and were classified into four DOD groups (medium-rare or less, medium, medium-well, and well-done or more), and found no interaction between quality grade and DOD. Consumers rated steaks cooked to medium-rare or less, highest for overall liking, and flavor desirability, steaks cooked to medium and well-done or higher similar, with medium-well rated the lowest. Similarly, McKenna et al. (2004) evaluated three quality grades (Low Choice, High Select and Low Select) and multiple DOD on the Longissimus muscle and found no interaction between quality grade and DOD. Moreover, the effect of DOD on consumer palatability was dependent upon the location (Dallas and San Antonio) and cookery method (outdoor grill, broil, indoor grill, pan-broil, pan-fry, simmer/stew, other) of the consumers. Medium and Well-done or more were rated the highest for overall liking for San Antonio, while Medium-rare or less was rated higher than Medium-well, but was similar to Medium and Well-done or more.

Studies have also evaluated the effect of marbling and DOD on objective measurements of shear force. Obuz et al. (2004) evaluated two quality grades (Top Choice and Select) and nine endpoint temperatures (40, 45, 50, 55, 60, 65, 70, 75, 80°C) across three muscles (longissimus lumborum, biceps femoris, deep pectoralis) using two cookery methods (belt grill and water bath) and found an interaction between quality grade and DOD for the longissimus muscle only. As temperatures increased from 55°C, WBSF numerical values increased for both quality grades, however, USDA Choice was only more tender than Select at 75 and 80°C. Thus, only at high temperatures did marbling "protect" the steak from the negative effects of increased cooking temperatures. However, Parrish et al. (1973) found no interaction between final internal temperature and marbling degree for WBSF when evaluating the longissimus from three marbling degrees (slight, modest, moderately abundant) pulled off a broiler at three temperatures (60, 70, and 80°C). Quality grade and endpoint temperatures did not have an effect on WBSF values. Similarly, Vote et al. (2000) found no interaction between two endpoint temperatures (66 and 77°C) and two quality grades (Choice and Select) for WBSF values. Select had higher shear values than Choice, and steaks cooked to 77°C had higher shear values than Select. In contrast Lucherk et al. (2016) found interaction between quality grade (Prime, Top Choice, Low Choice, Select, and Standard) and DOD (R = 60°C; M = 71°C; WD = 77°C) of the longissimus muscle SSF values. When cooked to R, there was no difference between Prime, Select, and Standard shear values, but when cooked to M, Select and Standard had 41 and 37% respectively higher shear values than Prime, and increased to 46 and 67% when cooked to WD.

The effect of enhancement on beef palatability

Various research has been conducted to evaluate the impact of added moisture to beef palatability. Enhancement of beef cuts has been shown to increase consumer ratings of beef palatability traits (Robbins et al., 2003; Brooks et al., 2010; Lucherk et al., 2016; McKillip et al., 2017). Enhancement technology could be used to add value and improve palatability to lower quality cuts.

A study conducted by McKillip et al. (2017) evaluated the effect of enhancing (108% of raw weight with water, salt, and alkaline phosphate solution) and not enhancing beef strip loins from three quality grades (Prime, Low Choice and Low Select) cooked to the three DOD (60°C, 71°C, 82°C) on beef palatability ratings. For all consumer ratings, no differences were found among the enhanced samples, and all enhanced samples were rated higher than non-enhanced for juiciness, tenderness, flavor and overall liking. Consumers rated Select enhanced samples 31.6 to 36.2% higher for all palatability traits than non-enhanced Select, while Prime samples were only rated 11.2 to 18.9% higher by consumers when enhanced compared to non-enhanced Prime samples. Similarly, Lucherk et al. (2016) evaluated the effect of two enhancement levels (injected at either 107% or 122% of raw weight with water, salt, alkaline phosphate solution) of

Select strip loins on beef palatability, as well as non-enhanced strip loins from five quality grades (Prime, Top Choice, Low Choice, Select, and Standard) cooked to three DOD (60°C, 71°C, 82°C). Consumers rated the low enhanced (injected at 107% of raw weight) Select samples similar to Prime for juiciness, tenderness, and overall liking, while high enhanced samples (injected at 112% of raw weight) were rated similar to Prime for only juiciness. Thus, low enhanced samples were rated 24.8 to 40.7% higher by consumers than non-enhanced Select samples, while high-enhanced samples were rated 29.8 to 56.5% higher for juiciness, tenderness, flavor and overall liking. In that study, consumers rated both enhanced samples high for beef flavor identity, indicating consumers could not differentiate salt flavor from beef flavor. It should be noted, that currently in the United States, the USDA regulates enhancement, and is against the law to injected meat products more than 10% of a solution (USDA FSIS, 2013). Likewise, a study conducted by Robbins et al. (2003) evaluated the effect of non-enhanced and enhanced (110% of raw weight with sodium chloride, and sodium tripolyphosphate solution) beef inside round roast and strip loins from high Select or Low Choice carcasses, on consumer palatability ratings. Roasts were cooked in a convection oven and steaks were cooked on open hearth grill to an internal temperature of 72°C. For both roasts and steaks, enhancement increased consumer ratings for tenderness, juiciness, beef flavor and overall acceptability 10.4 to 20.1% for roasts and 10.7 to 16.9% for steaks compared to non-enhanced samples. Though, all carcasses used were either High Select or Low Choice, comparisons against marbling levels were not made. Furthermore, a study conducted by Brooks et al. (2012) evaluated the effect of enhancement on Select beef strip loins form cattle fed Zilpaterol hydrochloride for four different duration times (0, 20, 30, 40 days). Strip loins were aged at three different times (7, 14 or 21 days) and were either enhanced (injected at 110% of raw weight with a sodium chloride and sodium polyphosphate solution) or not enhanced. Steaks aged 14 and 21 days were fed to consumers, and for each aging time, enhanced steaks were rated higher by consumers for all palatability traits. When aged 14 days, tenderness, juiciness, and overall liking were rated 13.1 to 17.1% higher for enhanced samples with flavor seeing a 5.1% increase in consumer ratings. A similar trend was seen when consumers were fed steaks aged 21 days, with enhancement increasing consumer ratings for flavor by 8.4%, and consumers rating tenderness, juiciness, and overall liking 15.1 to 17.8% higher than non-enhanced samples. Therefore, enhancement enables increased palatability of lower valued cuts.

References

Acheson, R. J., D. R. Woerner, and J. D. Tatum. 2014. Effects of USDA carcass maturity on sensory attributes of beef produced by grain-finished steers and heifers classified as less than 30 months old using dentition. J. Anim. Sci. 92:1792-1799. doi:10.2527/jas.2013-7553

Akinwunmi, I., L. Thompson, and C. Ramsey. 1993. Marbling, fat trim and doneness effects on sensory attributes, cooking loss and composition of cooked beef steaks. J. Food Sci. 58:242-244.

American Meat Science Association. 1978. Guidelines for cookery and sensory evaluation of meat. 1 ed. American Meat Science Association Chicago, IL.

American Meat Science Association. 1995. Research guidlines for cookery, sensory evaluation, and instrumental tenderness measurements of fresh meat. National Live Stock and Meat Board, Chicago, IL.

American Meat Science Association. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

Behrends, J. M., K. J. Goodson, M. Koohmaraie, S. D. Shackelford, T. L. Wheeler, W. W. Morgan, J. O. Reagan, B. L. Gwartney, J. W. Wise, and J. W. Savell. 2005. Beef customer satisfaction: USDA quality grade and marination effects on consumer evaluations of top round steaks1. J. Anim. Sci. 83:662-670. doi:10.2527/2005.833662x

Brooks, J. C., J. M. Mehaffey, J. A. Collins, H. R. Rogers, J. Legako, B. J. Johnson, T. Lawrence, D. M. Allen, M. N. Streeter, W. T. Nichols, J. P. Hutcheson, D. A. Yates, and M. F. Miller. 2010. Moisture enhancement and blade tenderization effects on the shear force and palatability of strip loin steaks from beef cattle fed zilpaterol hydrochloride. J. Anim. Sci. 88:1809-1816. doi:10.2527/jas.2009-2383

Certified Angus Beef. 2018. Degree of doneness. https://www.certifiedangusbeef.com/kitchen/doneness.php Accessed 20 May 2018.

Campion, D. R., J. D. Crouse, and M. E. Dikeman. 1975. Predictive value of USDA beef quality grade factors for cooked meat palatability J. Food Sci. 40:1225-1228. doi:10.1111/j.1365-2621.1975.tb01057.x

Corbin, C. H., T. G. O'Quinn, A. J. Garmyn, J. F. Legako, M. R. Hunt, T. T. N. Dinh, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Sci. 100:24-31. doi:10.1016/j.meatsci.2014.09.009

Cox, R. J., J. M. Thompson, C. M. Cunial, S. Winter, and A. J. Gordon. 1997. The effect of degree of doneness of beef steaks on consumer acceptability of meals in restaurants. Meat Sci. 45:75-85. doi:http://dx.doi.org/10.1016/S0309-1740(96)00080-0

Cross, H. R., M. S. Stanfield, and E. J. Koch. 1976. Beef palatability as affected by cooking rate and final Internal temperature. J. Anim. Sci. 43:114-121.

Dolezal, H. G., G. C. Smith, J. W. Savell, and Z. L. Carpenter. 1982. Comparison of subcutaneous fat thickness, marbling and quality grade for predicting palatability of beef. J. Food Sci. 47:397-401. doi:doi:10.1111/j.1365-2621.1982.tb10089.x

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. J. Anim. Sci. 91:1024-1034. doi:10.2527/jas.2012-5514

Food and Drug Administration. 2010. Topline Frequency Report, FDA Division of Social Sciences, Silver Spring, MD.

Folch, J., M. Lees, and G. H. Sloane Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 266:497-509.

Food Network Kitchen. 2017. The Right Way to Know When Your Steak is Done Cooking. Food Network. Available from: https://www.foodnetwork.com/how-to/packages/food-network-essentials/how-to-check-steak-doneness

Gilpin, G. L., O. M. Batcher, and P. A. Deary. 1965. Influence of marbling and final internal temperature on quality characteristics of broiled rib and eye of round steaks. Food Tech. 19:834-837.

Gomes, C. L., S. B. Pflanzer, A. G. Cruz, P. E. de Felício, and H. M. A. Bolini. 2014. Sensory descriptive profiling and consumer preferences of beef strip loin steaks. Food Res. Int. 59:76-84. doi:10.1016/j.foodres.2014.01.061

Huffman, K. L., M. F. Miller, L. C. Hoover, C. K. Wu, H. C. Brittin, and C. B. Ramsey. 1996. Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. J. Anim. Sci. 74:91-97.

Hunt, M. R., A. J. Garmyn, T. G. O'Quinn, C. H. Corbin, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2014. Consumer assessment of beef palatability from four beef muscles from USDA Choice and Select graded carcasses. Meat Sci. 98:1-8. doi:10.1016/j.meatsci.2014.04.004

Igo, M. W., A. N. Arnold, R. K. Miller, K. B. Gehring, L. N. Mehall, C. L. Lorenzen, R. J. Delmore, D. R. Woerner, B. E. Wasser, and J. W. Savell. 2015. Tenderness assessments of top loin steaks from retail markets in four U.S. cities. J. Anim. Sci. doi:10.2527/jas.2015-9085

Killinger, K. M., C. R. Calkins, W. J. Umberger, D. M. Feuz, and K. M. Eskridge. 2004. Consumer visual preference and value for beef steaks differing in marbling level and color. J. Anim. Sci. 82:3288-3293. doi:10.2527/2004.82113288x

Koeppl, P. T. 1998. Focus groups on barriers that limit consumers' use of thermometers when cooking meat and poultry products, USDA FSIS, Washington, D.C.

Legako, J. F., J. C. Brooks, T. G. O'Quinn, T. D. J. Hagan, R. Polkinghorne, L. J. Farmer, and M. F. Miller. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat Sci. 100:291-300. doi:10.1016/j.meatsci.2014.10.026

Longhorn Steakhouse. 2015. Cook Different Temperature Steaks. Longhorn Steakhouse Grilling Season. Available from: http://www.expertgriller.com/chef-tips/how-to-cook-steak-at-different-temperatures-for-groups/

Lorenzen, C. L., V. K. Davuluri, K. Adhikari, and I. U. Grün. 2005. Effect of end-point temperature and degree of doneness on sensory and instrumental flavor profile of beef steaks. J. Food Sci. 70:S113-S118. doi:10.1111/j.1365-2621.2005.tb07114.x

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top loin steak. J. Anim. Sci. 77:637-644.

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Sci. 122:145-154. doi:10.1016/j.meatsci.2016.08.005

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2017. Assessment of objective measures of beef steak juiciness and their relationships to sensory panel juiciness ratings1,2. J. Anim. Sci. 95:2421-2437. doi:10.2527/jas.2016.0930

McKenna, D. R., C. L. Lorenzen, K. D. Pollok, W. W. Morgan, W. L. Mies, J. J. Harris, R. Murphy, M. McAdams, D. S. Hale, and J. W. Savell. 2004. Interrelationships of breed type, USDA quality grade, cooking method, and degree of doneness on consumer evaluations of beef in Dallas and San Antonio, Texas, USA. Meat Sci. 66:399-406. doi:10.1016/s0309-1740(03)00126-8

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. E. Boyle, and T. G. O'Quinn. 2017. Sensory Evaluation of Enhanced Beef Strip Loin Steaks Cooked to

3 Degrees of Doneness. Meat and Muscle Biology 1:227-241. doi:10.22175/mmb2017.06.0033

Miller, M. F., L. C. Hoover, K. D. Cook, A. L. Guerra, K. L. Huffman, K. S. Tinney, C. B. Ramsey, H. C. Brittin, and L. M. Huffman. 1995. Consumer acceptability of beef steak tenderness in the home and restaurant. J. Food Sci. 60:963-965.

Miller, M. F., C. R. Kerth, J. W. Wise, J. L. Lansdell, J. E. Stowell, and C. B. Ramsey. 1997. Slaughter plant location, USDA quality grade, external fat thickness, and aging time effects on sensory characteristics of beef loin strip steak. J. Anim. Sci. 75:662-667.

Milligan, S. D., M. F. Miller, C. N. Oats, and C. B. Ramsey. 1997. Calcium chloride injection and degree of doneness effects on the sensory characteristics of beef inside round roasts. J. Anim. Sci. 75:668-672. doi:10.2527/1997.753668x

National Cattleman's Beef Association. 2016. Beef steak color guide. National Cattelmen's Beef Association, Centennial, CO.

National Livestock and Meat Board. 1979. Beef Steak Color Guide. N.L.M.B.

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. J. Food Sci. 80:S444-S449. doi:10.1111/1750-3841.12775

O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. J. Anim. Sci. 90:626-634. doi:10.2527/jas.2011-4282

O'Quinn, T. G., J. F. Legako, J. C. Brooks, and M. F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience1. Translational Animal Science 2:26-36. doi:10.1093/tas/txx008

Obuz, E., M. E. Dikeman, J. P. Grobbel, J. W. Stephens, and T. M. Loughin. 2004. Beef longissimus lumborum, biceps femoris, and deep pectoralis Warner–Bratzler shear force is affected differently by endpoint temperature, cooking method, and USDA quality grade. Meat Sci. 68:243-248. doi:https://doi.org/10.1016/j.meatsci.2004.03.003

Parrish, F. C., Jr., D. G. Olson, B. E. Miner, and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. J. Anim. Sci. 37:430-434.

Robbins, K., J. Jensen, K. J. Ryan, C. Homco-Ryan, F. K. McKeith, and M. S. Brewer. 2003. Consumer attitudes towards beef and acceptability of enhanced beef. Meat Sci. 65:721-729.

Savell, J. W., R. E. Branson, H. R. Cross, D. M. Stiffler, J. W. Wise, D. B. Griffin, and G. C. Smith. 1987. National consumer retail beef study: palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. 52:517-519.

Savell, J. W., and H. R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. Designing Foods: Animal Product Options in the Marketplace. National Academy Press, Washington, D.C.

Savell, J. W., H. R. Cross, and G. C. Smith. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. J. Food Sci. 51:838-839. doi:10.1111/j.1365-2621.1986.tb13946.x

Schmidt, T. B., M. P. Keene, and C. L. Lorenzen. 2002. Improving consumer satisfaction of beef through the use of thermometers and consumer education by wait staff. J. Food Sci. 67:3190-3193. doi:10.1111/j.1365-2621.2002.tb08880.x

Smith, G. C., and Z. L. Carpenter. 1974. Eating quality of animal products and their fat content. Changing the fat content and composistion of animal products. p 124-137. National Academy Press, Washington, D.C.

Smith, A. M., K. B. Harris, A. N. Haneklaus, and J. W. Savell. 2011. Proximate composition and energy content of beef steaks as influenced by USDA quality grade and degree of doneness. Meat Sci. 89:228-232. doi:https://doi.org/10.1016/j.meatsci.2011.04.027

Smith, G. C. 2018. Photographs of steaks cooked to different degrees of doneness.

Steak University. 2018. Done To Perfection: Your Guide To Steak Doneness. Available from: https://www.mychicagosteak.com/steak-university/2016/05/11/done-perfection-guide-steak-doneness/

Stradley, L. 2016. Internal Temperature Cooking Chart - Steak Temperature Chart. https://whatscookingamerica.net/Information/MeatTemperatureChart.htm Accessed 31 May 2018.

USDA-FSIS. 2013. Water in Meat and Poultry. In (Vol. 2016).

USDA. 2014. Inspection & Grading of Meat and Poultry: What Are the Differences? https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/production-and-inspection/inspection-and-grading-of-meat-and-poultry-what-are-the-differences_ 2018.

Vote, D. J., W. J. Platter, J. D. Tatum, G. R. Schmidt, K. E. Belk, G. C. Smith, and N. C. Speer. 2000. Injection of beef strip loins with solutions containing sodium tripolyphosphate, sodium lactate, and sodium chloride to enhance palatability. J. Anim. Sci. 78:952-957. doi:/2000.784952x

Wheeler, T. L., S. D. Shackelford, and M. Koohmaraie. 1998. Cooking and palatability traits of beef longissimus steaks cooked with a belt grill or an open hearth electric broiler. J. Anim. Sci. 76:2805-2810.

Wheeler, T. L., S. D. Shackelford, and M. Koohmaraie. 1999. Tenderness classification of beef: IV. Effect of USDA quality grade on the palatability of "tender" beef longissimus when cooked well done1. J. Anim. Sci. 77:882-888. doi:10.2527/1999.774882x

Yancey, J. W. S., J. K. Apple, and M. D. Wharton. 2016. Cookery method and endpoint temperature can affect the Warner-Bratzler shear force, cooking loss, and internal cooked color of beef semimembranosus and infraspinatus steaks. J. Anim. Sci. 94:4434-4446. doi:10.2527/jas2016-0651

Yancey, J. W. S., M. D. Wharton, and J. K. Apple. 2011. Cookery method and end-point temperature can affect the Warner–Bratzler shear force, cooking loss, and internal cooked color of beef longissimus steaks. Meat Sci. 88:1-7. doi:https://doi.org/10.1016/j.meatsci.2010.11.020

Chapter 2 - Evaluation of beef strip loins from five quality treatments cooked to six degrees of doneness

Introduction

The beef marbling insurance theory was first proposed by Smith and Carpenter (1974) and states "*…the presence of higher levels of marbling allows for the use of high-temperature, dry-heat methods of cookery and/or the attainment of advanced degrees of final doneness without adversely affecting the ultimate palatability of the cooked meat*". In this way, marbling provides some "insurance" for consumers for meats that are either cooked too long, too rapidly, or cooked incorrectly (Savell and Cross, 1988). No study has extensively evaluated the interaction between marbling level and degree of doneness (**DOD**) on consumer eating satisfaction. Numerous studies have demonstrated the positive effect of marbling level on beef palatability (Smith et al., 1985; O'Quinn et al., 2012; Emerson et al., 2013; Corbin et al., 2015), but the overwhelming majority of these studies have used only a single DOD. Additionally, previous work evaluating the effects of DOD on beef palatability have used only a limited number or even single marbling levels (Savell et al., 1999; Schmidt et al., 2002; Lorenzen et al., 2005; O'Quinn et al., 2015a).

In addition to marbling, moisture enhancement positively affects beef eating quality (Vote et al., 2000; Robbins et al., 2003; Brooks et al., 2010). It is plausible that added moisture through enhancement technology may "protect" these products against elevated DOD in a similar manner as marbling, although, to date, it is unclear if moisture enhanced beef would be consistent with the "insurance theory".

Several studies have shown 51 to 76% of consumers prefer a medium or higher DOD (Mckillip et al., 2018; Cox et al., 1997; Schmidt et al., 2002) and therefore further examination of this idea could benefit the industry by identifying products that will meet consumer eating expectations based on their preferred degree of doneness. Thus, the objectives of this study were to evaluate the extent marbling compensates for reduced beef palatability at elevated degrees of doneness and to determine the relationship of residual moisture and fat in cooked steaks to beef palatability, specifically beef juiciness.

Materials and Methods

Sample collection

Paired beef strip loins (IMPS # 180) were collected from a Midwestern commercial beef processor from four USDA quality treatments [Prime, Top Choice (Modest^{00} – Moderate^{100} marbling), Low Choice, and Select; *n* = 12 pairs/quality grade]. An additional 12 pairs of USDA Select strip loins were collected for moisture enhancement. During collection, the Kansas State University (**KSU**) research team collected carcass data which included carcass lean maturity, skeletal maturity, overall maturity, marbling score, preliminary fat thickness, adjusted fat thickness, ribeye area, hot carcass weight, kidney pelvic, and heart fat as well as USDA yield grade. Subprimals were vacuum packaged, transported under refrigerated (4°C) temperatures to the KSU Meat Laboratory, and aged at 2-4°C for 21 d from the time of harvest.

On d 14 of aging, strip loins designated for moisture enhancement were enhanced with an alkaline phosphate solution using a multi-needle injector (Schroder Model IMAX 420, Wolf-Tec Inc., Kingston, NY). The enhancement solution (Brifisol 512, ICL Food Specialties, Saint Louis, MO) was formulated to result in 0.4% sodium phosphate and 0.3% salt at a 10% target pump-level (pH = 7.46). Strip loins were weighed before and 30 min after enhancement to determine actual percentage pump (7.8% ± 0.80%). Enhanced strip loins were re-vacuum packaged and aged for the final 7 d of the aging period.

After the 21 d aging period, strip loins were fabricated from anterior to posterior into 2.5-cm thick steaks. The most anterior (wedge) steak was designated for pH and raw proximate analysis. A pH meter (model HI 99163; Hannah Instruments, Smithfield, RI) also measured the pH on this steak. The following three consecutive steaks were grouped together, with a total of three groups per strip loin, and a total of six groups per strip loin pair. Within each strip loin pair, groups were randomly assigned one of six degrees of doneness (**DOD**) based on the Beef Steak Color Guide (NCBA, 2016), which were described as: very-rare (**VR**; 55°C), rare (**R**; 60°C), medium-rare (**MR**; 63°C), medium (**M**; 71°C), well-done (**WD**; 77°C), or very well-done (**VWD**; 82°C), . Steak within a group was randomly assigned to either: consumer sensory panel analysis, trained sensory panel analysis, or objective tenderness and juiciness measurement and cooked proximate analysis. All steaks were assigned a randomized four digit identification number, vacuum packaged, and frozen (-40°C) until subsequent analysis.

Consumer sensory panels

Untrained consumer panelists (*n* = 360) were recruited from around the Manhattan, KS area and were monetarily rewarded for their participation. A total of 45 panels took place at the KSU Meat Science Sensory Laboratory with eight consumers participating on each panel. Panelists were placed in individual sensory booths and evaluated samples under low intensity (< 107.64 lumens) red incandescent lighting to conceal differences in DOD among samples.

Each panelist was given a tablet (Model 5709 HP Steam 7; HewlettPackard, Palo Alto, CA) to fill out a digital survey (Qualtrics Software, Provo, UT). Surveys contained a demographics questionnaire, a purchasing motivator survey, and 8 sample evaluation surveys. Before the start of each panel, consumers were given verbal instructions on how to use the tablets and fill out the survey. Panelists were additionally provided with a napkin, fork, water cup, expectorant cup, apple juice and unsalted crackers. The apple juice and crackers served as palate cleansers between samples.

Consumers rated traits of importance when purchasing beef steaks on continuous lines scales with anchors at 0 and 100 for the purchasing motivator survey. The 0 anchor indicated extremely unimportant and the 100 anchor indicated extremely important. Additionally, consumers evaluated each sample for juiciness, tenderness, flavor, and overall liking on continuous line scales with anchors at 0, 50 (the midpoint), and at 100. The 0 anchors were extremely dry, extremely tough, dislike extremely; the 50 anchors were neither dry nor juicy, tough nor tender, like nor dislike; the 100 anchors were extremely juicy, extremely tender, and like extremely. Moreover, consumers rated each trait as either acceptable or unacceptable using yes/no questions. Lastly, consumers rated each sample for their perceived quality level, as either unsatisfactory, everyday quality, better than everyday quality, or premium quality.

Steaks were thawed 24 h at 2-4°C prior to sensory evaluation. Raw weights were recorded for cook loss calculation. Steaks were cooked to their designated DOD on a clamshell grill (Cuisiart Griddler Deluxe, Model GR-150, East Windsor, NJ) with temperatures monitored using a probe thermometer (Super-Fast Thermopen, ThermoWorks, American Fork, UT). Steaks were removed from the grill and allowed to rest for 3 min prior to cutting. Peak temperatures and cooked weights were recorded following the rest period. The longissimus muscle was cut into 2.5-cm thick × 1-cm × 1-cm pieces and 2 pieces were immediately served to consumers. Consumers were fed 8 randomized samples representing differences in quality treatment and DOD. This study was analyzed as an incomplete block design so quality treatment × DOD were equally represented over the course of the 45 panels.

Trained sensory panels

Sensory panelists were trained according to the American Meat Science Association (**AMSA**) Sensory Guidelines (AMSA, 2015). Panelists were trained at 15 training sessions 2 weeks prior to panels, using anchors and methods similar to those described by Lucherk et al. (2016). Similar to consumer sensory panelists, trained sensory panelists evaluated samples in individual sensory low intensity (< 107.64 lumens) red incandescent lighting. There were a total of 45 trained panel sessions with each consisting of 8 trained panelists per panel. Steaks were cooked as described previously for consumer evaluation. Raw weights, cooked weights, and peak temperature were recorded for cook loss calculation. After cooking, steaks were sliced into 2.5-cm thick × 1-cm × 1-cm cuboids and placed into double broilers to keep samples warm before evaluation. In the same manner as with consumer panels, panelists were fed eight samples in random order to represent differences in DOD and quality treatment.

Panelists were provided with a napkin, water cup, expectorant cup, apple slices and unsalted crackers for palate cleansers. Additionally, panelists were provided with the same electronic tablets equipped with a survey created through the same software as for consumer panels. Panelists evaluated samples on 0 to 100 continuous line scales for initial and sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, salt flavor intensity, and off flavor intensity. The 0 anchors were labeled as extremely dry, extremely tough, none, and bland; and the 100 anchors were labeled as extremely juicy, extremely tender, abundant, and intense. Additionally, there were midpoint (50) anchors for initial juiciness, sustained juiciness, myofibrillar tenderness and overall tenderness that were labeled as: neither dry nor juicy, and neither tough nor tender. If a salt or off flavor was not detected, panelists could select a box labeled as “not applicable”.

Slice shear force

All cooking procedures described for sensory panel evaluation were followed. The protocol outlined by Shackleford et al. (1999) was used to determine slice shear force (**SSF**) values. Briefly, a cut was made 2 cm from the lateral end of the longissimus lumborum muscle, followed by a second cut made 5 cm from the first cut to determine muscle fiber orientation. A 1-cm × 5-cm slice was cut at a 45°angle parallel to the muscles fibers using a double bladed knife. The still warm sample was sheared using SSF machine (Model GR-152; Tallgrass Solutions, Manhattan, KS) to obtain the peak force required to shear perpendicular to the muscles fibers approximately in the middle of the slice.

Pressed juice percentage

The methods outlined by Lucherk et al. (2017) were used to determine pressed juice percentage (**PJP**). In brief, a 1-cm thick slice was removed immediately medial to the SSF sampling and was cut, parallel to the muscle fiber orientation, into three 1-cm wide pieces. Each piece was individually placed on two sheets of filter paper (VWR Filter Paper 415, 12.5 cm, VWR International, Radnor, PA), weighed, and compressed (Instron Model 5569, Canton, MA) at 78.45 N of force for 30 s. Final weights of the filter paper sheets were taken without the sample to determine PJP. The three PJP values were averaged for each steak.

Warner-Braztler shear force

After SSF and PJP sampling, the remainder of the steak was refrigerated (2-4°C) over-night prior to Warner-Bratzler shear force (**WBSF**) determination. Using the protocol outlined in the AMSA sensory guidelines (AMSA, 2015), six cores (1.27 cm diameter) were removed and sheared perpendicular to the muscle fiber orientation using an Instron (Instron Model 5569, Canton, MA) with a crosshead speed of 250 mm/minute and a load cell of 100 kg. The peak force was recorded for each core. The six WBSF values were averaged for each steak. The remainder of the WBSF steak and the sheared cores were combined with previous refrigerated SSF steak pieces that contained the same four digit identification number, and then were diced for same day homogenization for cooked proximate analysis.

Proximate analysis

Anterior steaks were thawed 24 h prior to homogenization for raw proximate analysis. Steak pieces remaining after shear force testing were used for determination of cooked moisture and fat percentage. All external fat and accessory muscles were removed prior to being diced and dipped into liquid nitrogen. Steaks were then homogenized (Waring Products Division; Hartford, CT) and stored in VWR Sterile Sample Bags (VWR International LLC, Pittsburgh, PA) bags in a -80°C freezer until analysis. Moisture analysis was conducted using the approved AOAC drying oven method (AOAC, 1995). Furthermore, raw fat analysis was performed using an approved modified methanol-chloroform method as described by Folch, Lees, and Stanley (1957).

Statistical analysis

Statistical analyses were conducted using the procedures of SAS (Version 9.4 SAS Inst., Inc., Cary, NC). The PROC GLIMMIX procedure in SAS was used to evaluate treatment effects and their interactions with an α of 0.05. Data were analyzed as a split-plot with the whole plot factor of quality treatment and sub-plot factor of degree of doneness. A model with a binomial error distribution was utilized for acceptability data. For all analyses, the Kenward –Roger approximation was utilized. When the overall treatment effect or effect interactions were significant ($P < 0.05$), the PDIFF option was used to separate means. Moreover, the SLICE option was used for significant ($P < 0.05$) quality treatment × DOD interactions. PROC REG was used for determination of simple linear regressions and Pearson correlation coefficients were calculated and tested for significance using PROC CORR. Additionally, logistic regression models were calculated using PROC LOGISTIC.

Results

Consumer demographics

Consumer demographics of the 350 participants that filled out the demographic questionnaire for the consumer sensory evaluation are presented in Table 2.1. Over half (52.6%) of the participants were male, with the majority being Caucasian (80.9%), and single (54.6%). Additionally, 49.2% of the participants were 20 to 39 years of age, with 35.7% over 50 years of age. Moreover, 22.9% were a college graduate, and 41.6 % had some college or technical school, with 39.5% having an annual household less than $50,000, 45.2% between $50,000 and $100,000, and 34.6% having a household income over $100,000. Over half (52.0%) of the participants rated flavor as the most important palatability trait to them when they consume beef, and medium-rare was the most popular DOD preferred (41.1%). Most (43.9%) of the consumers consumed beef at least three times a week.

Consumer sensory evaluation

For consumer palatability scores, there was no ($P > 0.05$) quality treatment × DOD interaction for all palatability traits, including juiciness ($P = 0.06$). The main effects of quality treatment and DOD for consumer palatability ratings are presented in Table 2.2. For quality treatment, enhanced Select was rated the highest ($P < 0.05$) by consumers for juiciness, tenderness, flavor, and overall like. For the non-enhanced samples, each decrease in quality grade resulted in a concurrent decrease ($P < 0.05$) in consumer ratings for tenderness, juiciness, flavor, and overall like, with the exception of Top Choice being similar ($P > 0.05$) to Low Choice for all traits, and Low Choice being similar ($P > 0.05$) to Select for tenderness.

Consumers rated samples drier ($P < 0.05$) as DOD increased from VR to VWD, with only R having a similar ($P > 0.05$) juiciness rating to VR and MR. For tenderness, an increase ($P < 0.05$) in DOD resulted in tougher consumer ratings (VR = R = MR > M > WD > VWD). A similar trend was seen for flavor, where samples cooked from VR to M were rated similar ($P > 0.05$) and higher ($P < 0.05$) than those cooked to VWD, with WD being similar ($P > 0.05$) to only M, and higher ($P < 0.05$) than VWD. Samples cooked from VR to M were similar ($P > 0.05$) but higher ($P < 0.05$) than those cooked to WD and VWD for consumer overall liking scores.

Consumers were additionally asked a yes or no question, of whether each trait was acceptable. There was a quality treatment × DOD interaction ($P < 0.05$) for juiciness, tenderness, and overall like acceptability (Table 2.3). For juiciness acceptability, there were no differences ($P > 0.05$) among quality treatments when samples were cooked to VR. At R, Select had the lowest ($P < 0.05$) percentage of samples rated acceptable, with all other quality treatments having similar ($P > 0.05$) percentages; but when cooked to MR, Select was similar ($P > 0.05$) to Prime and Top Choice. At M, enhanced Select samples had the highest ($P < 0.05$) percentage of steaks rated acceptable for juiciness, and Select had the lowest ($P < 0.05$), with no difference ($P > 0.05$) among Prime, Top Choice, and Low Choice samples. When cooked to WD, a similar trend was seen, but Top Choice and Low Choice samples were also similar ($P > 0.05$) to Select. At the highest DOD, enhanced Select and Prime samples had the highest ($P < 0.05$) percentage of steaks rated acceptable, with no differences ($P > 0.05$) among Top Choice, Low Choice, and Select.

For tenderness acceptability, when samples were cooked to VR, enhanced Select samples had the highest ($P < 0.05$) percentage of steaks rated acceptable with all non–enhanced samples similar ($P > 0.05$). When cooked to R, enhanced Select samples were similar ($P > 0.05$) to

Prime, and had the highest ($P < 0.05$) percentages of samples rated acceptable, with no differences ($P > 0.05$) among Top Choice, Low Choice, and Select. When steaks were cooked to MR, Prime, Top Choice, Low Choice, and enhanced Select all had similar ($P > 0.05$) and higher ($P < 0.05$) percentages of steaks rated acceptable than Select. At M, Select had the lowest ($P < 0.05$) percentage of steaks rated acceptable for tenderness, but enhanced Select had a higher ($P < 0.05$) percentage than Top Choice, and Low Choice, with Prime being intermediate ($P > 0.05$) to enhanced Select samples and both Choice treatments. When cooked to WD, enhanced Select, Prime, and Top Choice were similar ($P > 0.05$), and had the highest ($P < 0.05$) percentage of steaks rated acceptable, with no difference ($P > 0.05$) between Low Choice and Select. At the highest DOD, enhanced Select samples had a higher ($P < 0.05$) percentage of steaks rated acceptable for tenderness than Low Choice and Select, and were similar ($P > 0.05$) to Prime, and Top Choice; however, Top Choice possessed a higher ($P < 0.05$) percentage than Low Choice, but had a similar ($P > 0.05$) percentage of steaks rated acceptable as Select.

For overall like acceptability, at VR, enhanced Select samples had a higher ($P < 0.05$) percentage of steaks rated acceptable than Top Choice, with Prime, Low Choice, and Select being similar ($P > 0.05$) and intermediate to both. enhanced Select, Prime, and Top Choice all had similar ($P > 0.05$) percentages of steaks rated acceptable overall when cooked to R, MR, WD, and VWD, and were similar ($P > 0.05$) to Low Choice at MR and R. When cooked to M, Select had the lowest ($P < 0.05$) percentage of steaks rated acceptable overall than all other quality treatments, but was similar ($P > 0.05$) to Low Choice at VR, R, WD, and VWD.

There was no interaction ($P = 0.36$) for the percentage of samples rated acceptable for flavor (Table 2.2). For the main effect of quality treatment, enhanced Select samples had the highest ($P < 0.05$) percentage of steaks rated acceptable for flavor, followed by Prime ($P < 0.05$), with Top Choice, Low Choice, and Select all having similar ($P > 0.05$), and lower ($P < 0.05$) percentages. For the main effect of DOD, samples cooked from VR to WD had a similar ($P > 0.05$) percentage of samples rated acceptable for flavor, and had higher ($P < 0.05$) percentages than steaks cooked to VWD.

Finally, consumers were asked to identify the perceived quality level of each sample, choosing among unsatisfactory, everyday, better than every day, and premium quality. There was a quality treatment × DOD interaction ($P < 0.01$) for the everyday, and better than everyday perceived quality levels (Table 2.3). For everyday quality, when cooked to VR, Prime had the lowest ($P < 0.05$) percentage of samples rated as every day quality, followed by enhanced Select, which was lower ($P < 0.05$) than all other treatments. Additionally, at VR, Select had a higher ($P < 0.05$) percentage samples rated everyday quality than Low Choice, with Top Choice being intermediate ($P > 0.05$) to both. However, at R, MR, and M, enhanced Select samples had the lowest percentage of steaks rated as everyday quality, but had a similar ($P > 0.05$) percentage as Prime when cooked to WD and VWD. Of the non–enhanced samples, Prime had a lowest ($P < 0.05$) percentage of steaks rated as everyday quality when cooked to R and M, but was similar ($P > 0.05$) to all of the other non–enhanced treatments when cooked to MR and VWD. Top Choice, Low Choice, and Select had a similar ($P > 0.05$) percentage of samples classified as everyday quality at R, M, and WD.

When cooked to VR, Prime had the highest ($P < 0.05$) percentage of samples rated as better than everyday quality, with Select having a lower ($P < 0.05$) percentage than Low Choice, and enhanced Select samples having a similar ($P > 0.05$) percentage to all treatments other than Prime. At R, Prime had a higher ($P < 0.05$) percentage of steaks classified as better than everyday quality than only Select, with all other quality treatments being similar ($P > 0.05$) to both. When cooked to MR, Prime, Top Choice, and enhanced Select had a similar ($P > 0.05$) and higher ($P < 0.05$) percentage of steaks identified as better than everyday quality than Select, with Low Choice similar ($P > 0.05$) to all other quality treatments. At M, enhanced Select samples had a higher ($P < 0.05$) percentage of samples rated as better than everyday quality than all treatments other than Prime, with Select having the lowest ($P < 0.05$) percentage. When cooked to WD, no difference ($P > 0.05$) was found among Prime, Top Choice, Select or enhanced Select samples, with only enhanced Select and Prime having a greater ($P < 0.05$) percentage of samples classified as better than everyday quality than Select. Lastly, at the highest DOD, no difference ($P > 0.05$) was found among Select, Low Choice, and Top Choice for the percentage of samples identified as better than everyday quality, with enhanced Select samples having a higher ($P < 0.05$) percentage than all treatments other than Prime.

The main effect of quality treatment and DOD for the percentage of samples rated by consumers as unsatisfactory and premium quality is presented in Table 2.3. For quality treatment, enhanced Select samples had the lowest ($P < 0.05$) percentage of samples rated as unsatisfactory quality, while Select had the greatest ($P < 0.05$), with no differences ($P > 0.05$) among the other non–enhanced samples. enhanced Select samples had the greatest ($P < 0.05$) percentage of steaks rated as premium quality, followed by Prime, with Select having a lower ($P < 0.05$) percentage than all treatments other than Low Choice.

For DOD, VWD samples had a higher ($P < 0.05$) percentage of samples rated as unsatisfactory than all other DOD, except WD. Very rare, R, MR, and M all had a similar ($P > 0.05$) percentage of samples rated as unsatisfactory quality. Also, VR had a higher ($P < 0.05$) percentage of samples rated as premium quality than all DOD other than R. There was no difference ($P < 0.05$) in the percentage of samples rated as premium quality among steaks cooked to R, MR, M, and WD.

Trained sensory evaluation

There were quality treatment × DOD interactions ($P < 0.01$; Table 2.4) for initial juiciness, sustained juiciness, and salt flavor intensity. Prime and enhanced Select samples were rated similar ($P > 0.05$) for initial juiciness across all DOD. At VR and R, Top Choice was similar ($P > 0.05$) to Prime and enhanced Select samples, as well as Low Choice, while Select samples were rated drier ($P < 0.05$) than all other quality treatments, except were similar ($P > 0.05$) to Low Choice. At MR, Prime was rated juicier ($P < 0.05$) than Low Choice and Select, with Top Choice being intermediate ($P > 0.05$) to Prime and Low Choice. When cooked to M, for non-enhanced samples, each decrease in marbling level resulted in drier ($P < 0.05$) ratings (Prime > Top Choice > Low Choice > Select). However, when cooked to WD and VWD, Low Choice became intermediate ($P > 0.05$) to Top Choice and Select samples.

For sustained juiciness, enhanced Select samples had similar ($P > 0.05$) juiciness ratings when cooked to all DOD, except when cooked to MR, at which trained panelists rated enhanced Select samples juicier ($P < 0.05$). Prime was rated juicer ($P < 0.05$) than all other non-enhanced samples when cooked to M, and was similar ($P > 0.05$) to Top Choice at a MR DOD and lower. Moreover, Top Choice steaks were only rated juicer ($P < 0.05$) by trained panelists than Low Choice steaks when cooked to M, and Low Choice was only rated juicer ($P < 0.05$) than Select when cooked to M as well.

As degree of doneness increased, salt flavor intensity decreased (VR = R = MR ≥ M > WD >VWD; $P < 0.05$) for enhanced Select steaks, with no difference ($P > 0.05$) occurring for all other quality treatments among DOD.

The main effects of quality treatment and DOD were significant ($P < 0.05$) for all other trained sensory traits (Table 2.5). For myofibrillar and overall tenderness, enhanced Select was similar ($P > 0.05$) to Prime, and both were rated more tender ($P < 0.05$) than all other quality treatments. Top Choice was similar ($P > 0.05$) to Low Choice for myofibrillar and overall tenderness, with Select being rated the toughest ($P < 0.05$) of all treatments. Prime and enhanced Select samples contained the least ($P < 0.05$) amount of connective tissue, with no difference ($P > 0.05$) among all other quality treatments. As quality grade increased, so did beef flavor intensity, with Prime having the highest ($P < 0.05$) beef flavor scores, and Low Choice and Select having the lowest ($P < 0.05$) and similar ($P > 0.05$) scores. There were no differences ($P > 0.05$) among quality treatments for off flavor intensity.

For the main effect of DOD, WD and VWD samples were rated the toughest ($P < 0.05$) for myofibrillar tenderness, with VR samples being rated more tender ($P < 0.05$) than all other samples, being similar ($P > 0.05$) to only MR. For overall tenderness, as DOD increased, toughness increased (VR = R = MR > M > WD = VWD; $P > 0.05$). Samples cooked to VR contained the greatest ($P < 0.05$) amount of connective tissue, but were similar ($P > 0.05$) to R and WD. Samples cooked to MR and VWD had similar ($P > 0.05$) and lower ($P < 0.05$) connective tissue amounts than samples cooked to VR and R, but were similar ($P > 0.05$) to M and WD as well. Additionally, VWD, WD, and VR samples contained the lowest ($P < 0.05$) beef flavor ratings than steaks cooked to all other DOD, except had similar ($P > 0.05$) beef flavor ratings to MR. Furthermore, steaks cooked to M had similar ($P > 0.05$) beef flavor ratings to those cooked to R, but were rated higher ($P < 0.05$) than MR. Similar to quality treatment, no differences ($P > 0.05$) were found among DOD for off flavor intensity.

Proximate composition

Table 2.6 shows the values for the raw proximate analysis. As expected, an increase in quality grade resulted an in increase (P < 0.05) in fat percentage (Prime > Top Choice > Low Choice > Select) with the enhanced Select samples having a similar (P > 0.05) fat content with the non-enhanced Select. Additionally, increased quality grade resulted in a decrease (P < 0.05) in moisture percentage (Select ≥ Low Choice > Top Choice > Prime) with the enhanced Select samples having the greatest (P < 0.05) amount of moisture. For combined raw moisture and fat percentage, enhanced Select and Prime samples were similar (P > 0.05) and had a greater (P < 0.05) combined percentage than all other quality treatments, with Top Choice having a greater (P < 0.05) percentage than Select, and Low Choice being similar (P > 0.05) to both Select and Top Choice.

There were quality treatment × DOD interactions (P < 0.05) for cooked moisture, fat, and moisture and fat percentage (Table 2.7). As DOD increased, moisture percentage decreased (P < 0.05; VR > R > MR > M = WD > VWD). For cooked moistures, regardless of DOD, enhanced Select samples contained the greatest (P < 0.05) amount of moisture. For non-enhanced samples, as quality grade increased, moisture percentage decreased (P < 0.05) for all DOD. Only at R, M, and VWD were Low Choice samples similar (P > 0.05) to Select for moisture content. Regardless of DOD, for cooked fat percentages, enhanced Select samples were similar (P > 0.05) to non-enhanced Select, with Prime having the greatest (P < 0.05) fat percentage at each DOD, followed by Top Choice. Low Choice had a similar (P > 0.05) fat percentage as enhanced Select and non-enhanced Select samples when cooked to M and higher. Enhanced Select samples had the greatest (P < 0.05) combined moisture and fat percentage when cooked to VR, M, WD, and VWD, and was only similar (P > 0.05) to Prime at R and MR. Top Choice, Low Choice, and

Select had similar (P > 0.05) combined cooked moisture and fat percentages when cooked to VR, R, and VWD, but Top Choice had greater (P < 0.05) combined cooked moisture and fat percentage than Select at MR, M, and WD.

Pressed juice percentage

There was a quality treatment × DOD interaction (P < 0.05) for PJP (Table 2.7). Few differences occurred for PJP at VR, with Select only having a greater (P < 0.05) PJP than enhanced Select samples, and no differences (P > 0.05) were found among the other quality treatments. No differences (P > 0.05) occurred among quality treatments when cooked to M. Enhanced Select samples were similar (P > 0.05) to all other quality treatments at R, with Select only having a greater (P < 0.05) PJP than Top Choice and Prime. Additionally, when cooked to WD, enhanced Select samples only had a higher PJP than Top Choice and Low Choice (P < 0.05), while there were no differences (P > 0.05) among non-enhanced samples. Lastly, when cooked to VWD, enhanced Select had the greatest (P < 0.05) PJP with no differences (P > 0.05) among non-enhanced samples.

Objective measurements of tenderness

Results for objective measurements of tenderness, as well as cook loss, are presented in Table 2.8. There were no quality treatment × DOD interactions for WBSF (P = 0.09), SSF (P > 0.05) or cook loss (P = 0.36). Enhanced Select samples had the least (P < 0.05) cook loss among all quality treatments with no differences (P > 0.05) found among all non-enhanced samples. Cook loss increased (P < 0.05) as DOD increased (VWD > WD > M > MR > R > VR). For WBSF, Select possessed the highest shear values (P < 0.05), while enhanced Select and Prime had the lowest (P < 0.05) shear values. Samples cooked to VR had the highest WBSF values, with MR having lower (P < 0.05) WBSF values than all other treatments except R. For SSF, an increase in quality treatment generally resulted in a decrease in SSF. Select steaks had a higher ($P < 0.05$) shear value than all other treatments, except was similar ($P > 0.05$) to Top Choice steaks. Top Choice was similar ($P > 0.05$) to Low Choice but had higher ($P < 0.05$) shear values than Prime and enhanced Select samples. Lastly, Prime had similar ($P > 0.05$) WBSF values as Low Choice and enhanced Select samples. A similar trend was seen in SSF as in WBSF, with VR samples being tougher ($P < 0.05$) than all other DOD.

Relationships among traits

Pearson correlation coefficients were used to determine relationships among traits (Table 2.9). When evaluating the correlation coefficients, cooked moisture was associated ($P < 0.01$) with consumer juiciness ($r = 0.27$), tenderness ($r = 0.17$), flavor liking ($r = 0.23$), and overall liking ($r = 0.19$), while cooked fat was associated ($P < 0.05$) with consumer juiciness ($r = 0.12$) and tenderness ($r = 0.15$). Aside from cook loss on the samples evaluated during the sensory panels, the strongest ($P < 0.01$) correlations for consumer juiciness, tenderness, flavor liking, and overall liking occurred with combined cooked moisture and fat ($r = 0.69$, $r = 0.56$, $r = 0.45$, and $r = 0.49$, respectively). The highest PJP correlation ($P < 0.05$) was seen for trained initial and sustained juiciness scores ($r = 0.69$ and $r = 0.68$) and was associated ($P < 0.05$) with consumer juiciness ratings ($r = 0.47$). Consumer cook loss was moderately negatively associated ($P < 0.01$) with consumer juiciness scores ($r = -0.72$) and tenderness ($r = -0.52$). Similarly, trained cook loss was moderately negatively associated ($P < 0.01$) with trained initial and sustained juiciness scores ($r = -0.89$). Furthermore, SSF and WBSF were negatively associated ($P < 0.01$) with consumer tenderness ($r = -0.34$ and $r = -0.46$, respectively), and were additionally negatively associated ($P < 0.01$) with trained myofibrillar tenderness ($r = -0.41$ and $r = -0.55$, respectively), overall tenderness ($r = -0.43$ and $r = -0.58$, respectively), and positively associated ($P < 0.01$)

with connective tissue amount (r = 0.35 for both). Marbling score was associated (P < 0.05) with trained beef flavor intensity scores (r = 0.46), but was not correlated (P > 0.05) to consumer flavor liking.

Regression analysis

Linear regression models (Table 2.10) were calculated using cooked moisture, fat, and the combination of cooked moisture and fat for predicting consumer and trained panelists' ratings for beef juiciness. All equations were significant (P < 0.05). When using cooked moisture as a predictor juiciness, equations had an adjusted R^2 value of 0.07 and 0.09 for consumer and trained juiciness respectively. Cooked fat had an adjusted R^2 value of 0.01 and 0.03 for predicting consumer and trained juiciness, respectively. However, combined moisture and fat percentage had an adjusted R^2 value of 0.47, 0.71, and 0.72 for consumer juiciness, trained initial and sustained juiciness, respectively.

Additionally, logistic regression (Table 2.11) analyses were performed to predict the probability of a sample being rated juicy (mean juiciness score > 50) by consumers and trained panelists using the same traits discussed above. Similar to the linear regressions, cooked moisture had low adjusted R^2 values, being 0.04, 0.07, and 0.09 as well as cooked fat with adjusted R^2 values of 0.05, 0.06 and 0.03 for consumer, trained initial and trained sustained juiciness scores, respectively. Conversely, cooked moisture and fat possessed adjusted R^2 values of 0.45, 0.74, and 0.69 for consumer, trained initial and sustained juiciness scores respectively. The logistic equation determined (Fig. 1) for the probability of a consumer rating a steak juicy using cooked moisture and fat percentage was

$$P = [e^{(-50.97 + 0.75 \times \mathrm{CMF})}] / [1 + e^{(-50.97 + 0.75 \times \mathrm{CMF})}]$$

where CMF is the cooked moisture and fat percentage. The model identified combined cooked moisture and fat percentages of 68.25, 69.85, and 71.20% for a probability of 50, 75, and 90% probability of a consumer rating a steak juicy.

Discussion

Marbling and degree of doneness

The insurance theory states increased marbling compensates for the negative effects of increased DOD on beef palatability (Smith and Carpenter, 1974). In our study, there was no interaction for quality treatment × DOD for all consumer rating data, similar to the findings of Lucherk et al. (2016), McKillip et al. (2017), and Lorenzen et al. (1998). In all of these studies, as DOD increased, palatability ratings decreased. Moreover, as quality grade or marbling level increased in each of these studies, palatability ratings for the traits of juiciness, flavor, tenderness, and overall liking increased. The lack of a significant quality treatment × DOD interaction for palatability ratings in our study, as well as these other studies, indicate the negative impact of increased DOD on juiciness, tenderness, flavor, and overall liking was the same across all quality treatments. Thus, the effect of marbling on palatability was independent of DOD, which is not consistent with the insurance theory for the rating data.

However, within our study, clear evidence of the insurance theory lies within the palatability trait of juiciness, specifically shown within the acceptability data. An interaction was found for the percentage of steaks rated acceptable for juiciness by consumers. When evaluating juiciness on an acceptability (yes/no) basis, an increase in marbling modified the point at which a sample became unacceptable. For each quality treatment, there appears to be a DOD threshold where there is a sharp reduction in the percentage of steaks rated acceptable for juiciness. For example, Select steaks had the largest decrease (19%) in the number of steaks rated acceptable when DOD increased from MR to M. Similar to Select, Low Choice samples did not have a marked decrease in the percentage of samples rated acceptable for juiciness as DOD increased from VR to MR, but decreased 13% when DOD increased from MR to M. Prime steaks were able to maintain a steady, slight decline in the percentage of samples rated acceptable across all degrees of doneness, and did not have the same dramatic drop off in percentage of steaks rated acceptable due to increased degree of doneness observed in the other quality treatments, as the percent decrease was never greater than 5% between consecutive DOD increases, indicating Prime samples were less affected by increased DOD than the lowered marbled steaks. Lastly, due to the added moisture, enhanced Select samples were able to maintain acceptable juiciness from VR through WD, but similar to the other quality grades, experienced a dramatic drop (17%) in the percentage of samples rated acceptable for juiciness when DOD increased from WD to VWD.

These results differ from McKillip et al. (2017) and Lucherk et al. (2016), as these authors found no interaction between quality treatment and DOD for the percentage of steaks rated acceptable for all palatability traits. However, in both studies, only three DOD's were evaluated, and only three marbling levels were evaluated by McKillip et al. (2017). Additionally, the study by Lucherk et al. (2016) fed consumers steaks of only their preferred DOD under white florescent lighting as opposed to feeding consumers all DOD under red lighting as was done in the current study. These methodological differences, perhaps, contributed to the observed differences in results compared to the current study.

This trend of marbling compensating for increased DOD was also observed in our study with trained sensory panel results, in which a quality treatment × DOD interaction was found for initial and sustained juiciness. The magnitude of the negative impact of increased DOD was dependent upon quality treatment. When samples were cooked to MR and lower, Prime was rated 12 to 18% higher than Select steaks, but this difference dramatically increased to 66, 98, and 123% when cooked to M, WD and VWD for initial juiciness. A similar trend was found for sustained juiciness, as Prime was only rated 8, 12, and 11% higher than Select steaks when cooked to VR, R and MR, but this difference increased to 38, 63, and 87% at M, WD and VWD, respectively. The added marbling enabled Prime steaks to maintain a high level of juiciness, even at elevated DOD. Conversely, the higher DOD clearly had a greater negative impact on the Select samples due to their lower marbling content. The study conducted by Lucherk et al. (2016) produced similar results and reported an interaction for trained sensory panel juiciness ratings, where Prime was rated 18, 51, and 54% higher than Select for initial juiciness, and 25, 68, and 65% for sustained juiciness when cooked to R, M, and WD, respectively. McKillip et al. (2018) served trained panelists under red lightning three DOD (R, M and VWD) and found an interaction only with trained initial juiciness, where Prime was rated 15, 34, and 80% higher than Select when cooked to R, M, and VWD, respectively. However, our results differ than those produced by Akinwunmi et al. (1993) and Dikeman et al. (2013). Akinwunmi et al. (2013) evaluated two marbling degrees (slight and modest) cooked to three DOD (60, 71, and 77°C) and found no interactions for sensory ratings, and only found differences among DOD, where steaks cooked to 60°C were rated juicier than all other DOD. Moreover, Dikeman et al. (2013) evaluated longissimus muscle steaks from two quality grades (Select and Choice) cooked to two endpoint temperatures (62.8 and 71.1°C) and additionally two aging methods (dry and wet aging) and found no quality grade × DOD interaction for any of the trained palatability trait ratings, as well as no differences between quality treatments. Similar to Akinwunmi et al. (1993), samples cooked to 62.8°C were rated juicier than 71.1°C (Dikeman et al., 2013). However, in both studies, limited marbling levels and endpoint temperatures were evaluated, limiting the authors abilities to draw conclusions across the entire range of quality grades and DOD used in the current study.

Though there was an interaction for the objective measurement of juiciness, PJP, very few differences were found within each DOD. Most notably, no differences occurred between non-enhanced samples when cooked to the highest DOD. This objective measurement of juiciness has been shown to be associated with consumer juiciness ratings (Lucherk et al., 2017; McKillip et al., 2017), with moderate correlations (r = 0.45, r = 0.55, respectively) found in both studies. In our study, PJP alone did not seem to match the differences that were detected by our trained sensory panelists when steaks were cooked to various DOD.

Our data presents limited evidence that increased marbling counteracts the negative impacts of increased DOD on tenderness. There was a quality treatment × DOD interaction for percentage of steaks rated acceptable by consumers for tenderness. Yet, Low Choice was the only treatment that had a distinctive drop in the percentage of steaks rated acceptable for tenderness, which was 16%, and occurred when DOD increased from M to WD. However, Prime had 24% more steaks rated acceptable than Select when cooked to M, and 18% more at WD and VWD. Furthermore, Prime steaks had 23% more steaks rated acceptable for tenderness than Low Choice at WD and VWD. Therefore, increased marbling in Prime steaks allowed the samples to have a higher percentage of steaks rated acceptable for tenderness at increased DOD, supporting the insurance theory. Moreover, no interaction was observed for both WBSF and SSF measurements of tenderness. For WBSF and SSF, increased marbling resulted in a more tender shear value. However, increased DOD generally resulted in tougher shear values. Steaks cooked to MR possessed the most tender shear values, except had similar values to R for WBSF as well as M for SSF, which aligns with studies that indicate increased tenderness in beef occurs in the first phase of cooking, up to 65°C (Davey and Niederer, 1977). Our results differ than those of Obuz et al. (2004). In that study, when evaluating the effect of two quality grades (Top Choice and Select) cooked to nine (40, 45, 50, 55, 60, 65, 70, 75, 80°C) endpoint temperatures using two cookery methods, a quality grade × DOD interaction was found for the longissimus muscle. Top Choice samples possessed a lower WBSF value than Select samples when cooked to the two highest endpoint temperatures, yet no sensory analyses were conducted. Similar to Obuz et al. (2004), a DOD × quality grade interaction was detected for WBSF values when evaluating three endpoint temperatures (57, 68, 74°C) and two quality grades (Choice and Select) of the longissimus muscle by Luchak et al., 1998. Choice samples were only lower in shear force than Select when cooked to the highest endpoint temperature, however, no interaction was observed for trained sensory panel tenderness, with no differences occurring between the quality grades, but decreasing with increased endpoint temperature (57°C > 68°C > 74°C). Moreover, Lucherk et al. (2016) reported a quality treatment × DOD interaction for SSF, where no differences occurred among non-enhanced samples when cooked to R, but Prime, Top Choice, and Low Choice produced lower shear values than Select and Standard samples when cooked to WD. Yet, in the trained sensory evaluations, no interaction was observed for tenderness ratings. Collectively, these studies combined with our results offer only limited support of the insurance theory as it relates to beef tenderness, with conflicting reports being found throughout published literature.

The lack of interaction between quality treatment and DOD for consumer ratings, the percentage of steaks rated acceptable, and trained flavor ratings indicated that there was no added benefit to increased marbling for the trait of flavor when cooked to increased DOD.

However, flavor was the trait DOD had the least negative impact on. Though consumers rated higher DOD lower for flavor, in terms of acceptability, only samples cooked to VWD had a lower percentage of steaks rated acceptable than all other DOD, with no difference occurring among all other DOD. Yet, VWD still maintained a high (76%) percentage of steaks rated acceptable for flavor. For trained sensory panel beef flavor scores, though there were differences detected by trained panelists, there was only a 2.2 unit difference from the highest rating to the lowest, supporting the consumer data that there were very few detectable differences. Multiple studies have found no differences in flavor among trained panelists when evaluating across multiple DOD (Lorezen et al. 2005; Gomes et al., 2014; Akinwunmi et al., 1993), when using similar cooking methods. Thus, flavor is the palatability trait that is impacted the least by the marbling level at increased DOD**.**

Proximates and their relationships to beef palatability

For raw proximate analysis, fat percentages were similar to those reported by Smith et al. (2011). The same method of fat determination was used in our study (modified Folch, Lees and Sloane Stanley method., 1957). Our values for moisture percentages were higher than those reported by Smith et al. (2011) but more closely matched the numbers reported by Lucherk et al. (2016), McKillip et al. (2017) and O'Quinn et al. (2012).

In the study conducted by Smith et al. (2011), cooked proximate analysis was conducted, but contrary to our data, those authors found no interaction for quality treatment and DOD. Thus, the reported raw fat percentages of the steaks were averaged across the three quality grades (Prime, Choice and Select) and across each DOD in that study, limiting the ability to make a direct comparison to the current work. In that study, as DOD increased, fat percentage increased as well, with a 32% increase in fat from the averaged raw fat percentage, when cooked to MR and M, and a 37% increase from the raw percentage when cooked to VWD. It has been widely reported that increased DOD results in increased cook losses, primarily through the evaporation of moisture (Wheeler et al., 1999; Lorenzen et al., 2005; Yancey et al., 2016), thus explaining the increased concentration of fat in the final cooked product. However, the objective of the Smith et al. (2011) study was to evaluate cooked fat percentage from a nutrient standpoint at various DOD and not to evaluate the impact of fat level or DOD on sensory traits.

Few studies have evaluated cooked moisture and fat, but even fewer, if any, have evaluated their relationship to beef overall palatability. In our study, the highest correlation to consumer overall liking was seen with combined cooked moisture and fat percentages. In fact, individually, moisture and fat percentage were weakly associated with all consumer palatability traits but had a much closer association to those traits when combined. This indicates the importance of both moisture and fat percentage, and their relationship to the consumer beef eating experience. A similar trend was seen with trained palatability traits, as alone, moisture and fat were weakly associated with juiciness (r = 0.17 to 0.31), and tenderness (r = 0.17 to 0.22), but when combined, were highly correlated to initial and sustained juiciness (r = 0.84 and 0.85) and to myofibrillar and overall tenderness (r = 0.71 to 0.68). Interestingly, cooked moisture and fat had the highest correlation to trained juiciness ratings, aside from cooking loss, even more so than a method developed to measure beef strip steaks juiciness, PJP. Cooking loss has been shown to be moderately to highly negatively correlated to consumer (r = -0.76 and r = -0.51) and trained juiciness (r = -0.88 and r = -0.75) ratings (McKillip et al., 2017; Lucherk et al., 2017, respectively), but has limited predictive power as it is most commonly measured and reported on the steaks evaluated by the sensory panelists. Our results are similar to these previous studies, as cooking loss had the highest correlation to consumer and trained sensory panel juiciness ratings.

Many previous attempts have been made to predict consumer juiciness scores. In one such study, when using a logistic regression, the PJP method had an adjusted R^2 of 0.21 and was the best method (besides cooking loss) for predicting consumer juiciness ratings out of 36 other methods used to determine beef juiciness (Lucherk et al., 2017). Additionally, when using simple linear regressions, PJP possessed higher R^2 than all other methods (R^2 = 0.48 and 0.45) when used to predict trained initial and sustained juiciness respectively. However, our data indicates combined cooked moisture and fat are better predictors of consumer and trained juiciness ratings (R^2 = 0.45, 0.74 and 0.69). The logistic regression determined that a combined cooked moisture and fat percentage of 68.3, 69.9, and 71.2% is needed for a probability of 50, 75, and 90% chance of a consumer rating that steak juicy. Our data indicates multiple methods to achieve these various levels. For example, Select when cooked to M possesses enough combined moisture and fat for a 75% chance of a juicy consumer rating, but for Prime, that occurs when cooked to WD, and then VWD for enhanced Select samples. These data clearly indicate that both fat and moisture can be used interchangeably to ensure juiciness and provide definitive evidence in support of the insurance theory as it related to beef juiciness.

Conclusion

Increased marbling helps to compensate the negative effects of increased cooking temperatures, specifically on the palatability trait of juiciness, but does not provide the same level of protection for tenderness and flavor. These results can help consumers and foodservice better identify products that will meet their own and their customers' expectations for juiciness, dependent upon their preferred DOD. Additionally, increased marbling or the addition of moisture through enhancement can enable strip loin steaks to maintain an acceptable juiciness level, even at advanced DOD. Therefore, our data supports the insurance theory, specifically with the palatability trait of juiciness.

References

Akinwunmi, I., L. Thompson, and C. Ramsey. 1993. Marbling, fat trim and doneness effects on sensory attributes, cooking loss and composition of cooked beef steaks. J. Food Sci. 58:242-244.

AMSA. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

AOAC. 1995. Removal of Moisture, Official Method 8.2.1.1. 16th ed. Assoc. Off. Anal. Chem., Arlington, VA.

Brooks, J. C., J. M. Mehaffey, J. A. Collins, H. R. Rogers, J. Legako, B. J. Johnson, T. Lawrence, D. M. Allen, M. N. Streeter, W. T. Nichols, J. P. Hutcheson, D. A. Yates, and M. F. Miller. 2010. Moisture enhancement and blade tenderization effects on the shear force and palatability of strip loin steaks from beef cattle fed zilpaterol hydrochloride. J. Anim. Sci. 88:1809-1816. doi:10.2527/jas.2009-2383

Corbin, C. H., T. G. O'Quinn, A. J. Garmyn, J. F. Legako, M. R. Hunt, T. T. N. Dinh, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Sci. 100:24-31. doi:10.1016/j.meatsci.2014.09.009

Cox, R. J., J. M. Thompson, C. M. Cunial, S. Winter, and A. J. Gordon. 1997. The effect of degree of doneness of beef steaks on consumer acceptability of meals in restaurants. Meat Sci. 45:75-85. doi:http://dx.doi.org/10.1016/S0309-1740(96)00080-0

Davey, C. L., and A. F. Niederer. 1977. Cooking tenderizing in beef. Meat Sci 1:271-276. doi:10.1016/0309-1740(77)90022-5

Dikeman, M. E., E. Obuz, V. Gök, L. Akkaya, and S. Stroda. 2013. Effects of dry, vacuum, and special bag aging; USDA quality grade; and end-point temperature on yields and eating quality of beef Longissimus lumborum steaks. Meat Sci. 94:228-233.

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. J. Anim. Sci. 91:1024-1034. doi:10.2527/jas.2012-5514

Folch, J., M. Lees, and G. H. Sloane Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 266:497-509.

Gomes, C. L., S. B. Pflanzer, A. G. Cruz, P. E. de Felício, and H. M. A. Bolini. 2014. Sensory descriptive profiling and consumer preferences of beef strip loin steaks. Food Res. Int. 59:76-84. doi:10.1016/j.foodres.2014.01.061

Lorenzen, C. L., V. K. Davuluri, K. Adhikari, and I. U. Grün. 2005. Effect of end-point temperature and degree of doneness on sensory and instrumental flavor profile of beef steaks. J. Food Sci. 70:S113-S118. doi:10.1111/j.1365-2621.2005.tb07114.x

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top loin steak. J. Anim. Sci. 77:637-644.

Luchak, G. L., R. K. Miller, K. E. Belk, D. S. Hale, S. A. Michaelsen, D. D. Johnson, R. L. West, F. W. Leak, H. R. Cross, and J. W. Savell. 1998. Determination of sensory, chemical and cooking characteristics of retail beef cuts differing in intramuscular and external fat. Meat Sci. 50:55-72.

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Sci. 122:145-154. doi:10.1016/j.meatsci.2016.08.005

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2017. Assessment of objective measures of beef steak juiciness and their relationships to sensory panel juiciness ratings1,2. J. Anim. Sci. 95:2421-2437. doi:10.2527/jas.2016.0930

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. E. Boyle, and T. G. O’Quinn. 2017. Sensory Evaluation of Enhanced Beef Strip Loin Steaks Cooked to 3 Degrees of Doneness. Meat and Muscle Biology 1:227-241. doi:10.22175/mmb2017.06.0033

NCBA. 2016. Beef steak color guide. National Cattelmen’s Beef Association, Centennial, CO.

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. J. Food Sci. 80:S444-S449. doi:10.1111/1750-3841.12775

O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. J. Anim. Sci. 90:626-634. doi:10.2527/jas.2011-4282

Obuz, E., M. E. Dikeman, J. P. Grobbel, J. W. Stephens, and T. M. Loughin. 2004. Beef longissimus lumborum, biceps femoris, and deep pectoralis Warner–Bratzler shear force is affected differently by endpoint temperature, cooking method, and USDA quality grade. Meat Sci. 68:243-248. doi:https://doi.org/10.1016/j.meatsci.2004.03.003

Robbins, K., J. Jensen, K. Ryan, C. HOMCO-RYAN, F. McKeith, and M. Brewer. 2002. Enhancement effects on sensory and retail display characteristics of beef rounds. J. Mus. Foods 13:279-288.

Savell, J. W., and H. R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. Designing Foods: Animal Product Options in the Marketplace. National Academy Press, Washington, D.C.

Savell, J. W., C. L. Lorenzen, T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, and J. O. Reagan. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top sirloin steak. J. Anim. Sci. 77:645-652.

Schmidt, T. B., M. P. Keene, and C. L. Lorenzen. 2002. Improving consumer satisfaction of beef through the use of thermometers and consumer education by wait staff. J. Food Sci. 67:3190-3193. doi:10.1111/j.1365-2621.2002.tb08880.x

Shackelford, S., T. Wheeler, and M. Koohmaraie. 1999. Evaluation of slice shear force as an objective method of assessing beef longissimus tenderness. J. Anim. Sci. 77:2693-2699.

Smith, A. M., K. B. Harris, A. N. Haneklaus, and J. W. Savell. 2011. Proximate composition and energy content of beef steaks as influenced by USDA quality grade and degree of doneness. Meat Sci. 89:228-232. doi:https://doi.org/10.1016/j.meatsci.2011.04.027

Smith, G. C., and Z. L. Carpenter. 1974. Eating quality of animal products and their fat content. Changing the fat content and composistion of animal products. p 124-137. National Academy Press, Washington, D.C.

Smith, G. C., Z. L. Carpenter, H. R. Cross, C. E. Murphey, H. C. Abraham, J. W. Savell, G. W. Davis, B. W. Berry, and F. C. Parrish Jr. 1985. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7:289-308.

Vote, D. J., W. J. Platter, J. D. Tatum, G. R. Schmidt, K. E. Belk, G. C. Smith, and N. C. Speer. 2000. Injection of beef strip loins with solutions containing sodium tripolyphosphate, sodium lactate, and sodium chloride to enhance palatability. J. Anim. Sci. 78:952-957. doi:/2000.784952x

Wheeler, T. L., S. D. Shackelford, and M. Koohmaraie. 1999. Tenderness classification of beef: IV. Effect of USDA quality grade on the palatability of “tender” beef longissimus when cooked well done1. J. Anim. Sci. 77:882-888. doi:10.2527/1999.774882x

Yancey, J. W. S., J. K. Apple, and M. D. Wharton. 2016. Cookery method and endpoint temperature can affect the Warner-Bratzler shear force, cooking loss, and internal cooked color of beef semimembranosus and infraspinatus steaks. J. Anim. Sci. 94:4434-4446. doi:10.2527/jas2016-0651

Table 2-1. Demographic profile of consumer study participants (*n* = 350)

Characteristic	Response	Percentage of Consumers
Gender	Male	52.6
	Female	47.4
Household size	1 people	12.9
	2 people	13.7
	3 people	13.7
	4 people	29.7
	5 people	19.1
	6 people	5.1
	> 6 people	5.7
Marital status	Married	45.4
	Single	54.6
Age, yr	Under 20	15.1
	20 to 29	38.9
	30 to 39	10.3
	40 to 49	19.4
	50 to 59	11.4
	Over 60	4.9
Ethnicity	African-American	3.1
	Asian	2.3
	Caucasian/White	80.9
	Hispanic	7.7
	Native American	0.9
	Other	0.9
	Mixed Race	4.3
Annual household income, $	< 25,000	23.6
	25,000 – 34,999	8.1
	35,000 – 49,999	7.8
	50,000 – 74,999	14.1
	75,000 – 99,000	11.8
	100,000 – 149,999	19.3
	150,000 – 199,999	8.7
	> 199,999	6.6
Highest level of education completed	Non – high school graduate	3.7
	High school graduate	12.9
	Some college/technical school	41.6
	College graduate	22.9
	Post – college graduate	18.9
Most important palatability trait	Flavor	52.0
	Juiciness	13.1
	Tenderness	34.9
Preferred degree of doneness	Very-rare	0.9
	Rare	8.0
	Medium-rare	41.1
	Medium	24.0
	Medium-well	14.6
	Well-done	7.4
	Very well-done	4.0
Beef consumption	1 to 3	43.9
	4 to 6	37.8
	7 to 9	11.3
	> 9	7.0

Table 2-2. Least squares means for consumer (n = 360) ratings[1] of the palatability traits, as well as the percentage of beef strip loin steaks from five quality treatments and six degrees of doneness[2] identified as certain perceived quality levels and rated acceptable for flavor

Treatment	Juiciness	Tenderness	Flavor	Overall like	Flavor, %	Unsatisfactory quality	Premium quality
Quality							
Prime	71.3^{b}	70.6^{b}	62.7^{b}	65.5^{b}	85.0^{b}	12.3^{b}	12.7^{b}
Top Choice[3]	64.1^{c}	60.0^{c}	56.7^{c}	58.2^{c}	78.1^{c}	14.8^{b}	6.7^{c}
Low Choice	60.8^{c}	57.7^{cd}	55.4^{c}	56.9^{c}	79.4^{c}	15.3^{b}	4.9^{cd}
Select	55.6^{d}	52.4^{d}	50.9^{d}	50.0^{d}	74.3^{c}	23.9^{a}	3.4^{d}
Select enhanced[4]	77.9^{a}	77.1^{a}	75.9^{a}	75.7^{a}	94.0^{a}	5.8^{c}	34.2^{a}
SEM	1.76	2.12	1.45	1.60	2.22	2.59	3.18
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[2]							
Very-rare	77.4^{a}	69.4^{a}	62.0^{a}	63.2^{a}	84.6^{a}	13.2^{bc}	16.0^{a}
Rare	73.9^{ab}	68.0^{a}	64.4^{a}	66.0^{a}	85.2^{a}	10.0^{c}	11.8^{ab}
Medium-rare	72.3^{b}	68.9^{a}	62.0^{a}	65.5^{a}	86.1^{a}	9.3^{c}	9.4^{b}
Medium	65.6^{c}	64.1^{b}	61.0^{ab}	62.1^{a}	83.7^{a}	13.3^{bc}	8.5^{bc}
Well-done	58.1^{d}	58.6^{c}	58.2^{b}	57.1^{b}	82.0^{a}	16.2^{ab}	7.4^{bc}
Very well-done	48.8^{e}	52.5^{d}	54.1^{c}	53.6^{b}	76.3^{b}	20.3^{a}	4.7^{c}
SEM	1.57	1.69	1.56	1.62	2.16	2.14	2.03
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Quality treatment × Degree of doneness							
P – value	0.06	0.23	0.76	0.49	0.36	0.19	0.24

[abcde] Means lacking a common superscript within DOD or quality treatment, in the same column differ ($P < 0.05$).

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

[2]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C.

[3]Modest^{00} – moderate^{100}.

[4]Enhanced to 110% of raw weight with a water, salt, and alkaline phosphate solution.

Table 2-3. Interaction ($P < 0.01$) of quality treatment and degree of doneness[1] for the percentage of steaks rated acceptable and identified as a certain perceived quality level by consumers (n = 360)

Degree of doneness/ quality treatment	Juiciness, %	Tenderness, %	Overall like, %	Everyday quality	Better than everyday quality
Very-rare					
Prime	92.8	88.9[b]	85.5[ab]	15.7[d]	52.2[a]
Top Choice[2]	91.5	82.8[b]	74.2[b]	46.1[ab]	22.7[bc]
Low Choice	92.9	83.9[b]	85.6[ab]	35.6[bc]	36.6[b]
Select	96.9	87.3[b]	86.7[ab]	51.7[a]	19.1[c]
Select enhanced[3]	94.7	98.0[a]	93.6[a]	28.5[c]	27.5[bc]
SEM	2.96	4.43	4.94	5.56	5.49
Rare					
Prime	97.9[a]	95.9[a]	92.5[a]	28.3[b]	39.5[a]
Top Choice[2]	92.7[a]	81.7[b]	84.2[ab]	48.3[a]	26.6[ab]
Low Choice	99.0[a]	90.0[b]	89.7[ab]	53.3[a]	30.6[ab]
Select	82.2[b]	81.1[b]	80.4[b]	58.2[a]	24.5[b]
Select enhanced[3]	98.9[a]	97.0[a]	93.6[a]	15.1[c]	31.6[ab]
SEM	4.14	4.58	4.37	5.52	5.44
Medium-rare					
Prime	93.9[ab]	94.1[a]	91.9[a]	43.1[a]	39.8[a]
Top Choice[2]	91.8[ab]	91.4[a]	87.7[ab]	38.2[a]	44.5[a]
Low Choice	98.0[a]	94.2[a]	90.9[a]	53.2[a]	33.1[ab]
Select	86.5[b]	75.7[b]	78.3[b]	51.1[a]	19.9[b]
Select enhanced[3]	96.9[a]	94.1[a]	95.9[a]	17.9[b]	35.3[a]
SEM	3.64	5.17	4.55	5.50	5.47
Medium					
Prime	90.7[b]	91.0[ab]	83.4[b]	32.7[b]	32.9[ab]
Top Choice[2]	89.9[b]	87.7[b]	82.8[b]	54.2[a]	25.7[b]
Low Choice	85.3[b]	88.8[b]	83.2[b]	52.6[a]	23.4[b]
Select	67.1[c]	66.6[c]	62.9[c]	52.7[a]	11.6[c]
Select enhanced[3]	97.9[a]	98.1[a]	96.9[a]	16.7[c]	40.3[a]
SEM	5.24	5.89	5.52	5.52	5.38
Well-done					
Prime	86.5[b]	90.9[a]	81.2[a]	44.6[bc]	30.7[a]
Top Choice[2]	76.0[bc]	86.5[a]	73.9[a]	53.2[ab]	19.9[ab]
Low Choice	74.4[bc]	72.6[b]	79.8[b]	62.2[a]	12.7[b]
Select	64.3[c]	72.8[b]	72.1[b]	49.9[ab]	19.2[ab]
Select enhanced[3]	95.9[a]	95.1[a]	94.8[a]	29.9[c]	29.8[a]
SEM	5.39	5.48	5.07	5.55	5.02
Very well-done					
Prime	81.9[a]	88.7[a]	74.3[ab]	45.6[ab]	29.2[ab]
Top Choice[2]	67.4[b]	81.2[ab]	75.0[ab]	57.7[a]	20.9[bc]
Low Choice	59.8[b]	65.5[c]	58.7[c]	52.1[ab]	13.6[c]
Select	61.9[b]	70.4[bc]	65.3[bc]	45.6[ab]	12.5[c]
Select enhanced[3]	79.1[a]	90.2[a]	84.5[a]	39.2[b]	34.9[a]
SEM	5.49	5.89	5.60	5.52	5.21

[abc] Means within DOD, of the same column without common superscript differ ($P < 0.05$).

[1]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C.

[2]Modest[00] – moderate[100].

[3]Enhanced to 110% of raw weight with a water, salt, and alkaline phosphate solution.

Table 2-4. Least squares means of the interaction ($P < 0.01$) between quality treatment and degree of doneness[1] for trained sensory panel juiciness and scores[2]

Degree of doneness/ quality treatment	Initial juiciness	Sustained juiciness
Very-rare		
Prime	89.0[a]	85.3[a]
Top Choice[3]	86.7[ab]	82.0[ab]
Low Choice	82.1[bc]	76.0[bc]
Select	79.1[c]	71.2[c]
Select enhanced[4]	90.2[a]	87.0[a]
SEM	2.34	2.60
Rare		
Prime	86.9[a]	81.9[ab]
Top Choice[3]	83.0[ab]	76.7[bc]
Low Choice	77.6[bc]	70.8[c]
Select	73.6[c]	65.4[c]
Select enhanced[4]	89.4[a]	85.5[a]
SEM	2.34	2.60
Medium-rare		
Prime	83.6[ab]	78.6[b]
Top choice[3]	79.4[bc]	72.7[bc]
Low choice	75.2[c]	66.5[c]
Select	74.9[c]	65.9[c]
Select enhanced[4]	88.9[a]	84.4[a]
SEM	2.34	2.60
Medium		
Prime	68.1[a]	60.4[a]
Top Choice[3]	60.9[b]	51.7[b]
Low Choice	49.3[c]	39.2[c]
Select	41.0[d]	29.0[d]
Select enhanced[4]	67.6[a]	59.6[a]
SEM	2.34	2.57
Well-done		
Prime	58.7[a]	49.6[a]
Top Choice[3]	40.3[b]	30.6[b]
Low Choice	36.0[bc]	24.5[bc]
Select	29.76[c]	19.7[c]
Select enhanced[4]	60.5[a]	51.3[a]
SEM	2.34	2.57
Very well-done		
Prime	48.5[a]	39.2[a]
Top Choice[3]	31.1[b]	22.0[b]
Low Choice	26.0[bc]	17.8[bc]
Select	21.8[c]	12.6[c]
Select enhanced[4]	49.6[a]	39.9[a]
SEM	2.34	2.57

[abcd] Means within DOD, of the same column without common superscript differ ($P < 0.05$).

[1]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C.

[2]Sensory scores: 0 = extremely dry; 50 = neither dry nor juicy; 100 = extremely juicy.

[3]Modest[00] – moderate[100].

[4]Enhanced to 110% of raw weight with a water, salt and alkaline phosphate solution.

Table 2-5. Least squares means for trained panel sensory ratings[1] of beef strip steaks from five quality treatments cooked to six degrees of doneness[2]

Treatment	Myofibrillar tenderness	Connective tissue amount	Overall tenderness	Beef flavor	Off flavor
Quality					
Prime	79.8[a]	5.1[b]	77.7[a]	42.8[a]	0.1
Top Choice[3]	70.0[b]	8.0[a]	65.8[b]	40.0[b]	0.6
Low Choice	67.6[b]	7.6[a]	63.4[b]	35.8[d]	0.5
Select	61.4[c]	9.1[a]	56.4[c]	35.0[d]	0.7
Select enhanced[4]	84.0[a]	3.6[b]	82.6[a]	37.9[c]	0.3
SEM	1.76	0.75	1.96	0.71	0.2
P – value	< 0.01	< 0.01	< 0.01	< 0.01	0.25
Degree of doneness[2]					
Very-rare	80.4[a]	7.8[a]	76.5[a]	37.7[c]	0.7
Rare	77.8[b]	7.7[ab]	74.6[a]	39.2[ab]	0.3
Medium-rare	78.9[ab]	5.9[c]	76.2[a]	38.0[bc]	0.6
Medium	69.3[c]	6.4[bc]	65.3[b]	39.6[a]	0.6
Well-done	65.4[d]	6.6[abc]	61.7[c]	37.6[c]	0.2
Very well-done	63.7[d]	5.6[c]	60.7[c]	37.4[c]	0.2
SEM	1.10	0.57	1.23	0.63	0.2
P – value	< 0.01	< 0.01	< 0.01	< 0.01	0.2
QT × DOD					
P – value	0.11	0.67	0.10	0.74	0.37

[abce] Means lacking a common superscript within DOD or quality treatment, in the same column differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely tough/bland; 50 = neither tough nor tender; 100 = extremely tender/intense.

[2]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C.

[3]Modest^{00} – moderate^{100}.

[4]Enhanced to 110% of raw weight with a water, salt and alkaline phosphate solution.

Table 2-6. Least square means ($P < 0.01$) for raw moisture and fat content of beef strip loin steaks from five quality treatments

Treatment	Raw moisture, %	Raw fat, %	Raw moisture + fat[3], %
Quality treatment			
Prime	63.8[d]	13.7[a]	77.5[a]
Top Choice[1]	67.4[c]	9.4[b]	76.8[b]
Low Choice	69.9[b]	6.4[c]	76.3[bc]
Select	71.1[b]	4.8[d]	75.9[c]
Select enhanced[2]	72.6[a]	5.1[d]	77.6[a]
SEM	0.41	0.41	0.41
P – value	< 0.01	< 0.01	< 0.01

[abcd]Means in the same column lacking common superscripts differ ($P < 0.05$).
[1]Modest[00] – moderate[100].
[2]Enhanced to 110% of raw weight with a water, salt and alkaline phosphate solution.
[3]Combined moisture and fat percentage.

Table 2-7. Least squares means of the interaction ($P < 0.05$) between quality treatment and degree of doneness[1] for cooked proximates and pressed juice percentage (PJP)[2]

Degree of doneness/ quality treatment	Moistures, %	Fat, %	Moisture + Fat[5], %	PJP, %
Very-rare				
Prime	60.4[e]	13.7[a]	74.1[b]	24.3[ab]
Top Choice[3]	63.3[d]	10.1[b]	73.4[bc]	24.7[ab]
Low Choice	66.0[c]	7.2[c]	73.1[bc]	25.3[ab]
Select	67.8[b]	4.7[d]	72.5[c]	25.4[a]
Select enhanced[4]	69.8[a]	5.6[cd]	75.4[a]	23.5[b]
SEM	0.53	0.59	0.36	0.67
Rare				
Prime	58.9[d]	15.5[a]	74.4[a]	23.4[c]
Top Choice[3]	62.4[c]	10.2[b]	72.6[b]	23.9[c]
Low Choice	65.4[b]	7.3[c]	72.7[b]	25.1[bc]
Select	66.7[b]	5.4[d]	72.1[b]	26.5[ab]
Select enhanced[4]	69.4[a]	5.5[d]	74.8[a]	25.0[bc]
SEM	0.53	0.59	0.36	0.67
Medium-rare				
Prime	58.0[e]	15.0[a]	73.0[ab]	23.5[b]
Top Choice[3]	62.1[d]	10.8[b]	72.9[b]	23.9[b]
Low Choice	64.7[c]	7.2[c]	71.9[c]	23.4[b]
Select	66.4[b]	5.3[d]	71.7[c]	26.5[a]
Select enhanced[4]	68.9[a]	5.1[d]	74.0[a]	27.0[a]
SEM	0.53	0.59	0.36	0.67
Medium				
Prime	55.0[d]	17.1[a]	72.1[b]	19.3
Top Choice[3]	59.9[c]	11.3[b]	71.2[bc]	20.4
Low Choice	62.8[b]	7.6[c]	70.4[cd]	19.5
Select	63.9[b]	6.1[c]	70.0[d]	20.4
Select enhanced[4]	66.9[a]	6.5[c]	73.4[a]	19.0
SEM	0.53	0.59	0.36	0.67
Well-done				
Prime	56.6[e]	13.9[a]	70.5[b]	19.8[ab]
Top Choice[3]	59.6[d]	9.3[b]	68.8[c]	18.4[b]
Low Choice	61.5[c]	8.5[c]	68.1[cd]	18.0[b]
Select	63.2[b]	5.9[c]	68.6[d]	19.6[ab]
Select enhanced[4]	67.0[a]	6.1[c]	72.2[a]	20.7[a]
SEM	0.53	0.59	0.36	0.67
Very well-done				
Prime	53.2[d]	16.4[a]	69.6[b]	16.6[b]
Top Choice[3]	58.5[c]	9.6[b]	68.1[c]	15.7[b]
Low Choice	60.6[b]	7.2[c]	67.8[c]	16.4[b]
Select	61.2[b]	5.9[c]	67.2[c]	16.5[b]
Select enhanced[4]	64.9[a]	6.1[c]	71.0[a]	18.6[a]
SEM	0.53	0.60	0.37	0.67

[abcd] Means within DOD, of the same column without common superscript differ ($P < 0.05$).

[1]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C.

[3]Modest[00] – moderate[100].

[4]Enhanced to 110% of raw weight with a water, salt and alkaline phosphate solution.

[5]Combined moisture and fat percentage.

Table 2-8. Least squares means for beef strip loin objective measures Warner-Braztler shear force (WBSF), Slice shear force (SSF), and cook loss[1]

Treatment	WBSF, kg	SSF, kg	Cook loss[1], %
Quality treatment			
Prime	2.2[c]	12.0[cd]	15.2[a]
Top Choice[2]	2.6[b]	14.3[ab]	15.1[a]
Low Choice	2.7[b]	13.1[bc]	15.7[a]
Select	3.2[a]	14.8[a]	15.6[a]
Select enhanced[3]	2.07[c]	10.9[d]	13.4[b]
SEM	0.10	0.55	0.29
DOD[4]			
Very-rare	2.9[a]	15.6[a]	8.6[f]
Rare	2.4[cd]	12.4[cd]	10.7[e]
Medium-rare	2.3[d]	11.6[d]	12.0[d]
Medium	2.5[bc]	12.1[cd]	16.6[c]
Well-done	2.5[c]	12.8[bc]	19.4[b]
Very well-done	2.7[b]	13.5[b]	22.7[a]
SEM	0.07	0.38	0.23
QT × DOD			
P – value	0.09	0.05	0.36

[abce]Means lacking a common superscript within DOD or quality treatment, in the same column differ ($P < 0.05$).

[1]Cook loss = [(raw weight – cooked weight) / raw weight] × 100.

[2]Modest[00] – moderate[100].

[3]Enhanced to 110% of raw weight with a water, salt and alkaline phosphate solution.

[4]Degrees of doneness follow the "Beef Steak Color Guide" (National Cattlemen's Beef Association, 2016): very-rare = 55°C; rare = 60°C; medium-rare = 63°C; medium = 71°C; well-done = 77°C; very well-done = 82°C

Table 2-9. Pearson correlation coefficients for objective measurements, cooked and raw proximates, and consumer and trained sensory scores, and cook loss

	Cook loss[1], %					Cooked proximates, %			Raw proximates, %			
Consumer[6]	Consumer	Trained	PJP[2]	SSF[3]	WBSF[4]	Moistures	Fats	Moistures + fats[5]	Moistures	Fats	Moistures + fats[5]	Marbling score
Juiciness	-0.72**		0.47**	-0.24**	-0.37**	0.27**	0.12*	0.69**	-0.05	0.12*	0.23**	0.12*
Tenderness	-0.52**		0.31**	-0.34**	-0.46**	0.17**	0.15**	0.56**	-0.09	0.16**	0.24**	0.14**
Flavor liking	-0.39**		0.17**	-0.29**	-0.37**	0.23**	0.03	0.45**	0.05	0.02	0.21**	0.00
Overall liking	-0.45**		0.24**	-0.32**	-0.42**	0.19**	0.09	0.49**	-0.01	0.09	0.23**	0.07
Trained[7]												
Initial juiciness		-0.89**	0.69**	-0.12*	-0.33**	0.31**	0.17**	0.84**	-0.11*	0.18**	0.22**	0.15**
Sustained juiciness		-0.89**	0.68**	-0.11*	-0.33**	0.30**	0.18**	0.85**	-0.12*	0.19*	0.22**	0.16**
Myofibrillar tenderness		-0.61**	0.42**	-0.41**	-0.55**	0.20**	0.21**	0.71**	-0.13*	0.24**	0.36**	0.19**
Connective tissue amount		-0.03	0.13*	0.35**	0.35**	0.04	-0.09	-0.07	0.06	-0.11*	-0.17**	-0.08
Overall tenderness		-0.57**	0.37**	-0.43**	-0.58**	0.17**	0.22**	0.68**	-0.14**	0.25**	0.37**	0.21**
Beef flavor intensity		-0.04	0.04	-0.15**	-0.31**	-0.38**	0.55**	0.22**	-0.45**	0.47**	0.16**	0.46**
Salt flavor intensity		-0.22**	0.11*	-0.28**	-0.34**	0.55**	-0.35**	0.40**	0.49**	-0.35**	0.33**	-0.41

[1]Cook loss = [(raw weight – cooked weight) / raw weight] × 100.
[2]PJP: percentage of moisture loss during compression for 30 seconds.
[3]Slice shear force.
[4]Warner-Braztler shear force.
[5]Combined moisture and fat percentage.
[6]Consumer sensory scores: 0 = extremely dry/tough/dislike; 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike; 100 = extremely juicy/tender/like extremely.
[7]Trained sensory scores: 0 = extremely dry/tough/bland; 50 = neither tough nor tender/dry nor juicy; 100 = extremely juicy/tender/intense.
* $P < 0.05$
** $P < 0.01$

Table 2-10. Simple linear regression equations for predicting consumer and trained sensory juiciness ratings[1] for beef strip loins using the percentage of cooked fat, moisture or moisture and fat in the sample

Measurement	Intercept	Regression coefficient	Adjusted R^2	P – value
Consumer juiciness				
Cooked moisture	4.03	0.99	0.07	< 0.01
Cooked fat	61.86	0.49	0.01	0.02
Cooked moisture + fat[2]	-263.90	4.61	0.47	< 0.01
Trained initial juiciness				
Cooked moisture	-33.49	1.56	0.09	< 0.01
Cooked fat	56.57	0.89	0.03	< 0.01
Cooked moisture + fat[2]	-483.76	7.67	0.71	< 0.01
Trained sustained juiciness				
Cooked moisture	-47.33	1.65	0.09	< 0.01
Cooked fat	47.63	1.03	0.03	< 0.01
Cooked moisture + fat[2]	-543.11	8.38	0.72	< 0.01

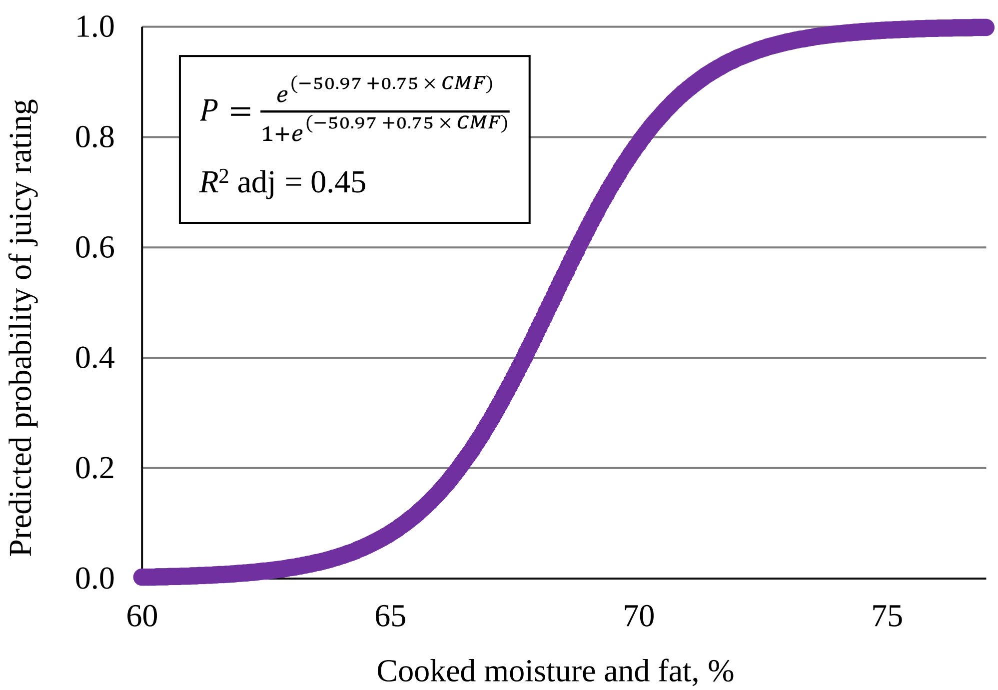
[1]Mean sensory juiciness rating of > 50 on the 100 point scale.
[2]Combined moisture and fat percentage.

Table 2-11. Logistic regression equations for predicting a juicy[1] sensory rating using the cooked percentage of fat, moisture, or fat and moisture in the sample

Measurement	Intercept	Regression coefficient	Adjusted R^2	P – value
Consumer juiciness				
Cooked moisture	-3.67	0.08	0.04	< 0.01
Cooked fat	0.57	0.13	0.05	< 0.01
Cooked moisture + fat[2]	-50.97	0.75	0.45	< 0.01
Trained initial juiciness				
Cooked moisture	-6.14	0.11	0.07	< 0.01
Cooked fat	-0.05	0.12	0.06	< 0.01
Cooked moisture + fat[2]	-100.40	1.44	0.74	< 0.01
Trained sustained juiciness				
Cooked moisture	-7.40	0.13	0.09	< 0.01
Cooked fat	-0.22	0.08	0.03	< 0.01
Cooked moisture + fat[2]	-88.71	1.25	0.69	< 0.01

[1]Mean sensory juiciness rating of > 50 on the 100 point scale.
[2]Combined moisture and fat percentage.

Figure 2-1. The predicted probability of sample being classified as juicy (mean juiciness rating > 50) by consumers based on cooked moisture and fat percentage



Appendix A - Tables

Table A-1. Beef strip loin steak purchasing motivators1 of consumers (*n* = 350) who participated in the consumer panels

Trait	Importance
Price	71.6[a]
Size, weight, and thickness	67.6[ab]
USDA grade	63.5[bc]
Color	60.7[cd]
Marbling	61.5[cd]
Familiarity with cut	58.1[de]
Nutrient content	54.6[ef]
Animal welfare	53.0[f]
Eating satisfaction claims	52.3[f]
Growth hormone use in animal	43.1[g]
Antibiotic use in animal	42.5[gh]
Packaging type	39.1[ghi]
Animal fed a forage-based(grass) diet	38.9[hi]
Natural or organic claims	37.6[i]
Animal fed a corn-based diet	37.9[i]
Brand of product	36.7[i]
SEM	2.1
P – value	< 0.01

[abcdefghi] Means lacking a common superscript differ ($P < 0.05$).

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

Table A-2. Least squares means for beef grading measures of carcasses of varying fat level and quality measurements

Treatment	Lean maturity[1]	Skeletal maturity[1]	Overall maturity[1]	USDA marbling score[2]	Preliminary fat thickness, cm	Adjusted fat thickness, cm	Ribeye area, cm^2	Hot carcass weight, kg	Kidney, pelvic, heart fat, %	Yield grade
Prime	165.00	172.50	169.17	811.67[a]	4.35[a]	4.47[a]	13.54	1033.25[a]	3.38[ab]	5.28[a]
Top Choice	170.00	173.33	172.50	604.17[b]	4.13[ab]	4.29[ab]	13.98	1058.92[a]	3.63[a]	5.04[ab]
Low Choice	172.50	171.67	171.67	457.50[c]	3.64[bc]	3.80[bc]	15.10	1046.67[a]	3.08[bc]	4.18[c]
Select	170.00	170.00	170.83	336.25[d]	3.36[c]	3.47[c]	13.83	928.50[b]	2.29[d]	3.80[c]
Select Enhanced[3]	172.50	171.67	174.17	355.42[d]	3.60[bc]	3.71[c]	13.60	991.25[ab]	2.83[c]	4.34[bc]
SEM	3.43	3.53	3.27	9.70	0.21	0.20	0.44	28.85	0.16	0.25
P - value	0.53	0.97	0.86	< 0.01	0.01	0.01	0.10	0.02	< 0.01	< 0.01

[abc]Least squares means in the same column of the same section without a common superscript differ ($P < 0.05$).
[1]100: A; 200: B; 300: C; 400: D; 500: E.
[2]200: Traces; 300: Slight; 400: Small; 500: Modest; 600: Moderate; 700: Slightly Abundant, 800: Moderately Abundant.
[3]Enhanced to 110% of raw weight with a water, salt, and alkaline phosphate solution.

Appendix B - Data Sheets

<u>Enhancement Data Sheet</u>

Loin ID	Green weight	Enhanced weight	Percent pump

Moisture Analysis Data Sheet

Sample ID	**Weight of pan**	**Weight of sample**	**Dried weight of sample in pan**

IMF Analysis Data Sheet

Sample ID	Weight of tube	Wet sample	Dry sample in tube weight

Peak Temperature and Cook Loss Data Sheet

Sample ID	Peak temperature	Raw weight	Cooked weight

Slice Shear Force Data Sheet

Sample ID	**SSF value**

Sample ID	**SSF value**

PJP Data Sheet

Sample ID	Rep	Filter paper weight	Filter paper + sample	Wet filter paper
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			
	1			
	2			
	3			

Appendix C - Consumer and Trained Evaluation Forms

INFORMED CONSENT STATEMENT

1. I volunteer to participate in research involving Sensory Evaluation of Meat. This research will be conducted by personnel in the Department of Animal Sciences and Industry at Kansas State University.

2. I fully understand the purpose of the research is for the evaluation of beef steaks, pork chops, lamb chops, goat meat, poultry meat, ground meat, and processed meat products from the previously mentioned species for the sensory traits of tenderness, juiciness, flavor intensity, connective tissue amount, off flavor presence, odor, and color and sensory evaluation will last approximately one hour.

3. I understand that there are minimal risks associated with participating and that those risks are related to possible food allergies. All meat products will be USDA inspected and all ingredients are GRAS (generally accepted as safe) by FDA.

4. I understand that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring confidentiality of my performance and responses.

5. My participation in this study is purely voluntary; I understand that my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

6. If I have any questions concerning my rights as a research subject, injuries or emergencies resulting from my participation, I understand that I can contact the Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3224.

7. If I have questions about the rationale or method of the study, I understand that I may contact, Dr. Travis O'Quinn, 247 Weber Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3469 or Sally Stroda, 107 Weber Hall, at 785-532-1273.

I have read the Subject Orientation and Test Procedure statement and signed this informed consent statement, this ________________________ day of _____________________, __________.

_____________________________ _____________________________

Printed name Signature

Please sign and return one copy. The second copy is for your records.

<u>Demographics Questionnaire</u>

Big Panel #

Please tell us a little about yourself:

Panelist Number

Gender

Male

Female

Household Size

1 Person

2 People

3 People

4 People

5 People

6 People

> 6 People

Marital Status

- Single
- Married

Age

- Under 20
- 20 to 29 years old
- 30 to 39 years old
- 40 to 49 years old
- 50 to 59 years old
- Over 60

Ethnic Origin

- African-American
- Asian
- Caucasian/White
- Hispanic
- Native American
- Other
- Mixed Race

Annual Household Income

- < $25,000
- $25,000 - $34,999
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - 149,999
- $150,000 - $199,999
- > $199,999

Highest Level of Education Completed

- Non-High School Graduate
- High School Graduate
- Some College / Technical School
- College Graduate
- Post-College Graduate

When eating beef, what palatability trait is the most important to you?

- Flavor
- Juiciness
- Tenderness

When eating beef steaks, what degree of doneness do you prefer?

- Very Rare
- Rare
- Medium-Rare
- Medium
- Medium-Well
- Well-Done
- Very Well-Done

How many times a week do you consume beef?

0 3 6 9 12 15 18 21

None

Purchasing Motivators

Please indicate the importance of each trait when purchasing fresh beef steaks:

Animal Welfare

Extremely Unimportant 0 — Extremely Important 100

Antibiotic use in the animal

Extremely Unimportant 0 — Extremely Important 100

Brand of Product

Extremely Unimportant 0 — Extremely Important 100

Color

Extremely Unimportant 0 — Extremely Important 100

Animal fed a corn-based diet

Extremely Unimportant 0 — Extremely Important 100

Animal fed a forage-based (grass) diet

Extremely Unimportant 0 — Extremely Important 100

Eating Satisfaction Claims (ex: Guaranteed Tender)

Extremely Unimportant 0 — Extremely Important 100

Familiarity with cut

Extremely Unimportant 0 — Extremely Important 100

Growth hormone use in the animal

Extremely Unimportant 0 — Extremely Important 100

Natural or Organic Claims

Extremely Unimportant 0 — Extremely Important 100

Nutrient content

Extremely Unimportant 0 — Extremely Important 100

Packaging Type

Extremely Unimportant 0 — Extremely Important 100

Price

Extremely Unimportant 0 — Extremely Important 100

Size, weight and thickness

Extremely Unimportant 0 — Extremely Important 100

USDA Grade

Extremely Unimportant 0 — Extremely Important 100

Marbling

Extremely Unimportant 0 — Extremely Important 100

>>

Consumer Sample Evaluation Survey

Round 1

Sample Number

Sample #

Juiciness

Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
0	50	100

Juiciness

Was the sample acceptable for juiciness?

Acceptable

Unacceptable

Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Tenderness

Was the sample acceptable for tenderness?

Acceptable

Unacceptable

Flavor

Dislike Extremely	Neither Like nor Dislike	Like Extremely
0	50	100

Flavor

Was the sample acceptable for flavor?

- Acceptable
- Unacceptable

Overall Liking

	Dislike Extremely	Neither Like nor Dislike	Like Extremely
	0	50	100
Overall			

Was the sample acceptable overall?

- Acceptable
- Unacceptable

Please choose one of the following to rate the quality of the beef sample you have just eaten.

- Unsatisfactory
- Everyday Quality
- Better than everyday quality
- Premium Quality

Trained Panel Evaluation Survey

Panelist

Sample Number

Initial Juiciness

Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
0	50	100

Initial Juiciness

Sustained Juiciness

Extremely Dry	Neither Juicy nor Dry	Extremely Juicy
0	50	100

Sustained Juiciness

Myofibrillar Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Myofibrillar Tenderness

Amount of Connective Tissue

None	Abundant
0	100

Amount of Connective Tissue

Overall Tenderness

Extremely Tough | Neither Tough nor Tender | Extremely Tender

0 | 50 | 100

Overall Tenderness

Beef Flavor Intensity

Extremely Bland | Extremely Intense

0 | 100

Beef Flavor Intensity

Salt Flavor Intensity

Extremely Bland | Extremely Intense | Not Applicable

0 | 100

Salt Flavor Intensity

Off Flavor Intensity

Extremely Bland | Extremely Intense | Not Applicable

0 | 100

Off Flavor Intensity

Off Flavor Description