The role of beef degree of doneness on consumer visual and palatability perceptions

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Abstract

The objective of part one was to determine the impact of feeding consumers with varying DOD preferences steaks cooked to multiple DOD on their perceptions of palatability. Paired Low Choice (small^{00} to small^{100} marbling) strip loin steaks were used. Each pair of steaks were randomly assigned to a DOD of either rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], medium-well [74°C (165°F)], or well-done [77°C (170°F)]. Consumer panelists were prescreened and assigned to panels based on their DOD preference. In the first round of serving, consumers were served 1 sample from each of the 5 DOD, under low-intensity red incandescent lighting in order to mask any DOD differences among samples. Round 2 consumers were fed under white incandescent lights. There were no consumer preference × steak DOD interactions or consumer preference effects ($P > 0.05$) for tenderness, juiciness, and flavor when steaks were evaluated under both lighting types. Within the white-light testing, the consumer preference × DOD interaction for overall liking was marginally significant ($P = 0.078$). Overall, when steaks were overcooked, palatability ratings decreased; however, undercooking had a positive effect on palatability perception, regardless of the consumer's DOD preference.

The objective of part two was to access if published cooking temperatures correlate with DOD. Twenty-four strip loins representing 5 quality treatments were collected. Steaks were cooked to an endpoint temperature of either very rare [55°C (130°F)], rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], well-done [77°C (170°F)], or very well-done [82°C (180°F)]. L*, a*, and b* was evaluated at multiple time points using a Hunter Lab Miniscan spectrophotometer and pictures were taken immediately. A separate digital survey for consumers and chefs was made for the electronic evaluation of the pictures of the cooked steaks.

There were time × DOD interactions ($P < 0.05$) for L*, a*, and b*. For very rare, rare, medium-rare, and medium, a* values increased ($P < 0.05$) over time. However, for well-done, time only had a minimal impact ($P < 0.05$) on a* values. When consumers determine DOD cooking beef in their home, they typically use color (54%), a food thermometer (16%), feel or firmness (15.7%) and time (10.4%). Of consumers that utilized a thermometer, 69% reported the temperature they use as their indication of DOD is the temperature they pull off the heat, whereas 31% reported the temperature they use for DOD determination is the temperature following the post-cooking temperature rise. The majority (66%) of chefs reported using feel or firmness for DOD indication, whereas 28% stated they use a thermometer, color (1.2%). There were no quality grade effects ($P > 0.05$) for any DOD of the steak pictures evaluated by consumers or chefs. Ultimately, consumers were able to accurately match the DOD of the steak pictured to the correct end-point temperature, although this percentage ranged from only 27 to 35%. Additionally, chefs were unable to accurately identify DOD of steaks cooked to specified end-point temperatures. This can create challenges for foodservice establishments to deliver upon consumers DOD preferences.

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Dedication

This thesis is dedicated to my family, Shane, Kianne, and Luke Prill. Thank you for pushing me to further my education and follow my dreams.

Chapter 1 - Review of Literature

Degree of doneness impact on palatability

Palatability is defined as the overall eating experience surrounding a food product. In the beef industry, tenderness, juiciness, and flavor are associated with beef palatability and overall eating experience (Smith and Carpenter, 1974; Platter et al., 2003; O'Quinn et al., 2018). Multiple studies have identified tenderness as the most important beef palatability trait (Dikeman, 1987; Miller et al., 1995a). Although today, consumers expect their steak at retail or foodservice to be tender, magnifying the impact of both juiciness and flavor on beef palatability. In more recent studies, consumers reported flavor as the most important factor considered when evaluating beef palatability (McKillip et al., 2017; Wilfong et al., 2016; Drey et al., 2018). The odds of overall palatability failing when tenderness, flavor, and juiciness is unacceptable alone is 69%, 76%, and 66%, respectively (O'Quinn et al., 2018). This provides evidence that overall beef acceptability is dependent upon the success of all three traits. However, additional emotional effects go into consumer perceptions (Desmet and Schifferstein, 2008). The complexity of a consumer's overall eating experience should continue to be a top priority for meat and sensory scientists in order to continue to improve beef quality and the eating experience received by today's consumers.

Degree of doneness (**DOD**) is a gauge of how thoroughly cooked a cut of meat is based on the color after cooked. Increased DOD have been reported to have an inverse relationship to consumer palatability traits. Some of the first research that incorporated DOD evaluated the longissimus muscle at three DOD (60, 71, or 82°C). Steaks were broiled and removed from the heat once they reached their assigned temperature. The authors reported tenderness, juiciness, and flavor ratings decreased (Gilpin et al., 1965). Additionally, Parrish et al. (1973) evaluated the

longissimus dorsi at (60, 70, or 80°C) and also determined ratings of tenderness, juiciness, flavor, and overall liking decreased as internal temperature increased. Cross et al. (1976) reported that internal temperature had a significant impact on tenderness, juiciness, and flavor ratings. Various other researchers have shown the effect DOD has on palatability ratings (Lorenzen et al., 1999; Lucherk et al., 2016; McKillip et al., 2017). Two more extensive DOD studies that incorporate the six DOD as reported by the National Cattleman's Beef Association (**NCBA**) include Lorenzen et al. (2005) and Drey et al. (2018). Drey et al. (2018) evaluated 5 quality treatments (Prime, Top Choice, Low Choice, Select, and Select enhanced) and cooked them to 6 end-point temperatures (55, 60, 63, 71, 77, 82°C). Steaks were cooked on an electric clam-style grill and pulled off of the heat so that their end-point temperature would peak at the assigned temperature (Drey et al., 2018). Drey et al. (2018) reported results from 360 consumers that evaluated samples under red-light using a continuous line scale. Furthermore, Lorenzen et al. (2005) utilized steaks from 3 Average Choice animals. Steaks were cooked by open-hearth broiler to 6 end-point temperatures (55, 60, 63, 71, 77, 82°C); however, once they reached their final end-point temperature they were removed from the grill (Lorenzen et al., 2005). Ninety-six consumers evaluated samples under red-light using a 9-point hedonic scale (Lorenzen et al., 2005). Figure 1.1 depicts the regression in consumer palatability ratings across all six DOD from the previous studies discussed. In order to make a direct comparison, all data reported was converted to a percentage. The regression models explained 82 and 85% of the variability of the rating data for tenderness ($r^2 = 0.82$) and juiciness ($r^2 = 0.85$), respectively. Additionally, the regression model only explained 7% of the variation for flavor ($r^2 = 0.07$); however, a more fitted regression line for overall liking ($r^2 = 0.64$) to explain how detrimental DOD is on overall liking. For every 3°C increase in temperature, there was a corresponding decrease in consumer

ratings of 4.74% for tenderness, 2.85% for juiciness, 2.37% for flavor, and 6.69% for overall liking.

The overall effect of DOD comes down to the fact that palatability attributes decline. As internal temperature increases, beef steaks become tougher (Cover et al., 1962; Parrish et al., 1973). Drey et al. (2018) evaluated Warner-Bratzler shear force and reported medium-rare being the most tender, only similar to rare, while very rare steaks were the toughest. Lorenzen et al. (2005) reported Warner-Bratzler shear force results stating well-done and very well-done were the toughest, and no other differences were found amongst the other 4 lower DOD. Additionally, in regard to juiciness, Lucherk et al. (2016) stated that the greater the internal cooking temperature, the less juicy a meat cut will be. As internal temperature increased, pressed juice percentage (an instrumental measure of juiciness) decreased (Lucherk et al., 2016; Drey et al., 2018). In regard to flavor, products of the Maillard reaction and other flavor contributing compounds such as fatty acids and amino acids have been shown to increase with DOD (Legako, 2015). In trained descriptive sensory analysis, panelists rated well-done with the most beef flavor attribute; however, no differences were found in regard to flavor liking across six DOD (Lorenzen et al., 2005). Although flavor compounds are more abundant when cooked to higher temperatures, consumers did not rate steaks accordingly.

Temperatures

There are various sources that have differing opinions on the beef temperatures that correspond to each DOD. The temperature to which a steak is cooked can be reported as the temperature at which the steak is removed from the heat or a peak temperature that accounts for post-cooking temperature rise. Furthermore, DOD specifically is based on perceived color. The commonly used beef DOD temperatures are published by NCBA. They publish a Beef Steak

Color Guide with steak pictures associated with each temperature (NCBA, 2008). The reported six DODs on the steak color guide are: very rare 54°C (130°F), rare 60°C (140°F), medium-rare 63°C (145°F), medium 71°C (160°F), well-done 77°C (170°F), and very well-done 82°C (180°F). However, it is unclear if these temperatures are pull-off the heat temperatures or carry-over cooking, peak temperatures. The history behind these reported temperatures' dates back to 1979 when the National Livestock and Meat Board in cooperation with Texas A&M University attempted to better define DOD with the first Beef Steak Color Guide. According to this guide, the DODs were very rare 55°C (131°F), rare 60°C (140°F), medium-rare 65°C (149°F), medium 70°C (158°F), well-done 77°C (167°F), and very well-done 77°C (176°F). Drey (2018) reported through personal communication with Dr. Gary Smith and Dr. Russell Cross, that the temperatures were decided upon by an expert panel of meat science professionals following visual appraisal of the steaks cooked to differing end-points. The American Meat Science Association (**AMSA**) Guidelines for Cookery and Sensory Evaluation of Meat has played a vital role defining a uniform methodology used to prepare, cook, and evaluate meat samples (AMSA, 1995). In 1995, the AMSA included a beef steak color guide and that was adopted as the official guide for the NCBA. Although differing from the original temperatures from Texas A&M, the AMSA guide reported medium-rare at 63°C (145°F). The most current AMSA sensory guidelines do not include a beef steak color guide, but instead indicate that color is not an indication of doneness and that internal temperature should be utilized (AMSA, 2016). But, in this updated version, it is recommended, depending on the cooking method, to account for carry-over cooking, and utilize the peak temperature of the steak for uniformity purposes.

Certified Angus Beef reports a rare DOD corresponds to 52°C (125°F) and well-done corresponding to 71°C (160°F) (Certified Angus Beef, 2018; Table 1.1). Furthermore, the

website even gives instructions to pull steaks off the heat when the thermometer is -15°C (5°F) below the preferred DOD and during rest the steak temperature will rise (Certified Angus Beef, 2018). Additionally, Michael Ollier, the corporate chef for Certified Angus Beef brand, created his own DOD chart to visually show how all DOD from rare to well-done should look when cooked to the correct temperatures. He cooked uniform steaks to precise temperatures using a sous vide machine and a meat thermometer. Similarly, What's Cooking America reports 49 to 52°C (120 to 125°F) as rare and 71°C (160°F) or greater as well-done. Additionally, their internal temperature cooking chart described the color and feel of each DOD. Very-rare is described as deep red color and barely warm, with a squishy feel. Medium-well is described as mostly gray-brown throughout and firm to the touch (Stradley, 2018). Moreover, What's Cooking America defines carry-over cooking as the residual heat transferring to the hotter exterior to the cooler center of the meat, suggesting consumers allow for a -15 to -12°C (5 to 10°F) rise in temperature following removal from the heat (Stradley, 2018). Char-Broil, an industry leader in gas, charcoal, and electric grills, states the "difficulty of grilling a steak is knowing when it's just right." Their suggestion to consumers is to use a meat thermometer, stating that 27 to 38°C (80 to 100°F) correlates to very-rare, and 71 to 79°C (160 to 175°F) represents well-done. Interestingly enough, Char-Broil also provides an estimated cooking time for consumers; however, they do state that time will vary based on cut, thickness, grill type, and grill temperature. For strip loin steaks they suggest 4 to 6 minutes cooking time for rare and 6 to 8 minutes cooking time for medium (Char-Broil, 2018). The Food Network Magazine provides a chart with USDA Safe Minimum and Food Network Kitchen temperatures. Within the medium-well row, it states the USDA Safe Minimum is 63°C (145°F) with a 3-minute rest. They state rare corresponds to 52°C (125°F) with a 3-minute rest and well-done relates to 68+°C (155+°F)

(Food Network Kitchen, 2018). Martha Stewart Living reported a chart with beef DOD, stating the USDA guideline versus professional kitchens, although no details were given pertaining to how they collected the temperatures (Stewart, 2006). This chart defines rare as 46°C (115°F) and well-done as 71°C (160°F). The difference between USDA and professional kitchens reported for medium-rare is from -9 to -4°C (15 to 25°F) (Stewart, 2006). The previously discussed DOD charts are consistent in the fact that they report beef steak cooking temperatures lower than what is published and recommended for use in research. On the other hand, Beef It's What's for Dinner website that is sponsored by Beef Checkoff, reports the temperatures that are published by NCBA on their website stating medium-rare is 63°C (145°F) and well-done 77°C (170°F) (Beef Checkoff, 2018). The complications with nearly all these sources that are available for consumers, is the definition of pull-off the heat temperature or carry-over cooking. Some of these sources report these temperatures as peak temperatures, others recommend the temperatures as pull-off temperatures, and others still do not specify. This lack of consistency creates confusion for consumers and is likely reflected in their perceptions of DOD. The beef industry is lacking a standard protocol for cooking beef steaks, and this will inherently affect how consumers not only cook beef in their home, but also creates a disconnect from consumer to chef when ordering steaks at restaurants.

The USDA Food Safety and Inspection Service (**FSIS**) recommends using a food thermometer to ensure safety and to determine desired doneness (FSIS, 2000). When focus groups were asked how they determine DOD, most consumers stated they use the "eye-ball" method and learned it by practice and trial and error through experience (Koeppl, 1998). Some consumers even stated that when in doubt, overcooking is better than undercooking (Koeppl, 1998). Ultimately, overcooking may come from the fact that the emotion of fear is most

commonly associated with consuming fish and meat products (Desmet and Schifferstein, 2008). McCurdy et al. (2005) also utilized focus groups to gain knowledge on consumers feelings and usage of thermometers. Consumers responded to prompted questions, stating they typically do not use thermometers because of lack of time, laziness, and forgetfulness (McCurdy et al., 2005). Additionally, when asked what would motivate them to use a food thermometer, most commonly mentioned was illness; however, consumers also stated, improved meat quality and the avoidance of overcooking would also motivate them to use a thermometer (McCurdy et al., 2005).

Consumers preferred degree of doneness

Figure 1.2 includes consumer DOD preference from studies by Branson et al. (1986), Cox et al. (1997), Drey et al. (2018), McKillip et al. (2017), Reicks et al. (2011), Schmidt et al. (2002), and Vierck et al. (2018). An overwhelming 53 to 67% of consumers reported they prefer beef steaks cooked to medium-rare and medium. Based on data from Longhorn Steakhouse from May 2016 to 2017, consumers ordered rare (2.5%), medium-rare (22.5%), medium (37.5%), medium-well (25.8%), and well-done (11.7%) (Hickey and Dottle, 2017). Cox et al. (1997) assessed consumers for their attitude toward meat products. The consumers that ordered their steak well-done reported their preference was emotive, citing food safety concerns and disliking to blood (Cox et al., 1997). The consumers who ordered their steak to a lower DOD, reported their focus was on the more attractive palpability traits (Cox et al., 1997). Additionally, researchers have studied if geographical location has an effect on consumers preference. Savell et al. (1999) reported consumers in Houston tended to cook steaks to a more advanced DOD, and consumers in San Francisco tended to cook steaks to a less advanced DOD.

Schmidt et al. (2002) conducted a study in two parts in which half the consumers were 'educated' by wait staff as to what DOD meant versus no education or help from wait staff. Wait staff provided verbal description and visual illustration of the different DOD prior to the consumer ordering. Authors described the DOD as follows: very rare: red color throughout and center cool to touch; rare: red in the center; medium-rare: reddish pink center; medium: light pink in center; well-done: light brown in center; and very well-done: darker brown throughout, dry texture. Results showed consumers that received DOD education had greater ratings for flavor-like and overall-like; however, no differences were seen for tenderness or juiciness (Schmidt et al., 2002).

A study conducted by Chan et al. (2013) validated the use of internal pictures as a more accurate representation of a consumer's preferred DOD versus terms such as rare and medium. The authors utilized longissimus lumborum steaks, cooked on double sided grills to rare (3 min; 60°C, 140°F), medium (4 min; 70°C, 158°F), medium-well (4.5 min; 75°C, 167°F), well-done (5 min; 80°C, 176°F), and very well-done (5.5 min; 85°C, 185°F). To study the consumer's perception of doneness, two panel sessions were conducted, one for both the external and internal surface of the cooked steak and secondly, for the corresponding photographs of each sample. Perception scores for both external and internal surfaces between different presentation methods and corresponding photos, were not significantly different (Chan et al., 2013). Ultimately, the authors concluded that for assessing consumer preference for meat doneness, photographs can be used as a valid approach.

Factors affecting cooked color

Changes in color, interpreted as DOD upon completion of cooking, might be influenced by many factors including animal maturity, type of muscle, fat content (marbling), added

ingredients, method of cooking, pH, length of cooking, and internal temperature (Mancini and Hunt, 2005). Most cooked beef color research has revolved around ground beef patty color, especially in regard to persistent pinking and premature browning.

Many researchers have studied the influence on packaging on internal cooked color. Increased use of modified atmosphere packaging (**MAP**) has proven beneficial for fresh meat color; however, has increased the incidence of premature browning (Mancini and Hunt, 2005). Most research has been conducted in regard to premature browning in beef patties, although in a study conducted by Seyfert et al. (2004), the authors injected beef round steaks with water, salt, phosphate, and natural flavorings to 6%, followed by packaging steaks in high-oxygen MAP for 7 days. Following storage time, all the steaks were cooked to an internal temperature of 71.1°C (160°F) or a medium DOD. Steaks prematurely turned brown and there was no pink center as expected (Seyfert et al., 2004). The high levels of oxygen in this packaging system maximized oxymyoglobin formation on the surface and in some cases, deep within the product interior.

High pH protects myoglobin from heat denaturation allowing for maintenance of color (Trout, 1989). Trout (1989) analyzed the variation in myoglobin denaturation as influenced by pH and cooking temperature. This study evaluated the effect of sodium chloride and sodium tripolyphosphate. The presence of sodium chloride in cooked ground beef patties increased percent myoglobin denatured and therefore would decrease the pinkness of the cooked product (Trout, 1989). Ground beef and ground beef plus tripolyphosphate with pH 5.5, 6.0, 6.5, and 7.0 was cooked to 55°C (131°F), 62°C (144°F), 69°C (156°F), 76°C (169°F), and 83°C (181°F) and evaluated for percent myoglobin denaturation (Trout, 1989). The authors reported increasing the pH decreased the percent myoglobin denaturation at lower DODs, except where the myoglobin was completely denatured at 83°C (181°F). Another study by Bernofsky et al. (1959) evaluated

ground flank steak cooked in a forced-air oven to 40°C (104°F), 60°C (140°F), 65°C (149°F), and 80°C (176°F). The authors reported the amount of pigmentation remaining depended on its temperature and how long it was held at the temperature; however, they did not report how time held affected the cooked color (Bernofsky et al.,1959).

Fat content is another factor that can influence raw and cooked meat color. In a study conducted by Berry (1998) authors assessed beef patties with 5, 10, 15, 20, or 25% fat content. Patties were cooked from thawed and frozen state on electric griddles to 71°C (160°F) (Berry 1998). Authors reported DOD of the beef patties assigned by two trained evaluators based on the Kansas State University Ground Beef Cooked Color Guide. Between patties with different fat contents, no differences in DOD were seen (Berry 1998). In contrast, Troutt et al. (1992) reviewed the chemical properties of ground beef containing 5, 10, 15, 20, 25, and 30% fat. Samples were cooked on and electric skillet to 71°C (160°F) or 77°C (171°F). The authors reported no differences for a* or b* between the two DODs (Troutt et al., 1992). Additionally, there were no a* or b* differences between any of the fat contents (Troutt et al., 1992). For L*, patties cooked to 77°C (171°F) were darker than 71°C (160°F), as well as patties with 30% fat content were lighter compared to all other treatments (Troutt et al., 1992).

In a study conducted by McKillip et al. (2017), authors analyzed 3 quality grades including Prime, Low Choice, and Low Select, as well as an enhancement treatment of each quality grade. The enhancement solution was formulated to result in 0.35% NaCl and 0.40% sodium phosphate at a target 8% pump in the final injected product. After slicing, the raw wedge steak which was utilized for color values and pH was allowed to bloom for 15 minutes. All 3 enhancement treatments resulted in greater pH values compared to non-enhanced (McKillip et al., 2017). Regardless of enhancement, Prime steaks were the lightest (McKillip et al., 2017).

Select enhanced had the lowest a* and b*, being only similar to Low Choice enhanced, no differences were seen amongst non-enhanced treatments (McKillip et al., 2017).

Yancey et al. (2011) reported instrumental color values from longissimus thoracis steaks cooked to 65.5°C (150°F), 71.1°C (160°F), 76.6°C (170°F) on five different cooking methods including forced-air oven, air-impingement oven, electric griddles, char-grill, and clam-shell grill. Medium-rare steaks were the lightest, most red, and yellow, well-done steaks were the least red and yellow, although similar to medium for L* (Yancey et al., 2011). Although differences in color between temperatures remained consistent, there were differences between cookery methods as well. The ovens and the electric griddle produced lighter colored steaks, with the griddle being similar to the char-grill which was similar to the clam-shell (Yancey et al., 2011). For a* clam-shell grills were less red than the ovens and char-grill, being similar to electric griddles (Yancey et al., 2011). Additionally, steaks cooked on the char-grill had the greatest b* compared to all other cooking methods (Yancey et al., 2011). Zhu and Brewer (1999) reported that an a* change of 0.589 under Illuminant A was required for visually perceptible differences. Overall, there are many factors to consider when evaluating cooked color formation. All of these variables play a vital role in consumers visual appraisal of DOD on beef patties and steaks alike.

Under- and overcooking

The most extensive DOD in-restaurant study was conducted by Cox et al. (1997). Cox sampled over 3,400 consumers in 9 restaurants. Consumers ordered their steak cooked to their preference, once served, steaks were visually assessed for observed DOD and sensory ratings (Cox et al., 1997). Consumers ordered rare (4.5%), medium-rare (19.8%), medium (33.6%), medium-well (14.9%), and well-done (27.2%). Although, this study had several limitations including that within the restaurant there was no control, retail cut was not held constant, steaks

were cooked using normal commercial practices and equipment, and more specifics or temperatures were not provided. Additionally, consumers were only fed one steak, not allowing for measurement of the change in ratings within consumer depending on the DOD they received. Cox et al. (1997) reported 30% of consumers considered their steak was not delivered as ordered. If the difference in DOD ordered was under- or overcooked by one DOD, tenderness ratings scores fell 6.5 and 17.8%, meanwhile, steaks that were delivered two DODs under- or overcooked tenderness ratings dropped 16.2 and 24.5% (Cox et al.,1997). When served three DODs different than what the consumer ordered, tenderness ratings continued to decline by 17.8 and 27.7% (Cox et al., 1997). The authors found no differences among DODs, inferring consumers who receive their steak to the DOD ordered, have similar experiences of tenderness, juiciness, and flavor. Cox et al. (1997) ultimately concluded overcooking had a greater negative impact versus steaks perceived to be undercooked. Furthermore, Cox et al. (1997) noted a disconnect in communication of DOD between chefs and consumers, even stating that photographic standards may be more appropriate than terms such as rare, medium, and well-done.

In another study by Schmidt et al. (2002), authors reported consumer ratings for steaks that were cooked correctly, under-, and overcooked. Consumers ordered very rare (1%), rare (10%), medium-rare (30%), medium (37%), medium-well (5%), well-done (18%), and very well-done (1%). Out of the 210 consumers, more perceived their steak to be undercooked (23.8%) versus overcooked (17.1%) (Schmidt et al., 2002). Results showed undercooking did not affect tenderness or juiciness ratings, and had a similar affect to overcooking on flavor-like and overall-like (Schmidt et al., 2002). Unfortunately, since this was not the objective of their study, they did not report how severely the steak's DOD was missed and consumers were only fed one

steak. Standardization and education of cooks' determination of endpoint temperature and perceptions of DOD can improve consumers' satisfaction of beef. Schmidt et al. (2002), concluded further research focusing on consumers' and chefs' perception of the varying DOD was necessary.

Importance of color

Consumers generally assess doneness of cooked beef using interior color visual appearance (Suman et al., 2016). When conducting consumer panels within the realm of meat science, red filtered lights are most commonly used to mask the color differences in situations where steak cooked color is variable. AMSA (2015) suggests only using colored lights when absolutely necessary to mask differences because non-typical responses from consumers are more likely.

Imram (1999) stated, "the first taste is almost always with the eye", meaning that visual sensations help contribute to consumer perception since the first encounter with food products is often visual. Inherently color will affect subsequent willingness to accept a product. The effect of visual sensations should not be underestimated. In a study observing instrumental color measurements of fruit juices and milk, Hetherington and MacDougall (1991) concluded that human perception of quality is dependent on the visual image. It has been well established that color and appearance can have a halo-effect which modifies subsequent flavor perception and food acceptability (Hutchings, 1994; Kostyla et al., 1978).

Maga (1974) tested the influence of color on taste thresholds. Concentrations of sweet, sour, bitter, and salty were evaluated in colorless, red, green, and yellow water solutions (Maga, 1974). No significant differences due to color affected salty taste sensitivity; however, green color statistically increased sweet taste threshold, had no effect on bitter, and decreased

sensitivity to sour (Maga, 1974). Red color did not affect the taste sensitivity of sweet or sour, and decreased bitter taste sensitivity (Maga, 1974). In the case of yellow, thresholds for sour and sweet sensitivity decreased, and had no effect on bitter (Maga, 1974). It can be inferred; psychological color association can alter basic taste sensations and thus may impact beef in the same manner as these other products.

In a study conducted by Garber et al. (2000) authors evaluated the effects of food color on perceived flavor. Consumers were served three flavors of powdered drink mix, including grape, orange, and fruit. Each flavor was served in three different colors: purple, orange, and clear. Their hypothesis included that differently colored versions of otherwise identical beverages would evoke distinct flavor profiles. The beverage color manipulation had a significant effect on consumers' abilities to correctly identify fruit flavor. Consumers results showed that color dominated flavor expectation and identification, confirming the important role beverage color plays in consumers' abilities to correctly identify beverage flavors (Garber et al., 2000). Results also indicated clear color has equal color identity to orange and purple, with flavor expectations of its own (Garber et al., 2000).

In a study by Desmet and Schifferstein (2008) authors described two experiments that focused on the sources of positive and negative emotions in food experiences. In study one, consumers simply described emotional responses, then in study two, consumers tasted a sweet snack, savory snack, and pasta meal to measure their emotional response. Pleasant emotions were reported more often than unpleasant ones; however, fear was described to be typically associated with fish and meat products (Desmet and Schifferstein, 2008). While assessing the five sources of food emotion Desmet and Schifferstein (2008) described actions of associated agents such as “I was angry because the cook prepared a meal that I do not like” as an example

of a strong emotional experience that would be unfavorable. Consumers stated a reason anger can be an emotion associated with a food experience is when someone did not do a good job preparing the food (Desmet and Schifferstein, 2008). Although the consumers were never fed steak, we can infer consumers emotional behavior would depend on DOD.

Hetherington et al. (1990) evaluated the relationship among sensory evaluation and optical measurements of green, orange, and red tomatoes. Instrumental color measurements were taken for each tomato and panelists were asked to evaluate ripeness. L* and b* were in the same location on the principal component analysis plot as hardness, whereas a* was opposite closer to ripeness (Hetherington et al., 1990). Additionally, a* had a significant relationship ($r^2 = 0.7$) with the modulus, instrumental firmness measurement of the tomatoes. Authors concluded it is possible to predict sensory attributes from instrumental color data.

As seen across the previous studies in other foods and beverages, color is a major component of consumers perception. Inferences can be made that in beef DOD could potentially evoke differing emotional responses as well as flavor and acceptability ratings.

Chefs

Very little academic research has been done on chefs. Bass et al. (2009) conducted a nationwide internet-based survey, including 33 chefs, evaluating the acceptability of portion sizes and dimension of individual meat cuts. For the longissimus lumboruum muscle, the authors reported a quadratic relationship to the portion size of those cuts (Bass et al., 2009). Foodservice chefs indicated there is a range in acceptability for portion size (Bass et al., 2009). Additionally, 97% of chefs reported marketing ribeyes and strip loin steaks, whereas only 55% and 73% reported merchandising a top blade steak and bottom round steak, respectively (Bass et al., 2009).

In attempt to improve customer satisfaction through the use of thermometers Schmidt et al. (2002) compared the method of touch versus thermometers. Authors reported the steaks were cooked by experienced chefs to the consumers desired DOD on a Garland foodservice gas grill. Ultimately, within both panel sessions chefs that used thermometers more closely achieved the desired DOD with mean differences of 0.6°C and 1.3°C versus desired temperature (Schmidt et al., 2002). Chefs that utilized the touch method for determining DOD were 10.2°C too low when the consumers were educated on DOD and 27.6°C too low when the consumers ordered without guidance from the wait staff (Schmidt et al., 2002).

Lehmuller and Hunt (2000) conducted a study to determine chefs' appraisal of cooked color compared to endpoint temperature, and the differences in chefs perceived degrees of doneness. Twenty-two professional chefs who averaged 24 years of experience, received a variety of training experiences, and resided in diverse locations were used for evaluation. Ninty-five percent reported determining doneness of steaks by touch (Lehmuller and Hunt, 2000). For visual evaluation, beef eye of rounds were roasted to 43°C (109°F), 49°C (120°F), 54°C (129°F), 60°C (140°F), 71°C (160°F), and 77°C (170°F), then cross-sections were evaluated visually under standardized lighting (Lehmuller and Hunt, 2000). Additionally, authors reported that 49°C (120°F) was most commonly associated with rare although this is tremendously lower than current published sources stating rare at 60°C (140°F) (Lehmuller and Hunt, 2000). Based on color, chefs assigned a degree of doneness and estimated the endpoint temperature. Over 85% of the chefs correctly identified doneness of pieces cooked very rare, medium-rare, medium-well, and well-done; however, samples cooked medium were rated mostly as medium-rare, and rare samples were correctly identified by only five chefs (Lehmuller and Hunt, 2000). Even when allowing a 5 to 6°F variance, chefs generally were unable to correctly determine actual endpoint

temperatures based on visual color (Lehmuller and Hunt, 2000). Lehmuller and Hunt (2000) concluded that internal temperatures used by chefs tended to be lower than those published by AMSA, USDA, or Food and Drug Administration. Differences exist in the perceptions of doneness between culinary professionals and meat researchers and these may have consumer acceptability implications for whole muscle products.

It is inevitable that the divide between consumers and chefs' interpretation of DOD is a frustrating factor for chefs. In an article published by Quora, respondents listed a point scale on how upset chefs get when certain situations arise, topping the list was "steak was cooked perfectly, but they [consumer] thought medium meant medium-rare." Additionally, other factors impacting the situation of a steak getting returned include the chef's mood, the wait staff's and consumer's attitude, how busy the restaurant is, and the cut that has to be recooked (Sutton, 2017).

In an article titled, "Restaurants are cooking your steak wrong on purpose" by New York Post, the author states receiving extremely underdone steaks and his opinion is that the trend of undercooking just spiked within the last year (Cuozzo, 2018). Hanson, the owner of Henry at Life Hotel who previously ran four steakhouses under the BR Guest banner, including the Strip House chain states kitchens error on the rare side, knowing the steak can always be rescued with a minute or two more heat, "If a customer says their steak is overcooked, it can only be thrown out" (Cuozzo, 2018). Additionally, Desmet and Schifferstein (2008) described examples for each emotional type and in regard to chef's anger it was described as "cooks get angry with themselves when they spoil food while preparing the food." Cuozzo (2018) also interviewed Chef, Josh Capon who brings light to a 'new' DOD of "medium-rare plus." He also states, "At this rate, we soon might have to ask for it medium-well to guarantee it won't be raw." At Porter

House New York in Midtown, executive chef and co-owner Michael Lomonaco says more than 60% of his customers order medium-rare" (Cuozzo, 2018). An article published by Boston Eaters, chefs were asked how they would like to respond to consumers that ordered steak well-done. Michael Schlow, chef and owner of Via Matta, Tico, and Alta Strada, responded, "I would ask, have you ever closed your eyes and tasted a medium rare steak side-by-side with a well-done steak? I think part of it is the color for people. It certainly can't be that they like it drier. They look at it and maybe get a little squeamish" (Blumenthal, 2014).

Longhorn Steakhouse shared a year's worth of steak orders from all of its 491 United States' locations, revealing how Americans ordered different cuts of steak. Jens Dahlmann, the executive chef at Longhorn, interviewed in the article published by Five Thirty Eight, states that the DOD the consumer orders is retail cut dependent (Hickey and Dottle, 2017). Longhorn Steakhouse reported prime rib had the greatest occurrence of being ordered rare or medium-rare, whereas a T-bone steak had the highest share of medium-well and well-done orders (Hickey and Dottle, 2017).

Overall, chefs frustration with consumers could be decreased by reducing the gap in disconnect of DOD perception. Across the foodservice industry, delivering the preferred DOD becomes crucial to consumer ratings. Moving forward, finding innovative ways to communicate with consumers that have created new DODs in their mind will be vital.

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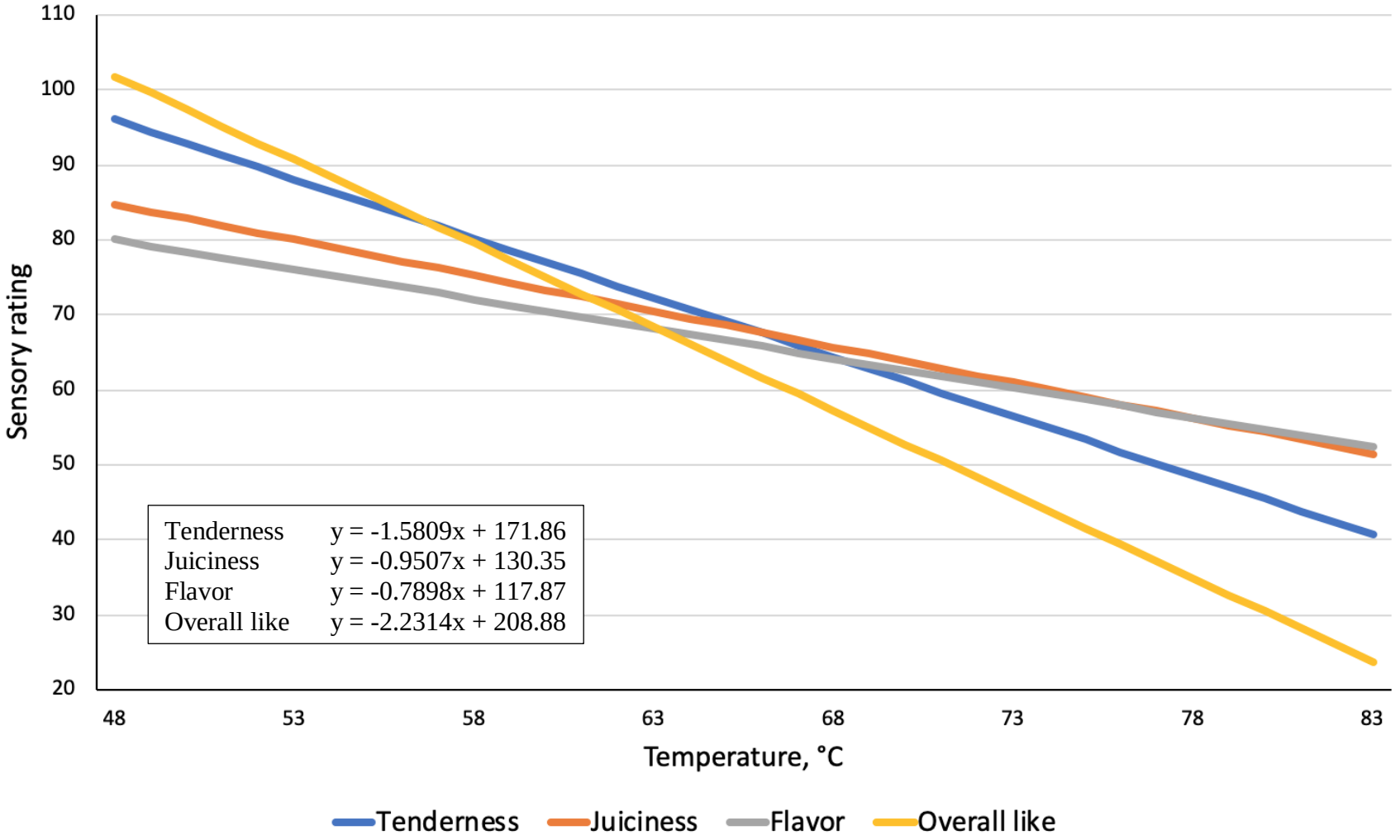

Figure 1.1 End-point temperature effects on beef steak palatability as shown by various research studies[1]

[1]Gilpin et al., 1965; Parrish et al., 1973; Lorenzen et al., 2005; McKillip et al., 2017; Drey et al., 2018

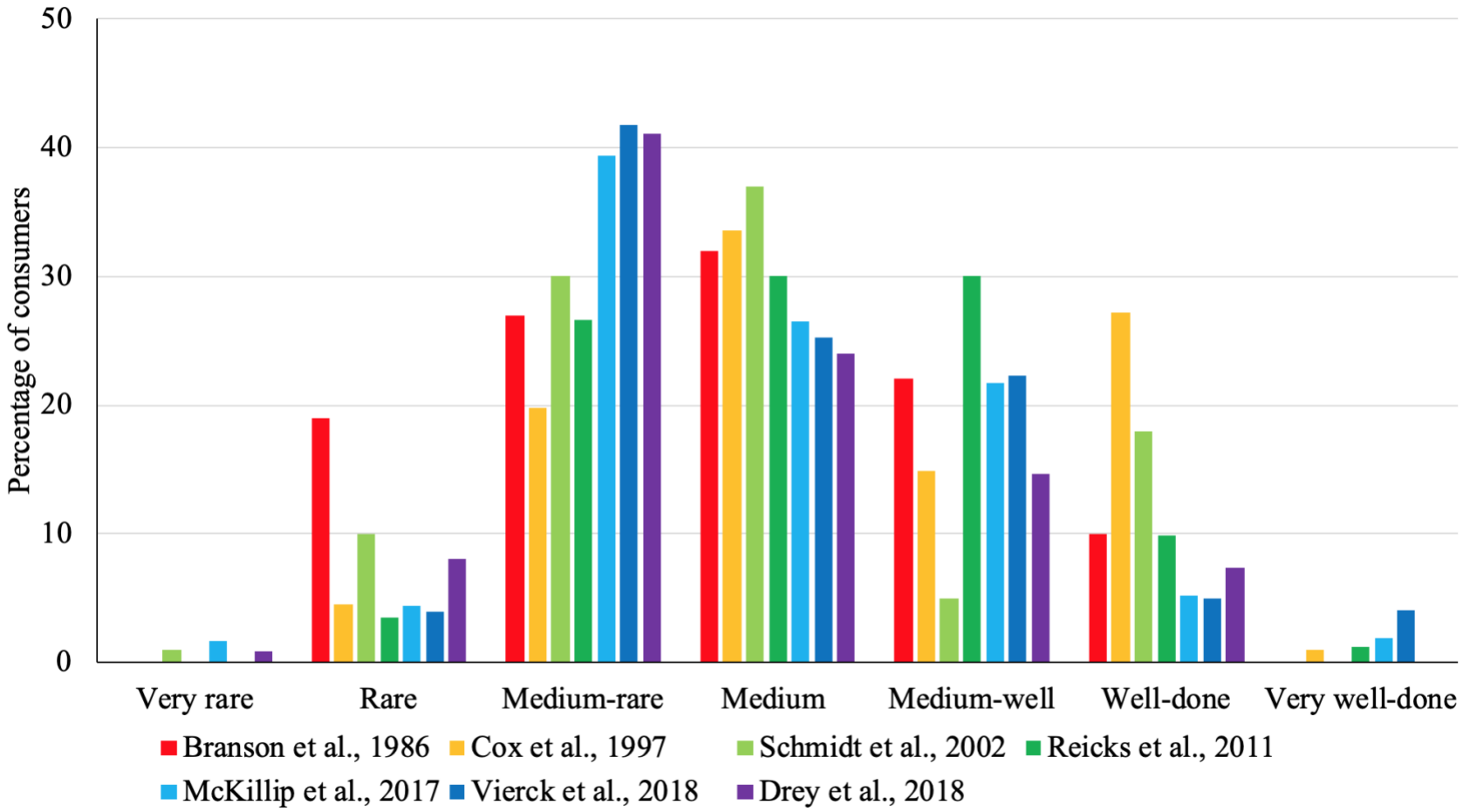

Figure 1.2 Preferred degree of doneness by consumers presented by various research studies

Table 1.1 Published temperatures corresponding to beef degree of doneness

Degree of doneness	Beef It's What's for Dinner[1]	Certified Angus Beef[2]	Char-Boil[3]	What's Cooking America[4]	Food Network Kitchen[5]
	Peak temperature	Pull-off of the heat	Unspecified	Unspecified	Pull-off of the heat
Very rare	55°C (130°F)	-	26 – 38°C (80 – 100°F)	26 – 38°C (80 – 100°F)	-
Rare	60°C (140°F)	52°C (125°F)	49 – 51°C (120 – 125°F)	49 – 51°C (120 – 125°F)	51°C [125°F]
Medium-rare	63°C (145°F)	57°C (135°F)	55 – 57°C (130 – 135°F)	55 – 57°C (130 – 135°F)	55 – 57°C (130 – 135°F)
Medium	71°C (160) °F	63°C (145°F)	60 – 63°C (140 – 145°F)	60 – 63°C (140 – 145°F)	57 – 60°C (135 – 140°F)
Medium-well	-	66°C (150°F)	65 – 69°C (150 – 155°F)	65 – 69°C (150 – 155°F)	60 – 66°C (140 – 150°F)
Well-done	77°C (170°F)	71°C (160°F)	71>°C (160 >°F)	71>°C (160 >°F)	69+°C (155+°F)
Very well-done	82°C (180°F)	-	-	-	-

[1] Beef Checkoff., 2018.
[2] Certified Angus Beef., 2018.
[3] Char-Broil., 2018.
[4] Stradley, L., 2018.
[5] Food Network Kitchen., 2018.

Chapter 2 - Profiling the impact of visual degree of doneness on palatability ratings of beef strip loin steaks served to consumers of differing degree of doneness preferences

ABSTRACT

The objective of this study was to determine the impact of feeding consumers with varying degree of doneness (**DOD**) preferences steaks cooked to multiple DOD on their perceptions of beef palatability. Paired Low Choice (small^{00} to small^{100} marbling) frozen strip loin steaks were used in this study. Each pair of steaks were randomly assigned to a DOD of either rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], medium-well [74°C (165°F)], or well-done [77°C (170°F)]. Consumer panelists were prescreened for DOD preference (rare, medium, or well-done) prior to sensory panels and were assigned to panels based on their DOD preference. In the first round of testing, consumers were served 1 sample from each of the 5 DOD in random order under low-intensity red incandescent light in order to mask any DOD differences among samples. In round 2 of testing, consumers were fed the paired samples cooked to the same DOD under white incandescent lights. There were no consumer DOD preference × steak DOD interactions or consumer DOD preference effects ($P > 0.05$) for tenderness, juiciness, and flavor when steaks were evaluated under both light types. Within the white-light testing, the consumer DOD preference × steak DOD interaction for overall liking was marginally significant ($P = 0.078$). Sensory rating means decreased ($P < 0.05$) as the DOD above the consumer's preferred DOD increased, with steaks cooked four DOD over their preferred DOD being rated the toughest and lower for flavor liking ($P < 0.05$) than steaks at their preference. These results indicate that when steaks are cooked above a consumer's preferred DOD, palatability ratings decrease; however, cooking steaks to DOD below a consumer's

preference does not have a negative impact and may positively impact palatability perception, regardless of the consumer's DOD preference.

INTRODUCTION

Degree of doneness (**DOD**) has a large impact on consumer beef eating satisfaction (Cross et al., 1976; Drey et al., 2018). As DOD increases, palatability is often severely reduced (Lucherk et al., 2016). As internal temperature increases, beef steaks become tougher (Cover et al., 1962; Parrish et al., 1973), less juicy (Lucherk et al., 2016), and overall liking decreases (Lorenzen et al., 1999). Additionally, greater internal cooking temperatures result in an increased probability of an unacceptable overall eating experience by consumers.

It is noteworthy that much of the published literature evaluating the impact of DOD on beef palatability has utilized red-light to mask differences in DOD (Lorenzen et al., 2005; McKillip et al., 2017; Drey et al., 2018). This practice is suggested by the American Meat Science Association (**AMSA**) Sensory Guidelines (AMSA, 2015), but is not reflective of the eating experience a consumer receives when they can visually assess DOD prior to consuming a steak at home or in a restaurant. Research has indicated the factors outside of the taste factors alone, including visual cues, can have a large impact on consumer sensory ratings (Imram, 1999). Previous beef research has shown if steaks are not cooked to match consumer preferences for DOD, their overall eating experience is diminished (Cox et al., 1997).

Large differences exist in consumer DOD preferences. Branson et al. (1986), Cox et al. (1997), Drey et al. (2018), McKillip et al. (2017), Reicks et al. (2011), Schmidt et al. (2002), and Vierck et al. (2018) reported 4 to 19% of consumers prefer rare, 24 to 37% prefer medium, and 5 to 27% prefer well-done. Consumers typically visually appraise steaks to determine DOD and

use the extent of myoglobin denaturation and the resulting color change as their visual cue for DOD assessment (Trout, 1989; Suman et al., 2016). If the consumer determines the steak to be either under- or overcooked, it can have an impact on their eating experience (Schmidt et al., 2002). However, the extent to which under- and overcooking by multiple DOD can affect palatability is unclear. Additionally, it is not known if under- and/or overcooking has the same impact on consumers of various DOD preferences. Therefore, using consumers of various DOD preferences under both red and white-lighting, the objectives of this study to evaluate the impact of DOD on beef palatability ratings of strip loin steaks cooked to multiple DOD and to assess the impact of both under- and overcooking on beef palatability ratings.

MATERIALS AND METHODS

The Kansas State University Institutional Review Board approved all procedures for use of human subjects in sensory panel evaluations (IRB: #7740.4, November 15, 2017).

Experimental treatments

Low Choice (small^{00} to small^{100} marbling) frozen steaks (N = 360) were selected from steaks remaining from the studies by Drey et al. (2018) and Vierck et al. (2018). Steaks used for this study were selected in pairs, with each pair consisting of two consecutively cut steaks from strip loin fabrication. Each pair (n = 180) of steaks were randomly assigned to a DOD of either rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], medium-well [74°C (165°F)], or well-done [77°C (170°F)]. Steaks remained frozen until subsequent consumer sensory analysis.

Consumer sensory panel testing

Consumer panels were conducted at Kansas State University in Manhattan, KS. Consumers were prescreened to participate in panels based on their DOD preference. Panels were conducted with all panelists in the session preferring steaks cooked to either rare, medium, or well-done. Consumer panelists (N = 283; 95/rare; 95/medium; 93/well-done) were recruited by email from surrounding communities and compensated with cash for their participation. Testing took approximately one hour and panelists were only allowed to participate once.

Steaks utilized for consumer panels were thawed 24 hours prior to consumer testing at 2 to 4°C. Steaks were weighed prior to cooking and a probe thermometer (Super-Fast Thermopen, ThermoWorks, American Fork, UT) was inserted into the geometric center of each steak and remained in place during the cooking process. Steaks were cooked on clam-style grills (Cuisinart Griddler; Cuisinart, Stamford, CT) set to a surface temperature of 177°C and removed following cooking so that the peak end-point temperature would correspond to the assigned DOD of either rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], medium-well [74°C (165°F)], or well-done [77°C (170°F)] (AMSA, 2016; National Cattleman's Beef Association (**NCBA**), 2008). The steaks were then cut into 2.5-cm thick × 1-cm × 1-cm cuboid pieces and two pieces were immediately served to consumers.

Each panelist was provided an electronic tablet (Model 5709 HP Steam 7; HewlettPackard, Palo Alto, CA) to fill out a digital survey (Qualtrics Software, Provo, UT). Surveys contained a basic demographic questionnaire, a purchasing motivator survey, and 10 sample evaluation surveys. Before the start of each panel, consumers were given verbal instructions on how to use the tablets, fill out the survey, and cleanse their palette. Panelists were

provided with a napkin, fork, water cup, expectorant cup, apple juice, and unsalted crackers to serve as palette cleansers.

For the purchasing motivator survey, consumers rated traits for importance when purchasing beef steaks on continuous lines scales with anchors at 0 and 100. The 0-anchor indicated extremely unimportant and the 100-anchor indicated extremely important.

Serving of samples was conducted in 2 rounds. In the first round, consumers were served 1 sample from each of the 5 degrees of doneness in a random order under low-intensity red incandescent lighting in order to mask any DOD differences among samples. Each sample was evaluated for tenderness, juiciness, flavor, and overall liking on continuous line scales. Scales were anchored at each end and mid-point with descriptive terms: 100 = extremely tender, juicy, and like extremely; 50 = neither tough nor tender, juicy and neither dislike or like; 0 = extremely tough, dry, and dislike extremely. Consumers also rated each palatability trait as acceptable or unacceptable (yes/no), and upon completion, classified the sample as either unsatisfactory, everyday quality, better than everyday, or premium quality.

Following the first round of 5 samples, consumers were prompted to wait for further instruction. Round 2 testing procedures were identical to round 1, although consumers were fed under white incandescent lights in the sensory booths, with the white fluorescent background lighting turned on. This allowed for the consumers to visually evaluate the DOD of samples during testing. Samples evaluated in round 2 were paired with samples from round 1 and cooked to the same DOD, allowing for a direct comparison of consumer ratings between the rounds. By screening the consumers beforehand for DOD preference, this allowed for a measure of the impact of "missing" the consumer's ideal DOD and allowed for a quantification of the impact of both under- and overcooking steaks on consumer beef palatability ratings.

Statistical methods

Statistical analyses were conducted in SAS (Version 9.4) using PROC GLIMMIX with $\alpha = 0.05$. Consumer data were analyzed using a split-plot model with consumer DOD preference as the whole plot factor and steak DOD as the subplot factor. The model included the fixed effects of consumer DOD preference, steak DOD, and their interaction. For all significant interactions, the SLICE option of the LS MEANS statement was used to restrict comparisons to within consumer DOD preference. Demographic data were summarized using PROC FREQ. Additionally, all acceptability data were analyzed with a model that included a binomial error distribution. The Kenward-Roger approximation was used for estimating denominator degrees of freedom for all data analyses.

RESULTS AND DISCUSSION

Participant demographics and factors emphasized when purchasing beef

Table 2.1 shows the demographic profile of consumers varied, yet were comparable to those reported in other beef consumer work conducted in Manhattan, KS (Drey et al., 2018; McKillip et al., 2017; Vierck et al., 2018; Wilfong et al., 2016). Male and female consumers were similarly represented, while the majority of consumers were Caucasian/White and single. Forty-six percent of the panelists consumed beef one to three times a week and flavor was identified by 54% of consumers as be the most important palatability trait when eating beef, with only 13% of consumers reporting juiciness as the most important. In other recent beef studies, consumers also reported flavor as the most important palatability trait (Corbin et al., 2015; Lucherk et al., 2016; McKillip, 2016; Wilfong et al., 2016); however, earlier studies by Dikeman (1987), Miller et al. (1995), and Huffman et al. (1996) identified tenderness as the most

important trait. Additionally, purchasing motivators (Table 2.2), showed price was the most ($P < 0.05$) important factor considered by consumers when purchasing beef, followed by size, weight, and thickness, color, and marbling, which were all more important ($P < 0.05$) than all other factors considered, other than USDA grade. Brand, natural or organic claims, and corn-based or forage-based diet were all rated the least ($P < 0.05$) important, but were similar ($P > 0.05$) to packaging type. These results resemble other studies where consumer purchasing motivators have been evaluated; however, Vierck et al. (2018) reported price was similar to size, weight, and thickness, and color, whereas in the current study price was the single most important trait considered. Furthermore, Lucherk et al. (2016) previously reported consumers deemed animal welfare similar in importance to packaging type, brand, natural claims, and antibiotic use in the animal, but in our study, consumers considered animal welfare as more important than these other traits.

Consumer palatability ratings of beef strip loin steaks

Red filtered lights are most commonly used to mask the color differences in situations where steak cooked color is variable. The AMSA suggests only using colored lights when absolutely necessary to mask differences because non-typical responses from consumers are more likely (AMSA, 2015). When evaluating the impact of red versus white-light, consumers rated steaks greater ($P < 0.05$) for juiciness, flavor, and overall liking under the white-lights; however, for tenderness there were no differences ($P > 0.05$; data not presented in tabular format). With the addition of the sensory cue of sight under the white-light, there was an overwhelming positive effect, where consumers were unwilling to rate steaks as critical as they previously had within red-light testing, regardless of DOD differences. Imram (1999) stated, “the first taste is almost always with the eye”, meaning that visual sensations help contribute to

consumer perception since the first encounter with food products is often visual. Inherently color will affect a consumer's subsequent willingness to accept a product. The effect of visual sensations should not be underestimated. In a study evaluating instrumental color measurements of fruit juices and milk, Hetherington and MacDougall (1991) concluded that human perception of quality is dependent on the visual image. Moreover, it has been well established that color and appearance can have a halo effect, which alters subsequent flavor perception and food acceptability (Hutchings, 1994; Kostyla et al., 1978).

Recent studies conducted at Kansas State University using Low Choice, 21-day aged strip loins, utilized both red and white-light consumer sensory testing. Consumers served under white-lights in studies conducted by Wilfong et al. (2016), Nyquist et al. (2018), and Vierck et al. (2018) all reported comparable consumer palatability mean ratings to the white-light test portion of this study. Additionally, similar to the current work, studies where consumers were fed under red-lights (McKillip et al., 2017; Drey et al., 2018), reported means within each sensory characteristic, similar to our study and lower when compared to the previously mentioned white-light studies. Collectively, this provides additional support for current AMSA recommendations regarding the use of red-lighting with consumers, as the consumers in the current study as well as in previous work, have evaluated samples differently under red versus white-lighting, with samples evaluated under white-lighting typically receiving higher ratings.

There were no ($P > 0.05$) consumer DOD preference × steak DOD interactions, nor consumer DOD preference effects for tenderness, juiciness, and flavor when steaks were evaluated under both lighting types. This indicates all consumers, regardless of DOD preference, rated juiciness, tenderness, and flavor similar. Within both lighting types, there were DOD effects ($P < 0.05$) for all palatability traits (Table 2.3). Within red and white-light testing, rare

and medium-rare were rated similar ($P > 0.05$), but more tender, juicy, and flavorful ($P < 0.05$) when compared to other DOD. Additionally, for tenderness and flavor, medium and medium-well steaks were similar ($P > 0.05$) in both red and white-light testing. In the red-light test, juiciness ratings for medium and medium-well were similar ($P > 0.05$); however, within the white-light test medium-well was rated drier ($P < 0.05$) when compared to medium. Steaks cooked to well-done were rated the toughest, driest, and least flavorful ($P < 0.05$) when compared to all other treatments in both lighting scenarios. Despite well-done consumers visually appraising rare steaks prior to consumption in the white-light tests, they assessed samples similar to the consumers who preferred rare for tenderness, juiciness, and flavor, and vice versa for the consumers who preferred rare. This may be in part due to the anchors used on the palatability scales. For tenderness and juiciness, scale anchors were more objective in nature, labeled as a degree of toughness or juiciness, rather than an opinion driven liking scale. Using these scales, consumers of all DOD preferences would have rated samples based on the magnitude of tenderness and juiciness, despite their own preference.

Some of the first research that incorporated DOD, evaluated the longissimus muscle at 60, 71, and 82°C, and the authors reported tenderness, juiciness, and flavor ratings decreased as temperature increased (Gilpin et al., 1965). Various other researchers have also shown the effect DOD has on palatability ratings (Parrish et al., 1973; Lorenzen et al., 2005; McKillip et al., 2017; Drey et al., 2018). Two of the more extensive DOD studies that incorporated all 6 DOD reported by the NCBA include Lorenzen et al. (2005) and Drey et al. (2018). Data from the 5 previously mentioned studies was pulled together to evaluate the effect of consumer palatability ratings across all six DOD (Figure 1.1). In order to make a direct comparison, all data reported was converted to a percentage. The regression models explained 82 and 85% of the variability of the

rating data for tenderness (r^2 = 0.82) and juiciness (r^2 = 0.85), respectively. Additionally, the regression model only explained 7% of the variation for flavor (r^2 = 0.07); however, a more fit regression line for overall liking (r^2 = 0.64) to explain how detrimental DOD is on overall liking . For every 3°C increase in temperature, there was a corresponding decrease in consumer ratings of 4.74% for tenderness, 2.85% for juiciness, 2.37% for flavor, and 6.69% for overall liking.

The overall effect of DOD comes down to the fact that palatability attributes decline. As internal temperature increases, beef steaks become tougher (Cover et al., 1962; Parrish et al., 1973). Drey et al. (2018) evaluated Warner-Bratzler shear force of steaks cooked to 6 degrees of doneness and reported medium-rare as the most tender, only similar to rare. Lorenzen et al. (2005) reported Warner-Bratzler shear force results, and found well-done and very well-done were the toughest, and no other differences were found among the other 4 lower DOD. Consumers in the current study, were able to detect tenderness differences within the lower DODs and support Drey et al. (2018) by rating rare and medium-rare as the most tender. Additionally, in regard to juiciness, Lucherk et al. (2016) stated that the greater the internal cooking temperature, the less juicy a meat cut will be. As internal temperature increased, pressed juice percentage (an instrumental measure of juiciness) decreased (Lucherk et al., 2016; Drey et al., 2018). Consumers in the current study also perceived well-done to be the least juicy. Furthermore, in trained descriptive sensory analysis, panelists rated well-done with the most beef flavor attribute; however, no differences were found in regard to flavor liking across 6 degrees of doneness (Lorenzen et al., 2005). Consumers in the current study found differences in flavor, with well-done being rated the lowest.

There were no consumer preference × steak DOD interactions ($P > 0.05$) for the percentage of samples rated acceptable for juiciness and flavor under red or white-lights. Within red and white-light testing for juiciness acceptability, rare and medium-rare steaks had a similar ($P > 0.05$) percentage of samples rated acceptable, but a greater percentage than all other DOD ($P < 0.05$; Table 2.3). In the red-light test, juiciness ratings for medium and medium-well were similar ($P > 0.05$); however, within the white-light test, medium-well had a lower ($P < 0.05$) percentage of samples rated acceptable for juiciness when compared to medium. Under both red and white-lights, steaks cooked to well-done had the lowest ($P < 0.05$) percentage of samples rated acceptable for juiciness when compared to all other treatments. Under red-lights, rare, medium-rare, and medium had a greater ($P < 0.05$) percentage of steaks rated acceptable for flavor, although rare and medium were also similar ($P > 0.05$) to medium-well. Under white-light, rare was rated similar to medium-rare and medium ($P > 0.05$) for the percentage of steaks rated acceptable for flavor. Additionally, well-done had the lowest ($P < 0.05$) percentage of steaks rated as acceptable for flavor, being similar ($P > 0.05$) only to medium-well under both lighting scenarios.

Within the white-light testing, the consumer DOD preference × steak DOD interaction for overall liking was marginally significant ($P = 0.078$; Table 2.4). There was also a consumer DOD preference × steak DOD interaction ($P < 0.05$) under white-lights for the percentage of samples rated acceptable for tenderness and overall, whereas there were no interactions under red-light ($P > 0.05$) for these traits. Within red and white-light tests, consumers that preferred rare, rated rare and medium-rare the greatest ($P < 0.05$) for overall liking and percentage of steaks rated acceptable for tenderness. Well-done was rated with the lowest ($P < 0.05$) overall liking and percentage of samples rated as acceptable for tenderness, being similar ($P > 0.05$) to

medium-well, which was also similar ($P > 0.05$) to medium. Additionally, rare, medium-rare, and medium had the greatest ($P < 0.05$) for percentage of steaks rated acceptable overall by consumers who preferred rare. Well-done had the lowest ($P < 0.05$) of steaks rated as acceptable overall from rare consumers, also being similar ($P > 0.05$) to medium and medium-well in the red-light test. Under both red and white-lights consumers who preferred medium rated rare and medium-rare the greatest ($P < 0.05$) for overall liking; whereas well-done was rated with the lowest ($P < 0.05$) overall liking, being only similar ($P > 0.05$) to medium-well in the red-light test. Furthermore, under red-lights medium consumers perceived rare, medium-rare, and medium-well with the highest ($P < 0.05$) percentage of steaks rated as acceptable for tenderness, being similar ($P > 0.05$) to medium. However, in the white-light test, rare had the highest ($P < 0.05$) percentage of steaks rated as acceptable for tenderness, only being similar ($P > 0.05$) to medium-rare. When well-done was evaluated by medium consumers they had the lowest ($P < 0.05$) percentage of steaks rated as acceptable for tenderness. Medium consumers perceived well-done steaks with the lowest percentage of steaks rated as acceptable overall; however, in the white-light test well-done was similar ($P > 0.05$) to medium-well. For well-done consumers under the red-lights, rare and medium-rare were rated with the greatest ($P < 0.05$) overall liking, being similar ($P > 0.05$) to medium-well, whereas well-done was rated with the lowest ($P < 0.05$) overall liking, being only similar ($P > 0.05$) to medium. When well-done consumers were fed under white-lights there were no significant differences ($P > 0.05$) for overall liking. Additionally, well-done consumers evaluated rare and medium-rare with the highest ($P < 0.05$) percentage of steaks rated as acceptable for tenderness, being similar ($P > 0.05$) to medium, whereas well-done was rated with the lowest ($P < 0.05$) percentage rated as acceptable for tenderness, being only similar ($P > 0.05$) to medium-well. When well-done consumers were fed

under white-lights there were no significant differences ($P > 0.05$) for tenderness acceptability. Consumers who preferred well-done found no significant differences ($P > 0.05$) in overall acceptability under red-lights; however, under white-lights, medium-rare had the highest ($P < 0.05$) percentage of steaks rated acceptable overall, being similar ($P > 0.05$) to medium and medium-well.

Inherently for the traits that were more objective in nature and had anchors that were listed with more objective terms (tenderness and juiciness), consumer opinions were not strongly biased by the visual appearance of the steak's DOD; however, when consumers assessed overall liking or whether or not the sample was acceptable on scales that were more opinion based (acceptability), the consumers' DOD bias was more evident. In a study conducted by Garber et al. (2000), consumers were served 3 flavors of drink mix in 3 different colors. Consumer results showed that color dominated their expectation of beverages, confirming the important role color plays in consumers' abilities to correctly identify beverage acceptability (Garber et al., 2000). Previously in beef, Cox et al. (1997) assessed consumers for their attitude toward meat products. The consumers that ordered their steak well-done reported their preference was emotive, citing food safety concerns and disliking of blood. In an article published by Boston Eaters, chefs were asked how they would like to respond to consumers that ordered steak well-done. Michael Schlow, chef and owner of Via Matta, Tico, and Alta Strada, responded, "I think part of it is the color for people. It certainly can't be that they like it drier. They look at it and maybe get a little squeamish" (Blumenthal, 2014). That "squeamish" feeling is ultimately what drives a consumer to consistently order well-done steaks and serving undercooked steaks is unacceptable for them in regard to sensory ratings and emotionally. Well-done consumers in this study changed their ratings substantially. Inferences can be made that those results are due to the "squeamish" feeling

and emotional disliking when consumers who preferred well-done saw the samples under white-light.

Perceived quality of strip loin steaks

There were no consumer preference × steak DOD interactions ($P > 0.05$) for the percentage of samples rated as everyday quality or premium quality (Table 2.5). Under red-lights, medium-well and well-done had the highest ($P < 0.05$) percentage of samples rated as everyday quality, rare and medium were similar ($P > 0.05$), with medium-rare having the fewest perceived as everyday quality ($P < 0.05$), being only similar to rare ($P > 0.05$). Within the white-light testing, rare and medium-rare steaks had the lowest percentage of samples rated as everyday quality ($P < 0.05$), whereas, medium, medium-well, and well-done had the highest ($P < 0.05$) and were similar ($P > 0.05$). Under white-lights the percentage of rare and well-done steaks rated as everyday quality dropped 20 and 9%, respectively, compared to the red-light test. Under red and white-lights, consumers reported the greatest percentage of rare and medium-rare steaks as premium quality ($P < 0.05$). Additionally, medium and medium-well were similar ($P > 0.05$); however, well-done had the fewest ($P < 0.05$) samples perceived as premium. Although results from red and white-light tests followed the same trend for premium quality, the percentage of rare and medium-rare steaks increased over 11% for consumers when seen under the white-light.

There were consumer preference × steak DOD interactions for the percentage of samples rated as unsatisfactory and better than everyday quality ($P < 0.05$; Table 2.6). For consumers who preferred rare, unsatisfactory ratings for medium-rare and medium actually decreased under white-lights; however, well-done unsatisfactory ratings increased 44% when seen under white-lights. For consumers who preferred medium, unsatisfactory percentages for medium-rare decreased under white-lights; however, medium-well unsatisfactory ratings increased 8% when

seen under white lights. Under red-lights, there were no differences ($P > 0.05$) for the percentage of samples rated as unsatisfactory for well-done consumers. Under white-lights, well-done consumers rated medium with the lowest ($P < 0.05$) percentage of unsatisfactory quality, also being similar ($P > 0.05$) to medium-rare and medium-well. No differences ($P > 0.05$) were found within well-done consumers for better than everyday quality for red and white-light tests.

Impact of under- and overcooking

By screening the consumers for DOD preference, this allowed for a measure of the impact of "missing" the consumer's preferred DOD and allowed for a quantification of the impact of under- and overcooking steaks on consumer palatability and acceptability ratings. In order to describe how severely steaks were under- or overcooked, terms one under/over, two under/over, three under/over, and four over/under, were used to describe the difference of the steak served in comparison to their preferred DOD. Overall, when steaks were undercooked, they were rated higher for all ratings and when steaks were overcooked, ratings decreased, regardless of the consumer's DOD preference (Figure 2.1). For tenderness, flavor, and overall liking ratings, when steaks were cooked below the consumer's preference, ratings increased ($P < 0.05$) compared to their preferred DOD. When steaks were cooked below the consumer's preference, juiciness ratings increased ($P < 0.05$), except one under was similar ($P > 0.05$) when compared to their preferred DOD. Steaks cooked four DOD over the consumer's preferred DOD were rated tougher ($P < 0.05$) and lower ($P < 0.05$) for flavor liking than steaks cooked to their preferred DOD. However, for juiciness and overall liking overcooked steaks were rated similar ($P > 0.05$) to their preferred DOD. Although not significant at each successive DOD, sensory rating means decreased as the amount of overcooking increased from two over to four over the consumers' preferred DOD. Additionally, for the change in the percentage of steaks rated as acceptable for

each sensory attribute, overall undercooking had a more positive effect (Figure 2.2). Although not significant at each successive DOD, sensory rating means increased from one under, to two under, to three under. However, at four under the consumers' preferred DOD, the percentage of steaks rated as acceptable for the sensory attribute dropped and was similar ($P > 0.05$) to the consumers preferred, with the exception of juiciness acceptability where four under the consumers' preferred DOD was greater ($P > 0.05$) than the preferred DOD. Although not significant at each successive DOD, sensory rating means decreased as the amount of overcooking increased compared to the consumers' preferred DOD. As DOD progressed from one over to four over the consumers preference, the mean for the percentage of steaks rated as acceptability for each sensory attribute decreased.

Two previous studies have attempted to predict the effects of under- and overcooking on steak palatability. Within each of these studies, the attempt was made to feed consumers their preferred DOD and have them assess whether the steak served met their expectations. Cox et al. (1997) sampled over 3,400 consumers in nine restaurants. Consumers ordered their steak cooked to their preference. Once served, steaks were visually assessed for observed DOD and sensory ratings (Cox et al., 1997). Cox et al. (1997) reported 30% of consumers considered their steak was not delivered as ordered. If the difference in DOD ordered was under- or overcooked by one DOD, tenderness ratings scores fell 6.5 and 17.8%, meanwhile, steaks that were delivered two DODs under- or overcooked tenderness ratings dropped 16.2 and 24.5% (Cox et al.,1997). When served three DODs different than what the consumer ordered, tenderness ratings continued to decline by 17.8 and 27.7% (Cox et al., 1997). In the current study, ratings for steaks undercooked in regard to the consumers preference did not decline. Similarly, within the current study and Cox et al. (1997), there is a similar stair-step in the decline of ratings as the DOD got further

overcooked from their preference. The authors found no differences in palatability ratings among DODs, inferring that consumers who received their steak cooked to the DOD ordered all had similar experiences of tenderness, juiciness, and flavor. Similarly, to the current study, Cox et al. (1997) ultimately concluded overcooking had a greater negative impact versus steaks perceived to be undercooked. Furthermore, Cox et al. (1997) noted a disconnect in communication of DOD between chefs and consumers, even stating that photographic standards may be more appropriate than terms such as rare, medium, and well-done.

In another study by Schmidt et al. (2002), the authors reported consumer ratings for steaks that were cooked correctly, under-, and overcooked. Out of the 210 consumers, more perceived their steak to be undercooked (23.8%) versus overcooked (17.1%) (Schmidt et al., 2002). The results showed undercooking did not affect tenderness or juiciness ratings, and had a similar affect to overcooking on flavor-like and overall-like (Schmidt et al., 2002). Unfortunately, since this was not the objective of their study, the authors did not report how severely the steak's DOD was missed and consumers were only fed a single steak. By feeding the consumers in our study each DOD under red and white-light, we were able to quantify the change in ratings due to DOD within each consumer. Perhaps in the Schmidt et al. (2002) study, steaks were not severely enough undercooked for the consumer to detect the differences in sensory ratings seen in the current study. Additionally, unlike our results, consumers in the Schmidt et al. (2002) study, perceieved the impact of under- and overcooking to both be negative. Moreover, Schmidt et al. (2002), concluded further research focusing on consumers' and chefs' perception of the varying DOD was necessary.

CONCLUSION

When the consumers were blinded to the DOD under red-lights, there were no differences among consumers of varying DOD preferences in how they evaluated steaks. The sensory cue of sight significantly impacted palatability ratings. As the consumers DOD preference increased, the more their ratings differed than in the red-light test. Overall, regardless of the consumers DOD preference, undercooking had a positive effect versus their preferred DOD, and overcooking negatively impacted sensory ratings. Therefore, it is better for steaks served at restaurants to err on the side of being undercooked in order to maximize the consumers eating experience.

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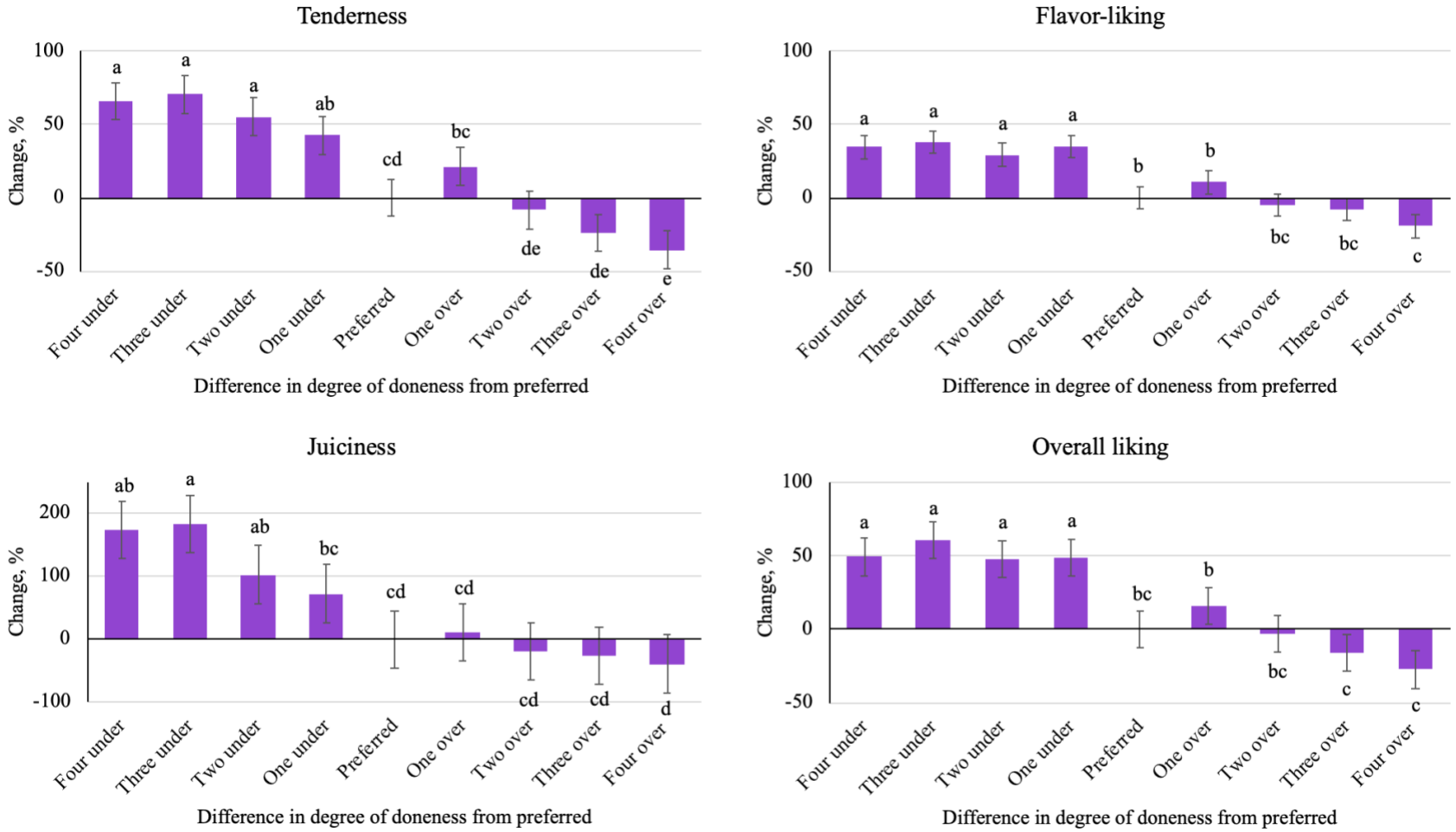

Figure 2.1 Percentage change in the sensory rating between the red-light and white-light testing to represent the impact of under and overcooking steaks on consumer palatability ratings.

[abcde] Means within the same sensory characteristic without a common superscript differ ($P < 0.05$).

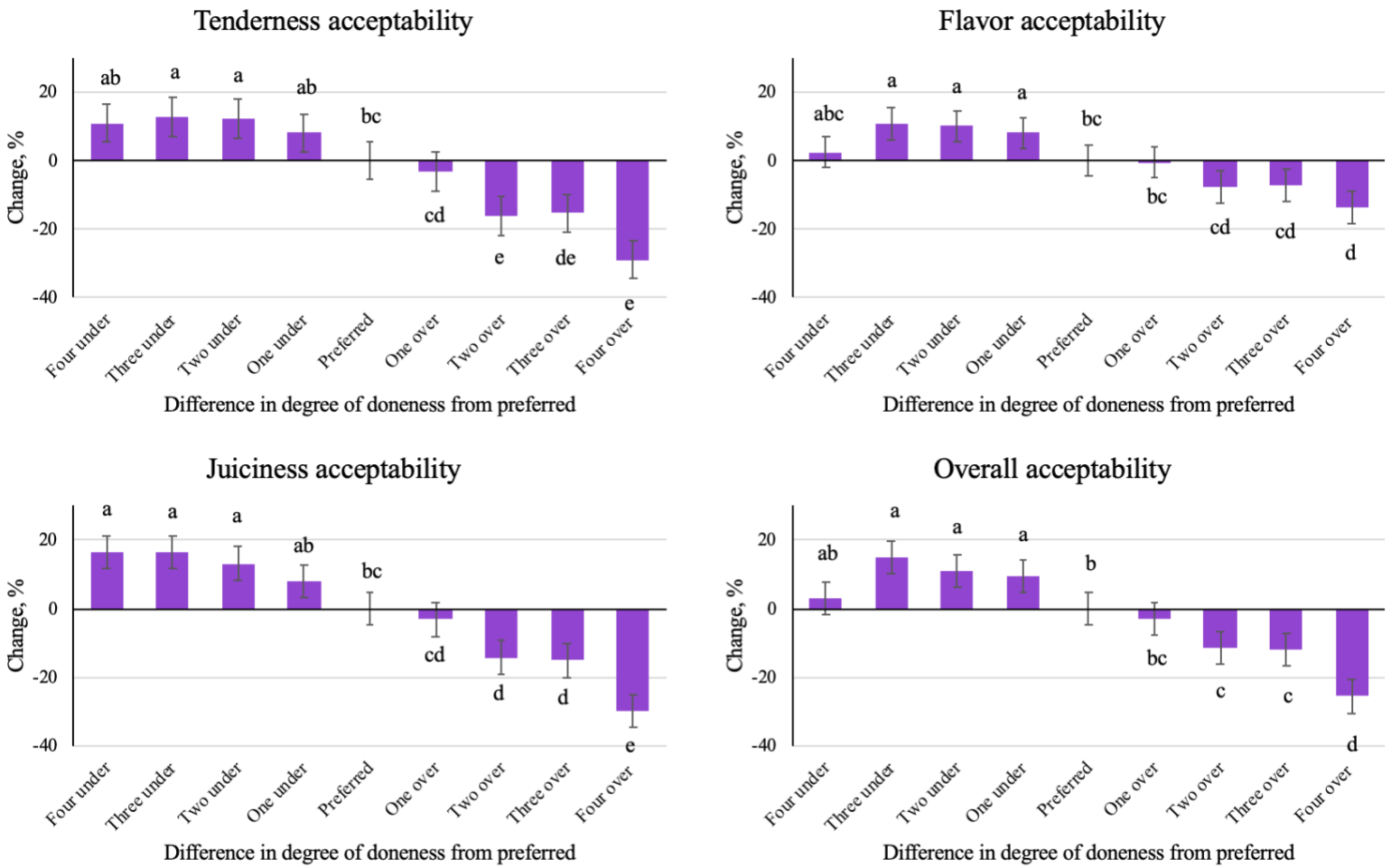

Figure 2.2 Percentage change in the sensory acceptability ratings between the red-light and white-light testing to represent the impact of under and overcooking steaks on the percentage of samples rated acceptable for each palatability trait.

[abcde] Means within the same sensory characteristic without a common superscript differ ($P < 0.05$).

Table 2.1 Demographic characteristics of consumers (*N* = 283) who participated in sensory panels

Characteristic	Response	Percentage of consumers
Sex	Male	49.2
	Female	50.7
Household size	1 person	20.4
	2 people	19.4
	3 people	15.1
	4 people	24.3
	5 people	14.1
	6 or more people	6.3
Marital status	Single	57.2
	Married	42.7
Age group	Under 20	12.3
	20-29	42.4
	30-39	10.6
	40-49	16.6
	50-59	11.6
	Over 60	6.3
Ethnic origin	African-American	6.0
	Caucasian/white	73.4
	Hispanic	12.4
	Asian	4.2
	Native American	0.7
	Mixed race	2.1
	Other	1.0
Annual household income, $	Less than 25,000	22.0
	25,000 to 34,999	8.9
	35,000 to 49,999	9.9
	50,000 to 74,999	16.3
	75,000 to 100,000	14.2
	More than 100,000	28.4
Highest level of education completed	High school graduate	13.4
	Some college/technical school	34.2
	College graduate	29.3
	Post graduate	20.1
Weekly beef consumption	1 to 3 times	46.0
	4 to 6 times	31.7
	7 or more times	22.3
Most important palatability trait when eating beef	Flavor	54.4
	Juiciness	12.7
	Tenderness	32.8

Table 2.2 Fresh beef steak purchasing motivators of consumers (*N* = 283) who participated in consumer sensory panels

Characteristic	Importance of each trait[1]
Price	72.4[a]
Size, weight, and thickness	67.6[b]
Color	65.3[b]
Marbling	64.9[b]
USDA grade	63.4[bc]
Familiarity with cut	60.0[cd]
Eating satisfaction claims	57.7[d]
Animal welfare	55.9[d]
Nutrient content	55.9[d]
Antibiotic use in the animal	47.4[e]
Growth hormone use in the animal	44.9[ef]
Packaging type	41.3[fg]
Animal fed a forage-based diet	40.1[g]
Animal fed a corn-based diet	38.9[g]
Natural or organic claims	38.4[g]
Brand	38.0[g]
SEM	2.4
P – value	< 0.01

[abcdefg] Means without a common superscript differ ($P < 0.05$).

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

Table 2.3 Consumer (*N* = 283) palatability ratings[1] and acceptability percentage[2] of strip loin steaks cooked to various degrees of doneness when evaluated under red and white lights

Treatment	Tenderness	Juiciness	Flavor	Juiciness acceptability	Flavor acceptability
Red-light testing					
Rare	71.8[a]	76.7[a]	66.2[a]	94.9[a]	88.5[ab]
Medium-rare	71.8[a]	73.9[a]	66.7[a]	93.9[a]	89.8[a]
Medium	60.4[b]	59.9[b]	59.4[b]	85.4[b]	86.3[ab]
Medium-well	61.1[b]	56.0[b]	57.0[b]	81.2[b]	82.7[bc]
Well-done	52.5[c]	48.6[c]	52.5[c]	67.2[c]	79.2[c]
SEM	2.1	2.2	1.8	3.4	2.8
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
White-light testing					
Rare	74.0[a]	80.2[a]	69.1[a]	97.2[a]	90.8[ab]
Medium-rare	73.9[a]	77.5[a]	70.4[a]	95.2[a]	92.6[a]
Medium	60.1[b]	61.7[b]	62.4[b]	85.8[b]	86.6[bc]
Medium-well	59.0[b]	56.8[c]	59.9[b]	79.5[c]	84.6[cd]
Well-done	50.1[c]	48.9[d]	54.8[c]	69.4[d]	78.2[d]
SEM	2.4	2.2	2.0	3.2	2.9
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

[abcd] Means within the same section (red-light or white-light) of the same column without a common superscript differ ($P < 0.05$).

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

[2]Percentage of samples rated as acceptable for each palatability trait.

Table 2.4 Interaction means for overall liking ratings[1] and acceptability percentage[2] of beef strip steaks cooked to various degrees of doneness for tenderness and overall liking by consumers (*N* = 283; 95 rare; 95 medium; 93 well-done preference[2]) evaluated under red and white lights

	Rare consumers[3]			Medium consumers[3]			Well-done consumers[3]		
Treatment	Overall liking	Tenderness acceptability	Overall acceptability	Overall liking	Tenderness acceptability	Overall acceptability	Overall liking	Tenderness acceptability	Overall acceptability
Red-light testing									
Rare	71.7^{a}	97.2^{a}	95.2^{a}	65.9^{a}	95.5^{a}	92.2^{a}	66.7^{a}	95.4^{a}	86.9
Medium-rare	73.5^{a}	98.1^{a}	93.2^{ab}	65.8^{a}	94.6^{ab}	93.2^{a}	66.4^{a}	95.4^{a}	92.1
Medium	63.8^{b}	88.4^{b}	88.2^{abc}	57.6^{b}	85.9^{bc}	79.9^{b}	58.9^{bc}	89.6^{ab}	90.0
Medium-well	57.5^{bc}	86.4^{bc}	86.2^{bc}	55.5^{bc}	89.9^{ab}	86.1^{ab}	63.6^{ab}	85.6^{bc}	83.8
Well-done	52.3^{c}	74.9^{c}	78.9^{c}	49.3^{c}	73.2^{c}	72.4^{c}	54.4^{c}	81.4^{c}	82.7
SEM	2.9	5.6	4.7	2.9	5.8	5.3	2.9	4.9	4.3
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.26
White-light testing									
Rare	75.7^{a}	98.2^{a}	95.0^{a}	70.4^{a}	98.2^{a}	95.2^{ab}	65.4	88.3	79.4^{bc}
Medium-rare	75.6^{a}	99.1^{a}	97.0^{a}	73.2^{a}	95.5^{ab}	96.2^{a}	67.7	90.3	91.0^{a}
Medium	63.9^{b}	86.8^{b}	91.0^{ab}	60.4^{b}	87.9^{bc}	87.2^{bc}	62.3	90.3	90.0^{ab}
Medium-well	60.2^{bc}	84.7^{bc}	83.8^{b}	57.6^{b}	80.9^{c}	78.9^{cd}	61.3	85.2	85.8^{ab}
Well-done	53.2^{c}	70.8^{c}	70.0^{c}	48.4^{c}	70.8^{d}	68.2^{d}	57.4	77.8	76.2^{c}
SEM	2.9	6.0	5.4	2.9	6.3	5.5	2.9	5.3	5.0
P – value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.07	0.08	0.02

[abcd] Means within the same section (red-light or white-light) of the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 100 = like extremely; 50 = neither dislike or like; 0 = dislike extremely.

[2]Percentage of samples rated as acceptable for each palatability trait.

[3]Consumers were screened for their preferred degree of doneness prior to panels but evaluated all five degrees of doneness.

Table 2.5 Percentage of beef strip steaks cooked to various degrees of doneness categorized as perceived eating quality levels by consumers (*N* = 283) when evaluated under red and white lights

Treatment	Everyday quality	Premium quality
Red-light testing		
Rare	44.8[bc]	11.4[a]
Medium-rare	40.8[c]	11.8[a]
Medium	50.2[b]	4.5[b]
Medium-well	60.6[a]	4.3[b]
Well-done	59.2[a]	1.2[c]
SEM	3.1	2.5
P – value	< 0.01	< 0.01
White-light testing		
Rare	25.2[b]	22.4[a]
Medium-rare	30.6[b]	23.1[a]
Medium	53.4[a]	8.0[b]
Medium-well	49.5[a]	8.2[b]
Well-done	49.8[a]	2.4[c]
SEM	3.1	3.2
P – value	< 0.01	< 0.01

[abc] Means within the same section (red-light or white-light testing) of the same column without a common superscript differ ($P < 0.05$).

Table 2.6 Interaction means for the percentage of beef strip steaks cooked to various degrees of doneness categorized as perceived eating quality levels by consumers (*N* = 283; 95 rare; 95 medium; 93 well-done preference[1]) evaluated under red and white lights

	Rare consumer[1]		Medium consumer[1]		Well-done consumer[1]	
Treatment	Unsatisfactory quality	Better than everyday quality	Unsatisfactory quality	Better than everyday quality	Unsatisfactory quality	Better than everyday quality
Red-light testing						
Rare	1.9^{c}	39.0^{a}	5.9^{d}	28.4^{ab}	9.2	37.6
Medium-rare	4.9^{bc}	43.2^{a}	7.9^{cd}	34.7^{a}	6.1	35.5
Medium	8.9^{ab}	35.8^{a}	19.2^{ab}	20.0^{b}	9.2	36.6
Medium-well	15.0^{a}	17.9^{b}	12.0^{bcd}	16.8^{b}	11.2	25.8
Well-done	18.1^{a}	20.0^{b}	27.7^{a}	16.8^{b}	11.2	21.5
SEM	4.3	5.1	5.2	4.9	3.5	5.0
P – value	< 0.01	< 0.01	< 0.01	0.01	0.73	0.07
White-light testing						
Rare	2.0^{c}	52.6^{a}	7.0^{cd}	42.0^{a}	16.5^{a}	29.8
Medium-rare	3.0^{c}	43.0^{a}	4.9^{d}	35.6^{ab}	11.3^{ab}	34.1
Medium	6.0^{c}	24.9^{b}	14.1^{bc}	30.2^{ab}	6.1^{b}	28.7
Medium-well	15.2^{b}	21.7^{b}	20.3^{ab}	22.8^{bc}	13.4^{ab}	26.5
Well-done	32.2^{a}	15.4^{b}	28.8^{a}	13.4^{c}	21.9^{a}	25.4
SEM	5.4	5.5	5.2	5.5	2.9	5.3
P – value	< 0.01	< 0.01	< 0.01	< 0.01	0.04	0.73

[abcd] Means within the same section (red-light or white-light testing) of the same column without a common superscript differ ($P < 0.05$).

[1]Consumers were screened for their preferred degree of doneness prior to panels but evaluated all five degrees of doneness.

Chapter 3 - Do published cooking temperatures correspond with consumer and chef perceptions of beef degrees of doneness?

ABSTRACT

The objective of this study was to determine the effect of quality grade and time after cooking on the instrumental color of steaks cooked to varying degrees of doneness (**DOD**), as well as assess consumer and foodservice steak preparation practices and consumer and chefs' abilities to identify DOD. Steaks from 24 beef strip loins from 12 animals from each of five quality treatments were used for this study. Steaks were cooked to an endpoint temperature of either very rare [55°C (130°F)], rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], well-done [77°C (170°F)], or very well-done [82°C (180°F)]. L*, a*, and b* was evaluated at 0, 1, 2, 3, 6, 9, and 12 min post-cutting using a Hunter Lab Miniscan spectrophotometer and digital pictures were taken immediately on an internal slice of the steak. A separate digital survey for consumers and chefs was created for the evaluation of the pictures of the cooked steaks. There were time × DOD interactions ($P < 0.05$) for L*, a*, and b*. For very rare, rare, medium-rare, and medium, a* values increased ($P < 0.05$) over time. However, for well-done, time only had a minimal impact ($P < 0.05$) on a* values and no differences ($P > 0.05$) were seen across time for very well-done. These results provide insight into cooked beef color changes related to time and how this might impact DOD perceptions by consumers. When consumers determine DOD when cooking beef in their home, they typically use color (54%), a food thermometer (16%), feel or firmness (15.7%) and time (10.4%). Of consumers that utilized a thermometer, 69% reported the temperature they use as their indication of DOD is the temperature they pull off the heat, whereas 31% reported the temperature they use for DOD determination is the temperature following the post-cooking temperature rise. The majority

(66%) of chefs reported using feel or firmness for DOD indication, whereas 28% stated they use a thermometer, color (1.2%). There were no quality grade effects ($P > 0.05$) for any DOD of the steak pictures evaluated by consumers or chefs. Consumers were able to accurately match the DOD of the steak pictured to the correct end-point temperature, although this percentage ranged from only 27 to 35%. Additionally, chefs were unable to consistently and accurately identify DOD of steaks cooked to specified end-point temperatures. This can create challenges for foodservice establishments to deliver upon consumers DOD preferences. Differences exist in the perceptions of doneness between culinary professionals and meat researchers and these may have consumer acceptability implications for whole muscle products.

INTRODUCTION

Degree of doneness (**DOD)** is important to achieving optimal palatability (Lorenzen et al., 2005; Lucherk et al., 2016; Drey et al., 2018). An increase in internal temperature results in greater myoglobin denaturation and a subsequent cooked brown color (Mancini and Hunt, 2005). Previous research has demonstrated cooked color has a large impact on consumer perception (Suman et al., 2016). Furthermore, consumers' perception of the DOD they are served can impact their eating satisfaction (Cox et al., 1997; Schmidt et al., 2002). There are various sources that have differing opinions on the beef temperatures that correspond to each DOD (Table 3.1). The temperature to which a steak is cooked can be reported as the temperature at which the steak is removed from the heat or a peak temperature that includes the post-cooking temperature rise.

A set of commonly used beef DOD temperatures are published by the National Cattleman's Beef Association (**NCBA**). They publish a Beef Steak Color Guide with steak pictures associated with each temperature (NCBA, 2008). The reported six DODs on the steak

color guide are: very rare 54°C (130°F), rare 60°C (140°F), medium-rare 63°C (145°F), medium 71°C (160°F), well-done 77°C (170°F), and very well-done 82°C (180°F). However, it is unclear if these temperatures are pull-off the heat temperatures or peak temperatures. The history behind these reported temperatures' dates back to 1979 when the National Livestock and Meat Board in cooperation with Texas A&M University attempted to better define DOD with the first Beef Steak Color Guide. Drey (2018) reported through personal communication with Dr. Gary Smith and Dr. Russell Cross, the temperatures were decided upon by an expert panel of meat science professionals following visual appraisal of the steaks cooked to differing end-points.

The American Meat Science Association (**AMSA**) Guidelines for Cookery and Sensory Evaluation of Meat has played a vital role defining a uniform methodology used to prepare, cook, and evaluate meat samples (AMSA, 1995). In 1995, the AMSA included a beef steak color guide and that was adopted as the official guide for the NCBA. The most current AMSA sensory guidelines do not include a beef steak color guide, but instead indicate that color is not an indication of doneness and that internal temperature should be utilized (AMSA, 2015). But, in this updated version, it is recommended, depending on the cooking method, to account for carry-over cooking, and report peak temperatures. Little research has extensively studied consumers' DOD cooking practices in addition to their ability to identify steak DOD. An additional component is foodservice chefs' preparation of steaks, as it provides a critical link between the beef industry and consumers. Little research exists that has evaluated chefs' cooking methods and use of thermometers. It was therefore the objective of this study to assess if the visual DOD are in line with current published temperatures; as well, if consumers and chefs are in general agreement.

MATERIALS AND METHODS

The Kansas State University Institutional Review Board approved all procedures for use of human subjects in internet survey distribution (IRB: #9101 January, 2018).

Experimental treatments

Further details of sub-primal fabrication, enhancement, and steak allocation was described by Drey et al. (2018). In brief, 24 beef strip loins [Institutional Meat Purchasing Specifications #180; (North American Meat Institute, 2014)] representing four quality grades [Prime (slightly abundant^{00} – abundant^{100} marbling), Top Choice (modest^{00} – moderate^{100} marbling), Low Choice (small^{00} – small^{100} marbling), and Select (slight^{00} – slight^{100} marbling)] were collected from 12 animals at a Midwest beef processor and transported to the Kansas State University Meat Laboratory. An additional 24 Select loins were designated for enhancement using a water, salt, and sodium phosphate solution at a 7.8% ± 0.80% pump level. Following the 21 d age period, three consecutively cut steaks were grouped together to achieve 6 groups per carcass. Each group of steaks were randomly assigned DOD either of very rare [55°C (130°F)], rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], well-done [77°C (170°F)], or very well-done [82°C (180°F)] (AMSA, 2016; NCBA, 2008). Within the group, the steak randomly assigned to objective tenderness and juiciness measurement, and cooked proximate analysis was also utilized for cooked color readings and pictures. Following fabrication, all steaks were vacuum packaged and frozen at -40°C until further analysis.

Cooking

Steaks were thawed at 2 to 4°C for 24 h prior to cooking. Steaks were cooked on clam-style grills (Cuisinart Griddler; Cuisinart, Stamford, CT) set to a surface temperature of 177°C. A probe thermometer (Super-Fast Thermopen, ThermoWorks, American Fork, UT) was inserted

into the geometric center of each steak. The thermometer remained in place during the cooking process and steaks were removed following cooking so that the peak end-point temperature would correspond to the assigned DOD either of very rare [55°C (130°F)], rare [60°C (140°F)], medium-rare [63°C (145°F)], medium [71°C (160°F)], well-done [77°C (170°F)], or very well-done [82°C (180°F)] (AMSA, 2015; NCBA, 2008).

Color readings and photographs

Following cooking, steaks (N = 357) were rested for 3 min before cutting for evaluation. Each cooked steak was cut in half, perpendicular to the long axis of the steak, and photographs were taken immediately using a digital camera (Canon PowerShot SX620 HS) on a slice from the internal face of the lateral side (Figure 3.1). The camera was programmed to take each photograph in portrait mode, 15.2 cm distance from the face of the steak, on a solid black background under florescent lights (Figure 3.2). Instrumental color was measured on the internal face of the medial side of the cooked steak and was evaluated immediately for L*, a*, and b* using a Hunter Lab Miniscan spectrophotometer (Illuminant A, 1.27-cm aperture, 10° observer; Hunter Associates Laboratory, Reston, VA) at three locations on the steak slice and averaged. L*, a*, and b* were evaluated at 1, 2, 3, 6, 9, and 12 min post-cutting for each steak. Additional parts of the steak were designated for Slice Shear force, Warner-Bratzler shear force, Pressed Juice Percentage, and cooked proximate analysis. The results from these analyses are reported by Drey et al. (2018).

Visual survey distribution

A digital survey for consumers (N = 1,134) was made for electronic evaluation (Qualtrics Software, Provo, UT). A majority of consumers (approximately 90%) were participants in other sensory surveys conducted at Kansas State University. These consumers were provided an

electronic tablet (Model 5709 HP Steam 7; HewlettPackard, Palo Alto, CA) to fill out the survey. The remaining consumers (approximately 10%) who participated were recruited via email from a previous consumer database. Surveys contained a basic demographic questionnaire, followed by questions pertaining to temperature and DOD. Consumers were asked what DOD they prefer and how they determine DOD when served steaks at a restaurant. Additionally, consumers were asked about how they determine DOD when cooking beef themselves at home. Consumers were asked to fill in the blank for the temperatures that correspond which each DOD, which included an option of "I do not know." Finally, the Qualtrics Software selected 10 randomized photographs from the bank of pictures (N = 357) of varying DOD and quality grades for each consumer to identify the DOD of the steak pictured. The Qualtrics Software was programmed to balance the number of times each picture was evaluated across the entire study.

A digital survey (Qualtrics Software, Provo, UT) for chefs was also created for the electronic evaluation of the pictures of the cooked steaks. Chefs (N = 83) were recruited via email from around the United States using an established database of chefs from all segments of the industry. Chef demographics were assessed, including age, ethnicity, geographical location, education, and classification of chef. Furthermore, chefs were asked how they determine DOD when cooking steaks, what consumers order in their establishment, and if DOD is retail cut dependent. Chefs were then prompted to fill in the blank of what temperature they think corresponds with each DOD, which included an "I do not know" option. Additionally, chefs were asked to assess the DOD of 30 digital steak pictures representing multiple DOD and quality grades that the Qualtrics Software randomly selected from the bank of pictures (N = 357). In order to maintain balance across the study, the Qualtrics Software was preprogrammed to select pictures accordingly.

Statistical methods

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. Instrumental color data were analyzed as a split-plot with the whole plot factor of quality treatment and sub-plot factor of DOD. For instrumental color data, time was used as a repeated measure. All consumer and chef survey data were analyzed as a completely randomized design. For all analyses, the Kenward–Roger approximation was utilized. For all significant interactions the SLICE option of the LS MEANS statement was used to restrict comparisons to within DOD. Demographic data were summarized using PROC FREQ.

RESULTS AND DISCUSSION

L, a*, b**

There were no ($P > 0.05$) DOD × quality treatment × time interactions for L*, a*, or b*. For L*, there was a quality treatment × time interaction ($P < 0.05$; Table 3.2). There was no difference ($P > 0.05$) among quality treatments for L* value at any time point, except at 12 min, in which Top Choice samples were lighter ($P < 0.05$) than Select Enhanced samples. Additionally, there were time × DOD interactions ($P < 0.05$) for L*, a*, and b*. For L*, in very rare, rare, and medium-rare the color lightened ($P < 0.05$; Figure 3.3) as time progressed from 0 to 12 min. Whereas for well-done and very well-done, the color darkened ($P < 0.05$) over time. For very rare, rare, medium-rare, and medium, a* values increased ($P < 0.05$; Figure 3.4) over time. However, for well-done, time only had a minimal impact ($P < 0.05$) on a* values and no differences ($P > 0.05$) were seen across time for very well-done. For b*, values increased ($P < 0.05$; Figure 3.5) over time within each DOD; however, these changes were more prevalent at lower DOD, with increased ($P < 0.05$) b* values at each successive time point within very rare

samples, but similar ($P > 0.05$) across the final three time points for well-done and very well-done. For a*, quality treatment had an effect ($P < 0.05$; Table 3.3), with Select Enhanced having a lower ($P < 0.05$) value than all treatments other than Prime. Select Enhanced had a lower ($P < 0.05$) b* value than all other quality treatments, with no differences ($P > 0.05$) being found among the other quality grades. Zhu and Brewer (1999) reported an a* change of 0.589 was required before consumers perceived a significant difference in meat redness. This indicates that consumers would be able to detect changes in redness across time. It is inevitable that the divide between consumers and chef's interpretation of DOD is a frustrating factor for consumers and chefs alike. In an article published by Quora, respondents listed a point scale on how upset chefs get when certain situations arise, topping the list was "steak was cooked perfectly, but they [consumer] thought medium meant medium-rare" (Sutton, 2017). Degree of doneness, interpreted as changes in color upon completion of cooking, can be influenced by many factors including fat content (marbling), added ingredients, length of cooking, and internal temperature (Mancini and Hunt, 2005). The longer a consumer allows that steak to sit on their plate before determining DOD at a restaurant will alter their perception if that steak was cooked properly. Additionally, the longer it takes to eat that steak, DOD perceptions will change over time. Within very rare and rare DOD, consumers would be able to see increased redness between 0 to 1 minutes, 1 to 3 minutes, and every other time measurement. Additionally, for rare, although no difference would be detected between 0 and 1 minutes, consumers could visually see a redder color between 0 to 2 minutes and all other time measurements. For steaks cooked to medium-rare, consumers could detect a redder color between 0 to 1 minutes, 1 to 2 minutes, 3 to 6 minutes, and 6 to 12 minutes. As DOD increases, detected redness differences get further apart. Within medium steaks, consumers could detect a redder color between 0 to 2 minutes as well as

between 3 to 9 minutes. Steaks cooked to well-done would have no perceived color differences by the consumer across time, whereas for very-well done, between 0 to 3 minutes consumers could detect less red color. Thus, it is important for consumers in a restraint setting to use the initial color of the cooked steak when they first cut into the steak for DOD determination as the color will change the longer the steak sits on their plate.

The impact of time on cooked color was DOD dependent, with steaks cooked to lower DOD becoming lighter and redder in color with time and steaks cooked to higher DOD becoming darker. Additionally, quality treatment had no impact on cooked color measures of non-enhanced samples. In a study conducted by McKillip et al. (2017), the authors analyzed raw steak L*, a*, and b* of 3 quality grades including Prime, Low Choice, and Low Select, as well as an enhanced treatment of each quality grade. Regardless of enhancement, Prime steaks were the lightest. Select enhanced had the lowest a* and b*, being only similar to Low Choice enhanced, no differences were seen amongst non-enhanced treatments. The raw steak L*, a*, and b* further support the differences seen in the enhanced treatment within the current study's cooked L*, a*, and b*. For visual sensory panelists, L* and a* have been shown to be strongly correlated to muscle color (Brewer et al., 2001; Hulsegge et al., 2001); however, b* is more correlated to brown pigments (O'Sullivan et al., 2003). Hetherington et al. (1990) previously concluded it is possible to predict sensory attributes from instrumental color data in tomatoes. In beef, Yancey et al. (2011) reported instrumental color values from longissimus thoracis steaks cooked to 65.5°C (150°F), 71.1°C (160°F), and 76.6°C (170°F). Steaks cooked to 65.5°C (150°F) were the lightest, most red, and yellow, whereas steaks cooked to 76.6°C (170°F) were the least red and yellow, although similar to medium for L* (Yancey et al., 2011).

In a study conducted by Berry (1998) authors assessed beef patties with differing fat content. Between patties with different fat contents, no differences in DOD were observed. Troutt et al. (1992) reviewed the instrumental color properties of ground beef containing 5 to 30% fat. Samples were cooked to 71°C (160°F) or 77°C (171°F). In contrast to the current study, the authors reported no differences for a* or b* between the two DODs; however, similarly to results seen in this study, there were no a* or b* differences between any of the fat contents. For L*, patties cooked to 77°C (171°F) were darker than 71°C (160°F), as well as patties with 30% fat content were lighter compared to all other treatments. Within the treatments in our study, the percentage of intramuscular fat content would only range from about 4 to 14%, Prime steaks containing the most as reported by Drey et al. (2018). Our results coupled with previous literature provide insight into cooked beef color changes related to time and how this might impact DOD perceptions by consumers.

Consumer and chef participant demographics

Chefs were dispersed across the United States. Chef respondents were 87% male, with 67% between the age of 30 and 49, and 90% Caucasian/White (Table 3.4). Sixty percent reported their education as formal culinary school and 25% as informal, on the job training. Chefs classified the establishments they worked in as independent restaurants (18.1%), casual dining (13.3%), distributors (13.3%), and fine dining (12.1%). Additionally, 69% reported most commonly working with a Premium Choice beef product.

Additionally, the consumer survey was completed by 1,134 consumers. Consumers were majority female (51.5%), Caucasian/White (79.4%), 20 to 29 years old (39.0%), and single (52.2%; Table 3.5). Forty-seven percent of consumers reported consuming beef 1 to 3 times a week and 51% reported flavor as the most important palatability trait when eating beef. In other

recent beef studies consumers also reported flavor as the most important palatability trait (Corbin et al., 2015; Lucherk et al., 2016; McKillip et al., 2017); however, earlier studies by Dikeman (1987), Miller et al. (1995), and Huffman et al. (1996) identified tenderness as the most important trait.

Consumer knowledge of DOD

Forty-one percent of consumers reported medium-rare as their preferred DOD, followed by 23% preferring medium (Figure 3.6). In previous literature, 61 to 70% of consumers reported they prefer beef steaks cooked to at least medium (Branson et al., 1986; Reicks et al., 2011; Schmidt et al., 2002). More recently, 39 to 42% of consumers reported they prefer beef steaks cooked to medium-rare (McKillip et al., 2017; Vierck et al., 2018). Based on data from Longhorn Steakhouse from May 2016 to 2017, consumers ordered rare (2.5%), medium-rare (22.5%), medium (37.5%), medium-well (25.8%), and well-done (11.7%) (Hickey and Dottle, 2017). Cox et al. (1997) reported consumers that ordered their steak well-done reported their preference was primarily emotive, citing choosing this DOD due to food safety concerns and disliking of blood. In that same study, consumers who ordered their steak to a lower DOD, reported their focus was on the improved palpability traits at the lower DOD (Cox et al., 1997). Consumers with differing DOD preferences typically have their personal reasoning behind their preference. Perhaps compared to previous literature, over time consumers have gained more knowledge and trust of steaks cooked under a medium DOD. Additionally, in our study, in a restaurant setting, 59.9% of consumers reported they determine DOD after the first cut into the steak (Figure 3.7). Another 18.7% reported determining the DOD on the first bite. Suman et al. (2016) previously stated consumers generally assess doneness of cooked beef using interior color visual appearance, which supports the findings in this study. Furthermore, 20.3% of consumers

reported they determine DOD after waiting a couple minutes, this is where the color changes previously reported play a vital role in DOD perception. A consumer that orders very rare, rare, medium-rare, or medium will have significant changes occur on their plate in the redness of their steak before they determine if the DOD is correct. Whereas a consumer that orders well-done or very well-done will not detect any redness change so the timing on when they determine DOD is less detrimental.

Additionally, consumers were asked how they determine DOD when cooking beef at home (Figure 3.8). Fifty-four percent reported they use color, feel or firmness (15.7%) and time (10.4%). Additionally, 2.5% reported they do not determine DOD and 1.6% used a different method. Responses that fell in the "other" category included "luck", "juice", and "fat texture". Finally, only 16% of consumers reported using temperature or food thermometer for determining the correct DOD when cooking beef. Consumers that answered to using a food thermometer were then prompted to state the temperature they utilize, being either pull off the heat temperature or temperature following the post-cooking temperature rise (peak temperature). Of consumers that utilized a thermometer, 69% reported the temperature they use as their indication of DOD is the temperature they pull off the heat, whereas 31% reported the temperature they use for DOD determination is the temperature following the post-cooking temperature rise (Table 3.6). However, 61% of consumers that stated they use a carry-over temperature then reported they did not know the temperatures that correspond with each DOD. For the consumers that reported using carry-over cooking temperatures, 31.8% reported using 58 to 60°C (136 to 140°F) to correspond to rare and 33.3% reported 72 to 74°C (161 to 165°F) for well-done. Only 31.8, 21.7, 22.7, 19.1, and 14.3% of consumers were able to identify the temperature that matches the NCBA published numbers for rare, medium-rare, medium, medium-well, and well-done,

respectively. These percentages are concerningly very low for consumers knowledge of cooked beef temperatures. The percentage of consumers that reported temperatures two or more DODs off was overwhelming as well. For example, 36.4% of consumers reported using a peak temperature of less than 54°C (130°F) for rare. Twenty-four percent of consumers reported less than 71°C (160°F) and 24% reported over 80°C (176°F) for the carry-over temperature that corresponds to well-done.

Within consumers that stated they use pull-off the heat temperatures, 47.6% reported "I do not know" when asked to state the specific temperatures. There is more variation within the percentage of consumers that reported pull-off temperatures versus carry-over temperatures. This could be mostly attributed to the fact that various cooking methods will generate differences in post cooking temperature rise. What's Cooking America defines carry-over cooking as the residual heat transferring to the hotter exterior to the cooler center of the meat, suggesting consumers allow for a -15 to -12°C (5 to 10°F) rise in temperature following removal from the heat (Stradley, 2018). Of the consumers that reported a temperature, 27.6% reported using a temperature less than 49°C (120°F) to correspond with rare, then there was a large increase in temperature to medium-rare where 19.1% stated using 58 to 60°C (136 to 140°F). Additionally, 19.7% identified 61 to 63°C (141 to 145°F) for medium, 22.% use 66 to 68°C (151 to 155°F) for medium-well, whereas for well-done pull-off temperature, 51.5% reported using 69 to 74°C (156 to 165°F).

The USDA-Food Safety and Inspection Service (**FSIS**) recommends using a food thermometer to ensure safety and to determine desired doneness (FSIS, 2000). When focus groups were asked how they determine DOD, most consumers stated they use the "eye-ball" method and learned it by practice and trial and error through experience (Koeppl, 1998). Some

consumers even stated that when in doubt, overcooking is better than undercooking (Koeppl, 1998). Ultimately, overcooking may come from the fact that the emotion of fear is most commonly associated with consuming fish and meat products (Desmet and Schifferstein, 2008). McCurdy et al. (2005) also utilized focus groups to gain knowledge on consumers feelings and usage of thermometers. Consumers responded to prompted questions, stating they typically do not use thermometers because of lack of time, laziness, and forgetfulness (McCurdy et al., 2005). Additionally, when asked what would motivate them to use a food thermometer, the most commonly mentioned response was illness; however, consumers also stated, improved meat quality and the avoidance of overcooking would also motivate them to use a thermometer (McCurdy et al., 2005).

Even though using a thermometer sounds attractive, consumers have a variety of options when it comes to the source that they utilize for the temperature they will cook to (Table 3.1). The NCBA Beef Steak Color Guide reports six DODs being very rare 54°C (130°F), rare 60°C (140°F), medium-rare 63°C (145°F), medium 71°C (160°F), well-done 77°C (170°F), and very well-done 82°C (180°F) (NCBA, 2008). However, it is unclear if these temperatures are related to pull-off the heat or carry-over cooking peak temperature. Certified Angus Beef reports rare corresponds to 52°C (125°F) and well-done corresponding with 71°C (160°F) (Certified Angus Beef, 2018). Furthermore, the website even gives instructions to pull steaks off the heat when the thermometer is -15°C (5°F) below the preferred DOD, which indicates these temperatures correspond with end-point temperatures rather than pull-off temperatures (Certified Angus Beef, 2018). Similarly, What's Cooking America reports 49 to 52°C (120 to 125°F) as rare and 71°C (160°F) or greater as well-done (Stradley, 2018). Additionally, their internal temperature cooking chart described the color and feel of each DOD. Very-rare is described as deep red color and

barely warm, with a squishy feel, medium-well description is mostly gray-brown throughout and firm to the touch (Stradley, 2018). The previously discussed DOD charts and recommendations that are commonly available to consumers all report beef steak cooking temperatures lower than what is published by the NCBA and commonly utilized in research. This creates a large void in how they cook at home, what they expect from a restaurant setting, and how DOD research directly applies to them. Conversely, the Beef It's What's for Dinner website that is sponsored by the Beef Checkoff, reports the temperatures published by NCBA on their website stating medium-rare is 63°C (145°F) and well-done 77°C (170°F) (Beef Checkoff, 2018). The complication with nearly all these sources that are available for consumers, is the definition of pull-off the heat temperature or carry-over cooking.

Furthermore, Yancey et al. (2011) reported instrumental color values from longissimus thoracis steaks cooked to 65.5°C (150°F), 71.1°C (160°F), 76.6°C (170°F) on five different cooking methods including forced-air oven, air-impingement oven, electric griddles, char-grill, and clam-shell grill. Although differences in color between temperatures remained consistent, there were differences between cookery methods as well. The ovens and the electric griddle produced lighter colored steaks, with the griddle being similar to the char-grill which was similar to the clam-shell (Yancey et al., 2011). For a* clam-shell grills were less red than the ovens and char-grill, being similar to electric griddles (Yancey et al., 2011). Additionally, steaks cooked on the char-grill had the greatest b* compared to all other cooking methods (Yancey et al., 2011). Cooking method coupled with the temperature a consumer chooses to utilize will produce different results in DOD. Consumers are given different answers based on the source they choose to look at creating confusion that will inherently affect how consumers not only cook beef in

their home, but also create a disconnect from consumer to chef when ordering steaks at restaurants.

Chef use and knowledge of degree of doneness

The majority (66%) of chefs reported using feel or firmness for DOD indication, whereas 28% stated they use a thermometer, color (1.2%), and other (4.8%) (Figure 3.9). Chefs that reported "other" commonly listed "appearance", "time", or "a combination of multiple methods". Lehmuller and Hunt (2000) previously reported 95% of chefs determined doneness of steaks by touch. Chefs can get away with using the method of touch, as they cook hundreds of steaks within a given time period on the same equipment everyday. This allows the chefs to gain valuable experience and expertise as to how their own equiptment performs when cooking steaks that average consumers do not have. Within our study the chefs that reported they use thermometers stated the specific temperature they used were "pull-off the heat" temperature (14.5%) and "carry-over" cooking temperature (13.3%; Table 3.7). Of the chefs that reported using "carry-over" temperature, 63.6% use a temperature of less than 49°C (120°F) for rare, whereas 36.4% of chefs that reported "pull-off" temperatures stated rare as less than 49°C (120°F). For well-done, 54.6% of "carry-over" temperature chefs reported using between 69 and 71°C (156 and 160°F). Additionally, only 1% of chefs reported determining DOD using color. Much like the conclusion drawn from our study, Lehmuller concluded that internal temperatures used by chefs tended to be lower than those published by AMSA, USDA, or the Food and Drug Administration .

Schmidt et al. (2002) conducted a study in two parts in which half the consumers were 'educated' by wait staff as to what DOD meant versus no education or help from wait staff. Wait staff provided verbal description and visual illustration of the different DOD prior to the

consumer ordering. Results showed consumers that received DOD education had greater ratings for flavor-like and overall-like; however, no differences were seen for tenderness or juiciness (Schmidt et al., 2002). In attempt to improve customer satisfaction through the use of thermometers, Schmidt et al. (2002) also compared the method of touch for DOD determination versus thermometers. The authors reported steaks were cooked by experienced chefs to the consumers' desired DOD. Ultimately, within both panel sessions chefs that used thermometers more closely achieved the desired DOD with mean differences of 0.6°C and 1.3°C versus desired temperature (Schmidt et al., 2002). Chefs that utilized the touch method for determining DOD were 10.2°C too low when the consumers were educated on DOD and 27.6°C too low when the consumers ordered without guidance from the wait staff (Schmidt et al., 2002).

Furthermore, in our study chefs were asked if DOD was cut dependent and the specifics on why they believed that. Chefs responded yes (24.1%), no (30.1%), and maybe (45.8%; Table 3.4). Reasoning behind cut dependency was specified by "differing steak thicknesses", "variable marbling content", and "sometimes consumers do not have a choice, such as braises and stews". Jens Dahlmann, the executive chef at Longhorn, interviewed in the article published by Five Thirty Eight, states that the DOD the consumer orders is retail cut dependent (Hickey and Dottle, 2017). Longhorn Steakhouse reported prime rib had the greatest occurrence of being ordered rare or medium-rare, whereas a T-bone steak had the highest share of medium-well and well-done orders (Hickey and Dottle, 2017).

Evaluation of steak pictures cooked to six degrees of doneness

A study conducted by Chan et al. (2013) validated the use of internal pictures as a more accurate representation of a consumer's preferred DOD versus terms such as rare and medium. The authors utilized longissimus lumborum steaks, cooked to rare [60°C (140°F)], medium

[70°C (158°F)], medium-well [75°C (167°F)], well-done [80°C (176°F)], and very well-done [85°C (185°F)]. To study consumers' perceptions of doneness, two panel sessions were conducted, one for both the external and internal surface of the cooked steak and secondly, for the corresponding photographs of each sample. Perception scores for both external and internal surfaces between different presentation methods steak samples and corresponding photos, were not significantly different. Ultimately, authors concluded that for assessing consumer preference for meat doneness, photographs can be used as a valid approach.

In the current study, there were no quality grade effects ($P > 0.11$) for any DOD of the pictures evaluated by consumers. Consumers identified pictures of the steaks cooked to very-rare to be the greatest ($P < 0.05$; Figure 3.10) percentage rare, followed by very-rare and medium-rare which were similar ($P > 0.05$). Over 35% of consumers rated the pictures of very-rare steaks as medium-rare or a greater DOD. Considering chefs reported they cook to a lower temperature than the NCBA color guide temperatures, it makes sense consumers would associate the 54°C (130°F) color with rare instead of very-rare. For the pictures of rare steaks, the greatest ($P < 0.05$) percentage of consumers identified the steak as cooked to rare, followed by medium-rare, very-rare, and medium, which were all different ($P < 0.05$). Thirty-five percent were correct, 47.7% were within one DOD, and 16.4% reported two or more DODs off from rare. Within the pictures of the medium-rare steaks, consumers reported the greatest ($P < 0.05$) percentage of medium-rare, followed by rare. Very-rare and medium were similar ($P > 0.05$), indicating, medium-rare is more closely related to rare versus medium. Although, 34.6% of consumers perceived the medium-rare steak pictures as medium-rare, 45.3% were within one DOD, and there were still 20.2% of consumers that perceived two DODs off from medium-rare. Additionally, pictures of the medium steaks were evaluated with similar ($P > 0.05$) percentages

for medium and medium-well. The second greatest ($P < 0.05$) percentage was medium-rare, followed by well-done. The results from the pictures of medium and well-done steaks are interesting, since consumers were given the option of medium-well, within medium and well-done they each are similar ($P > 0.05$) to medium-well. This indicates, cooking well-done steaks to the lower temperature of medium-well would not have an impact on consumer's perception of the DOD. Pictures of the steaks cooked to very well-done were perceived as well-done ($P < 0.05$), followed by very well-done. Within the pictures of medium, well-done, and very well-done steaks, 27 to 29% perceived the correct DOD, 43 to 45 were within one DOD, and 26 to 29% were two or more DODs away from what the steak was actually cooked to. Ultimately, consumers are able to accurately match the DOD to the end-point temperature, although the percentage ranged from 27 to 35%. The question remains is that percentage high enough that the foodservice industry can be confident in consumers ability to identify the DOD they order.

There were no quality grade effects ($P > 0.05$) for any DOD of the pictures evaluated by chefs. While evaluating pictures of steaks cooked to very rare, the greatest ($P < 0.05$; Figure 3.11) percentage of chefs reported steaks were rare and medium-rare, which were not different ($P > 0.05$). Fourteen percent identified them as very rare, 38.9% were only one DOD off; however, 47.5% of chefs rated very rare steaks as medium-rare or even a greater DOD, being two or more DODs away from what the steak picture was actually cooked to. Ultimately, within the pictures, there were no steaks cooked to a low enough temperature for chefs to identify them as very rare. Furthermore, for pictures of steaks cooked to a rare DOD, the greatest ($P < 0.05$) percentage of chefs identified them as medium-rare. Only 24% identified them as rare, which was similar ($P > 0.05$) to medium. Fifty percent were within one DOD and 27% reported the rare steaks as medium or higher DOD. Uniquely, the greatest ($P < 0.05$) percentage of chefs were

able to correctly identify pictures of steaks cooked to medium-rare as medium-rare. Forty-seven percent reported rare or medium, whereas only 9% of chefs were two or more DODs away from medium-rare. Chefs perception of medium-rare and below tends to side with steaks cooked to lower temperatures, inferring steaks ordered between very rare and medium-rare chefs inherently tend to undercook. Assuming that for the consumer who prefers a lower DOD, undercooking is less detrimental than overcooking (Cox et al., 1997). Essentially for chefs', pictures of steaks cooked to a medium DOD did not exist. Moreover, for both pictures of steaks cooked to medium and well-done chefs perceived the greatest ($P < 0.05$) percentage as medium-well. Pictures of steaks cooked to medium had 26.5% identify them as such, 54.1% within one DOD, and 19.4 two or more DODs away from medium. Well-done steak pictures had 33.1 identify them as well-done, 53.6% report medium-well or very well-done, and 13.2% perceived a medium DOD or lower. Lastly, steaks cooked to very well-done had the greatest ($P < 0.05$) percentage of chefs report well-done, followed by very well-done. Only 11.7% reported medium-well or a lower DOD. Chefs are trained to cook steaks that are ordered medium-well or well-done to be closer to overdone because for the consumers that prefer those DODs, it is plausable that overdone is more acceptable versus underdone. Previously, Lehmuller and Hunt (2000) conducted a study to determine chefs' appraisal of cooked color compared to endpoint temperature, and the differences in chefs perceived DOD. For visual evaluation, beef eye rounds were roasted to 43°C (109°F), 49°C (120°F), 54°C (129°F), 60°C (140°F), 71°C (160°F), and 77°C (170°F), then cross-sections were evaluated visually under standardized lighting. The authors reported that 49°C (120°F) was most commonly associated with rare although this is tremendously lower than current published sources stating rare at 60°C (140°F); however, details pertaining to if these were pull-off or carry-over temperatures were not provided. Much like in this study, based on

color, chefs assigned a DOD. In contrast to our study, over 85% of the chefs correctly identified doneness of pieces cooked very rare, medium-rare, medium-well, and well-done. Steaks cooked medium were rated mostly as medium-rare, and rare samples were correctly identified by only 23% of chefs. However, Lehmuller and Hunt (2000) even allowed for a 5 to 6°F variance, and found chefs still were generally unable to correctly determine actual endpoint temperatures based on visual color.

In an article titled, "Restaurants are cooking your steak wrong on purpose" by the New York Post, the author states receiving extremely underdone steaks and his opinion is that the trend of undercooking just spiked within the last year (Cuozzo, 2018). Hanson, the owner of Henry at Life Hotel who previously ran four steakhouses under the BR Guest banner, including the Strip House chain states kitchens error on the rare side, knowing the steak can always be rescued with a minute or two more heat, "If a customer says their steak is overcooked, it can only be thrown out" (Cuozzo, 2018). Additionally, Desmet and Schifferstein (2008) described examples for each emotional type and in regard to chef's anger it was described as "cooks get angry with themselves when they spoil food while preparing the food." Cuozzo (2018) also interviewed Chef, Josh Capon who brings light to a 'new' DOD of "medium-rare plus." He also states, "At this rate, we soon might have to ask for it medium-well to guarantee it won't be raw." At Porter House New York in Midtown, executive chef and co-owner Michael Lomonaco says more than 60% of his customers order medium-rare (Cuozzo, 2018). An article published by Boston Eaters, chefs were asked how they would like to respond to consumers that ordered steak well-done. Michael Schlow, chef and owner of Via Matta, Tico, and Alta Strada, responded, "I would ask, have you ever closed your eyes and tasted a medium rare steak side-by-side with a

well-done steak? I think part of it is the color for people. It certainly can't be that they like it drier. They look at it and maybe get a little squeamish" (Blumenthal, 2014).

Color is a major component of consumers perception. In beef DOD evokes differing emotional responses as well as sensory and acceptability ratings. Overall, chefs frustration with consumers could be decreased by reducing the gap in disconnect of DOD perception. Across the foodservice industry, delivering the preferred DOD becomes crucial to consumer ratings. Moving forward, finding innovative ways to communicate with consumers that have created new DODs in their mind will be vital.

CONCLUSION

These results provide insight into cooked beef color changes related to time and how this might impact DOD perceptions by consumers. Although consumers do not have a good understanding of beef cooking temperatures, they are able to accurately identify DOD of steaks cooked to specified end-point temperatures although with less precision than chefs. Additionally, chefs do not consistently use the same method when determining DOD, and are unable to accurately identify DOD of steaks cooked to specified end-point temperatures. This can create challenges for foodservice establishments to successfully meet DOD preferences. Differences exist in the perceptions of doneness between culinary professionals and meat researchers and these may have consumer acceptability implications for whole muscle products.

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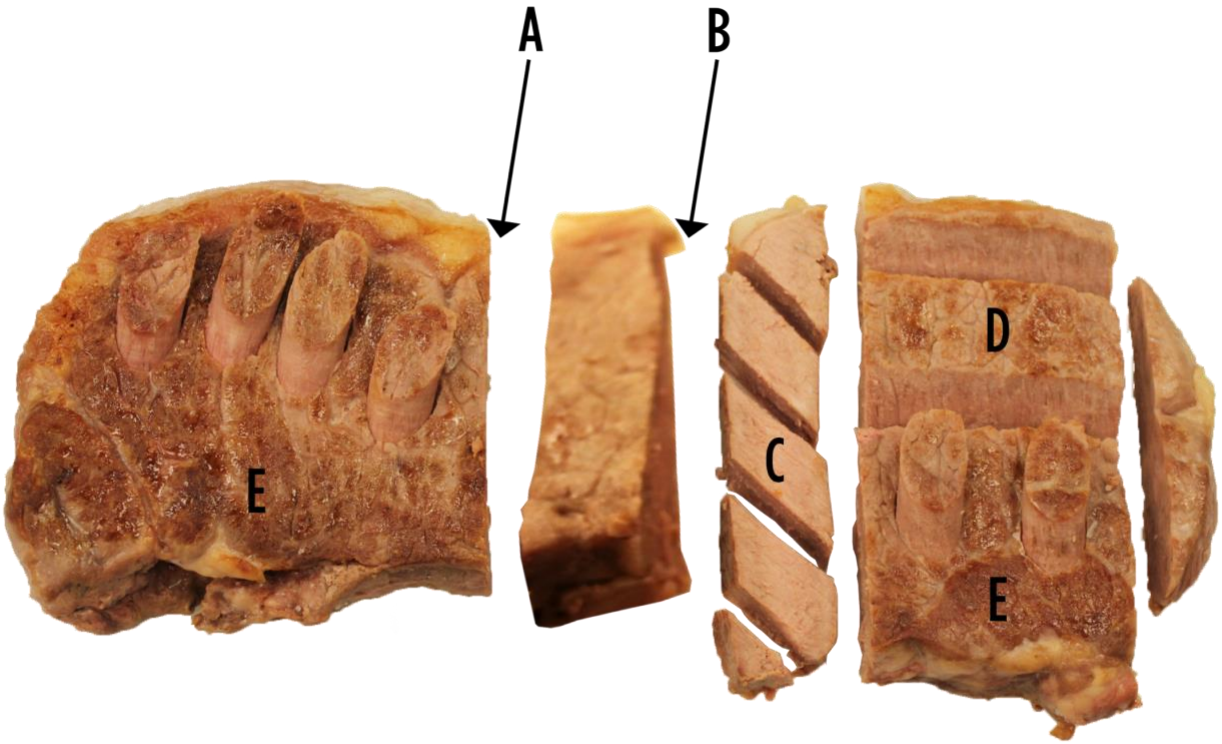


Figure 3.1 Diagram of steak utilized for color readings and pictures[1]

[1]A = cut surface utilized for color readings, B = cut surface utilized for picture, C = Pressed Juice Percentage, D = Slice Shear force, E = Warner-Bratzler Shear force

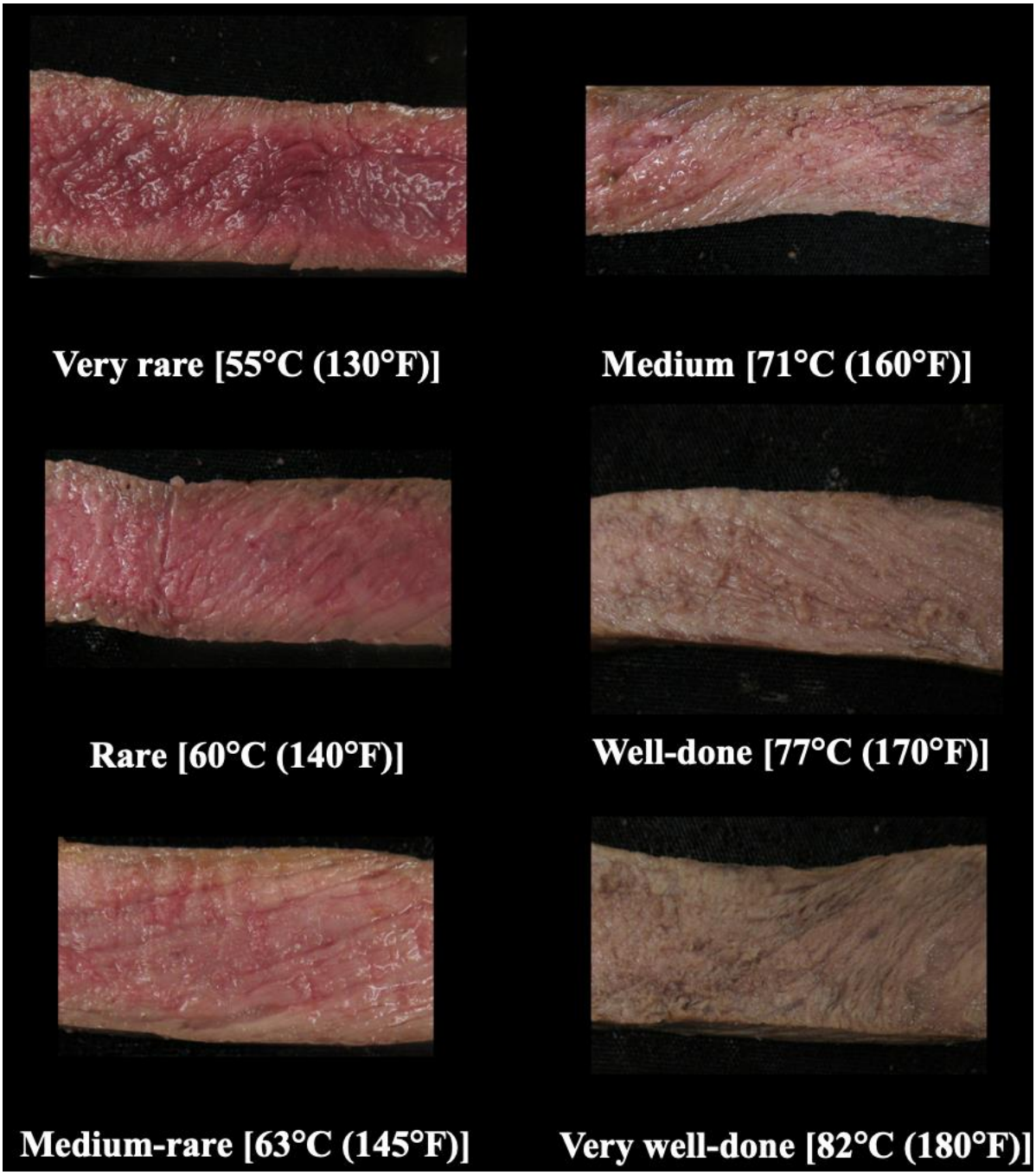


Figure 3.2 Beef steak degree of doneness pictures

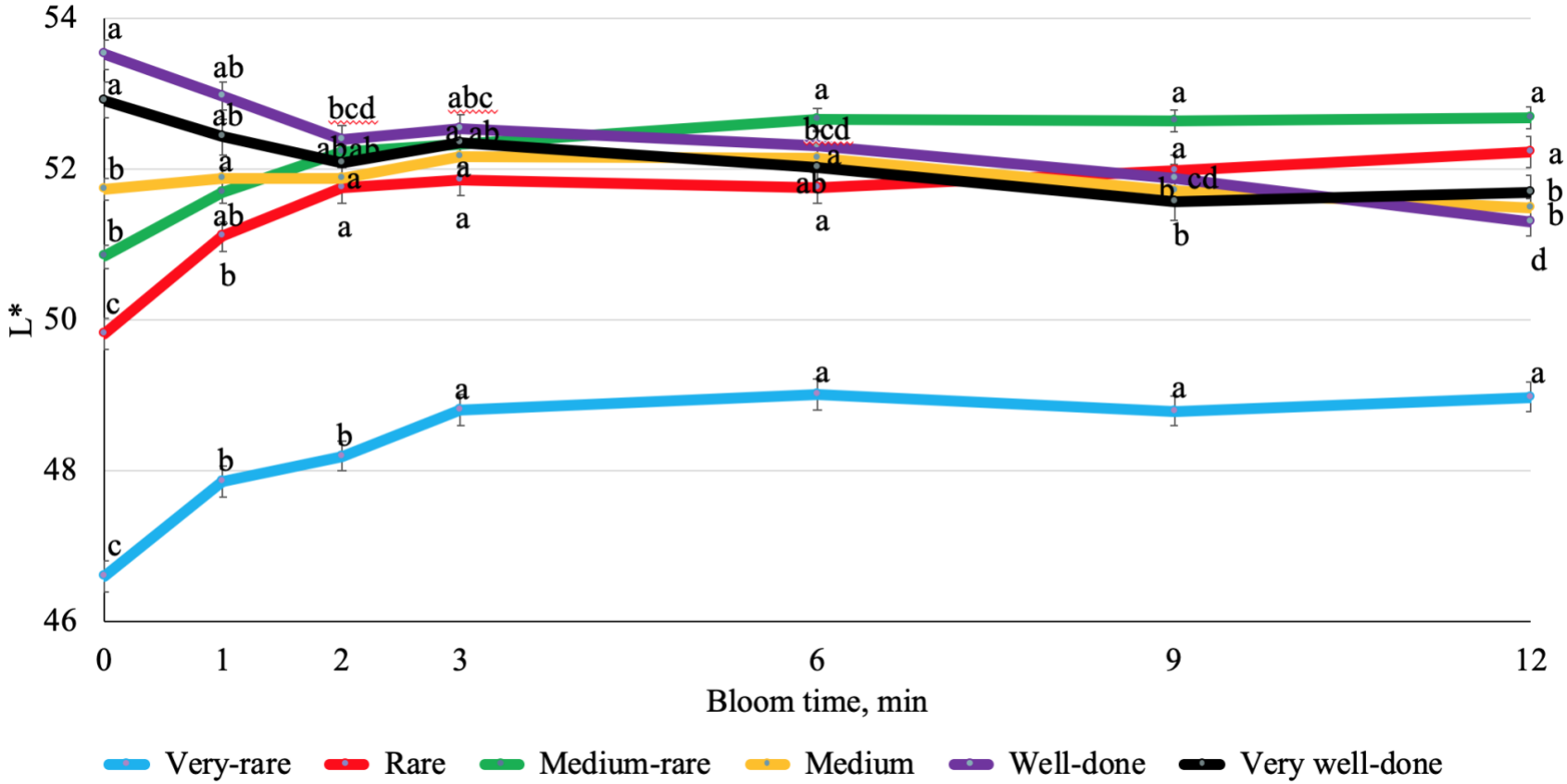


Figure 3.3 Interaction ($P < 0.01$) between time and degree of doneness on L*[1] color readings of beef steaks

[1] 0 = black, 100 = white.

[abcd] Means within a degree of doneness without a common superscript differ ($P < 0.05$).

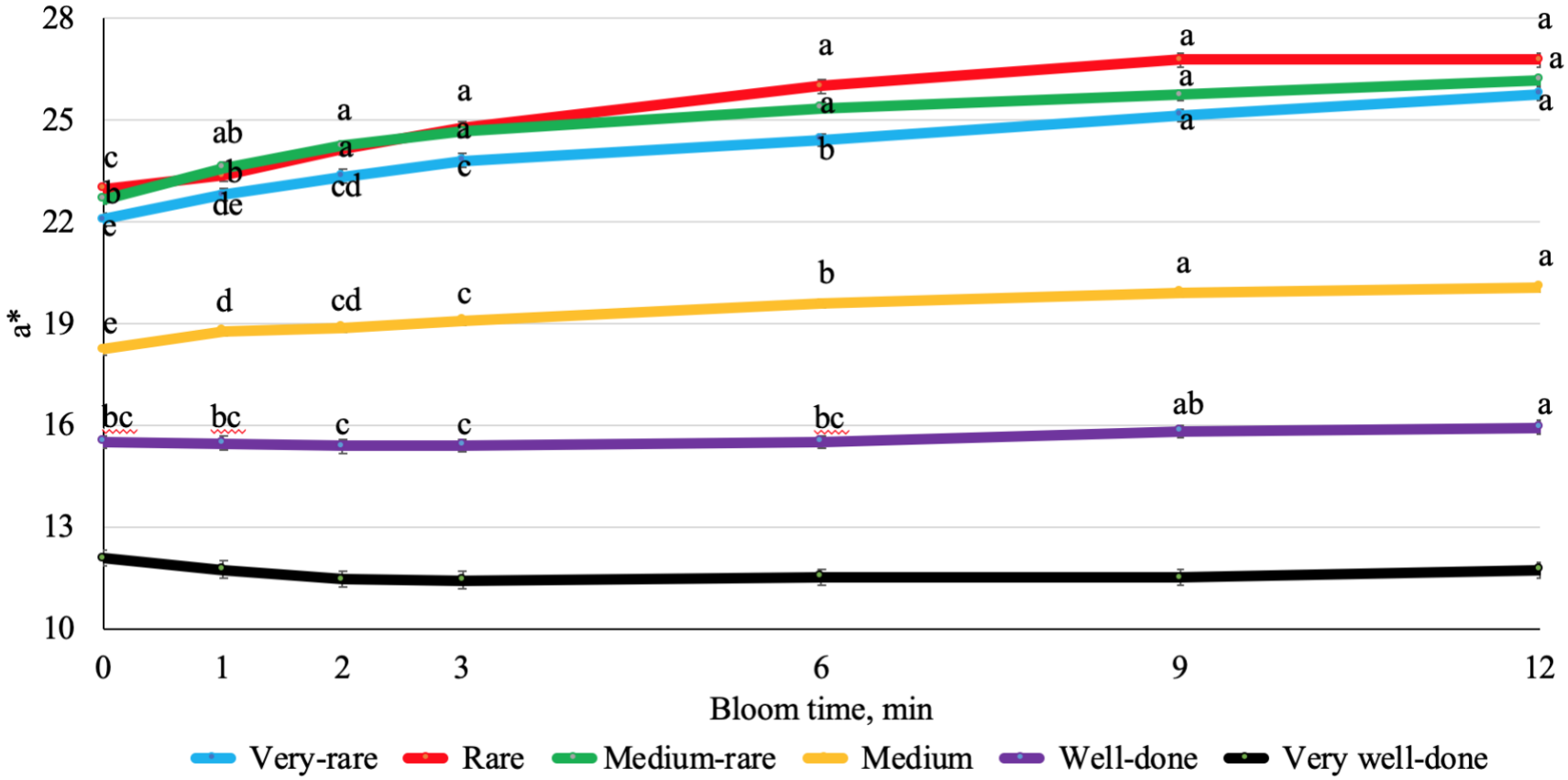


Figure 3.4 Interaction ($P < 0.01$) between time and degree of doneness on a*[1] color readings of beef steaks

[1] -60 = green, 60 = red.

[abcde] Means within a degree of doneness without a common superscript differ ($P < 0.05$).

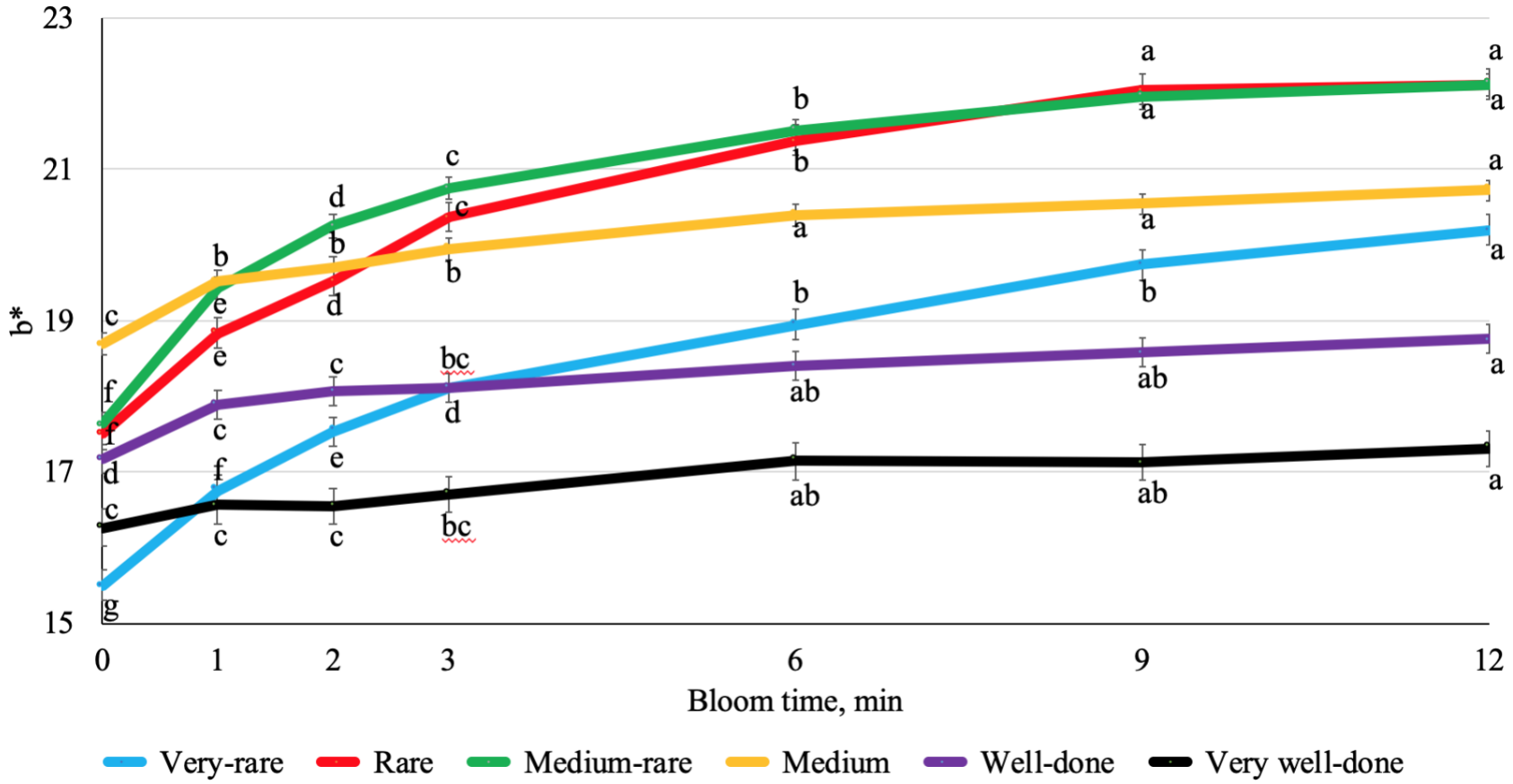


Figure 3.5 Interaction ($P < 0.01$) between time and degree of doneness on b*[1] color readings of beef steaks

[1] -60 = blue, 60 = yellow.

[abcdefg] Means within a degree of doneness without a common superscript differ ($P < 0.05$)

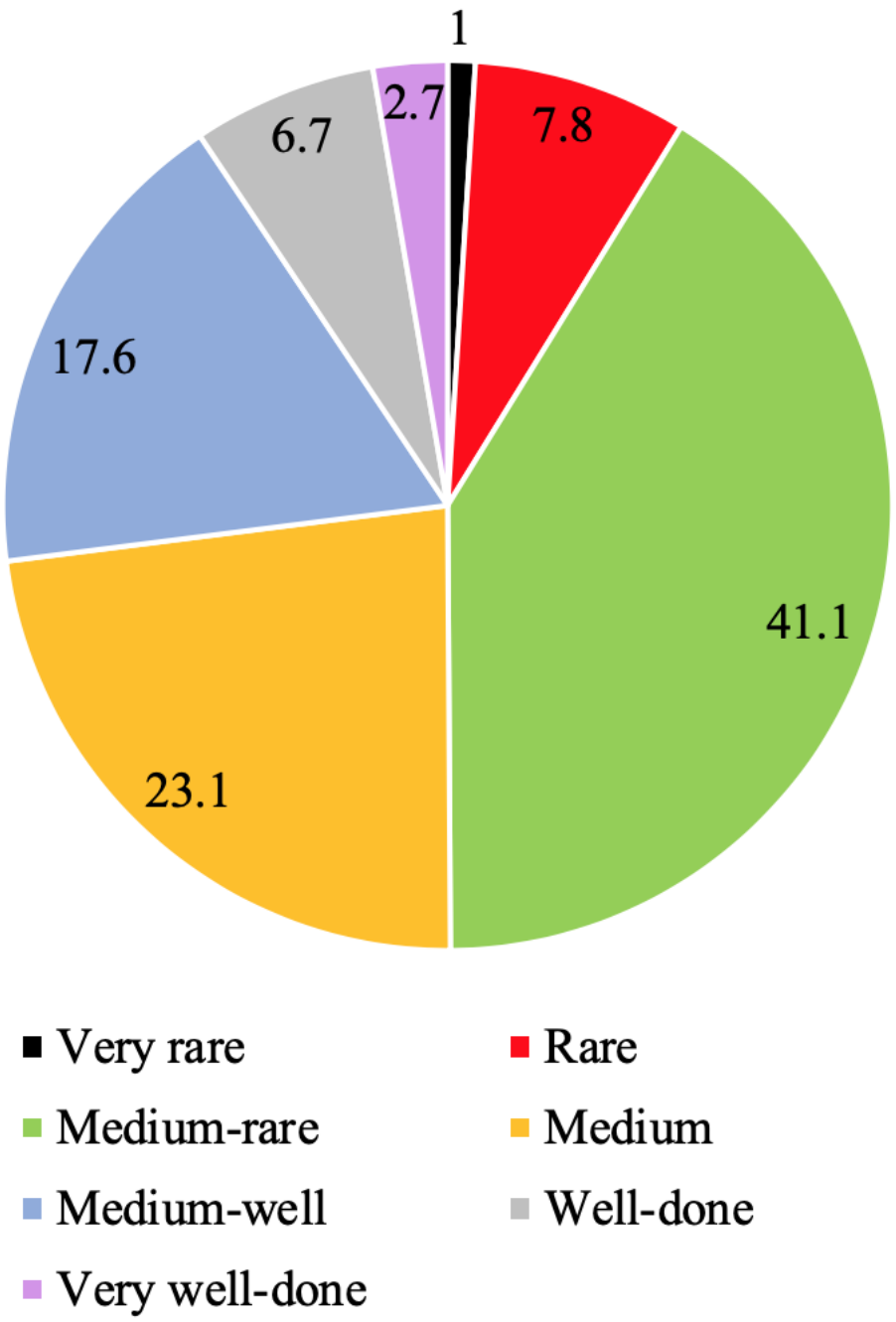


Figure 3.6 Consumer's (*n* = 1134) preferred degree of doneness

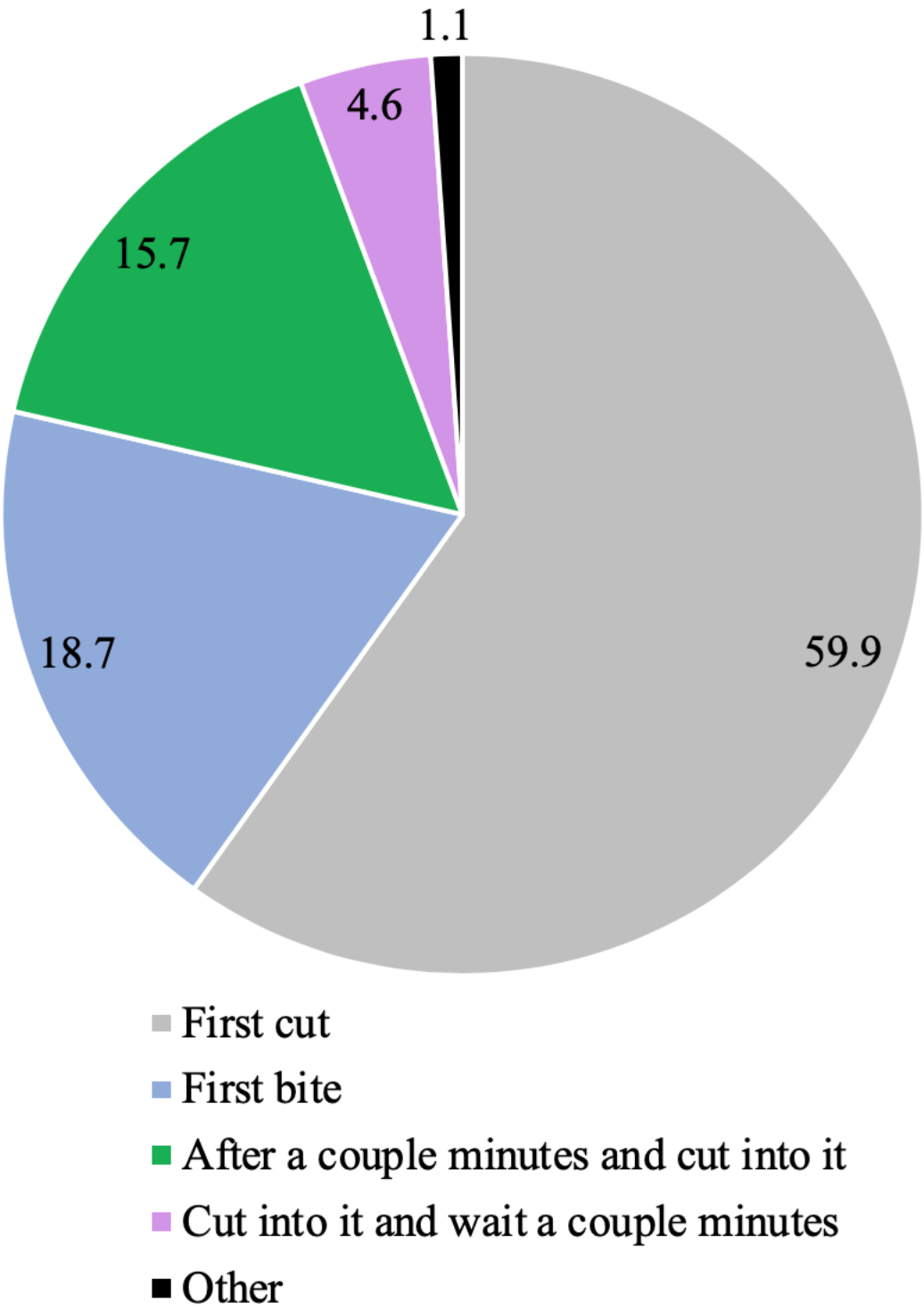


Figure 3.7 Consumer's (*n* = 1134) method of determining beef degree of doneness in a restaurant

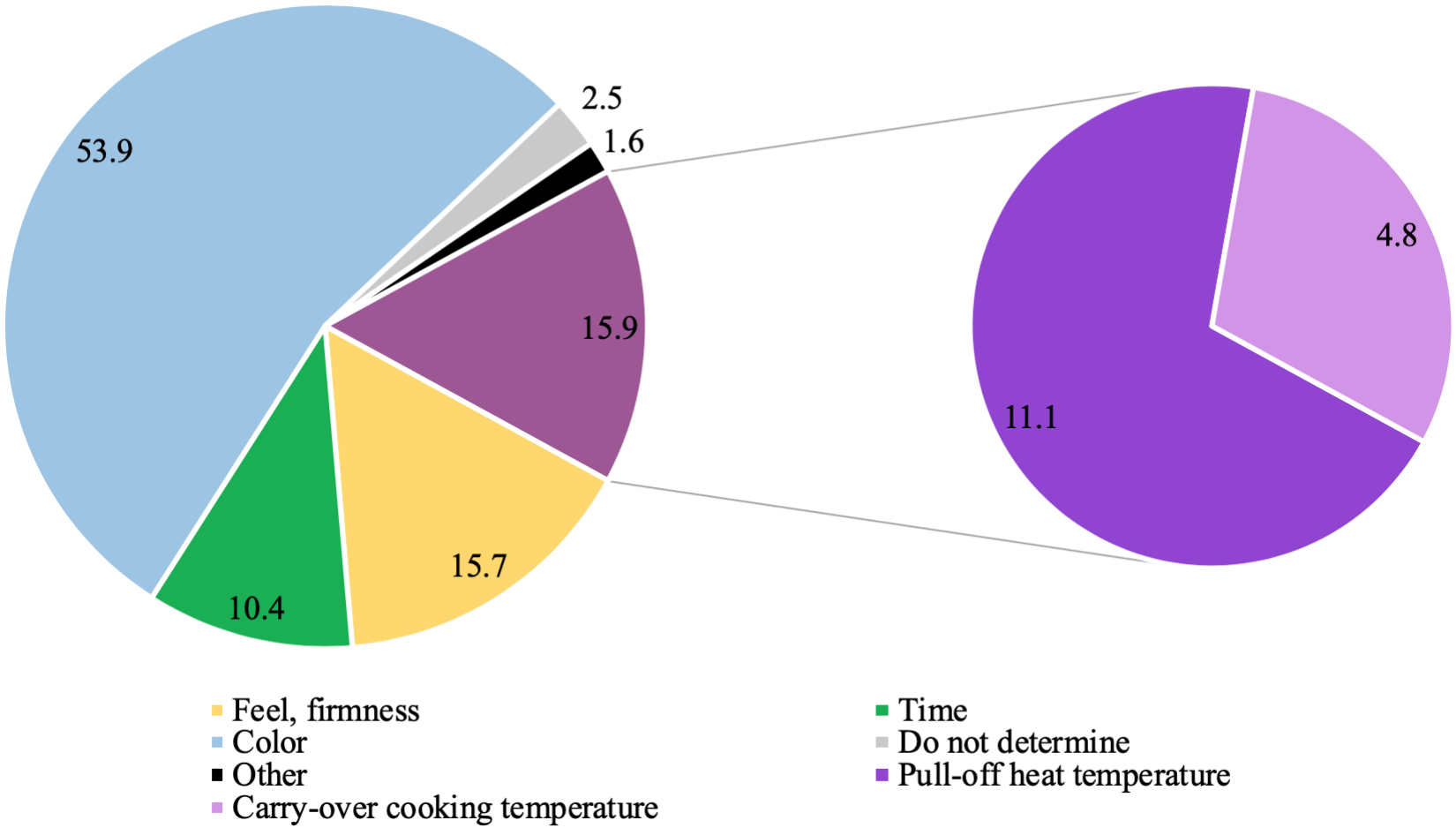


Figure 3.8 Consumer's (*n* = 1134) method of determining degree of doneness while cooking beef

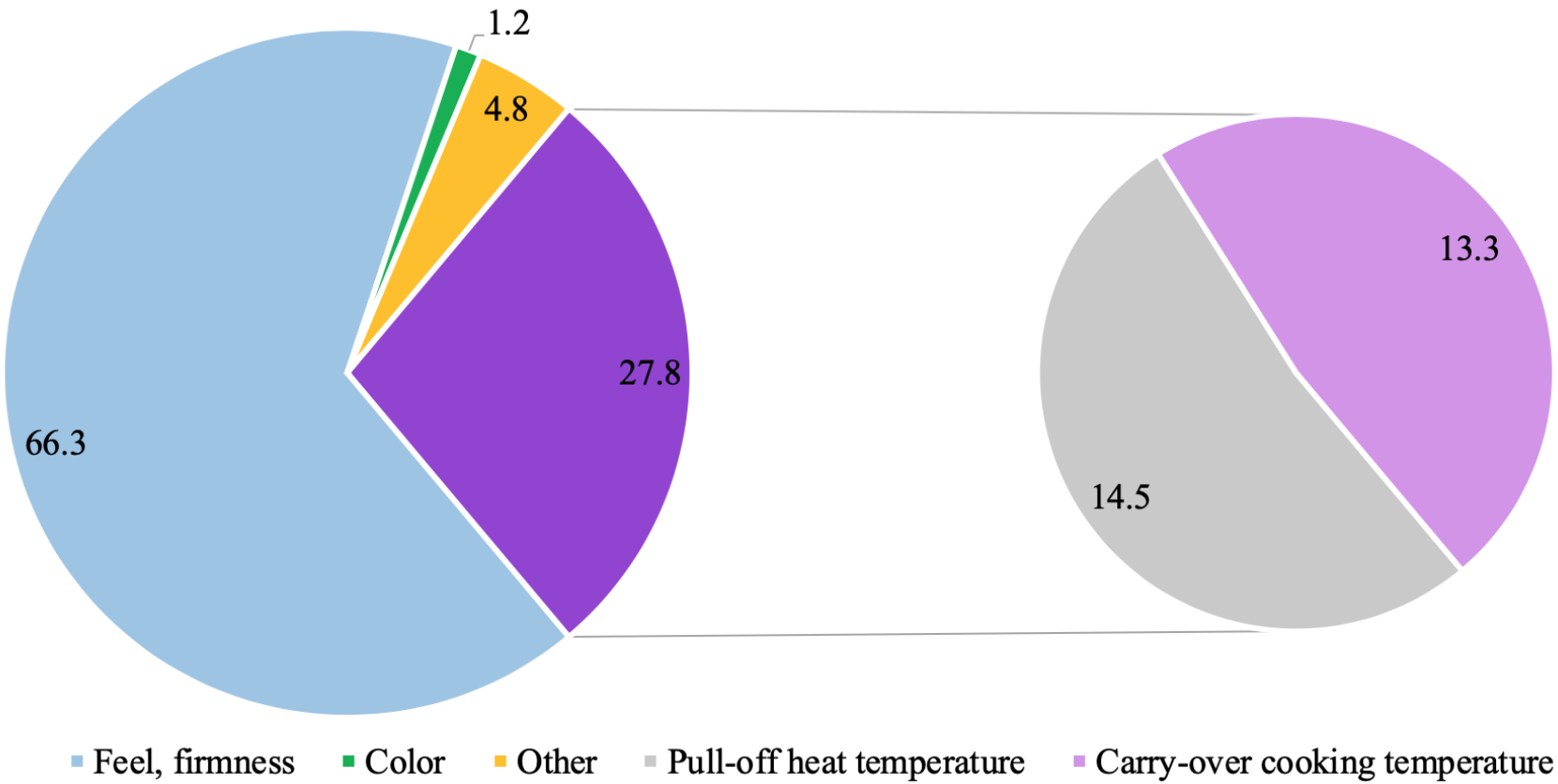


Figure 3.9 Chef's (*n* = 83) method of determining degree of doneness while cooking beef

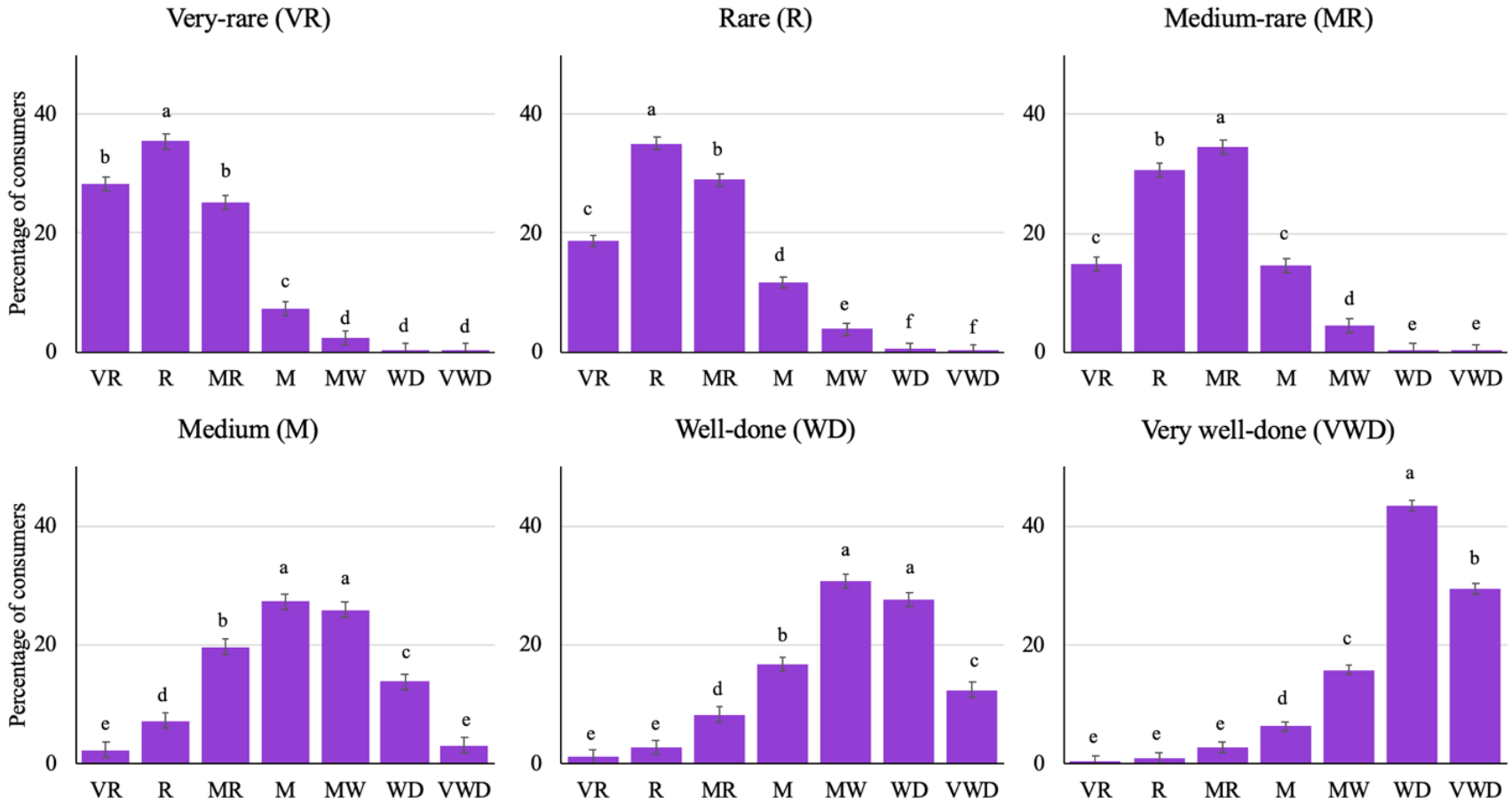


Figure 3.10 Percentage of consumers that correctly identified the represented degree of doneness.

[abcde] Means within a degree of doneness without a common superscript differ ($P < 0.05$).

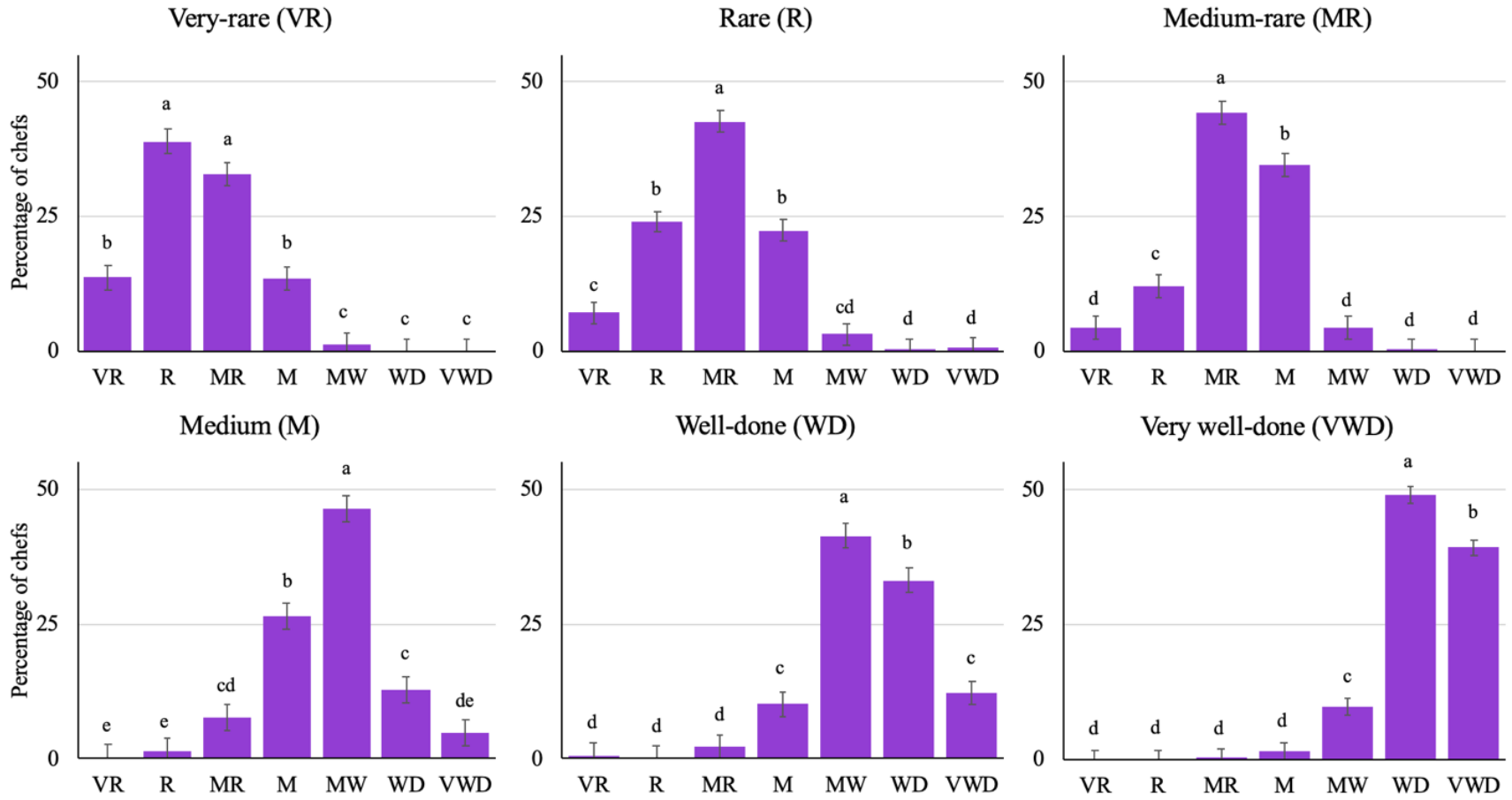


Figure 3.11 Percentage of chefs that correctly identified the represented degree of doneness.

[abcde] Means within a degree of doneness without a common superscript differ ($P < 0.05$).

Table 3.1 Published temperatures corresponding to beef degree of doneness

Degree of doneness	Beef It's What's for Dinner[1]	Certified Angus Beef[2]	Char-Boil[3]	What's Cooking America[4]	Food Network Kitchen[5]
	Peak temperature	Pull-off of the heat	Unspecified	Unspecified	Pull-off of the heat
Very rare	55°C (130°F)	-	26 – 38°C (80 – 100°F)	26 – 38°C (80 – 100°F)	-
Rare	60°C (140°F)	52°C (125°F)	49 – 51°C (120 – 125°F)	49 – 51°C (120 – 125°F)	51°C [125°F (+3 min rest)]
Medium-rare	63°C (145°F)	57°C (135°F)	55 – 57°C (130 – 135°F)	55 – 57°C (130 – 135°F)	55 – 57°C (130 – 135°F)
Medium	71°C (160) °F	63°C (145°F)	60 – 63°C (140 – 145°F)	60 – 63°C (140 – 145°F)	57 – 60°C (135 – 140°F)
Medium-well	-	66°C (150°F)	65 – 69°C (150 – 155°F)	65 – 69°C (150 – 155°F)	60 – 66°C (140 – 150°F)
Well-done	77°C (170°F)	71°C (160°F)	71>°C (160 >°F)	71>°C (160 >°F)	69+°C (155+°F)
Very well-done	82°C (180°F)	-	-	-	-

[1] Beef Checkoff., 2018.
[2] Certified Angus Beef., 2018.
[3] Char-Broil., 2018.
[4] Stradley, L., 2018.
[5] Food Network Kitchen., 2018.

Table 3.2 Interaction (P = 0.02) between quality treatment and time on L*[1] of beef steaks

	Quality treatment				
Bloom time, min	Select enhanced[2]	Select	Low Choice	Top Choice	Prime
Immediate	50.80	50.40	50.81	51.35	51.12
1	51.02	51.03	51.33	51.74	51.46
2	50.84	51.16	51.37	52.00	51.69
3	51.08	51.64	51.62	52.25	51.75
6	51.05	51.50	51.66	52.31	51.70
9	50.75	51.44	51.26	52.05	51.58
12	50.40[b]	51.34[ab]	51.30[ab]	52.13[a]	51.75[ab]
SEM	0.58	0.59	0.61	0.61	0.58
P – value	0.02	0.02	0.02	0.02	0.02

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

[1]L*: 0 = black, 100 = white.

[2]Enhanced to 108% of raw weight with water, salt, and alkaline phosphate solution.

Table 3.3 Effect of quality grade on color readings of beef steaks

	Instrumental color	
Quality treatment	a*[1]	b*[2]
Select enhanced[3]	19.05[b]	17.61[b]
Select	20.47[a]	19.24[a]
Low Choice	20.50[a]	19.39[a]
Top Choice	20.06[a]	19.26[a]
Prime	19.82[ab]	19.30[a]
SEM	0.35	0.21
P – value	0.02	< 0.01

[ab] Within a column, means without a common superscript differ ($P < 0.05$).

[1]a*: -60 = green, 60 = red.

[2]b*: -60 = blue, 60 = yellow.

[3]Enhanced to 108% of raw weight with water, salt, and alkaline phosphate solution.

Table 3.4 Demographic characteristics of chefs (*n* = 83) who participated in survey

Characteristic	Response	Percentage of consumers
Sex	Male	86.8
	Female	13.3
Age group	20-29	7.2
	30-39	32.5
	40-49	34.9
	50-59	19.3
	Over 60	6.0
Ethnic origin	Caucasian/white	90.4
	Hispanic	2.4
	Asian	1.2
	Mixed race	3.6
	Other	2.4
Geographical location	North	7.2
	South	12.1
	East coast	25.3
	West coast	34.9
	Mid-west	20.5
Training	Informal	25.3
	Formal culinary school	60.2
	Apprenticeship	7.2
	Other	7.2
Type of chef	Casual dining	13.3
	Fine dining	12.1
	Independent restaurant	18.1
	Corporate	10.8
	Distributor	13.3
	Research and development	6.0
	Culinary instructor	4.8
Quality grade most commonly worked with	Low Choice	6.0
	Premium Choice	68.7
	Prime	20.5
Percentage of steaks returned due to DOD	0 to 5	63.9
	6 to 10	26.5
	11 to 20	6.0
	20+	3.6
Is degree of doneness retail cut dependent	Yes	24.1
	No	30.1
	Maybe	45.8

Table 3.5 Demographic characteristics of consumers (*n* = 1134) who participated in survey

Characteristic	Response	Percentage of consumers
Sex	Male	48.5
	Female	51.5
Household size	1 person	15.0
	2 people	24.9
	3 people	17.0
	4 people	22.7
	5 people	11.4
	6 or more people	8.9
Marital status	Single	52.2
	Married	47.8
Age group	Under 20	10.2
	20-29	39.0
	30-39	16.2
	40-49	14.4
	50-59	11.0
	Over 60	9.2
Ethnic origin	African-American	4.6
	Caucasian/white	79.4
	Hispanic	5.8
	Asian	4.3
	Native American	0.9
	Mixed race	3.6
	Other	1.4
Annual household income, $	Less than 25,000	19.5
	25,000 to 34,999	8.3
	35,000 to 49,999	9.5
	50,000 to 74,999	16.0
	75,000 to 100,000	14.7
	More than 100,000	32.0
Highest level of education completed	High school graduate	10.2
	Some college/technical school	32.5
	College graduate	33.1
	Post graduate	23.1
Weekly beef consumption	1 to 3 times	47.4
	4 to 6 times	31.6
	7 or more times	21.0
Most important palatability trait when eating beef	Flavor	51.0
	Juiciness	16.5
	Tenderness	32.5

Table 3.6 Percentage of consumers that reported specific temperatures that correspond to each degree of doneness

	Pull-off of the heat (n = 126)					Carry-over cooking (n = 57)				
Temperature	Rare	Medium-rare	Medium	Medium-well	Well-done	Rare	Medium-rare	Medium	Medium-well	Well-done
I do not know	47.6	50.0	51.6	50.0	47.6	61.4	58.9	60.7	62.5	60.7
>120	27.6	4.8	-	-	-	13.6	4.4	--	-	-
121 – 125	12.1	4.8	-	-	-	9.1	-	-	-	-
126 – 130	19.0	11.1	3.3	-	-	13.6	8.7	4.6	-	-
131 – 135	3.5	14.3	1.6	4.8	-	9.1	13.0	4.6	-	-
136 – 140	12.1	19.1	18.0	-	1.5	31.8	13.0	9.1	14.3	-
141 – 145	13.8	15.9	19.7	4.8	1.5	9.1	21.7	4.6	4.8	9.5
146 – 150	3.5	9.5	13.1	15.9	1.5	9.1	21.7	31.8	-	9.5
151 – 155	1.7	6.4	9.8	22.2	1.5	4.6	8.7	13.6	9.5	-
156 – 160	1.7	7.9	16.4	19.1	22.7	-	4.4	22.7	33.3	4.8
161 – 165	3.5	1.6	11.5	15.9	28.8	-	4.4	-	19.1	33.3
166 – 170	-	-	3.3	9.5	18.2	-	-	-	14.3	14.3
171 – 175	1.7	1.6	-	3.2	9.1	-	-	4.6	-	4.8
176 – 180	-	-	1.6	3.2	7.6	-	-	4.6	-	19.1
181>	-	3.2	1.6	1.6	7.6	-	-	-	4.8	4.8

Table 3.7 Percentage of chefs that reported specific temperatures that correspond to each degree of doneness

	Pull-off of the heat (n = 11)					Carry-over cooking (n = 11)				
Temperature	Rare	Medium-rare	Medium	Medium-well	Well-done	Rare	Medium-rare	Medium	Medium-well	Well-done
>120	36.4	9.1	-	-	-	63.6	-	-	-	-
121 – 125	27.3	27.3	-	-	-	27.3	36.4	-	-	-
126 – 130	18.2	9.1	36.4	-	-	9.1	36.4	-	-	-
131 – 135	9.1	36.4	9.1	18.2	-	-	27.3	45.5	-	-
136 – 140	9.1	9.1	27.3	27.3	9.1	-	-	45.5	-	-
141 – 145	-	-	18.2	-	18.2	-	-	9.1	63.6	-
146 – 150	-	9.1	9.1	9.1	18.2	-	-	-	36.4	27.3
151 – 155	-	-	-	36.4	-	-	-	-	-	18.2
156 – 160	-	-	-	9.1	36.4	-	-	-	-	54.6
161 – 165	-	-	-	-	9.1	-	-	-	-	-
166 – 170	-	-	-	-	9.1	-	-	-	-	-

Appendix A - Tables

Table A.1 Consumer (n = 283) palatability ratings[1] under red and white lights for strip loin steaks

Sensory characteristic	Tenderness	Juiciness	Flavor	Overall liking
Red-light testing	63.5	63.0[b]	60.3[b]	61.5[b]
White-light testing	63.4	65.0[a]	63.3[a]	63.5[a]
SEM	0.99	0.95	0.89	0.88
P - value	0.92	0.04	< 0.01	0.02

[ab] Means of the same column without a common superscript differ ($P < 0.05$).

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

Appendix B - Consumer Panel Evaluation Forms

Demographic Survey

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

How many times a week do you consume beef?

0 3 6 9 12 15 18 21

None

Purchasing Motivator Survey

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

Animal Welfare

Extremely Unimportant Extremely Important

0 100

Antibiotic use in the animal

Extremely Unimportant Extremely Important

0 100

Brand of Product

Extremely Unimportant Extremely Important

0 100

Color

Extremely Unimportant Extremely Important

0 100

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 Extremely Important 0 100
	
Packaging Type	Extremely Unimportant Extremely Important 0 100
	
Price	Extremely Unimportant Extremely Important 0 100
	
Size, weight and thickness	Extremely Unimportant Extremely Important 0 100
	
USDA Grade	Extremely Unimportant Extremely Important 0 100
	

Marbling

	Extremely Unimportant	Extremely Important
	0	100

Sample Evaluation Survey

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

Appendix C - Consumer and Chef Survey Evaluation Forms

Recruiting Letters

Recruiting Letter for Consumer Panelists:

To all interested parties:

Kansas State University's Meat Science Program is conducting a survey which is an opportunity for community members to participate in valuable research. The survey is a portion of a research study evaluating the degree of doneness traits of beef.

The survey lasts approximately 20 minutes. Each participant will evaluate 10-30 different cooked beef sample pictures within the session. Participants will also be asked to voluntarily answer a few questions along with evaluating the meat. Each participant may only participate one time. Participants must be at least 18 years old up to 65 and consume beef at least once a week.

All information collected is confidential and your participation is completely voluntary. You can quit at any time without any penalty. You can stop at any time during the trial. You can skip any questions on the survey ballot that you don't feel comfortable answering. Your name will not be associated with any of your answers.
Please feel free to pass this information along to any groups in the community who may be interested. For any questions please contact myself, Dr. Travis O'Quinn, at 785-532-3469 or by email at travisoquinn@ksu.edu.

Thanks and look forward to hearing from you!

Travis O'Quinn

Recruiting Letter for Chef Panelists:

To all interested parties:

Kansas State University's Meat Science Program is conducting a survey which is an opportunity for chefs to participate in valuable research. The survey is a portion of a research study evaluating the degree of doneness traits of beef.

The survey lasts approximately 20 minutes. Each participant will evaluate 10-30 different cooked beef sample pictures within the session. Participants will also be asked to voluntarily answer a few questions along with evaluating the meat. Each participant may only participate one time. Participants must be at least 18 years old up to 65 and consume beef at least once a week.

All information collected is confidential and your participation is completely voluntary. You can quit at any time without any penalty. You can stop at any time during the trial. You can skip any questions on the survey ballot that you don't feel comfortable answering. Your name will not be associated with any of your answers.

Please feel free to pass this information along to any chefs who may be interested. For any questions please contact myself, Dr. Travis O'Quinn, at 785-532-3469 or by email at travisoquinn@ksu.edu.

Thanks and look forward to hearing from you!

Travis O'Quinn

Degree of Doneness Chef Picture Survey

Welcome to the research study!

INFORMED CONSENT STATEMENT

I volunteer to participate in research involving visual evaluation of beef. This research will be conducted by personnel in the Department of Animal Sciences and Industry at Kansas State University.

I fully understand the purpose of the research is for the evaluation of beef steaks for the traits of color, temperature, and degree of doneness and the survey evaluation will last approximately 20 minutes. 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.

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.

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. If I have questions about the rationale or method of the study, I understand that I may contact, Dr. Travis O'Quinn, 244 Weber Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3469.

- ○ I consent, begin the study (1)
- ○ I do not consent, I do not wish to participate (2)

How many years of experience do you have as a chef?

- ○ 0-2 years (1)
- ○ 3-4 years (2)
- ○ 5-6 years (3)
- ○ 7-8 years (4)
- ○ 9-10 years (5)
- ○ 11+ years (6)

What is your gender?

- ○ Male (1)
- ○ Female (2)

What is your age?

- ○ Under 20 (1)
- ○ 20-29 (2)
- ○ 30-39 (3)
- ○ 40-49 (4)
- ○ 50-59 (5)
- ○ Over 60 (6)

What is your ethnic origin?

- ○ African-American (1)
- ○ Asian (2)
- ○ Caucasian/White (3)
- ○ Hispanic (4)
- ○ Native American (5)
- ○ Other (6)
- ○ Mixed Race (7)

Which region most accurately describes where you are located.

- ○ Midwest (1)

- ○ South (2)
- ○ East Coast (3)
- ○ West Coast (4)
- ○ North (5)

What is the population of the city you serve?

- ○ 0 - 200,000 (1)
- ○ 201,000 - 400,000 (2)
- ○ 401,000 - 600,000 (3)
- ○ 601,000 - 800,000 (4)
- ○ 801,000 - 1,000,000 (5)
- ○ 1 - 2 million (6)
- ○ 2 million + (7)

Please classify your role as a chef.

- ○ Fine dining (1)
- ○ Casual dining (2)
- ○ Distributor chef (3)
- ○ Corporate lead (4)
- ○ R & D chef (5)
- ○ Culinary instructor (6)
- ○ Independent restaurant (7)
- ○ Other (8) _____

What grade of beef do you typically work with?

- ○ Prime (1)
- ○ Premium Choice (2)
- ○ Low Choice (3)
- ○ Select (4)
- ○ Enhanced (5)
- ○ Unsure (6)

Please rank from most (1) to least (5), the percentage of steaks in your establishment that are ordered from each degree of doneness.

_____ Rare (1)
_____ Medium Rare (2)
_____ Medium (3)
_____ Medium Well (4)
_____ Well Done (5)

Is the degree of doneness ordered retail cut dependent?

- ○ Definitely yes (1)
- ○ Probably yes (2)
- ○ Might or might not (3)
- ○ Probably not (4)
- ○ Definitely not (5) _____

Approximately what percentage of steaks get returned to the kitchen due to degree of doneness?

- ○ 0-5% (1)
- ○ 6-10% (2)
- ○ 11-15% (3)
- ○ 15-20% (4)
- ○ 21-25% (5)
- ○ 26%+ (6)

How do you determine degree of doneness?

- ○ Time (1)
- ○ Color (2)
- ○ Food Thermometer (3)
- ○ Feel, firmness (4)
- ○ Other (5) _____

If you use temperature to determine degree of doneness, does that temperature correspond with when it is pulled off of the heat or following post cooking temperature rise (carry over cooking)?

- ○ Pulled off of the heat (1)
- ○ Following post cooking temperature rise (carry over cooking) (2)

What temperature corresponds with RARE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with MEDIUM RARE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with MEDIUM?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

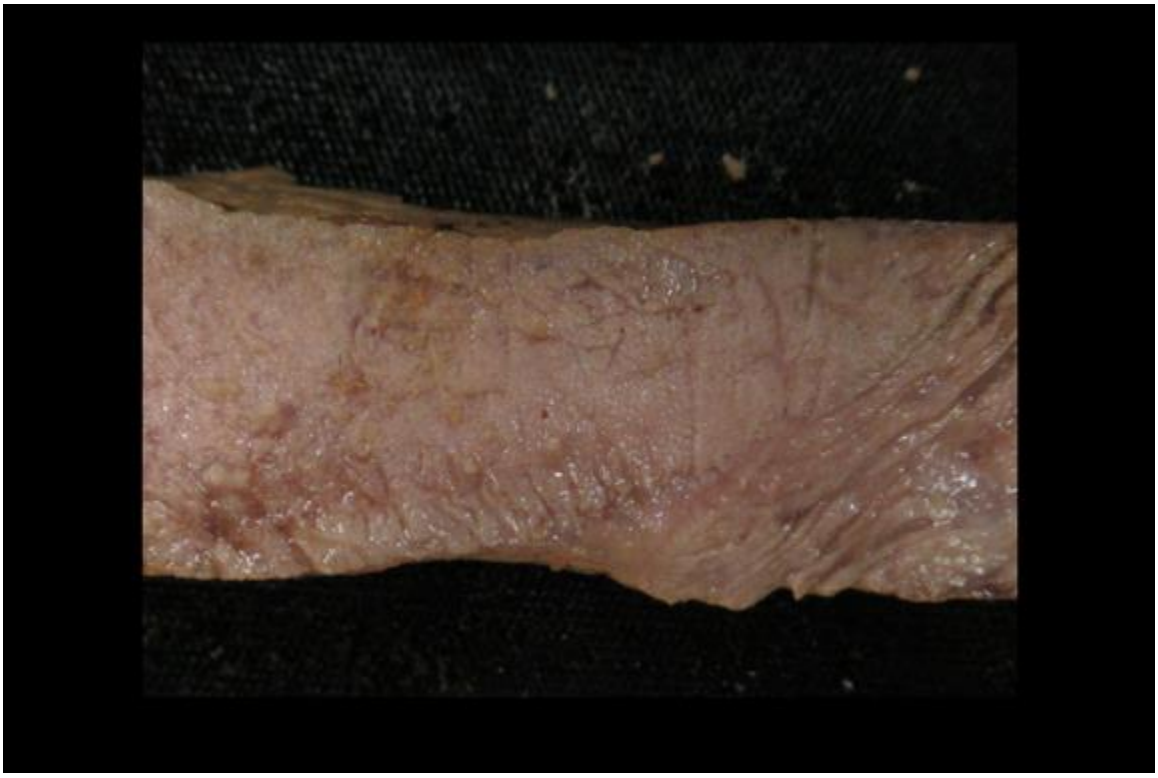
What temperature corresponds with MEDIUM WELL?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with WELL DONE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

1037



Steak number 1037 (Please select the number below).

- ○ 1037 (1)

What degree of doneness is the above steak?

- ○ Very Rare (1)
- ○ Rare (2)
- ○ Medium Rare (3)
- ○ Medium (4)
- ○ Medium Well (5)
- ○ Well Done (6)
- ○ Very Well Done (7)

1095

Steak number 1095. (Please select the number below.)

- ○ 1095

What degree of doneness is the above steak?

- ○ Very Rare (1)
- ○ Rare (2)
- ○ Medium Rare (3)
- ○ Medium (4)
- ○ Medium Well (5)
- ○ Well Done (6)
- ○ Very Well Done (7)

Degree of Doneness Consumer Picture Survey

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- ○ I consent, begin the study (1)
- ○ I do not consent, I do not wish to participate (2)

Please tell us a little about yourself:

Gender

- ○ Male (1)
- ○ Female (2)

Household Size

- ○ 1 Person (1)
- ○ 2 People (2)
- ○ 3 People (3)
- ○ 4 People (4)
- ○ 5 People (5)
- ○ 6 People (6)
- ○ > 6 People (7)

Marital Status

- ○ Single (1)
- ○ Married (2)

Age

- ○ Under 20 (1)
- ○ 20 to 29 years old (2)
- ○ 30 to 39 years old (3)
- ○ 40 to 49 years old (4)
- ○ 50 to 59 years old (5)
- ○ Over 60 (6)

Ethnic Origin

- ○ African-American (1)
- ○ Asian (2)
- ○ Caucasian/White (3)
- ○ Hispanic (4)
- ○ Native American (5)
- ○ Other (6)
- ○ Mixed Race (7)

Annual Household Income

- ○ < $25,000 (1)
- ○ $25,000 - $34,999 (2)
- ○ $35,000 - $49,999 (3)
- ○ $50,000 - $74,999 (4)
- ○ $75,000 - $99,999 (5)
- ○ $100,000 - 149,999 (6)
- ○ $150,000 - $199,999 (7)
- ○ > $199,999 (8)

Highest Level of Education Completed

- ○ Non-High School Graduate (1)
- ○ High School Graduate (2)
- ○ Some College / Technical School (3)
- ○ College Graduate (4)
- ○ Post-College Graduate (5)

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

- ○ Flavor (1)
- ○ Juiciness (2)
- ○ Tenderness (3)

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

- ○ Very Rare (1)
- ○ Rare (2)
- ○ Medium-Rare (3)
- ○ Medium (4)
- ○ Medium-Well (5)
- ○ Well-Done (6)
- ○ Very Well-Done (7)

How many times a week do you consume beef?

	0 3 6 9 12 15 18 21
None (1)	

How do you determine degree of doneness when cooking at home?

- ○ Time (1)
- ○ Color (2)
- ○ Food Thermometer (3)
- ○ Feel, firmness (4)
- ○ I do not determine degree of doneness (5)
- ○ Other (6) _____

If you use temperature to determine degree of doneness, does that temperature correspond with when it is pulled off of the heat or following post cooking temperature rise (carry over cooking)?

- ○ Pulled off of the heat (1)
- ○ Following post cooking temperature rise (carry over cooking) (2)

In a restaurant, at what point do you determine your steak was cooked to the correct degree of doneness?

- ○ First cut; immediately when served (i.e. when your server asks you to cut into your steak) (1)
- ○ After letting the steak sit for a couple minutes and then cutting into it (2)
- ○ After I taste the flavor of the first bite (3)
- ○ After I cut into it and let it sit for a couple minutes (4)

What temperature corresponds with RARE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with MEDIUM RARE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with MEDIUM?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

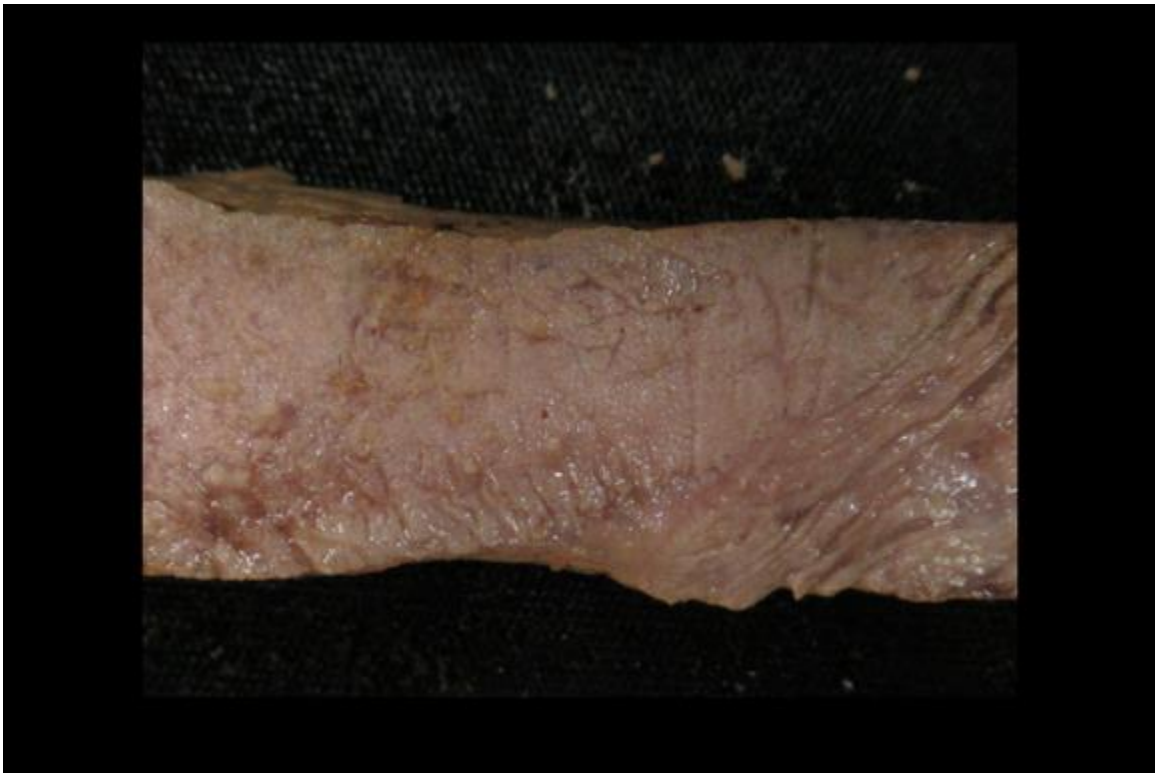
What temperature corresponds with MEDIUM WELL?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

What temperature corresponds with WELL DONE?
(Please type the temperature in the box.)

- ○ (1) _____
- ○ I do not know (2)

1037



Steak number 1037 (Please select the number below).

- ○ 1037

What degree of doneness is the above steak?

- ○ Very Rare (1)
- ○ Rare (2)
- ○ Medium Rare (3)
- ○ Medium (4)

- ○ Medium Well (5)
- ○ Well Done (6)
- ○ Very Well Done (7)

1095

Steak number 1095. (Please select the number below.)

- ○ 1095

What degree of doneness is the above steak?

- ○ Very Rare (1)
- ○ Rare (2)
- ○ Medium Rare (3)
- ○ Medium (4)
- ○ Medium Well (5)
- ○ Well Done (6)
- ○ Very Well Done (7)

Debriefing Statement

Shown after survey is completed:
Thank you for completing this survey. This study was conducted to evaluate published end-point cooking temperatures and how they align with visual perceptions of beef degrees of doneness. If you are interested in receiving the results of the survey, please contact Dr. Travis O'Quinn travisoquinn@ksu.edu. The study will be completed in approximately 8 months. Thank you again for your valued participation.

Appendix D - Data Sheets

Steak ID	L*	a*	b*