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Visual Degree of Doneness Impacts Beef Palatability for Consumers with Different Degree of Doneness Preferences[1]

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Abstract: The objective of this study was to determine the impact on beef palatability perceptions when consumers with varying degree of doneness (DOD) preferences are served steaks cooked to multiple DOD. Paired Low Choice strip loin steaks were randomly assigned to a DOD of either rare (60°C), medium-rare (63°C), medium (71°C), medium-well (74°C), or well-done (77°C). 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 under low-intensity red incandescent light 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 ($P > 0.05$) consumer DOD preference × steak DOD interactions or consumer DOD preference effects for tenderness, juiciness, and flavor ratings when steaks were evaluated under both lighting types. Within the white-lighting testing, there was a consumer DOD preference × steak DOD interaction ($P < 0.05$) for overall acceptability. Consumers who preferred steaks cooked to well-done reported no differences ($P > 0.05$) in overall palatability among DOD under white-lighting, whereas consumers who preferred steaks cooked to rare and medium rated steaks lower ($P < 0.05$) for overall palatability as DOD increased. Regardless of DOD preference, consumer sensory ratings decreased ($P < 0.05$) when steaks were cooked above the consumer's preferred DOD; whereas sensory ratings improved ($P < 0.05$) when steaks were served below the consumers' preferences. These results indicate that overcooking steaks has the greatest negative impact on beef palatability perception and thus, foodservice should err on the side of undercooking steaks to preserve, and potentially improve, eating satisfaction.

Keywords: beef, consumer, cooked color, degree of doneness, palatability
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Introduction

Degree of doneness (DOD) has a large impact on consumer beef eating satisfaction (Cross et al., 1976; Lucherk et al., 2016; Drey et al., 2019). As final cooked internal temperature increases, beef steaks become tougher (Cover et al., 1962; Parrish et al., 1973), less juicy (Lucherk et al., 2016; McKillip et al., 2017), and overall liking decreases (Lorenzen et al., 1999; Drey et al., 2019). Additionally, the likelihood of the consumer receiving an overall unacceptable eating experience is significantly increased with elevated DOD (Drey et al., 2019).

It is noteworthy that much of the published literature evaluating the impact of DOD on beef palatability has utilized red-lighting to mask differences in DOD (Lorenzen et al., 2005; McKillip et al., 2017; Drey et al., 2019). This practice is suggested by the American Meat Science Association (AMSA) Sensory Guidelines (AMSA, 2016), 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

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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. Previous studies have reported 4 to 19% of consumers prefer steaks cooked to rare, whereas 24 to 37% prefer medium, and 5 to 27% prefer well-done (Branson et al., 1986; Cox et al., 1997; Schmidt et al., 2002; Reicks et al., 2011; McKillip et al., 2017; Vierck et al., 2018; Drey et al., 2019). 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 the eating experience of consumers of various DOD preferences. Therefore, the objectives of this study were to evaluate the impact of DOD on beef palatability ratings of strip loin steaks cooked to multiple DOD using consumers with various DOD preferences under both red and white-lighting, 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, 15 Nov. 2017).

Strip loin steak allocation

Low Choice (small^{00} to small^{100} marbling), 21 d aged, frozen steaks (N = 360) were selected from steaks remaining from strip loins fabricated in the studies by Drey et al. (2019) and Vierck et al. (2018). Steaks used in the study were from strip loins within a normal pH range, with no dark cutters or beef with a lower than normal pH included in the study [pH and proximate data reported by Drey et al. (2019) and Vierck et al. (2018)]. Steaks used for the current study were selected in pairs, with each pair consisting of 2 consecutively cut steaks, and excluded all vein steaks. Each steak pair (N = 180) was randomly assigned to a DOD of either rare (60°C), medium-rare (63°C), medium (71°C), medium-well (74°C), or well-done [77°C (170°; National Cattlemen's Beef Association, 2016). All steaks were vacuum packaged (3 mil standard barrier, Prime Source Vacuum Pouches; Bunzl Processor Division, Koch Supplies, Kansas City, MO) in bags that possessed an oxygen transmission rate of 3.5 g^{-1} × 645.2 cm^{-2} × 24 h^{-1} at 21°C. Steaks remained in frozen (–40°C), in the absence of light, for no more than 12 mo prior to consumer sensory panel evaluation.

Consumer sensory panel testing

Consumer panels were conducted at Kansas State University (Manhattan, KS). Consumers were prescreened to participate in panels based on their DOD preference. Panels were conducted with all panelists in the panel 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 1 h and panelists were only allowed to participate once.

Steaks utilized for consumer panels were thawed 24 h 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 throughout 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. Steaks were then cut into 2.5 cm thick × 1 cm × 1 cm cuboid pieces and 2 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 pages. Before the start of each panel, consumers were given verbal instructions on how to use the tablets, fill out the survey, and cleanse their palate. Panelists were provided with a napkin, fork, water cup, expectorant cup, apple juice, and unsalted crackers to serve as palate 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 (110 lux) red incandescent lighting 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 flavor/overall extremely; 50 = neither tough nor tender, juicy and neither dislike or like flavor/overall; 0 = extremely tough, dry, and dislike flavor/overall extremely. Consumers also rated each palatability trait as either acceptable or unacceptable (yes/no), and on 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 (500 lux) in the sensory booths. 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. All consumers where fed under red-lighting in the first round of testing so as not to prompt them to consider differences in DOD in red-lighting testing that they may have been more aware of if they would have evaluated samples under white-lighting first. The small break between rounds coupled with the limited number of samples evaluated in the first round of testing was used to help prevent satiety effects on consumer ratings in the second round of testing.

Statistical methods

Statistical analyses were conducted in SAS (Version 9.4; SAS Inst. Inc., Cary, NC) 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 preferences. Demographic data were summarized using PROC FREQ. All consumer rating data were analyzed using a one-way ANOVA with a Gaussian distribution and all acceptability and quality level 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 continuous data analyses.

Results and Discussion

Participant demographics and factors emphasized when purchasing beef

Table 1 shows the demographic profile of consumers varied, yet were comparable to those reported in other beef consumer work conducted in Manhattan, KS (Wilfong et al., 2016a, 2016b; McKillip et al., 2017; Vierck et al., 2018; Drey et al., 2019). 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 1 to 3 times a week and flavor was identified by 54% of consumers as 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 (Lucherk et al., 2016; Wilfong et al., 2016b; 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. Additionally, purchasing motivators (Table 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 whether the animal was fed a corn-based or forage-based diet were all rated the least ($P < 0.05$) important, but were similar ($P > 0.05$) in importance to packaging type. These results resemble other studies where consumer purchasing motivators have been evaluated. However, Vierck et al. (2018) reported price was similar in importance 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 pack-

Table 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 to 29	42.4
	30 to 39	10.6
	40 to 49	16.6
	50 to 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

aging 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, 2016). When evaluating the impact of red versus white-lighting, consumers in the current study 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 white-lighting, there was an overwhelming positive effect, where consumers were unwilling to rate steaks as critically as they previously had under red-light testing, regardless of DOD differences. Imram (1999) stated, "the first taste is almost always with the eye", meaning that visual sensations help con-

tribute 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 (Kostyla et al., 1978; Hutchings, 1994).

Recent studies conducted at Kansas State University using Low Choice, 21-d aged strip loins, utilized both red and white-lighting consumer sensory testing. Consumers served under white-lights in studies conducted by Wilfong et al. (2016b), Nyquist et al. (2018), and Vierck et al. (2018) all reported comparable consumer palatability mean ratings to the white-lighting test portion of the current study. Additionally, similar to the current work, studies where consumers were fed under red-lights (McKillip et al., 2017; Drey et al., 2019), reported means within each sensory characteristic, similar to our study and lower when compared to the previously mentioned white-lighting 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 similarly. Within both lighting types, there were DOD effects ($P < 0.05$) for all palatability traits (Table 3). Overall, consumer ratings in both red and white-lighting testing decreased as DOD increased from rare to well-done. Within red and white-lighting testing, rare and medium-rare were rated similar ($P > 0.05$), but more tender, juicy, and flavorful ($P < 0.05$) when compared to the other DOD. Additionally, for tenderness and flavor, medium and medium-well steaks were similar ($P > 0.05$) in both red and white-lighting 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-lighting 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.

Numerous previous studies have shown similar declines in beef eating quality with increased DOD. Specifically, as internal temperature increases, beef steaks become tougher (Cover et al., 1962; Parrish et al., 1973). Drey et al. (2019) 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. Moreover, Lorenzen et al. (2005) reported for Warner-Bratzler shear force, well-done and very well-done as the toughest; however, no other differences were found among the 4 lower DOD evaluated. But, consumers in the current study were able to detect

Table 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

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

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

Table 3. Consumer ($N = 283$) palatability ratings[1] and acceptability percentages[2] of strip loin steaks cooked to various degrees of doneness when evaluated under red and white lights

Treatment[3]	Tenderness	Juiciness	Flavor	Juiciness acceptability	Flavor acceptability
Red-light testing					
Rare, 60°C	71.8[a]	76.7[a]	66.2[a]	94.9[a]	88.5[ab]
Medium-rare, 63°C	71.8[a]	73.9[a]	66.7[a]	93.9[a]	89.8[a]
Medium, 71°C	60.4[b]	59.9[b]	59.4[b]	85.4[b]	86.3[ab]
Medium-well, 74°C	61.1[b]	56.0[b]	57.0[b]	81.2[b]	82.7[bc]
Well-done, 77°C	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, 60°C	74.0[a]	80.2[a]	69.1[a]	97.2[a]	90.8[ab]
Medium-rare, 63°C	73.9[a]	77.5[a]	70.4[a]	95.2[a]	92.6[a]
Medium, 71°C	60.1[b]	61.7[b]	62.4[b]	85.8[b]	86.6[bc]
Medium-well, 74°C	59.0[b]	56.8[c]	59.9[b]	79.5[c]	84.6[cd]
Well-done, 77°C	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

[a–d] Means within a trait in the same section (red-light or white-light) with different letters are different ($P < 0.05$).

[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.

[3]Lighting condition under which steaks were evaluated and the degree of doneness of steaks evaluated.

tenderness differences within the lower DODs and support the findings of Drey et al. (2019) by indicating rare and medium-rare as more tender than all higher DOD evaluated. Additionally, in regards to juiciness, previous work by Lucherk et al. (2016), McKillip et al. (2017), and Gilpin et al. (1965) found that the greater the final cooked temperature, the less juicy a steak will be. Our current results support this and indicate that despite lighting type differences, steaks of increased DOD were drier than steaks cooked to lower DOD. The impact of DOD on flavor is less clear in the published literature. Numerous studies have reported decreased consumer flavor liking ratings with increased DOD (Gilpin et al., 1965; Parrish et al., 1973; McKillip et al., 2017; Drey et al., 2019), yet most of these decreases have been small (only 8 to 12% decrease from rare to well-done), compared to the observed tenderness and juiciness effects. Yet, other studies using trained sensory panelists have reported no difference in flavor traits (Lucherk et al., 2016; McKillip et al., 2017; Drey et al., 2019) among steaks cooked to various DOD, or even increased beef flavor ratings with increased DOD (Lorenzen et al., 2005). This previous work coupled with the results of the current study indicate that the observed differences in consumer responses for flavor may be the result of the halo-effect (Meilgaard et al., 2007), and the lower flavor responses could be a direct result of the lower tenderness and juiciness traits observed by the consumers.

There were no consumer DOD preference × steak DOD interactions ($P > 0.05$) for the percentage of samples rated acceptable for juiciness and flavor, with the percentage of samples rated acceptable for both traits decreasing with increased DOD (Table 3). Within red and white-lighting 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 ($P < 0.05$). In the red-lighting testing, juiciness ratings for medium and medium-well were similar ($P > 0.05$); however, within the white-lighting 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-lighting, 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.

Table 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[3]) evaluated under red and white lights

	Rare consumers[3]			Medium consumers[3]			Well-done consumers[3]		
Treatment[4]	Overall liking	Tenderness acceptability	Overall acceptability	Overall liking	Tenderness acceptability	Overall acceptability	Overall liking	Tenderness acceptability	Overall acceptability
Red-light testing									
Rare, 60°C	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, 63°C	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, 71°C	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, 74°C	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, 77°C	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, 60°C	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, 63°C	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, 71°C	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, 74°C	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, 77°C	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

$^{a–d}$ Means within a trait in the same section (red-light or white-light) with different letters are different ($P < 0.05$).

[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 5 degrees of doneness.

[4]Lighting condition under which steaks were evaluated and the degree of doneness of steaks evaluated.

Within white-lighting testing, the consumer DOD preference × steak DOD interaction for overall liking was marginally significant ($P = 0.078$; Table 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 ($P > 0.05$) under red-lighting for these traits. This provides evidence that for these traits (overall liking, tenderness and overall acceptability), the way consumers rated steaks under white-lighting, when they could see the degree of doneness of the sample, was dependent on their DOD preference. For overall liking ratings, under red-lighting, ratings decreased with increased DOD, with rare and medium-rare samples rated similar ($P > 0.05$) and greater ($P < 0.05$) than steaks cooked to the higher DOD for consumers of all DOD preferences. Conversely, well-done steaks had lower ($P < 0.05$) overall liking ratings for all consumer DOD preference groups than steaks cooked to medium and less, except for well-done consumers, in which well-done steaks were similar ($P > 0.05$) for overall liking ratings to medium steaks. However, under white-lighting, the consumer DOD preference groups differed. For both rare and medium consumers, results were similar as under red-lighting, with rare and medium-rare steaks having higher ($P < 0.05$) overall liking ratings than steaks cooked to medium and higher, and well-done steaks rated lower ($P < 0.05$) than steaks cooked to medium and less. But, for consumers who preferred well-done, under white-lighting when the DOD of the steak was visible, there were no differences ($P > 0.05$) in overall liking rating among the steaks cooked to the 5 different DOD. This differs greatly from the results of these same well-done consumers under the red-lighting, when the DOD was not distinguishable.

Similar results were found for both tenderness and overall acceptability (Table 4). For both traits, consumers who preferred medium and rare reported a lower ($P < 0.05$) percentage of samples rated acceptable as DOD increased from rare to well-done. Yet under white-lighting, this relationship was different among the 3 consumer DOD preference groups. The percentage of samples rated as acceptable for tenderness decreased ($P < 0.05$) for both rare and medium consumers as steak DOD increased. But, there were no differences ($P > 0.05$) among the steak DOD treatments for well-done consumers for the percentage of samples rated acceptable for tenderness. Furthermore, under white-lighting, consumers who preferred steaks cooked to rare, rated a lower ($P < 0.05$) percentage of samples cooked to

Table 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[1]	Everyday quality	Premium quality
Red-light testing		
Rare, 60°C	44.8^{bc}	11.4^{a}
Medium-rare, 63°C	40.8^{c}	11.8^{a}
Medium, 71°C	50.2^{b}	4.5^{b}
Medium-well, 74°C	60.6^{a}	4.3^{b}
Well-done, 77°C	59.2^{a}	1.2^{c}
SEM	3.1	2.5
P-value	< 0.01	< 0.01
White-light testing		
Rare, 60°C	25.2^{b}	22.4^{a}
Medium-rare, 63°C	30.6^{b}	23.1^{a}
Medium, 71°C	53.4^{a}	8.0^{b}
Medium-well, 74°C	49.5^{a}	8.2^{b}
Well-done, 77°C	49.8^{a}	2.4^{c}
SEM	3.1	3.2
P-value	< 0.01	< 0.01

$^{a–c}$ Means within a trait in the same section (red-light or white-light) with different letters are different ($P < 0.05$).

[1]Lighting condition under which steaks were evaluated and the degree of doneness of steaks evaluated.

well-done acceptable overall than all other DOD. But, in red-lighting testing, rare consumers found a similar ($P > 0.05$) percentage of well-done steaks acceptable as steaks cooked to both medium-well and medium. Likewise, rare consumers under red-lighting found a similar ($P > 0.05$) percentage of medium-well samples acceptable as all treatments other than rare. Yet, under white-lighting, both rare and medium rare samples had a higher ($P < 0.05$) percentage of samples rated acceptable overall than medium-well. This gives evidence as to the bias of consumers who prefer steaks cooked to rare against samples cooked to medium-well and higher.

A similar indication of the impact of DOD preference is evident among the consumers who preferred steaks cooked to well-done. For this group, no difference ($P > 0.05$) was found among the different DOD for the percentage of samples rated acceptable overall. Yet, under white-lighting, differences were found. Despite their stated preference, a lower ($P < 0.05$) percentage of samples cooked to well-done were rated acceptable overall than all treatments other than rare. Moreover, a greater ($P < 0.05$) percentage of medium-rare samples were rated acceptable overall than rare. These results would indicate that despite their preference for well-done, these consumers were more accepting of steaks cooked to lower DOD. Yet, there is a point (between medium-rare and rare) at which this tolerance of lower DOD reaches a threshold limit at which the steak will no longer be acceptable to the consumer and will be too undercooked for their preference. It is also noteworthy that the decrease in the percentage of samples rated acceptable overall under white-lights as steaks increased from rare to well-done was not as dramatic for consumers who preferred well-done compared both rare and medium. This could indicate some segmentation of the DOD preferences and tolerance among well-done consumers in the current study.

In the current study, 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. In that study, results showed that color dominated the consumers' expectations for the beverages, confirming the important role color plays in consumers' perceptions of food product acceptability (Garber et al., 2000). Previously in beef, Cox et al. (1997) assessed consumers for their attitude toward meat products. Consumers that ordered steaks 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 restaraunts, 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 steaks that are too undercooked is unacceptable for them in regard to sensory ratings and emotionally. Well-done consumers in the current study changed their ratings substantially based on the lighting scenario. Inferences can be made that those results are due to the "squeamish" feeling and emotional disliking when consumers who preferred well-done were served and saw rare samples under white-light.

Perceived quality of strip loin steaks

There were no consumer DOD preference × steak DOD interactions ($P > 0.05$) for the percentage of samples rated as everyday quality or premium quality (Table 5). Under red-lighting, medium-well and well-done had the highest ($P < 0.05$) percentage of samples

Table 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 consumers[1]		Medium consumers[1]		Well-done consumers[1]	
Treatment[2]	Unsatisfactory quality	Better than everyday quality	Unsatisfactory quality	Better than everyday quality	Unsatisfactory quality	Better than everyday quality
Red-light testing						
Rare, 60°	1.9^{c}	39.0^{a}	5.9^{d}	28.4^{ab}	9.2	37.6
Medium-rare, 63°C	4.9^{bc}	43.2^{a}	7.9^{cd}	34.7^{a}	6.1	35.5
Medium, 71°C	8.9^{ab}	35.8^{a}	19.2^{ab}	20.0^{b}	9.2	36.6
Medium-well, 74°C	15.0^{a}	17.9^{b}	12.0^{bcd}	16.8^{b}	11.2	25.8
Well-done, 77°C	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, 60°C	2.0^{c}	52.6^{a}	7.0^{cd}	42.0^{a}	16.5^{a}	29.8
Medium-rare, 63°C	3.0^{c}	43.0^{a}	4.9^{d}	35.6^{ab}	11.3^{ab}	34.1
Medium, 71°C	6.0^{c}	24.9^{b}	14.1^{bc}	30.2^{ab}	6.1^{b}	28.7
Medium-well, 74°C	15.2^{b}	21.7^{b}	20.3^{ab}	22.8^{bc}	13.4^{ab}	26.5
Well-done, 77°C	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

$^{a–d}$ Means within a trait in the same section (red-light or white-light) with different letters are different (P < 0.05).

[1]Consumers were screened for their preferred degree of doneness prior to panels but evaluated all 5 degrees of doneness.

[2]Lighting condition under which steaks were evaluated and the degree of doneness of steaks evaluated.

rated as everyday quality, whereas medium-rare had the fewest samples perceived as everyday quality (P < 0.05), being similar (P > 0.05) only to rare. Within the white-lighting testing, rare and medium-rare steaks had the lowest (P < 0.05) percentage of samples rated as everyday quality, whereas, medium, medium-well, and well-done had the highest (P < 0.05) and were all similar (P > 0.05). Under both lighting scenarios, the results for the percentage of samples classified as premium quality was the same. Under both lights, consumers reported the greatest (P < 0.05) percentage of rare and medium-rare steaks as premium quality and the fewest (P < 0.05) well-done steaks perceived as premium.

There were consumer preference × steak DOD interactions for the percentage of samples rated as unsatisfactory and better than everyday quality (P < 0.05; Table 6). For rare and medium consumers, the percentage of samples rated as better than everyday quality differed (P < 0.05) among DOD treatments under both white and red-lighting. However, there was no difference (P > 0.05) in the percentage of samples classified as better than everyday quality by well-done consumers under red or white-lighting. For the percentage of samples rated as unsatisfactory, there were differences (P < 0.05) found among DOD treatments for all consumer groups in both red and white-lighting scenarios, except for well-done consumers under red-lighting, in which there were no (P > 0.05) differences. Most notably, the percentage of well-done samples classified as unsatisfactory close to doubled (18.1 vs. 32.2%) for consumers who preferred rare in red vs. white-lighting testing. Additionally, though no differences were found under red-lights, well-done consumers found a lower (P < 0.05) percentage of medium samples unsatisfactory than either well-done or rare samples in white-lighting testing. These results further indicate the large impact that DOD has on consumer eating perceptions.

The impact of under- and overcooking

By screening the consumers for DOD preference, it 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. To indicate how severely steaks were under- or overcooked, the terms "1 under/over", "2 under/over", "3 under/over", and "4 over/under", are used to describe the difference between the DOD of the steak served in comparison to the consumer's preferred DOD. Overall, when steaks were undercooked, consumers gave higher palatability ratings; whereas when steaks were overcooked, palatability ratings decreased (Fig. 1). For tenderness, flavor, and overall liking rat-

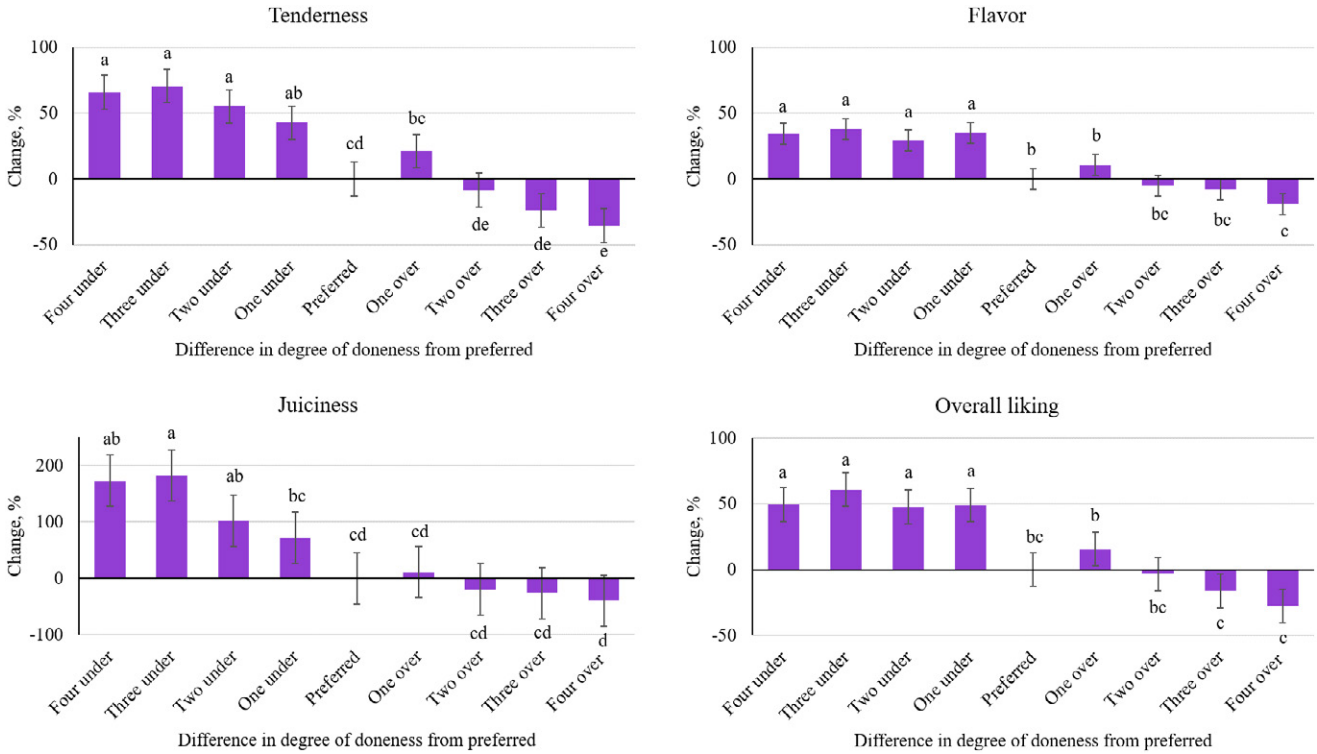

Figure 1. Percentage change in the sensory ratings between the red-light and white-light testing to represent the impact of under and overcooking steaks on consumer palatability ratings. [a–e] Means within the same sensory characteristic without a common superscript differ ($P < 0.05$).

ings, 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 when steaks were cooked 1 DOD under their preferred DOD. Steaks cooked 4 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 the consumer's preferred DOD. Although not significant at each successive DOD change, sensory rating means decreased as the amount of overcooking increased from 2 to 4 DOD over the consumers' preferred DOD.

Additionally, for the percentage of steaks rated as acceptable for each sensory attribute, overall, undercooking had a more positive effect than overcooking (Fig. 2). Although not significant at each successive DOD change, sensory rating means increased as DOD decreased from 1 to 3 DOD under the consumer's preferred DOD. However, when steaks were cooked 4 DOD under the consumer's preferred DOD, the percentage of steaks rated as acceptable for both flavor, tenderness, and overall dropped, and were similar ($P > 0.05$) to the percentage rated acceptable for the consumer's preferred DOD. However, when cooked 4 DOD below the consumer's preference, a greater ($P < 0.05$) percentage of samples were still rated as acceptable for juiciness compared to the consumer's preferred DOD. Similar to the sensory rating data, overall the percentage of samples classified as acceptable for sensory traits decreased as the degree of overcooking steaks increased.

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 these consumers assess whether the steak served met their expectations. Cox et al. (1997) sampled over 3,400 consumers in 9 restaurants and allowed them to order steaks cooked to their preferred DOD. 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 1 DOD, tenderness ratings scores fell 6.5 and 17.8%; meanwhile, steaks that were delivered 2 DODs under- or overcooked had tenderness ratings 16.2 and 24.5% lower than if at the correct DOD (Cox et al.,1997). Moreover, when served 3 DODs different than what the consumer ordered, tenderness ratings were reduced by 17.8 and 27.7% (Cox et al., 1997). In the cur-

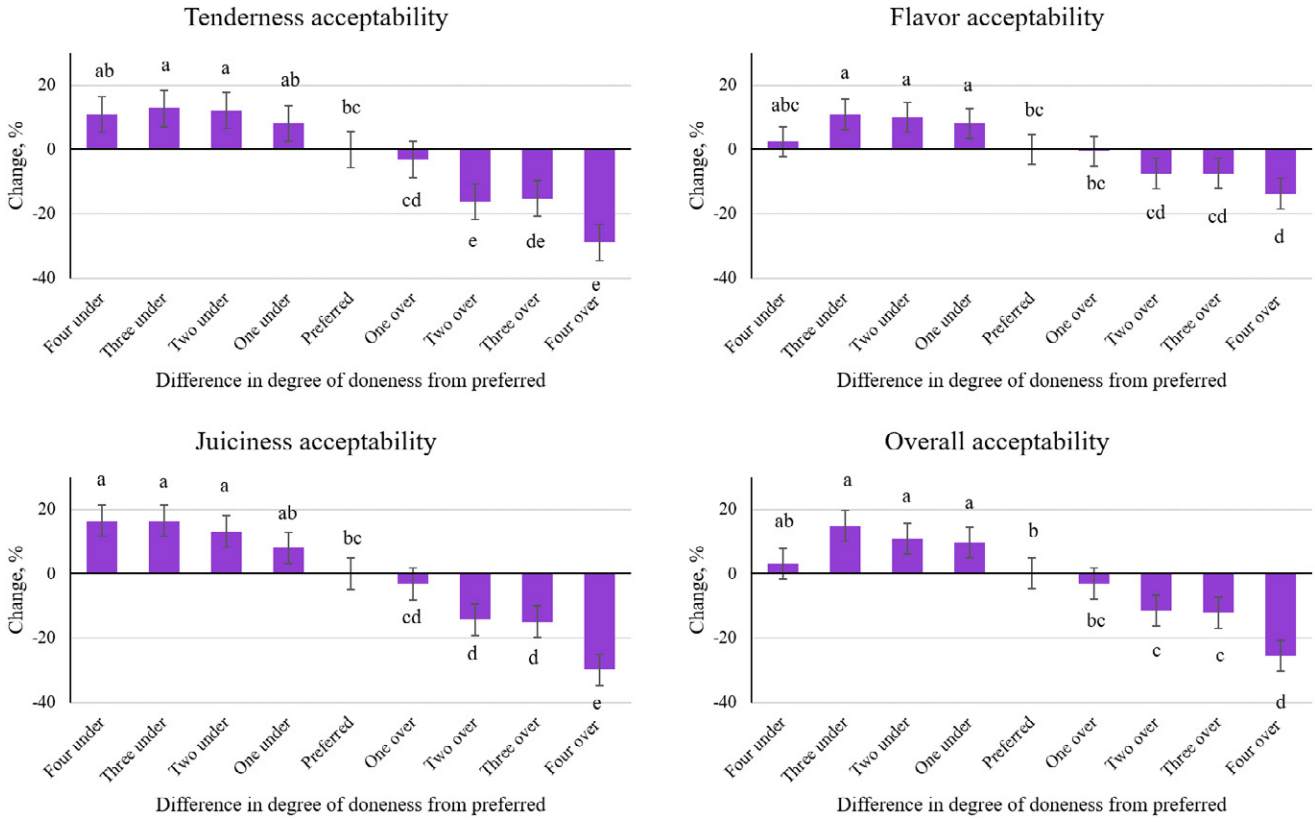

Figure 2. Change in the percentage of samples rated acceptable between the red-light and white-light testing to represent the impact of under and overcooking steaks. a–eMeans within the same sensory characteristic without a common superscript differ ($P < 0.05$).

rent study, ratings for steaks undercooked in regard to the consumer's preference did not decline, but instead increased. Though the magnitude of decline in palatability ratings in the current work is not as great as Cox et al. (1997), results from the current work do also demonstrate a stair-step decline of sensory ratings as the extent of overcooking increased. It is also noteworthy that in the study by Cox et al. (1997), 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. However, consumers in that study only evaluated a single steak that was intended to be at the DOD of their preference. This limited the authors' abilities to draw meaningful conclusions related to the impact of DOD across multiple DOD. Results from the current work would indicate that steaks of differing DOD provide consumers different eating experiences, regardless of their DOD preference. Ultimately, Cox et al. (1997) concluded overcooking had a greater negative impact versus steaks perceived to be undercooked and are in agreement with the results of the current work.

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%). 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-lighting, we were able to quantify the change in ratings due to DOD within each consumer response. Perhaps in the Schmidt et al. (2002) study, steaks were not severely enough undercooked for the consumers to detect the differences in sensory ratings seen in the current study. Additionally, unlike our results, consumers in the Schmidt et al. (2002) study, perceived the impact of under- and overcooking to both be negative.

Conclusion

When consumers were blinded to the DOD under red-lighting, there were few differences among consumers of varying DOD preferences in how they per-

ceived the palatability traits of steaks cooked to multiple DOD. But, the sensory cue of sight significantly impacted palatability ratings when consumers evaluated samples under white-lighting and could evaluate the DOD of samples prior to sample evaluation. Overall, regardless of the consumers' DOD preference, undercooking steaks had a positive effect on sensory ratings whereas overcooking negatively impacted sensory ratings. Therefore, it is better for steaks served at restaurants to err on the side of being undercooked to maximize the consumer's eating experience.

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