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Hey Good Looking, How Have You Been Cooking? The Role of Cooking Method on Cooked Color and Palatability of Beef Steaks

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Abstract

Cooking method and degree of doneness (DOD) are crucial in determining beef palatability, affecting key sensory attributes such as juiciness, tenderness, flavor, and color. While various cooking methods are commonly used to prepare beef, their impact on appearance at different DOD remains a point of interest, as consumers often rely on both internal and external color to assess doneness, shaping their expectations and overall eating experience. Thus, the objective of this study was to determine the palatability and appearance differences between six cooking methods and two DOD. Paired beef strip loins were denuded into the *longissimus lumborum* (LL) and sliced into 1-in. steaks, and then randomly assigned one of six cooking methods (sous vide, oven, grill, flat-top, clamshell, or air fryer) and a DOD (medium rare [MR, 145°F] or well done [WD, 170°F]). Steaks were aged 21 days at 40°F in the absence of light and then frozen at 40°F until use. Steaks were thawed for 24 hours and then cooked to their designated DOD, where end-point temperatures were monitored with a Thermapen. Consumers (n = 96 per DOD, n = 192 total) evaluated six samples using a 100-point line scale for juiciness, tenderness, flavor, overall liking, and overall appearance. Acceptability (acceptable/unacceptable) was determined for each trait. Consumers were asked about the visual expectations by determining (yes/no) if the steak's appearance matched the expected DOD. Consumers determined oven steaks were juicier and more tender ($P < 0.05$) than all other cooking methods, although overall liking did not differ ($P > 0.05$). Across methods, MR steaks were consistently rated higher ($P < 0.05$) than WD for juiciness, tenderness, flavor, and appearance, except for flat-top flavor ratings. Cooking method influenced the appearance ratings and visual expectations of DOD, suggesting that despite similar endpoint temperatures, differences in internal and external color influenced consumer perception and acceptability.

Introduction

Meat color is widely recognized as one of the most important attributes for consumers, spanning from purchase through consumption (Beyer et al., 2024; Prill et al., 2019a). While raw meat color has been extensively studied, the cooked color of whole muscles remains relatively underexplored. Cooked color refers to the visual appearance of a steak, both internally and externally (Beyer et al., 2024). This trait directly impacts

the eating experience by shaping consumer expectations of quality (Prill et al., 2019b). Importantly, it is the final pigment state at the time of consumption rather than the initial internal color that most strongly influences perception (Garber et al., 2000). Because of its central role in consumer satisfaction and perceived product quality, further research on cooked color is warranted.

Cooked color also represents a continuum of degrees of doneness, each carrying specific consumer expectations (Prill et al., 2019b). The concept of DOD was developed to standardize consistency in steak preparation, whether ordered at restaurants or cooked at home (Prill et al., 2019a). Defined by a range of internal peak temperatures from rare to well-done, these categories generally correspond with predictable internal colors (Prill et al., 2019a). The DOD is particularly important because it aligns with consumer preferences for flavor, texture, juiciness, and color, all of which contribute to the eating experience (Prill et al., 2019b).

Besides intrinsic carcass factors and DOD, the cooking method is the next most influential factor for palatability. While some studies have evaluated the impact of cooking method on beef flavor, internal or external color remains unmeasured. Cooking method is one of the primary factors that consumers have control over in producing a highly palatable beef product for consumption (Vierck et al., 2021). Different heat-transfer mechanisms and surface heating profiles can produce steaks that reach the same DOD yet differ in surface browning, internal color, and external appearance, differences consumers readily perceive as changes in palatability (Miller et al., 2023; Sepulveda et al., 2019; Prill et al., 2019b). While various cooking methods are commonly used to prepare beef, their impact on palatability and appearance at different DOD remains a point of interest. Therefore, the goal of this study was to determine the palatability and appearance differences between six cooking methods and two degrees of doneness.

Experimental Procedures

Paired beef strip loins (n = 12; Institutional Meat Purchase Specifications #180 [North American Meat Institute, 2014]). were collected at a commercial beef processing plant (USDA Choice, A Maturity) and transported to Kansas State University. Strip loins were denuded into the *longissimus lumborum* (LL) and sliced into 1-in. steaks. Steaks were randomly assigned to one of six cooking methods (sous vide, oven, grill, flat-top, clamshell, or air fryer) and a DOD (medium rare [MR, 145°F] or well done [WD, 170°F]). Steaks were aged for 21 days at 39.2°F in the absence of light and then frozen at -40°F until use. Prior to cooking, all steaks were thawed under refrigeration for 24 hours at a temperature of 35-40°F to ensure even and consistent internal temperatures during thermal preparation. Following thawing, steaks were cooked using one of the six previously described cooking methods. Each cooking method was carefully standardized in a preliminary study to ensure repeatability and accurate comparisons between treatments. Steaks were cooked to either a MR or WD degree of doneness, with internal temperatures verified using calibrated thermocouples or digital thermometers. For all cooking methods, endpoint temperatures were verified by inserting a Thermapen digital thermometer into the geometric center of each steak. Final internal temperature targets were 145°F for MR and 170°F for WD, consistent with industry standards.

Steaks designated for air frying were cooked at 400°F using a preheated Chefman ExacTemp Digital Air Fryer with temperature probe (Type K Thermaworks probe),

continuously monitored and inserted into the geometric center of each steak. Steaks were flipped once during cooking, with MR steaks flipped at an internal temperature of 90°F and WD steaks at 115°F. Cooking continued until internal target temperatures of 135°F for MR and 165°F for WD were reached, steaks were removed from the air fryer, and final endpoint temperatures were recorded. Oven (Blodgett Dual Flow) and grill (Char-Broil Grill2Go X200) steaks were prepared at an ambient cooking temperature of 350°F. Steaks were flipped once during the cooking process, with MR steaks turned at 85°F and WD steaks at 95°F. Cooking proceeded until internal temperatures reached 135°F for MR and 165°F for WD, where steaks were removed from the heat. Final endpoint temperatures were monitored using a Thermapen digital thermometer to ensure consistency across replicates. Flat-top (CPG Electric Countertop Griddle) steaks were cooked at 350°F, with surface temperature verified using an infrared thermometer. Steaks were cooked using a Cast Iron Construction Grill Press to aid in cooking. The MR steaks were flipped at an internal temperature of 85°F and removed at 135°F, while WD steaks were flipped at 90°F and removed at 165°F. Internal temperatures were recorded using a Thermapen inserted into the geometric center of each steak. Clamshell (Cuisinart Gridler Deluxe) steaks were cooked at 350°F between two heated plates without flipping, allowing for the simultaneous cooking of both sides. Steaks were monitored using a Thermapen thermometer and removed once internal temperatures of 135°F (MR) or 165°F (WD) were achieved. Sous vide (Anova Sous Vide Precision Cooker) steaks were vacuum-sealed, placed in food-grade plastic bags, and submerged in a water bath maintained at a constant temperature of 135°F for MR and 155°F for WD. All sous vide samples were cooked for one hour. Following the water bath, steaks were removed from their packaging and seared on a preheated flat-top at 350°F for approximately 30 seconds per side. After searing, internal temperatures were measured using a Thermapen, with MR steaks removed from the flat-top at 140°F and WD steaks at 167°F.

Consumers (n = 96 per DOD, n = 192 total) evaluated six samples (one per cooking method within each DOD) using a 100-point line scale and anchors were designated on both ends as well as at the midway point with descriptive terms for each, with 0 being extremely dry, tough, and dislike extremely and 100 being extremely juicy, tender, and like extremely. Acceptability (acceptable/unacceptable) was determined for each trait. Consumers were asked about the visual expectations by determining (yes/no) if the steak's appearance matched the expected DOD. Data were analyzed using SAS PROC GLIMMIX using a split-plot design, with cooking method as a whole-plot factor and DOD as the subplot factor. Alpha was set at 0.05.

Results and Discussion

All consumer sensory results data are found in Table 1. The consumers determined the oven steaks were juicier ($P < 0.05$) than the flat-top, air fryer, sous vide, and grill steaks, while being rated similar ($P > 0.05$) for juiciness compared to clamshell, consistent with the findings of Vierck et al. (2021) where oven and grill steaks were rated more tender and juicer ($P < 0.05$) than clamshell steaks. Similarly, oven samples were rated the most tender ($P < 0.05$) compared to all other cooking methods. There was an interaction ($P < 0.05$) between cooking method and DOD for flavor liking. The MR grill steaks had a higher ($P < 0.05$) flavor rating compared to all cooking methods within the WD DOD, as well as the MR sous vide and clamshell steaks. Vierck et al. (2021) also found that consumers rated grill steaks higher than clamshell steaks, consistent with the findings in this study. Within each cooking method, besides the flat-top, consumers

rated the MR samples higher for flavor liking ($P < 0.05$) compared to the WD samples. The flat-top samples were rated similarly ($P > 0.05$) between the MR and WD DOD. Even though consumers found differences ($P < 0.05$) in juiciness, tenderness, and flavor liking among the cooking methods, these did not ($P > 0.05$) illicit an impact on the overall liking scores. Consumers rated the highest ($P < 0.05$) percentage of steaks from the oven and clamshell as acceptable for juiciness. Similar to the overall liking results, the percentage of consumers who rated samples as acceptable for the remaining traits were similar ($P > 0.05$) among cooking methods.

DOD influenced all sensory attributes evaluated by consumers ($P < 0.05$). As expected, the MR steaks were rated higher ($P < 0.05$) than WD steaks for all traits: juiciness, tenderness, flavor, overall liking, and overall appearance. Subsequently, the percentage of consumers that rated each sample as acceptable for all traits (juiciness, tenderness, flavor, overall liking, and overall appearance) was higher ($P < 0.05$) in the MR samples than the WD.

This study aimed to understand the effect of cooking method on appearance rating and acceptability. Oven and flat-top steaks had a higher ($P < 0.05$) overall appearance rating compared to the clamshell, sous vide, and air fryer steaks, while being similar ($P > 0.05$) to the grill. However, there was an interaction ($P < 0.05$) for the visual expectation of the steaks when consumers were asked if it met their criteria for a MR or WD DOD. The WD air fryer steaks resulted in a higher ($P < 0.05$) percentage of consumers who determined it met their visual expectations compared to all treatment and DOD combinations, besides ($P > 0.05$) the sous vide cooked to a WD DOD.

Although consumers perceived juiciness, tenderness, flavor, and overall appearance differently for some cooking methods, the cooking method had no effect on overall liking. While the MR DOD rated higher than the WD DOD for almost all sensory traits, consumers found no difference between the two DODs for flavor liking scores within the flat-top steaks. Most interestingly, consumers determined differences in appearance within each DOD, indicating that while each cooking method resulted in similar end point temperatures, the cooking method impacted internal and external color, influencing the consumer's preference. This was supported by the interaction between DOD and cooking method for visual expectations where consumers determined that DOD and cooking method influenced the visual DOD.

Implications

While this project identified a relationship between cooking method, DOD, and consumer preferences, the cooked color attributes must be explored to understand the comprehensive implications for the consumer and food service industry.

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Table 1. Least squares means (n = 12) of consumer (n = 96) sensory panelist palatability ratings[1] for six cooking methods and two degrees of doneness

	Juiciness	Tenderness	Flavor	Overall liking	Overall appearance
Degree of doneness					
Medium rare, 145°F	68.22[a]	67.83[a]	66.23[a]	67.04[a]	67.15[a]
Well-done, 170°F	47.18[b]	56.40[b]	56.12[b]	54.62[b]	58.43[b]
SEM[2]	1.92	1.94	2.52	2.48	2.73
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Cooking method					
Sous vide	53.02[c]	62.41[b]	60.16[ab]	60.25	60.51[bc]
Oven	66.22[a]	69.16[a]	63.82[a]	65.11	66.42[a]
Flat-top	58.43[bc]	61.22[b]	56.88[a]	62.30	66.42[a]
Air fryer	53.51[c]	58.57[b]	56.88[b]	56.70	58.98[c]
Grill	52.94[c]	58.57[b]	63.77[a]	60.47	63.86[ab]
Clamshell	62.09[ab]	62.75[b]	58.03[b]	60.17	60.56[bc]
SEM[2]	3.14	2.40	2.56	2.55	2.24
*P-v*alue	< 0.01	< 0.01	0.01	0.05	< 0.01

[abc] Means within the same column without a common superscript differ ($P < 0.05$).
[1]Sensory scores: 0 = extremely dry/tough/dislike; 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike; 100 = extremely juicy/tender/like extremely.
[2]SEM (largest) of the least squares means.