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The Impact of Degree of Doneness, Muscle Source, and Bloom Time on Cooked Color and Cooked Color Stability

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Abstract

This study examined differences in color stability between three muscles with varying raw color stability cooked to three degrees of doneness (DOD). Steaks from the *longissimus lumborum* (LL), *psoas major* (PM), and *semitendinosus* (ST) were assigned to medium rare (MR), medium (MED), and well-done (WD) DOD. They were aged for 28 days in the absence of light at 34-38°F, then frozen at -4°F until evaluated. Steaks were thawed for 24 hours and then cooked to their designated DOD monitored with a Thermapen. The steaks were sliced to take objective L^* (lightness), a^* (redness), and b^* (yellowness) color readings measured at 0, 3, 6, and 9 minutes to observe how color stability changed. Spectral data were recorded and used to determine the percent oxymyoglobin (OMb) remaining in the muscle. There was an interaction ($P < 0.05$) between DOD and muscle for L^* and a^* readings. The ST had the highest L^* reading within the MR and MED DOD followed by the LL; however, there were no differences between muscles ($P > 0.05$) within the WD DOD. Within the MED DOD, the ST had the highest ($P < 0.05$) a^* reading followed by the LL while the LL had the highest ($P < 0.05$) a^* reading within the MR and WD DOD. There was an interaction ($P < 0.05$) between DOD and muscle and DOD and time for percent OMb. Within the MR samples, the LL and ST muscles resulted in similar ($P > 0.05$) percent OMb. The MR DOD had the highest ($P < 0.05$) percent OMb for 3, 6, and 9 minutes while the 0-minute readings for MR and MED were similar ($P > 0.05$) and higher ($P < 0.05$) than all time points for the WD DOD. These results indicate muscle, bloom time, and DOD impact the final internal pigment.

Introduction

Meat color is one of the most important attributes for consumers from purchase to consumption (Beyer et al., 2024a, Prill et al., 2019a). While raw color has been heavily researched, cooked color of whole muscles has remained relatively unexplored. Cooked color is the visual internal and external appearance of a steak (Beyer et al., 2024a). Cooked color impacts the eating experience for the consumer as it gives the consumer an expectation of quality (Prill et al., 2019b). However, the initial internal color is not nearly as important as the final pigment before consumption (Garber et al., 2000).

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Cooked color stability is how well meat maintains its color after being sliced. Cooked color plays a pivotal role in the eating experience and the consumer's perception of the quality of the product, therefore warranting further research.

Cooked color represents a spectrum of varying degrees of doneness (DOD), each with its own set of expectations from a consumer (Prill et al., 2019b). DOD were created to establish consistency when a consumer is ordering or cooking a steak (Prill et al., 2019a). DOD are the range of internal peak temperatures from rare to well-done that typically correlate to expected internal colors (Prill et al., 2019a). These are important to cater to personal preferences of flavor, texture, juiciness, and color.

Since cooked color of whole muscles is a relatively under-researched topic, the factors that impact it are also unknown. Salim et al. (2020) found myoglobin undergoes a series of post-translational changes during the cooking process that impact thermal stability and could impact cooked color stability. Based on research done by Beyer et al. (2024b), muscles could impact the final cooked color. Biochemical properties of muscles vary within the same carcass. Muscles have different fiber types and metabolic mechanisms, which can affect color, color stability, and potentially cooked color (Ramanathan et al., 2020). Understanding how these variables interact is essential for optimizing cooking processes and ensuring that the resulting color aligns with consumer expectations and standards. Therefore, the objective was to explore and analyze differences in cooked color and cooked color stability among three different muscles when cooked to three different degrees of doneness.

Experimental Procedures

Beef strip loins (n = 6; Institutional Meat Purchase Specification [IMPS] #180), tenderloins (n = 6; IMPS #189), and eye of rounds (n = 6; IMPS #171C) were selected based on varying raw color stability (USDA-AMS, 2020; North American Meat Institute, 2014). All carcasses were selected in a commercial Midwest beef processing plant (USDA Choice, A Maturity). The primals were collected and then brought back to North Dakota State University for further processing. The strip loins, tenderloins, and the eye of rounds were denuded into the *longissimus lumborum* (LL), *psoas major* (PM), and *semitendinosus* (ST). These subprimals were sliced into 1-in steaks and were randomly assigned a four-digit code and tag indicating their treatment designation including: raw, medium rare (MR), medium (MED), or well-done (WD). The steaks were vacuum sealed and then aged 28 d in the absence of light at 38-40°F before being frozen at -4°F until the time of use. Steaks were then thawed for 24 hours before being cooked to their designated degree of doneness (DOD). The samples were cooked on a Cuisinart Gridler Deluxe clamshell grill set to 350°F. Steaks were cooked to an internal peak temperature of 145°F (MR), 160°F (MED), or 170°F (WD), monitored with a Thermapen probe that was inserted in the geometric center of each steak. Immediately after peak temperatures were recorded, the steaks were sliced using a slice shear box to expose a 1-in internal surface used to determine color readings. Using the exposed internal surface, L^*, a^*, and b^* readings were taken using a HunterLab Miniscan Spectrophotometer (Illuminant A/10, aperture 1-in) after blooming for 0, 3, 6, and 9 minutes measured with a timer. The change between time points in the objective color readings was used to determine cooked color stability. Spectral data were recorded and used to determine the percent oxymyoglobin (OMb) remaining in the cooked steak, using the American Meat Science Association Color Guidelines (King et al., 2024).

The data were analyzed as a split split plot design using SAS PROC GLIMMIX with an alpha set at 0.05.

Results and Discussion

There was an interaction ($P < 0.05$) between the degree of doneness (DOD) and muscle for lightness (L^* readings; Table 1). Specifically, within the MED and MR DOD, the ST muscle had the highest ($P < 0.05$) L^* reading, followed by the LL. However, there were no significant differences ($P > 0.05$) in L^* readings between muscles at the well-done (WD) level. This means there was a different relationship between different muscles and degrees of doneness that influenced lightness. Beyer et al. (2024) found a similar relationship between the *biceps femoris,* LL, and *gluteus medias* and L^* values. The 0-, 3-, and 6-minute readings were all similar ($P > 0.05$) for L^* readings but the 9-minute reading resulted in the lightest ($P < 0.05$) L^* value. This indicates the final lightness was not developed until 9 minutes after slicing.

Like the L^* readings, there was an interaction ($P < 0.05$) between DOD and muscle for redness (a^* readings; Table 1). The a^* values are considered to be the most important factor when evaluating meat color (King et al., 2024). Within the MED doneness level, the ST muscle had the highest a^* reading, followed by the LL. However, within the MR and WD doneness levels, the LL had the highest a^* reading. This indicates that the LL keeps its redness throughout the cooking process better than the ST. These results support that muscle does impact the final color, consistent with findings from Beyer et al. (2024a). Therefore, other muscles should be evaluated in the future to fully understand the impact.

The OMb percentage was used as another measure to indicate color stability. There was an interaction ($P < 0.05$) between DOD and muscle and DOD and time for the OMb percentage (Figure 1). Within the MR samples, the LL and ST muscles resulted in higher OMb percentage readings compared to the PM. The MR DOD had the highest OMb percentage at 3, 6, and 9 minutes. The 0-minute readings for MR and MED were similar ($P > 0.05$) and higher when compared to all time points for WD DOD.

The color measurements were influenced by muscle, DOD, and time. This indicated that meat's final cooked color depends on multiple factors. Investigating these factors could help explain how raw color stability correlates to cooked color stability. The increase in OMb percentage after 0 minutes suggests that the remaining active myoglobin can retain its color stability over time. These results indicate that cooked color is complex and should be investigated further to understand if muscle should be included in cooking instructions or educational materials to consumers. Factors such as additional muscles and cooking methods should be investigated to evaluate their impact on cooked color.

Implications

Muscle influences cooked color and its stability, so if there are significant differences among muscles, it might be necessary to provide consumers with specific cooking instructions for each muscle.

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Table 1. Objective cooked color readings of three muscles within raw, medium rare, medium, and well-done degrees of doneness

Degree of doneness	Muscle[1]	*L**[2]	*a**[3]	*b**[4]	OMb[5] %
Medium rare	LL	55.54^{c}	26.48^{a}	21.74^{a}	66.21^{a}
	PM	51.81^{e}	24.36^{b}	18.66^{cd}	
	ST	57.36^{b}	21.88^{b}	20.88^{a}	65.65^{a}
Medium	LL	55.84^{c}	20.50^{c}	19.66^{bc}	61.21^{b}
	PM	53.41^{d}	20.75^{c}	18.56^{d}	61.24^{b}
	ST	59.30^{a}	21.88^{c}	20.70^{ab}	64.22^{ab}
Well-done	LL	55.49^{c}	16.59^{d}	17.87^{d}	52.20^{c}
	PM	53.59^{d}	14.52^{e}	15.96^{e}	52.20^{c}
	ST	55.10^{c}	13.47^{e}	16.61^{e}	48.84^{c}
SEM[6]		0.48	0.59	0.41	1.49
P - value		< 0.01	< 0.01	< 0.01	< 0.01

^{abcde} Means within the same column without a common superscript differ ($P < 0.05$).
[1]LL: *longissimus lumborum,* PM: *psoas major*, ST: *semitendinosus.*
[2]*L**: 0 = black, 100 = white.
[3]*a**: -60 = green, 60 = red.
[4]*b**: -60 = blue, 60 = yellow.
[5]Oxymyoglobin (OMb) calculated from the AMSA Color Guidelines.
[6]Standard error of the mean (largest) of the least squares means.

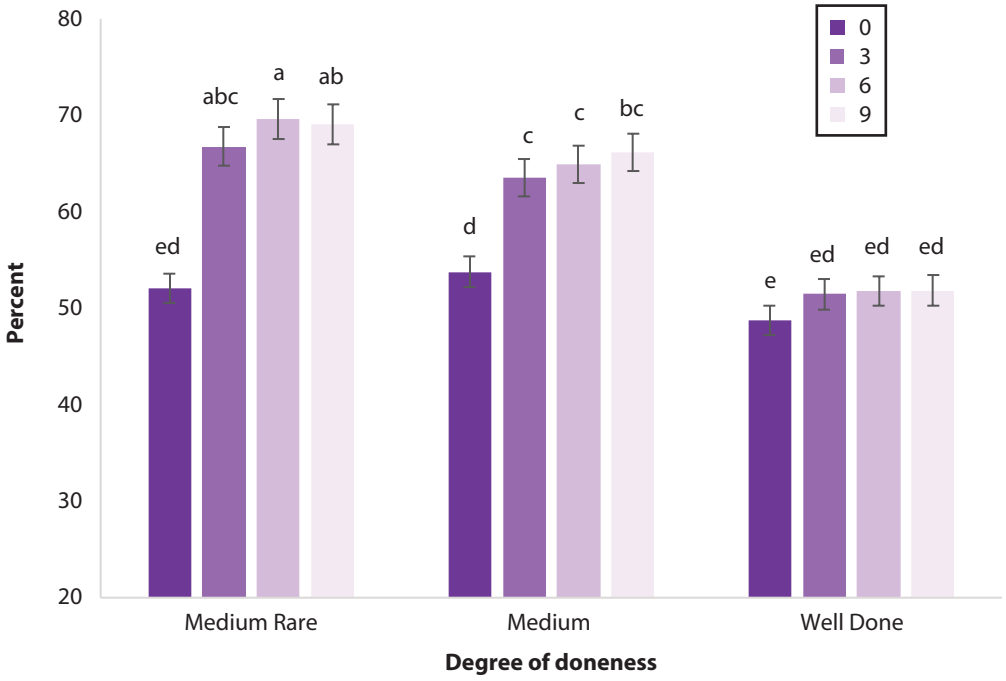

Figure 1. Degree of doneness and time (minutes) interaction on oxymyoglobin percentage.
^{abcde} Means within the same column without a common superscript differ (P < 0.05).