Within-Muscle Variation in Color and pH of Beef *Semimembranosus*


**Story in Brief**

A research trial was conducted to measure the within muscle variation in color and pH of the *semimembranosus* (SM), a muscle highly affected by chilling rate. *Semimembranosus* muscles from Prime (Pr), Choice (Ch), and Select (Se) grade carcasses (3 muscles/quality grade) were cut into 0.75-in-thick steaks and numbered 1 through 10, beginning at the dorsal end. Steaks were subsequently divided into 4 quadrants according to their location within the steak (CaD = caudal-distal; CaP = caudal-proximal; CrD = cranial-distal; and CrP = cranial-proximal). When comparing instrumental color differences, the steaks from the ventral portion were generally lighter, redder, and more yellow than those from the dorsal portion. Furthermore, steaks from quadrant CrD had the greatest (P < 0.05) *L*, *a*, and *b* values, whereas steaks from the most exterior quadrant CaP had the lowest (P < 0.05) *L*, *a*, and *b* values, with steaks from quadrants CrP and CaD having intermediate color values. Within steaks, pH was higher (P < 0.05) in the ventral-most steaks (steaks 7 through 9) than in dorsal-most steaks (steaks 1 through 5). Furthermore, pH was higher (P < 0.05) in steaks from quadrant CrD, followed by CrP, with the lowest pH values (P < 0.05) occurring within quadrant CaP. Traditionally, light meat color has been associated with low pH; however, unexpectedly, these results indicated the quadrant with the lightest color meat had the highest pH.

**Introduction**

The beef *semimembranosus* (SM) is a thick, large muscle that extends from the inner surface of a carcass to the femur. Variations in the initial color, color uniformity, and color stability within the muscle can be related to early postmortem conditions. Because of its location, the deep SM, the portion of the muscle closest to the femur, has a slower rate of chilling than the superficial portion, resulting in accelerated glycolysis and rapid pH decline postmortem (Sammel et al., 2002). Follett et al. (1974) indicated that use of an accelerated chilling system could reduce the rate of postmortem pH decline, resulting in improved muscle color and protein functionality of the deeper/thicker portions of the SM. Differences in postmortem temperature and pH decline in the deep and superficial SM may also alter oxidation and reduction of myoglobin, which is thought to be the ultimate factor affecting the color stability within the SM (Sammel et al., 2002). However, most research involving the SM does not differentiate between the two muscle portions; therefore, this study was undertaken to define the intramuscular pH and instrumental color differences within the SM of the beef round.

**Experimental Procedures**

Nine beef inside rounds (IMPS #168) from USDA Prime, Choice, and Select carcasses (3 inside rounds/quality grade) were obtained from a commercial slaughter facility, transported to the University of Arkansas Red Meat Abattoir, and aged at 35.6°F for 14 d from the box date. The SM was fabricated from each inside round and trimmed to 0.25 in or less of subcutaneous fat. Each muscle was faced and cut into ten 0.75-in-thick steaks perpendicular to the fiber direction, and steaks were numbered 1 through 10 starting with the first steak from the dorsal end. Steaks were subsequently divided into 4 quadrants based on measurements of steak width and depth (Fig. 1; CaD = caudal-distal; CaP = caudal-proximal; CrD = cranial-distal; and CrP = cranial-proximal).

Instrumental color readings of steaks were measured using a Hunter Miniscan XE (Model 45/0-L, Hunter Associates Laboratory Inc., Reston, Va.) after a 30-min bloom period. Instrumental color (*L*, *a*, *b* values) data were collected from taking the mean of 3 readings within each quadrant (CaD, CaP, CrD, and CrP) on the surface of each steak using Illuminant A and a 10° observer. Furthermore, the saturation index (*C*), or chroma, was calculated as 

\[ \sqrt{a^2 + b^2} \]

Statistical analysis. Data were analyzed using PROC MIXED of SAS (SAS Inst. Inc., Cary, N.C.) arranged in a split-plot design, with steak as the whole plot and quadrant as the sub-plot. The whole plot was blocked by muscle. The 3 quality grades were selected to increase the variation in the study, and quality grade was initially included in the model; however, with the exception of a 3-way interaction for pH, quality grade did not (P ≥ 0.05) affect SM color and was subsequently removed from the model. Least squares means were computed and statistically separated by pair-wise t-tests (PDIFF option) when the F-test was significant (P < 0.05).

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Results and Discussion

Quality Grade. Main effects of quality grade on $L^*$, $a^*$, $b^*$, saturation index, and pH are reported in Table 1. There were no (P ≥ 0.05) detectable differences among quality grades for any instrumental color measurements; yet, the SM from USDA Prime carcasses had a lower (P < 0.05) pH value than the SM from either USDA Choice or Select carcasses.

pH. There was no steak x quadrant interaction (P ≥ 0.05) for SM pH. However, pH values appeared to increase from the dorsal-most to the ventral-most steaks, with steaks 7 through 10 having higher (P < 0.05) pH values than steaks 1 through 4 (Fig. 2A). Also, steak 1 had a lower (P < 0.05) pH value than steaks from the ventral half (steaks 5 through 10) of the SM. Furthermore, pH values were highest (P < 0.05) in the CrD quadrant; whereas pH values for quadrant CaP were lower (P < 0.05) than quadrant CrP (Fig. 2B).

Instrumental Color Measurement. Regardless of steak location, those in the CrD quadrant were the lightest (highest $L^*$ values; P < 0.05) compared to other within-steak quadrants (steak location x quadrant, P < 0.05; Fig. 3). Within steaks 6 and 10, quadrant CaP was darker (lower $L^*$ values; P < 0.05) than quadrant CaD, whereas $L^*$ values were lower (P < 0.05) in quadrant CaP than either quadrants CrP or CaD in steaks 7 through 9. Additionally dorsally located steaks (steaks 1 and 2), quadrant CrP was darker (P < 0.05) than quadrant CaD.

Redness ($a^*$) values appeared to increase in steaks 1 through 6, with quadrant CrD of steaks 2 through 5 being redder (higher $a^*$ value; P < 0.05) than quadrants CrP, CaP, and CaD (steak location x quadrant, P ≥ 0.05; Fig. 4). The CrD quadrant was only redder (P < 0.05) than quadrant CaP in steaks 6 and 7, whereas both distal quadrants of steak 8 were redder (P < 0.05) than the proximal quadrants. In steak 9, quadrant CrD had the highest (P < 0.05), and quadrant CaP the lowest (P < 0.05), $a^*$ values, whereas the quadrants CrP and CrD were redder (P < 0.05) than quadrants CaP and CaD of steak 10.

Similar to the $L^*$ and $a^*$ results, yellowness ($b^*$) values (Fig. 5) and saturation index ($C^*$) values (Fig. 6) appeared to increase throughout the dorsal section (steaks 1 through 4), peak in the medial section (steaks 5 through 7), and appear to level off in the ventral portion (steaks 8 through 10) of the SM. Even though $b^*$ (steak location x quadrant, P < 0.05) and $C^*$ values (steak location x quadrant, P < 0.05) were similar (P > 0.05) within steak 1, the CrD quadrant of steaks 2, 3, 4, and 6, were more (P < 0.05) yellow (higher $b^*$ values) than the other three quadrants. In steaks 5 and 7; however, the CrD quadrant was only more (P < 0.05) yellow (higher $b^*$ values) and more vivid (higher $C^*$ values) than quadrants CrP and CaP. Although the cranial half of steak 8 had greater (P < 0.05) $b^*$ and $C^*$ values than the caudal half, quadrant CrD had the highest (P < 0.05), and quadrant CaP the lowest (P < 0.05), $b^*$ and $C^*$ values within steak 9, whereas both quadrant CaP and CrD had lower (P < 0.05) $b^*$ and $C^*$ values than quadrants CrP and CrD within steak 10.

There has been very little work done to define the color differences within the SM, with most prior research focusing almost exclusively on beef tenderness within the muscle. More research on the color uniformity within the SM could provide more information to improve the marketability of the SM, as well as the whole inside round.

The instrumental color results of this study are in agreement with those of Sammel et al. (2002), who reported that the deep portion of the SM was noticeably different in color than the superficial portion. They speculated that the color differences were caused by low pH and high temperature prior to chilling of the deep portion of the SM, which would lead to protein denaturation and the reduced color intensity and stability typically associated with it. Both glycolytic proteins, which prematurely halt glycolysis, and pigment proteins are denatured, creating a very light colored muscle. Results of this study indicate that the color in the deep portion of the SM was quite similar to PSE pork, having a more open structure and greater light scattering (Sammel et al., 2002). Further research is warranted to determine ways to create a more uniform colored SM, which will, in turn, lead to improved marketability and value.

Implications

These results have provided a detailed look into the color variation within the SM. From the information gathered, it can be concluded that there is a substantial amount of color variation within such a large muscle. The observed variation in beef color can be attributed to: 1) the lack of a uniform chilling rate due to the location and size of the SM; and 2) the rate of postmortem glycolysis that the SM undergoes during the conversion of muscle to meat. Further research will be necessary for a more in depth investigation of the relationship of color and pH in this inconsistent muscle.

Literature Cited


Table 1. Influence of USDA quality grade on the pH and instrumentally measured color of beef semimembranosus steaks

<table>
<thead>
<tr>
<th>Quality trait</th>
<th>Prime</th>
<th>Choice</th>
<th>Select</th>
<th>SE</th>
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<tr>
<td>Muscle pH</td>
<td>5.38*</td>
<td>5.57*</td>
<td>5.63*</td>
<td>0.049</td>
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<tr>
<td>Lightness ($L^*$)</td>
<td>44.37</td>
<td>45.47</td>
<td>45.19</td>
<td>1.431</td>
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<td>Redness ($a^*$)</td>
<td>34.40</td>
<td>33.76</td>
<td>33.12</td>
<td>0.551</td>
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<tr>
<td>Yellowness ($b^*$)</td>
<td>28.63</td>
<td>28.25</td>
<td>27.08</td>
<td>0.585</td>
</tr>
<tr>
<td>Saturation index ($C^*$)</td>
<td>44.76</td>
<td>77.03</td>
<td>42.78</td>
<td>0.790</td>
</tr>
</tbody>
</table>

*Means, within a row, with different superscript letters differ (P < 0.05).

1$L^*$ = a measure of darkness to lightness (greater $L^*$ value indicates a lighter color). $a^*$ = a measure of redness (greater $a^*$ value indicates a redder color). $b^*$ = a measure of yellowness (greater $b^*$ value indicates a more yellow color).

2$C^*$ = a measure of the total color/vividness of color (higher $C^*$ value indicates a more vivid color/more total color).

3$\geq$
Fig. 1. Within-steak location of quadrants in the *semimembranosus*: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

Fig. 2. Variation of pH between steaks (A) and within steaks (B) of the *semimembranosus*.

A

![Graph A]

Muscle pH

5.40 5.45 5.50 5.55 5.60

1 2 3 4 5 6 7 8 9 10

Steak number

Dorsal

e de de cde bcd abc a a a ab

Ventral

B

![Graph B]

Muscle pH

5.40 5.45 5.50 5.55 5.60

CrP CaP CrD CaD

b a c ab

Steak quadrant

A-e means, within a graph, with no letters in common differ (P < 0.05).

*Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.
Fig. 3. Within-muscle variation of lightness ($L^*$) of the *semimembranosus*. 
<sup>a-r</sup> means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

Fig. 4. Within-muscle variation of redness ($a^*$) of the *semimembranosus*. 
<sup>a-r</sup> means, within a graph, with no letters in common differ (P < 0.05). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.
Fig. 5. Within-muscle variation of yellowness ($b^*$) of the *semimembranosus*. 

a-o means, within a graph, with no letters in common differ ($P < 0.05$). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.

Fig. 6. Within-muscle variation of saturation index ($B$) of the *semimembranosus*. 

a-o means, within a graph, with no letters in common differ ($P < 0.05$). Steaks were divided into four quadrants: CrP = Cranial Proximal; CaP = Caudal Proximal; CrD = Cranial Distal; and CaD = Caudal Distal.