Color Stability of Hot and Cold Boned Longissimus and Psoas Major Muscle

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ABSTRACT

From eight cows, following electrical stimulation, the righthand-side longissimus and psoas major muscles were hot boned within 1 1/2 h post mortem, vacuum packaged and chilled at 1±1°C. The lefthand longissimus and psoas major muscles were cold boned and vacuum packaged after the carcasses had been chilled for 24 h (i.e. 1 1/2 h at -1 to -4°C, 3 m.s-1 immediately after slaughter followed by chilled storage at 1±1°C). After 12 d of storage at 1±1°C all primals were unpacked and cut into steaks which were subsequently displayed at 3±1°C under continuous illumination with a 300-400 Lux lamp. At days 0, 2, and 4 the color of the steaks was measured both instrumentally (Hunter L*, a*, b* and spectrum analysis) and visually (6-member butcher-panel). After 4 d of display steaks from hot boned psoas major muscles had a more stable color (higher a*- and chroma-values) than steaks from cold boned counterparts (P<0.05) which coincided with slightly, though not significantly, better color scores (P<0.10). The color stability of the longissimus muscle was not affected by time of boning. It is concluded that the color-stabilizing effect of hot boning is fairly small and probably of marginal significance to the retailer when electrical stimulation is included in the slaughtering process.

In the mind of the average consumer about to purchase meat, color becomes synonymous with meat quality. Meat color largely depends on myoglobin, a pigment with several forms. In freshly cut meat, packaged and over-wrapped with an oxygen-permeable film, the purple, reduced, myoglobin rapidly changes to the bright cherry-red oxymyoglobin. Oxidation of myoglobin to metmyoglobin is characterized by a discoloration that is not acceptable to the consumer. This red to greyish brown transition is commonly known as the “fading” of meat.

The judgement of the freshness of meat by the consumer, is largely determined by the relative contribution of the oxygenated and oxidized myoglobin. However, the consumer cannot accurately describe color (changes) in meat by visual judgement since humans often disregard physical factors like structural differences and meat juice and because they may include a decision on color acceptability (8). Therefore, meat color is generally assessed instrumentally. By means of reflection measurements, color can be described as coordinates, e.g., as L*, a*, and b* representing lightness, redness, and yellowness, respectively (10). The a*- and b*-values are included in two formulae denoting the so-called “hue” (H; also known as “tint”) and “chroma” (C; also known as “saturation”) of a certain color. The latter two parameters have been found useful to describe color changes in more descriptive terms. For instance, as oxymyoglobin oxidizes to metmyoglobin, the changes in meat color include a moderate increase in lightness, but a large loss in chroma (the meat appears duller and less saturated) and concomitant increase in hue (the meat color shifts from cherry-red to greyish brown) (16).

The initial development of redness of freshly cut meat is related to pigment concentration and controlled by several factors of which oxygen availability, temperature, pH, and extent of protein denaturation are the most important (14). These same variables affect fading. Metmyoglobin formation will increase when the enzymic reducing activity decreases, e.g., as a result of conditioning (1,7,16), partial denaturation produced by slow chilling (15,28) and electrical stimulation (4,5,20,21). In addition, the residual respiratory activity of the muscle also determines the rate of metmyoglobin formation (7,15,27).

The use of hot boning as part of the post-slaughter process raises the question of its influence on meat color and subsequent color stability during refrigerated display. Since after hot boning fairly low temperatures and high pH-values co-exist, the darker color of the hot boned meat (3,23,24,28) may be more stable.

Research on hot boning has ensued from the interest of wholesalers in a more economic slaughter technique. Scientific studies have primarily focused on solving the tenderness problems associated with hot boning. Other quality traits such as color have received relatively little attention. Yet, for the retail market the maintenance of an attractive bright, red meat color is of prime importance. The present study was designed to determine the color stability of steaks prepared from hot vs. cold boned beef muscles.
MATERIALS AND METHODS

Experimental

Eight cows of the Meuse Rhine Illsel (MRIJ) breed, age 3-4 years, were stimulated electrically within 5 min post mortem (85 V, 14 Hz, 30 s). Within 1.5 h post mortem the righthand side longissimus and psoas major muscles were hot boned. Immediately after excision muscles were vacuum-packaged and chilled at 0-2°C. Immediately after grading (at 30 min post mortem) the lefthand carcass-sides were subjected to 1.5 h blast-chilling at -1°C to -4°C, at an air velocity of 3 m s⁻¹ and subsequently stored overnight at 1±1°C. At approximately 24 h post mortem the lefthand side longissimus and psoas major muscles were cold boned, vacuum-packaged, and stored at 1±1°C.

After a cold storage period of 12 d, one steak was cut from the longissimus (caudal part) and from the muscle belly of the psoas major.

Steaks were packaged in polyvinylchloride film and allowed to oxygenate ('bloom') for 1 h before being displayed at 3±1°C, continuously illuminated with 300-400 Lux fluorescent light (Philips TL33). Both visual appraisal under fluorescent lighting (Philips TLD95) by a 6 member panel scoring individually and reflectance spectrophotometry were used to evaluate muscle color at days 0, 2, and 4 of display. Visual scores were assessed using a five-point scale: 1=lightly red, 2=dull red, 3=slightly dark red or brown, 4=dark red or brown, and 5=very dark red or brown (11).

Color was measured instrumentally by means of a Hunter Labscan SN12244, 10° Standard Observer, D65 illuminant, 30 mm opening, calibrated with black and white, and standardized with a pink tile (L=744, a=235, b=92). For each slice three random measurements (400-700 nm at 20 nm intervals) were averaged to reflect relative changes in oxymyoglobin and metmyoglobin as reported by Hunt (8). Group means were calculated from these averages.

Statistical analysis

Results were subjected to analysis of variance for each color attribute separately. Significances of differences within days and muscles were assessed by Student’s t-test for instrumental measurements and by Wilcoxon’s signed rank test for panel scores.

RESULTS

Analysis of variance revealed a significant (p<0.05) day-effect for all color attributes in both muscles. A significant effect of time of boning was found for a*-value, hue, and chroma of the psoas major and for difference in reflectance values of the longissimus at 630 and 580 nm (R630-R580) indicative for oxymyoglobin. Days of display and time of boning did not significantly interact.

Table 1 includes L*-, a*- and b*-values. The a*-values measured at day 0 indicate that oxygenation might not have been complete at the time of measurement. This means that only results of day 2 and 4 are valid for further discussion. Of the muscles investigated at day 4, the hot boned psoas major muscle was significantly more red (higher a*-values) than the cold boned counterpart. The psoas major showed a significant decrease in a*-and b*-values, indicative for increasing metmyoglobin concentration.

In Table 2 the values for hue, chroma, and (R630-R580) are presented. Chroma of the psoas major lower than that of the longissimus muscle. Only in the psoas muscle a significant decrease in R630-R580 was observed, indicating that the latter is more color stable. The increase in hue between day 2 and 4 was significant for cold boned psoas muscle.

Of the three attributes characterizing color [hue, chroma and lightness (L*)] only the difference in chroma between hot and cold boned psoas muscle at day 4 was significant. There was a tendency for hue to be lower in hot boned than in cold boned psoas (p<0.10).

Results of the subjective measurements (Fig. 1) indicate that influences of time of display and muscle were more important than influence of time of boning. Scores of hot boned psoas tended to be better (more brightly red) than those of cold boned psoas (p<0.10).

**TABLE 1.** The effect of time of boning on the color (L*, a*, and b*) of beef longissimus and psoas major muscles (n=8) during display storage.¹

<table>
<thead>
<tr>
<th>Hunter value</th>
<th>Psoas major</th>
<th>Longissimus</th>
<th>Display-time (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L*</td>
<td></td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>33.6 ± 0.7</td>
<td>32.8 ± 0.7</td>
<td>35.7 ± 0.4</td>
</tr>
<tr>
<td>2</td>
<td>34.1 ± 1.0</td>
<td>34.1 ± 0.6</td>
<td>35.3 ± 0.6</td>
</tr>
<tr>
<td>4</td>
<td>33.7 ± 0.9</td>
<td>33.4 ± 0.8</td>
<td>34.2 ± 0.7</td>
</tr>
<tr>
<td>a*</td>
<td></td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>20.3 ± 0.4</td>
<td>20.1 ± 0.4</td>
<td>20.6 ± 0.3</td>
</tr>
<tr>
<td>2</td>
<td>25.4 ± 0.7</td>
<td>24.7 ± 0.6</td>
<td>22.6 ± 0.4</td>
</tr>
<tr>
<td>4</td>
<td>24.3 ± 1.0</td>
<td>23.7 ± 0.7</td>
<td>20.3 ± 0.6</td>
</tr>
<tr>
<td>b*</td>
<td></td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>14.9 ± 0.6</td>
<td>15.1 ± 0.4</td>
<td>15.9 ± 0.5</td>
</tr>
<tr>
<td>2</td>
<td>18.1 ± 0.8</td>
<td>17.5 ± 0.6</td>
<td>17.5 ± 0.3</td>
</tr>
<tr>
<td>4</td>
<td>17.4 ± 0.9</td>
<td>16.8 ± 0.6</td>
<td>16.3 ± 0.3</td>
</tr>
</tbody>
</table>

⁰Within muscles, in rows, means with different superscript differ significantly (Student t-test, p<0.05); significant differences found with ANOVA not indicated.

**TABLE 2.** Chroma, hue, and oxymyoglobin (%) of hot and cold beef longissimus and psoas major muscles during display storage.¹

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Psoas major</th>
<th>Longissimus</th>
<th>Display-time (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chroma</td>
<td></td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>25.2 ± 0.6</td>
<td>25.1 ± 0.6</td>
<td>26.1 ± 0.5</td>
</tr>
<tr>
<td>(a*+b*)²/2</td>
<td>3.1 ± 1.0</td>
<td>3.0 ± 0.8</td>
<td>28.6 ± 0.5</td>
</tr>
<tr>
<td>0</td>
<td>29.9 ± 1.3</td>
<td>29.1 ± 1.0</td>
<td>26.0 ± 0.6</td>
</tr>
<tr>
<td>Hue</td>
<td></td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>36.3 ± 0.6</td>
<td>36.3 ± 0.6</td>
<td>37.5 ± 0.2</td>
</tr>
<tr>
<td>(tan⁻¹b/a)</td>
<td>3.5 ± 0.6</td>
<td>3.5 ± 0.3</td>
<td>38.3 ± 0.5</td>
</tr>
<tr>
<td>0</td>
<td>35.6 ± 0.5</td>
<td>35.4 ± 0.3</td>
<td>38.9 ± 0.5</td>
</tr>
<tr>
<td>Oxymygoblin</td>
<td>(R 630 - R 580)</td>
<td></td>
<td>Hot boned</td>
</tr>
<tr>
<td>0</td>
<td>18.9 ± 1.1</td>
<td>17.9 ± 0.8</td>
<td>20.7 ± 0.6</td>
</tr>
<tr>
<td>2</td>
<td>21.7 ± 1.3</td>
<td>20.0 ± 1.2</td>
<td>19.0 ± 0.8</td>
</tr>
<tr>
<td>4</td>
<td>19.9 ± 1.5</td>
<td>18.0 ± 1.4</td>
<td>15.3 ± 0.7</td>
</tr>
</tbody>
</table>

¹Means with different superscript differ significantly (Student t-test, p<0.05); significant differences found with ANOVA not indicated.
DISCUSSION

When hot boning is immediately followed by vacuum-packaging the meat is exposed to oxygen for only a short period of time. As the oxygen consumption rate of pre-rigor meat is fairly high, the partial pressure of oxygen within the package will decrease dramatically (13). Consequently hardly any oxymyoglobin or metmyoglobin will be formed. According to Krofp et al. (12) exposure to oxygen inactivates the metmyoglobin reducing activity. Therefore the hot boned meat may be expected to exhibit a better color stability. Potential differences in chilling rate may also contribute to this, as chilling of hot boned meat may be faster which results in less protein denaturation (28) and enzyme inactivation than in cold boned meat. However, it remains to be seen if a reduced enzyme inactivation contributes significantly to color stability, since both the metmyoglobin reducing activity and the oxygen consumption rate may stay higher in hot boned meat. The latter is reported to have an negative effect on color stability (18).

Specific research with regard to the effect of hot boning on color is limited. Recently Claus et al., using a similar methodology, (4) observed that hot boning resulted in a darker color, less oxymyoglobin and more metmyoglobin formation. Electrical stimulation alleviated these undesirable effects. The darker color resulting from hot boning is well-documented (9,22,25,28). Among the postulated mechanisms are faster chilling (1,25,26) and the superior waterholding properties of the hot boned meat (6,25,28). The absence of differences in lightness (L*-values) between hot and cold boned beef in our study may be due to electrical stimulation partially overriding the aforementioned effects of hot boning on lightness. The discrepancy between these and other observations, where a darker color was observed in hot boned meat even after electrical stimulation (3,17,23,24), may be due different chilling rates, storage times, or stimulation parameters.

Our results indicate a slightly positive effect of hot boning on color stability of psoas major muscle but not on that of longissimus muscle. Since the cold boned sides were blast-chilled it is likely that the chilling rates of the latter muscle were similar for hot and cold boning. Furthermore the longissimus is a rather color-stable muscle (18). The display period may therefore have been too short to reveal subtle differences.

Our findings do not confirm those of Claus et al. (4), who found that hot boning negatively affects color stability. Possibly the inclusion of an aging period in our study is responsible for this, since Ledward (15) suggests that in fresh meat the oxygen consumption rate largely determines metmyoglobin formation, whereas in aged meat the efficacy of the enzymic reducing system is more prominent.

CONCLUSION

Hot boning appears to enhance the color stability of the psoas major muscle. After 4 d of display storage, the hot boned muscle exhibited higher (Hunter) a*- and chroma-values. Color stability of the relatively color stable longissimus muscle was not affected by time of boning. It appears from this study that the color stabilizing effect of hot boning is rather small when electrical stimulation is included in the slaughter process. More investigations are necessary to determine the separate effects of electrical stimulation and hot boning on color stability.

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REFERENCES

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