Effect of temperature and pH on postmortem color development of porcine M. longissimus dorsi and M. semimembranosus

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Abstract

BACKGROUND: Purchasing pork that is boned within 1 h postmortem and not aged is customary in China, and final pork color would not be fully realized. The relationship between early postmortem, pre-rigor meat color and 24 h postmortem, post-rigor pork color was investigated and related to the rate of pH and temperature decline within the longissimus dorsi (LD) and the semimembranosus (SM) muscles of pork carcasses. Muscle color, pH and temperature were measured at 45 min and at 3, 9, 15 and 24 h postmortem in carcasses of F2 White Duroc and Chinese Erhualian pigs.

RESULTS: Pork color at 45 min postmortem was not indicative of that at 24 h postmortem in LD and SM, although muscle pH values and temperature at 45 min postmortem were significantly correlated with the LD and SM ultimate color. High muscle pH was associated with decreased $L^*$, whereas high muscle temperature increased $L^*$. Muscle pH and temperature had little effect on $a^*$ and $b^*$ in LD and color evolution in SM.

CONCLUSIONS: Results indicated that meat color inspected shortly after slaughter does not reflect post-rigor meat quality.

INTRODUCTION

Meat color is one of the most important concerns in the pork industry because it is always the first criterion by which consumers judge meat quality and freshness. Muscle color is influenced by many factors, including pH and temperature of muscles early postmortem. The rate and extent of pH and temperature decline early postmortem can influence muscle protein structure and the surface moisture of muscle, and consequently affect post-rigor meat color.

The majority of studies investigating the effects of early postmortem muscle temperature and pH on post-rigor pork color have focused on Western commercial pigs (Landrace, Large White and Duroc). In Western markets, pork quality is assessed on the basis of color at least 24 h postmortem, when pork color development is relatively completed. In wet markets in China, however, meat is purchased as a freshly prepared carcass and in many cases meat color is assessed by consumers within 1 h postmortem. Therefore, there is value in investigating the feasibility of predicting post-rigor eating quality and color from early postmortem color. Moreover, in recent years, the demand for pork from Chinese native Porcine M. longissimus dorsi and M. semimembranosus (SM) in a White Duroc × Chinese Erhualian cross and to evaluate whether color early postmortem can be used to predict ultimate meat color.

MATERIALS AND METHODS

Animals

All animals were from a four-generation family as described below. Two purebred White Duroc boars (Pig Improvement Company (PIC)) and 17 Chinese Erhualian dams were mated to produce F1 animals, from which nine boars and 59 sows were intercrossed to produce 1912 animals in six batches from 2002 to 2004. A total of 208 crossbred pigs were evaluated. The majority of studies investigating the effects of early postmortem muscle temperature and pH on post-rigor pork color have focused on Western commercial pigs (Landrace, Large White and Duroc).
of 781 female and castrated male F₂ animals from four of the six batches were included in this study. All F₀ pigs were determined to be non-carriers of the unfavorable RYR1 (615C) and PRKAG3 (200Q) alleles by DNA test.\textsuperscript{13,14}

**Muscle collection**

All F₂ animals at 240 ± 3 days of age were transported and slaughtered at a commercial abattoir where the pigs were kept in lairage overnight without feed but ad libitum access to water. Pigs were killed by severing the major blood vessels near the heart and were suspended to facilitate exsanguination. Following the completion of exsanguination, the pig carcass was scalded in hot water (60–70 °C), de-haired mechanically and then cooled in cold water (10–12 °C). At approximately 30 min postmortem, the LD and SM muscles were collected from the left side of each carcass and separated into several 3 × 9 cm pieces for meat for quality measurements. The carcass and meat samples for pH and temperature measurements were kept in a cool room at 12 °C until 45 min postmortem. Subsequently, all were stored in a refrigerator at 0–4 °C for the remaining 24 h postmortem.

**Muscle pH and temperature**

Muscle pH and temperatures were measured in the LD muscle from between the 11th and 14th ribs and in the center of the SM muscle. Muscle pH measurements were performed in duplicate and a single temperature measurement taken with a
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Delta 320 pH Meter (Mettler Toledo, Greifensee, Switzerland) at 45 min and at 3, 9, 15 and 24 h postmortem. The pH meter was fitted with an insertion glass electrode and an automatic temperature compensation probe. Just prior to pH measurement, the pH electrode was calibrated in buffers at pH 7.00 and 4.01. The average of the duplicate pH measurements from each sample was taken as the pH value for each muscle for subsequent statistical analysis.

Pork color

Pork color was measured in the LD on a portion of muscle from behind the last rib and in the SM adjacent to the portion used for pH measurement. Color was measured at 45 min and 24 h pm, respectively. Specifically, muscle color samples were allowed to bloom for 5 min at 12 °C and were measured using a Chroma Meter CM-2600d/2500d (Minolta Camera Co. Ltd, Osaka, Japan). Muscle color samples were then wrapped with a polyethylene film and chilled in a refrigerator at 4 °C until 24 h pm. The Chroma Meter was checked for calibration using a white tile (NC, USA). Sources of variation included season (denoted by batch), gender, full-sib family (denoted as litter), pH category and their interactions as fixed effects. Interaction effects remained in the model when they were significant; otherwise they were removed for the final analysis. The effect of breeding system on muscle pH was tested using a model similar to that used for muscle temperature, with the exception that putative pH categories were not included as a source of variation. Model fixed effects for color were similar to those in the model for temperature. Where there were significant sources of variation, differences between means were identified using least square means differences.

RESULTS AND DISCUSSION

In China, although the consumption of chilled meat is becoming increasingly common, most people still buy freshly slaughtered meat that is before or just at the onset of rigor mortis. Tristimulus values (L*, a* and b*) indicated that muscle color at 45 min postmortem was not indicative of muscle color at 24 h postmortem (Fig. 1). The extent of the change between L* at 45 min and at 24 h was very large (∆L* > 3 in all groups), while a* and b* were relatively stable (∆a* and ∆b* < 3 in all groups) (Fig. 1). Both ∆L* and ∆a* were consistently positive in all groups, which meant

Table 1. Least square means of pH values at 45 min and 3, 9, 15 and 24 h postmortem in four pH categories from both muscles

<table>
<thead>
<tr>
<th>Trait</th>
<th>Muscle and pH category</th>
<th>N</th>
<th>45 min</th>
<th>3 h</th>
<th>9 h</th>
<th>15 h</th>
<th>24 h</th>
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<td></td>
<td>ML45min</td>
<td>48</td>
<td>5.62 a</td>
<td>5.50 a</td>
<td>5.56 a</td>
<td>5.58 a</td>
<td>5.62 a</td>
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<tr>
<td></td>
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<td>110</td>
<td>6.28 bx</td>
<td>5.99 bx</td>
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<td></td>
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<td>6.37 cx</td>
<td>5.98 bx</td>
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<td>515</td>
<td>6.62 d</td>
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<td>6.31 c</td>
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<td>20.27 bx</td>
<td>8.51 acx</td>
<td>4.12 acx</td>
<td>3.22 acx</td>
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</tbody>
</table>

Means within muscle with letters in columns (a,b,c,d) indicate significant differences between pH category at P < 0.05 according to least square mean differences. Means between muscles within a pH category with letters in rows (x,y) are significantly different at P < 0.05 according to least square mean differences.
muscles became increasingly pale and red with time postmortem. These results indicated that pork color at 45 min pm was not indicative of that at 24 h postmortem and that prediction of ultimate pork color would not be possible by visual inspection shortly after slaughter. These results agree with those of Chizzolini et al., who also concluded that final pork color could not be predicted at 45 min using the SM, a muscle which has a very low incidence of PSE and DFD. To gain any prediction of eating quality, therefore, pork color must be measured as late as possible after slaughter, as Van der Wal and Walstra described. 

The major reason for the progressive change of meat color postmortem might be biochemical and physicochemical changes during aging, which may be affected by postmortem muscle temperature and pH. Least square means for $L^*$, $a^*$ (except in ML45min of LD) and $b^*$ at 24 h postmortem for the four groups within each of the muscle types appeared to be dependent upon muscle pH24h; that is, as pH24h increased, the $L^*$ and $a^*$ values decreased irrespective of whether the differences were significant or not (Fig. 1 and Table 1). This relationship was not observed between color and pH at 45 min postmortem, however, most likely due to the large amount of variation that was observed in tristimulus values at that time.
The regression coefficients indicated that all pH values from 45 min to 24 h were significant for the evolution of color parameters (Table 2) as pH values at all of the five time points were negatively associated with the variation in \(\Delta a^*\) and \(\Delta b^*\). Andersen et al. described that \(a^*\) and \(b^*\) were better related to the content of pigment proteins, which was poorly correlated with visual appearance.\(^8\) Our results suggested that, by high muscle pH decreasing \(a^*\) and \(b^*\) values, it may increase the content of brownish-grey metmyoglobin, although this was not substantiated in the present study. The results of the present study support those of Lindahl et al., who reported that \(b^*\) was influenced more by the myoglobin forms than by the internal reflectance and almost not at all by the pigment content.\(^9\)

The regression coefficients in this study also indicated that muscle temperature had less of an effect on meat color at 24 h postmortem than pH. The results of the present study agreed with those of Lindahl et al.,\(^2\) who found that the effect of muscle temperature was inconsistent. These authors found that high muscle temperatures at 30 min postmortem increased \(a^*\), while high muscle temperatures subsequent to that had the opposite effect.\(^3\) These authors also suggested that there might be two different temperature-dependent mechanisms that influenced \(a^*\) values at 24 h postmortem. In contrast to Lindahl et al.,\(^3\) the present study demonstrated that high muscle temperatures at 45 min postmortem decreased \(a^*\) values, but increased them at 3 h postmortem.

The results for the SM were similar to those in LD, although the degree of effect of muscle pH and temperature early postmortem on the \(L^*, \Delta L^*, \Delta a^*\) and \(\Delta b^*\) as estimated by PLS regression coefficients was less than that observed for the LD (Table 2). This indicated that the SM was less sensitive to the change of pH and temperature than the LD.

**CONCLUSIONS**
The ultimate pork color, an important determinant of meat quality, could not be predicted by color inspection shortly after slaughter. Muscle pH during the whole 24 h postmortem and muscle temperature at 45 min postmortem had a contrasting effect on \(L^*\) in LD in that high muscle pH decreased \(L^*\), whereas high temperature increased \(L^*\). Temperature and pH slightly affected \(a^*\) and \(b^*\) in LD and the color evolution in SM.

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**REFERENCES**