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# Quality attributes and color characteristics in three-piece boneless hams

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ABSTRACT

One hundred and fifty hams were selected on visual assessment of quality into normal (C) and two-tone (TT) groups. CIE LAB color and pH measurements were collected at the plant 48 h postmortem on the gluteus medius (GM), gluteus profundus (GP), and rectus femoris (RF), and again at 72 h on the semimembranosus (SM), biceps femoris (BF), semitendinosus (ST), and RF. Data were analyzed using GLM procedures of SAS, and correlations between color scores, pH, and drip loss were calculated. Plant and fabrication pH were lower ($P < 0.01$) in GM from TT hams compared with C. Muscles from TT hams had lower ($P < 0.01$) $L^*$ and $a^*$ values compared with C. The GM $L^*$ and GM pH values were correlated ($P < 0.05$) with $L^*$ values for all other muscles and drip loss in SM. These data show that GM color and pH are accurate predictors of pork quality attributes in the muscles of a three-piece boneless ham.



## 1. Introduction

It has been determined that color and appearance are the two most important factors determining consumers' meat selection preferences (Francis, 1977). Pork is ideally grayish-pink in color, but deviations from this are very common in the retail display case (Cannon et al., 1995; Wilson, Ginger, Schweigert, & Aunan, 1959). There is a phenomenon known as two toning in hams, which is the contrast in pigmentation both within muscles and between adjacent muscles. In pork, this primarily occurs at the junction between the longissimus dorsi and psoas major and between the different muscles found within the ham. Wilson et al. (1959) suggested that the degree of two toning was related to differences in the amount of myoglobin in the adjacent muscles; however, this theory may not fully explain two-tone color within muscles.

It has been reported that pale, soft, and exudative (PSE) pork has been associated with two toning due to the abundance of white or intermediate muscle fibers (Miller, Garwood, & Judge, 1975). Pale, soft and, exudative pork is defined as pork that has unacceptably high lightness values ($L^*$) and reduced water holding capacity, resulting in excessive cooking and processing losses (Forrest, Gundlach, & Briskey, 1963). Furthermore, PSE pork is a pH- and temperature-based phenomenon, meaning that it develops in muscle due to an accelerated rate of glycolysis early during postmortem metabolism while the carcass temperatures are still high (Bowker, Grant, Forrest, & Gerrard, 2000). The ultimate pH of PSE pork can range from 5.5 to 4.8 (Lawrie, 1958). Researchers have determined that muscles from PSE carcasses have a higher ratio of light muscle fibers to dark muscle fibers compared with muscles from normal carcasses (Dildey, Aberle, Forrest, & Judge, 1970). From this, it has been suggested that the size and number of light muscle fibers are the most important factors related to two-tone ham color.

The current literature describing the level of two-tone ham color in the U.S. pork industry is limited; however, a national survey conducted in the 1950s determined that 46.9% of the 584 pork carcasses evaluated expressed two-tone color (Self, Bray, & Reierson, 1957). In the pork chain quality audit conducted by Cannon et al. (1996), two-toned muscle color was observed in 12.7 % of the loins and 14.7% of the hams. For packers today, two toning in fresh pork is still an issue. Therefore, the objective of this study was to investigate quality attributes in hams that vary in visual quality.

## 2. Materials and methods

### 2.1. Ham collection

Fresh whole hams (NAMP, 401; $n = 150$; 75/treatment) were collected 24 h postmortem on three different days ($n = 50$) from a large, commercial pork plant located in the southeastern United States. Hams were evaluated immediately after separation from the remainder of the pork carcasses and were selected into two quality categories. The two categories developed were normal (C) and two tone (TT) based on visual muscle color uniformity in the butt-face of the ham. Approximately 45 min after selection, hams were again visually evaluated to confirm the prior selection decision. Hams that were not confirmed as TT were returned to the fabrication line, and additional hams were evaluated and selected, if necessary. The selection process continued until there were 25 hams/treatment/day. Following selection and confirmation, objective CIE (CIE, 1976) measures ($L^*$, $a^*$, and $b^*$) were collected on the gluteus medius (GM) and gluteus profundus (GP) using a Hunter Lab Miniscan XE Plus spectrophotometer (Model 45/0 LAV, 2.54-cm-diameter aperture, 10°

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standard observer, Illuminate D65; Hunter Associated Laboratories Inc., Reston, VA) and pH (Cole-Parmer meter, model 05669-00) was measured in the GM. Hams were then boxed and shipped to the University of Georgia Meat Science and Technology Center. At 48 h postmortem, CIE color ($L^*$, $a^*$, and $b^*$) values on the GM, GP, and RF were collected along with ultimate pH measurements in the GM.

### 2.2. Ham fabrication yields

Following color and pH determination, hams were fabricated according to the National Association of Meat Purveyors specifications (NAMP, 2007). Specifically, whole ham (NAMP, 401) weights were recorded. Hams were then skinned and trimmed to 0 cm subcutaneous fat (NAMP, 402A), and weights were collected. Hams were then fabricated into the outside (NAMP, 402E), inside (NAMP, 402 F), and knuckle (NAMP, 402H) to make a fresh ham (NAMP, 402G). The light butt was also removed. Weights of each piece were recorded individually. The percent lean cuts was determined using the equation [(inside + outside + knuckle + light butt) / skinned ham weight], and the percent three-piece boneless ham yield was determined using the equation [(inside + outside + knuckle)/skinned ham weight].

### 2.3. Color of ham muscles

Approximately 72 h postmortem, CIE ($L^*$, $a^*$, and $b^*$) values were collected on the semimembranosus (SM), biceps femoris (BF), semitendinosus (ST), and RF. The SM was divided into the anterior region (A) and posterior region (P), whereas the BF was divided into the dorsal (D) and ventral (V) regions, and the RF was divided into the inside (I) and outside (O).

### 2.4. Drip loss

A 1.27-cm slice was taken and trimmed free from subcutaneous fat and epimyseal connective tissue for drip loss analysis on the SM muscle following the procedures of Carr et al. (2005) with modifications. Samples were weighed and suspended in a bag for 24 h at 4 °C to collect any purge loss. Chops were then gently blotted and weighed, and the percent purge loss was calculated using the following equation [(Initial wt − Final wt) × 100%].

### 2.5. Lipid determination

From the previously fabricated SM, a 1.27-cm slice was cut, vacuum packaged, and frozen for subsequent analysis. Samples were powder homogenized, and lipid content was measured in duplicate using the procedure of Folch, Lees, and Sloane Stanley (1957) with modifications.

Tissue samples (2.5 g ± 0.1 g) were homogenized with 10 mL of methanol and 5 mL of chloroform (2:1 methanol–chloroform mixture) and allowed to stand for 1 h at 25 °C. Chloroform (5 mL) and 1 M KCl (5 mL) were added and samples were vortexed. Samples were then placed in an ice bath for 5 min and centrifuged at 2,000 ×$g$ for 10 min at 0 °C. The aqueous layer was discarded. The remaining lipid-containing layer was then dried overnight in a fume hood. After drying, samples were weighed and percent lipid was calculated using the following equation [((pan with lipid weight – pan weight)/sample weight) × 100%].

### 2.6. Moisture determination

From the same powder homogenized SM sample, moisture was measured in duplicate (AOAC, 1990). Disposable aluminum drying pans were dried overnight in a 90 °C oven. Tissue samples (1.0 g ± 0.1 g) were placed in pre-weighed, dried aluminum pans and in a 90 °C oven for 48 h. After drying, samples were cooled and weighed and the percent moisture was calculated using the following equation: ((wet sample weight − dry sample weight) / (wet sample weight)) × 100%.

### 2.7. Statistical analysis

Data were analyzed as a completely randomized block design using the GLM procedures of SAS (SAS Inst., Inc., Cary, NC), comparing two ham types (C and TT). The effect of day was tested and found to be non-significant. This was expected because the selection days occurred over a 5-week period in January and February. Least squares means were generated and separated using the LSD procedure with a significance level of $P \leq 0.05$. Pearson correlation coefficients were also calculated between CIE color scores for all muscles, plant pH, fabrication pH, % moisture, and % purge loss. Regression analyses were conducted comparing prefabrication GM $L^*$ values to $L^*$ values from the various muscles in the three-piece boneless ham.

## 3. Results and discussion

### 3.1. Whole ham pH and color

Two-tone hams had a significantly lower pH at 24 and 48 h postmortem compared with normal hams (5.73 vs. 5.61 and 5.75 vs. 5.57; Table 1). Similarly, pale two-toned hams (pH 5.42) and non-pale two-toned hams (pH 5.53) have been reported to have lower pH values than dark, firm and dry hams (pH 6.07) at 24 h postmortem (Briskey, Bray, Hoekstra, Phillips, & Grummer, 1959). Moreover, at 45 min postmortem, it has been documented that pH is significantly lower in PSE pork compared with normal pork (Bendall & Wismer-Pedersen, 1962; Briskey, 1964; Dildey et al., 1970; Josell, von Seth, & Tomberg, 2003; Lawrie & Gatherum, 1962). Other research determined that PSE longissimus lumborum muscles had significantly lower ultimate pH ($pH_u$ 5.50) compared with red, firm, and non-exudative muscle ($pH_u$ 5.73) (Warner, Kauffman, & Russel, 1993).

**Table 1**
pH measurements in the GM at 24 and 48 h postmortem from two-tone (TT) and normal hams (C) and color measurements in the gluteus medius (GM), gluteus profundus (GP), and rectus femoris (RF).

| Item | Treatment | | | |
|---|---|---|---|---|
| | C | TT | Pr > $F$ | SEM |
| pH | | | | |
| 24 h | 5.73 | 5.61 | <0.01 | 0.02 |
| 48 h | 5.75 | 5.57 | <0.01 | 0.02 |
| GM (24 h) | | | | |
| $L^*$[a] | 44.61 | 47.97 | <0.01 | 0.42 |
| $a^*$[b] | 10.13 | 8.91 | <0.01 | 0.17 |
| $b^*$[c] | 14.12 | 15.02 | <0.01 | 0.19 |
| GM (48 h) | | | | |
| $L^*$[a] | 49.09 | 53.83 | <0.01 | 0.36 |
| $a^*$[b] | 10.95 | 9.80 | <0.01 | 0.18 |
| $b^*$[c] | 17.41 | 17.61 | 0.32 | 0.14 |
| GP (24 h) | | | | |
| $L^*$[a] | 38.40 | 40.86 | <0.01 | 3.99 |
| $a^*$[b] | 13.69 | 13.55 | 0.57 | 1.49 |
| $b^*$[c] | 14.24 | 15.29 | <0.01 | 1.73 |
| GP (48 h) | | | | |
| $L^*$[a] | 41.12 | 43.38 | <0.01 | 0.46 |
| $a^*$[b] | 14.27 | 14.10 | 0.58 | 0.17 |
| $b^*$[c] | 18.15 | 18.56 | 0.10 | 0.20 |
| RF (48 h) | | | | |
| $L^*$[a] | 48.71 | 56.31 | <0.01 | 0.36 |
| $a^*$[b] | 8.87 | 7.57 | <0.01 | 0.27 |
| $b^*$[c] | 15.95 | 16.56 | 0.05 | 0.22 |

[a] $L^*$ = lightness, where 0 equals black and 100 equals white.
[b] $a^*$ = redness, from red (+) to green (−).
[c] $b^*$ = yellowness, from yellow (+) to blue (−).