The Effect of Age, Dietary Carbohydrate Source, and Feed Withdrawal on Broiler Breast Fillet Color

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ABSTRACT An experiment was conducted to determine the effect of bird age, diet (feeds formulated with 69.5% corn, 69.7% milo, or 73.6% wheat), and feed withdrawal times (0 or 8 hours) on color (CIE L*, lightness; a*, redness; and b*, yellowness) of raw broiler breast fillets. Broilers were placed on diets at 28 d of age. Replicate groups of 24 birds (eight each from different diet and four each either full fed or feed withdrawn) were processed (slaughtered and eviscerated under simulated commercial conditions) each day from 42 to 45 and 49 to 52 d of age (n = 192). Carcasses were chilled and deboned 4 h postmortem, and triplicate color measurements taken from the medial (bone) side of the fillet. Bird age did not significantly affect fillet color values. Fillets from the birds fed the wheat diet were significantly lighter than fillets from the corn or milo fed birds (48.9 vs. 46.9 and 46.7, respectively). The milo diet resulted in significantly redder fillets than corn or wheat (3.9 vs. 3.5 and 3.3, respectively). The corn diet produced significantly more yellow fillets than milo or wheat (4.8 vs. 2.4 and 2.6, respectively). Feed withdrawal significantly increased fillet lightness from an average of 46.1 to 48.9, decreased redness from 4.1 to 3.1, and increased yellowness from 2.8 to 3.7. Raw broiler breast fillet color is significantly affected by both diet and feed withdrawal, but not by age.

(Key words: age, diet, feed withdrawal, fillet color)

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INTRODUCTION

Many factors have been reported to affect poultry muscle color (Maga, 1994; Froning, 1995). Variation in muscle color is retained even through its conversion to meat and retail sale (Fletcher, 1999a; Wilkins et al., 2000). Research has shown that fillet color variation (mainly lightness or darkness) affects performance attributes of the fillets during further processing (Van Laack et al., 2000; Qiao et al., 2001). The authors reported that lighter-colored chicken fillets exhibited characteristics similar to a pale, soft, exudative (PSE) condition found in pork muscle, which results from a genetic susceptibility to stress. The lighter chicken fillets tended to perform poorly when further processed, in that marination absorption, cook yields, water-holding capacity, and emulsification capacity were lower than darker-colored meat. Handling practices immediately pre-slaughter that introduce stress may affect poultry muscle color (Froning et al., 1978; Ngoka et al., 1982; Babji et al., 1982). Other practices, including transportation, may affect color, as Froning et al. (1969b) reported exposure of live turkeys to exhaust fumes increased muscle redness. Preslaughter feed withdrawal, although probable that it affects physiology of live birds, has been shown to have no effect on either turkey or chicken muscle color (Ngoka et al., 1982; Kotula and Wang, 1994).

Inherent factors such as genetics and age of the animal, as well as long-term environmental influences such as diet, have been found to affect meat color. Genetic selection of broilers for increased meat yield affected meat color by increasing breast meat lightness and decreasing redness (Berri et al., 2001). Animal age may be important because the primary muscle pigment, myoglobin, has been shown to increase 11-fold in chicken leg muscle from day of hatch to 16 wk of age (Nishida and Nishida, 1985). Froning and Hartung (1967) reported that as turkey age increased raw muscle (breast and dark meat) became darker, and dark meat redness increased.

Diet has been shown to affect muscle color through the addition of nitrates or nitrites. Nitrates increased the redness of chicken breast meat and either chemical increased the redness of turkey meat (Froning et al., 1969a). Feeding mold culture material to turkeys increased muscle redness (Wu et al., 1994). Composition of the diet has been shown to affect muscle color of pigs

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Abbreviation Key: a* = redness; b* = yellowness; L* = lightness; PSE = pale, soft, exudative.
(Rosenvold et al., 2001). Geay et al. (2001) reviewed the nutritional factors that affect ruminant muscle color, stating that types of feed and additives change meat color of both cattle and sheep. Therefore, a variety of preslaughter factors have been reported to affect meat color. The objectives of this study were to determine the effects of age, diet, and feed withdrawal on broiler breast fillet color.

Three hundred straight run 28-d-old broilers were obtained from a commercial growout house, transported to the University of Georgia’s research farm in Athens, Georgia, and placed into broiler research housing. Twenty-five birds were placed into each of 12 pens, and three different feeds were assigned to four pens each. Feeds were formulated to be isocaloric with the major carbohydrate source in each a different grain. Diets were formulated with 69.5% corn as a control, 69.7% milo, or 73.6% wheat, with the remainder of the three formulations consisting of soybean meal, poultry byproduct meal, poultry fat, minerals, salt, and vitamins.

Eight birds from three pens, each pen representing a different feed type, were processed each day (42, 43, 44, and 45 d of age) during Week 1; eight birds from the same pens in the same order were then processed in Week 2 (49, 50, 51, and 52 d of age). Larger birds in each pen were subjectively chosen in each pen during Week 1 to minimize size differences between weeks. Twelve hours prior to processing, feed was withdrawn from all birds in the selected pens for 2 h; feed was then replaced for 2 h in an attempt to synchronize the birds’ feeding behavior. Feed and water were withdrawn 8 h and 4 h, respectively, from four birds from each pen prior to processing (8-h feed withdrawal), with the other birds remaining on feed and water (0-h feed withdrawal). Four of these nonwithdrawn birds were then caught, cooped, and transported (15 min) for processing along with the four 8-h feed-withdrawn birds.

Prior to slaughter, birds were electrically stunned for 12 s at 50 V AC (approximately 25 milliamperes), necks were manually cut, and birds were bled for 120 s. Carcasses were scalded at 53°C for 120 s in a batch scalding machine with water recirculation and were picked for 30 s in a Gordon Johnson single-pass in-line picker. Heads and feet were removed from carcasses and the viscera manually removed. Eviscerated carcasses were rinsed for 30 s in a prototype inside-outside bird washer and chilled for 30 min in a revolving ice water slush chiller, then placed in plastic bags and refrigerated for approximately 3 h. At approximately 4 h postslaughter, both fillets were removed from each carcass and individually tagged, weighed, and CIE L*, lightness; a*, redness; and b*, yellowness were determined from triplicate Minolta colorimeter measurements on the medial (bone) side of the fillet.

An experimental design of $8 \times 3 \times 2$ was used for the main effects of age, diet, and feed withdrawal, with four birds in each cell ($n = 191$, from 192 birds processed minus one destroyed carcass). Data were analyzed using general linear models design and means separated using least squares means with Tukeys mean separation procedures of SAS,$^4$ significance $P < 0.05$, (SAS Institute, 1999) for the main effects. Residual error was used as the error term throughout the analysis, except for the variable of carcass weight where a slight but significant interaction (age by feed withdrawal) was used as the error term. All data were pooled in absence of significant interactions.

Additionally, data were temporarily divided into Weeks 1 and 2 to test for any effect due to selective, subjective catching of larger birds during the first week (no significant differences or interactions for any main effects were observed; therefore, data were left in day of age form). Also right and left side fillets from the same bird were sampled and analyzed separately, then averaged together per bird because no significant interactions were observed. Further analysis of right and left fillet difference was conducted using SAS student’s $t$-test procedure.

RESULTS AND DISCUSSION

One bird of the 192 processed was destroyed prior to fillet removal due to an extended time between slaughter and chilling. This resulted in a total of 191 total birds sampled for fillet weight and color measurements. The subjective, selective catching of larger birds during the first week of the study did not appear to skew results as might be expected (if mostly males had been caught first, then mostly females would have been caught in the second week) as carcass weights, fillet weights, and muscle color measurements were not significantly different due to week. There was a significant difference between right and left fillets for fillet weight only, with no difference between L*, a*, or b*. The left fillet weight average of 134.2 ± 2.01 g was significantly greater than the right fillet average of 129.7 ± 1.88 g.

Age

There was no significant effect of age on carcass weight, fillet weight, or color measures. Pooled carcass weights ranged from 1,495.9 ± 42.2 g on the first day of the experiment to 1,569.9 ± 51.5 g on the last day of the experiment at 52 d of age. Subjectively choosing the largest birds the first 4 d of the 8-d period was apparently successful in removing the influence of age on animal weight and fillet weight. There was a significant interaction for carcass weight between age

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$^3$Johnson Food Equipment Co., Kansas City, KS.
$^4$Minolta Chroma Meter 300, Minolta Corp., Ramsey, NJ.
$^5$SAS Software Version 8, SAS Institute, Cary, NC.
and feed withdrawal treatment (Table 1). Carcass weights for birds 44 d old and feed withdrawn and 50 d old and full fed (1,451.62 ± 67.05 and 1,404.75 ± 47.39 g, respectively) were significantly lower than 45-d-old feed-withdrawn birds (1,771 ± 68.45 g). This variation in carcass weights over different days of age and feed withdrawal treatment is probably due to the normal variation of weights typically found in initially unselected and unsorted (by sex) flocks of birds.

Fillet weights ranged from 120.7 ± 4.7 g at 42 d of age to 131.3 ± 6.9 g at 52 d of age. L* values ranged from 47.45 ± 0.58 to 48.00 ± 0.19, a* values from 3.38 ± 0.21 to 3.75 ± 0.19, and b* values from 3.33 ± 0.41 to 3.00 ± 0.33, respectively, from 42 to 52 d of age. The results suggest age is not an important factor in regard to previous studies that reported an age effect on muscle color. Increasing muscle size, rather than age, therefore, may have been a factor in previous studies.

### Diet

Diet significantly affected carcass and fillet weights (Table 1). Birds fed the wheat diet had significantly lower carcass weight (1,488.3 ± 25.9 g) than birds from either the corn or milo diets (1,657.1 ± 30.3 and 1,614.6 ± 28.4 g, respectively), which were not different from each other. Fillet weights were also the lowest for the wheat fed birds (123.34 ± 2.85), with no differences in fillet weights of the corn and milo fed birds (137.14 ± 3.53 and 135.49 ± 3.38 g, respectively). Although all three diets were formulated to be isocaloric, birds fed the wheat diet either did not consume as much feed or did not convert it as efficiently to body or muscle mass. Also, birds were not weighed when originally assigned to treatment diets, so there is some chance that a larger percentage of smaller birds may have been unintentionally assigned to the wheat diet treatment.

### Feed Withdrawal

Feed withdrawal had no effect on carcass or fillet weight. This was expected as feed withdrawal would have been a factor in previous studies. Increasing muscle size, rather than age, may have been a factor in previous studies that reported an age effect on muscle color. Increasing muscle size, rather than age, may have been a factor in previous studies.

### Dietary Carbohydrate Source

Dietary carbohydrate source significantly affected color measures (L*, a*, and b*) as shown in Table 2. Fillets from the birds fed the wheat diet had a significantly higher L* value (47.46 ± 0.38) than fillets from the corn or milo diets, which were not significantly different (45.57 ± 0.41 and 45.39 ± 0.48, respectively) at 0 h of feed withdrawal. The pattern was the same at 8-h feed withdrawal, with fillets from birds fed the wheat diet significantly lighter (50.33 ± 0.51) than either the fillets of birds from corn or milo diets, which were not significantly different (48.17 ± 0.37 and 48.05 ± 0.35, respectively).

The milo fed birds produced fillets with significantly higher a* values (4.34 ± 0.17) than fillets from birds fed the wheat diet (3.80 ± 0.15), although fillets from corn fed birds (4.10 ± 0.12) were not different from either at 0 h feed withdrawal. At 8 h withdrawal, fillets from birds fed milo were significantly redder (3.47 ± 0.12) than either the fillets from the corn or milo diets, which were not different from each other (2.98 ± 0.13 and 2.84 ± 0.13, respectively).

For b* values, fillets from birds fed the corn diet were significantly higher (4.31 ± 0.30) than fillets from either the milo- or wheat-fed birds, which were not different from each other (1.93 ± 0.17 and 2.08 ± 0.21, respectively) at 0 h of feed withdrawal. At 8 h withdrawal, fillets from birds fed milo were significantly redder (3.47 ± 0.12) than either the fillets from the corn or milo diets, which were not different from each other (2.98 ± 0.13 and 2.84 ± 0.13, respectively).

Wheat-fed birds produced significantly lighter or paler fillets. Whether the effect was due to a lack of pigments otherwise present in corn and milo or a pH difference due to a physiological effect on the meat resulting from the wheat diet is unknown. Birds eating the milo diet produced significantly redder fillets than those from corn or wheat diets, yet the additional redness did not contribute to significant fillet darkening (lower L* values). Birds fed the corn diet produced fillets that were significantly more yellow (5.19 ± 0.31) than either the milo or wheat diet fillets (2.79 ± 0.23 and 3.03 ± 0.21, respectively).

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Feed withdrawal significantly affected muscle color as shown in Table 3. For each diet, feed withdrawal significantly increased \( L^* \) values, by an average of 2.71 or 5.9%. However, considering that most fillets are usually distributed within a 20-U \( L^* \) range as reported by Barbut (1997) and Wilkins et al. (2000), feed withdrawal had the effect of lightening fillets an approximate average of 13.6% of the normal distribution range across diets. Withdrawal significantly reduced \( a^* \) values for all diets by an average of 0.98 or a 24.0% reduction in \( a^* \). Feed withdrawal significantly increased \( b^* \) values, by an average of 0.90 or a 32.5% increase. Therefore, feed withdrawal produced significantly lighter, less red, and more yellow fillets. Two previous studies reported no effect on muscle color due to feed withdrawal using either turkeys or chickens (Ngoka et al., 1982; Kotula and Wang, 1994). Because of the stress of physical intrusion on the animal during feed withdrawal and the lack of nutrients short term (and temporary reduction of available glucose), feed withdrawal would seem likely to significantly affect muscle color. Other researchers have shown a significant negative correlation between \( L^* \) values and muscle pH, probably as a result of muscle glycogen undergoing conversion to lactic acid during postmortem physiological processes (Boulianne and King, 1995; Fletcher, 1999b) and changing reflectance properties of the muscle. Withdrawal effects on muscle color in this study may reflect the process of physical or nutritive stress in current commercial broiler stock.

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**TABLE 3. Means and SEM of \( L^* \), \( a^* \), and \( b^* \) breast fillet values from birds fed either a corn-, milo-, or wheat-based diets and withdrawn from feed 0 or 8 h before slaughter (\( n = 32 \))**

<table>
<thead>
<tr>
<th></th>
<th>( L^* )</th>
<th>( a^* )</th>
<th>( b^* )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hours withdrawn</strong></td>
<td>( 0 )</td>
<td>( 8 )</td>
<td>( 0 )</td>
</tr>
<tr>
<td>Corn</td>
<td>45.57±0.41</td>
<td>48.17±0.37</td>
<td>4.10±0.12</td>
</tr>
<tr>
<td>Milo</td>
<td>45.39±0.48</td>
<td>48.05±0.35</td>
<td>4.34±0.17</td>
</tr>
<tr>
<td>Wheat</td>
<td>47.46±0.38</td>
<td>50.33±0.51</td>
<td>3.80±0.15</td>
</tr>
</tbody>
</table>

\(^{a,b}\)Means within columns with differing superscripts are significantly different (\( P < 0.05 \)).

\(^{x,y}\)Means within variables (\( L^* \), \( a^* \), or \( b^* \)) within rows with differing superscripts are significantly different (\( P < 0.05 \)).

\( L^* = \) lightness; \( a^* = \) redness; \( b^* = \) yellowness.

\( n = 31 \).


