Small bird programs: Effect of phase-feeding, strain, sex, and debone time on meat quality of broilers

V. B. Brewer,* J. L. Emmert,† J.-F. C. Meullenet,‡ and C. M. Owens*1

*Department of Poultry Science, University of Arkansas, Fayetteville 72701; †Department of Animal Sciences, University of Illinois, Urbana-Champaign 61801; and ‡Department of Food Science, University of Arkansas, Fayetteville 72701

ABSTRACT Phase-feeding (PF) has been effective in maintaining broiler growth while reducing production cost, but the effect on different broiler strains grown in a small-bird production scenario has not been assessed. The objective of this study was to evaluate 3 commercial broiler strains typically used in a small-bird production scenario to assess the effect of various debone times and PF on yield and meat quality. Birds (n = 1,080) were fed either diets with average industry nutrient levels or diets with phased levels of amino acids. In total, 540 birds were commercially processed at 40 and 42 d of age. Breast fillets were harvested at 2, 4, and 6 h postmortem (PM). Muscle pH was measured at the time of debone and fillet dimensions, instrumental color (L*, a*, and b*), and pH were measured at 24 h PM. Fillets were cooked to 76°C and cook loss was calculated, followed by Meullenet-Owens Razor shear (MORS) analysis. Phase-feeding, strain, and sex had little effect on fillet yield, but deboning at 2 h PM resulted in a higher fillet yield compared with that of later debone times. Strain, sex, and debone hour had significant effects on fillet dimensions, with strain A producing longer and wider fillets than strains B and C. Males had larger fillets than females (longer and wider), whereas deboning early resulted in significantly thicker fillets compared with those of later deboning. There were no differences in fillet dimensions due to PF, however, uniformity was improved. The PF treatment did not affect pH, color, cook loss, or MORS energy. Deboning at 2 h PM resulted in higher MORS energy, indicating decreased tenderness in 2 of the strains, whereas in one strain, tenderness was not affected by debone time. Results of this study suggest PF does not adversely affect yield or meat quality of broilers in small-bird programs but strain, sex, and debone time can affect quality. Results also suggest that strain can effect tenderness of breast fillets when deboned prerigor.

Key words: broiler, phase-feeding, yield, meat quality, shear

INTRODUCTION

In the broiler industry, production efficiency is critical. Because of this, many processors are shifting toward deboning broiler breast fillets directly after leaving the chiller or after minimal aging periods. However, it is recommended that broiler breast meat be deboned sometime between 4 and 6 h postmortem (PM) so that toughening of meat does not occur (Stewart et al., 1984; Lyon et al., 1985; Dawson et al., 1987). It has been well-documented that removing meat, especially breast fillets and tenders, from the skeletal restraints before 4 h PM can allow for contraction of the muscle sarcomeres and results in breast fillet toughness (Lyon et al., 1992; Mehaffey et al., 2006).

The poultry industry is a consumer driven market. Because modern broilers have such growth potential, processors have targeted specific markets and grow birds to an age to meet these market needs (e.g., fast food market). For this market, smaller birds (40 d of age) are used so that portion sizes are more readily met at processing. In 2001, the food service market surpassed the retail market as the second largest outlet of chicken (largest being birds deboned for further processing), and greater than 50% of chicken that goes into the foodservice market segment is for fast food outlets (NCC, 2010).

Phase-feeding (PF), a feeding regimen designed for broilers that has the potential to significantly increase feed efficiency, decrease nitrogen excretion, and reduce production costs was the dietary treatment that was applied to these birds (Pope and Emmert, 2001; Pope et al., 2002, 2004; Brewer et al., 2006b). Previous re-
search has shown that PF does not effect meat quality (Brewer et al., 2006a); however, PF has never been studied in a shorter grow out (i.e., 40 d).

The objective of this study was to evaluate different commercial broiler strains typically used in a small-bird production scenario to assess the effect of various debone times and PF on yield and meat quality.

**MATERIALS AND METHODS**

**Experimental Design**

To simulate a small-bird production scenario, 3 commercial broiler strains, chosen for common use in small-bird production programs, were grown to 40 d of age. In total, 1,080 birds (n = 360 per strain) were grown in 6 replicates, each comprising equal parts male and female (n = 180). A photoperiod of 23L:1D was maintained, and both water and experimental diets were freely available. Birds were fed 1 of 2 dietary treatments: diets with average industry nutrient levels or diets with phased levels of amino acids. The PF treatments were formulated to match the nutrient requirements at 18 d (high nutrient) and 40 d (low nutrient). High and low nutrient density diets were blended to produce rations containing amino acid levels that matched the predicted PF requirements over 2-d intervals (Emmert and Baker, 1997); diets were switched every other day. All birds were processed on d 40 or 42 of age, with 3 replicates processed per day.

Birds were processed following a 10-h period of feed withdrawal on a commercial-style in-line system, including electrical stunning (11 V, 11 mA, 11 s), scalding (53.9°C, 2 min.), defeathering using in-line commercial picking equipment, and evisceration. Following evisceration, carcasses were placed in immersion chill tanks for a total of 90 min to an end-point temperature of 4°C. The chilling process included 15 min of prechill at 12°C and 75 min of chill at 1°C. After chilling, carcasses were well-packed and aged on ice until deboning at 2, 4, or 6 h PM.

Prior to deboning, ready-to-cook carcasses were weighed, and deboning was performed by 4 trained, experienced people. At each PM time, breast fillets (Pectoralis major) were harvested and weighed to assess yield and were then immediately measured for muscle pH and color (time of debone). Muscle pH was determined on all right-side fillets (cranial portion) using a Testo spear-tip probe and meter (Model 205 Testo, Inc., Sparta, NJ). Color measurements (L*, a*, and b*) were also made at 3 locations on the dorsal side of the right fillet using a Minolta colorimeter (CR-300, Konica Minolta, Ramsey, NJ), and all readings were averaged. Fillets were then zip-sealed in plastic bags, packed on ice, and held overnight in a 4°C cooler. After overnight storage, fillets were split into halves. Muscle pH and color were again measured (24 h PM) on the right fillet while the left fillet was vacuum-packed and frozen (−29°C) for later determination of cook loss and texture analysis. Fillet dimensions were also made at that time using calipers. Measurements included length at the longest point, width at the widest point, cranial thickness at the thickest portion of the fillet, and caudal thickness measured 2.54 cm from the bottom of the fillet.

Right breast fillets were removed from the freezer and allowed to thaw for 24 h before cooking. Fillets were cooked according to methods described by Sams (1990), with temperature modifications (endpoint temperature: 76°C) described by Mehaffey et al. (2006). Cook loss (%) was determined (Mehaffey et al., 2006) and fillets were sheared for texture analysis. For texture analysis, the Meullenet-Owens Razor Shear (MORS) method was conducted to determine shear energy, using a texture analyzer (model TAXT2; Texture Technologies, Scarsdale, NY) according to methods described by Cavitt et al. (2005) and as modified by Mehaffey et al. (2006). Briefly, an 8.9-mm-wide razor blade sheared the fillets perpendicularly at a crosshead speed of 5 mm/s. In this study, whole fillets were sheared in 4 locations and data were averaged for each fillet for statistical analysis. Razor blades were changed after the completion of 80 shears to ensure that blades did not dull.

**Statistical Analysis**

The experiment was analyzed as a completely randomized design using the GLM procedure of SAS. Factors considered included feeding regimen, strain, sex, and debone hour. Differences among treatment means were established using Duncan’s multiple range test, and means were considered significant at P < 0.05.

### Table 1. Meat quality of breast fillets from 3 broiler strains fed industry or phase-feeding (PF) diets

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Strain A</th>
<th>Strain B</th>
<th>Strain C</th>
<th>Pooled SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industry</td>
<td>PF</td>
<td>Industry</td>
<td>PF</td>
</tr>
<tr>
<td>pH at debone</td>
<td>5.84</td>
<td>5.83</td>
<td>5.80</td>
<td>5.78</td>
</tr>
<tr>
<td>L* at debone</td>
<td>49.0</td>
<td>48.9</td>
<td>48.9</td>
<td>49.0</td>
</tr>
<tr>
<td>Cook loss (%)</td>
<td>22.2</td>
<td>21.5</td>
<td>22.0</td>
<td>22.4</td>
</tr>
<tr>
<td>Shear energy (N × mm)</td>
<td>144.7</td>
<td>141.0</td>
<td>133.8</td>
<td>143.0</td>
</tr>
</tbody>
</table>

1Data of carcasses deboned at 6 h only; n = 60 per mean.
RESULTS AND DISCUSSION

Phase-feeding was the nutritional treatment applied to the birds used in the current study and employs phased amino acid levels to better meet the bird’s nutrition requirements. By doing so, valuable nutrients are not overfed throughout the life of the bird, and substantial savings have been previously observed with PF. In the current study, PF did not effect \( P > 0.05 \) any of the meat quality parameters measured at 2, 4, or 6 h PM (data from 6 h deboned fillets are shown in Table 1); therefore, information concerning the effects of PF on meat quality will be excluded from further discussion. Brewer et al. (2006a) also found that PF did not effect meat quality parameters when birds were grown to 60 d.

Body weight at the time of processing was measured and is presented in Table 2. Differences in growth due to strain have been well-documented (Bilgili et al., 1990; Acar et al., 1991; Mehaffey et al., 2006); however, in this study, there were no differences in live weight attributed to strain at the time of processing, with one exception that resulted in a live BW difference of < 100 g (strain A vs. strain C at 2 h PM). The lack of overall differences could be attributed to the young age of the flock at processing. Strain did not affect fillet yield at 6 h PM. Females also produced significantly thinner fillets than males at 2 and 4 h PM, but fillet width did not differ between male and females at any debone hour in this study. In general, deboning time did not affect fillet yield to a greater degree. Fillet yield was significantly decreased from 2 h to 4 or 6 h PM debone, regardless of strain. This reduction in yield when fillets were removed at 4 or 6 h PM could be attributed to greater muscle proteolysis, causing more tissue to be left on frame (Mehaffey et al., 2006). Also, it is plausible that moisture loss through drip during the aging of the carcasses before debone could decrease yield. This effect was more prominent for strain C, where there was not only a significant decrease in fillet yield from 2 to 4 h PM, but also a significant decrease in fillet yield from 4 to 6 h PM. This could indicate that, for some strains (e.g., strain C), it is important to remove the breast fillets before 6 h PM to reduce yield loss and increase profitability.

Fillet dimensions were measured to quantify any difference in footprint of fillets between strains and also sexes (Tables 3 and 4, respectively). There were minimal differences in fillet dimensions (length, width, and thickness) among the strains. At 2 h PM, fillets from both strains B and C were shorter compared with strain A fillets, and at 4 h PM, fillets from strains B and C were more narrow than strain A. Females had significantly more narrow fillets than males at 2 and 4 h PM, but filament width did not differ between male and females at 6 h PM. Females also produced significantly thinner fillets (cranial location; \( P < 0.05 \)) compared with males at 2, 4, and 6 h PM (thinner at the caudal point only at 4 h PM); however, filament length was not affected by sex at any debone hour in this study. In general, deboning time did not affect filament length, but deboning early PM (i.e., 2 h) resulted in thicker fillets at both cranial and caudal points compared with later debone times (eg., 6 h PM), which was expected because early deboning causes sarcomere shortening (Koonz et al., 1954).

Table 3. Fillet weight and dimensions from 3 broiler strains deboned at 2, 4, or 6 h postmortem

<table>
<thead>
<tr>
<th>Item</th>
<th>Strain A 2 h</th>
<th>Strain A 4 h</th>
<th>Strain A 6 h</th>
<th>Strain B 2 h</th>
<th>Strain B 4 h</th>
<th>Strain B 6 h</th>
<th>Strain C 2 h</th>
<th>Strain C 4 h</th>
<th>Strain C 6 h</th>
<th>Pooled SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>370a</td>
<td>363abc</td>
<td>357bcd</td>
<td>373ab</td>
<td>356de</td>
<td>353de</td>
<td>364bcd</td>
<td>350de</td>
<td>340f</td>
<td>0.001</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>17.85a</td>
<td>16.92ab</td>
<td>16.91b</td>
<td>16.41b</td>
<td>16.75ab</td>
<td>16.99b</td>
<td>16.10b</td>
<td>16.34b</td>
<td>16.66ab</td>
<td>0.15</td>
</tr>
<tr>
<td>Width (cm)</td>
<td>8.64bcd</td>
<td>8.74a</td>
<td>8.77a</td>
<td>8.46d</td>
<td>8.53d</td>
<td>8.72bc</td>
<td>8.47d</td>
<td>8.64bcd</td>
<td>8.61bcd</td>
<td>0.02</td>
</tr>
<tr>
<td>Cranial thickness (cm)</td>
<td>2.57a</td>
<td>2.31bc</td>
<td>2.21a</td>
<td>2.60a</td>
<td>2.26b</td>
<td>2.29bc</td>
<td>2.52ab</td>
<td>2.59a</td>
<td>2.27bc</td>
<td>0.03</td>
</tr>
<tr>
<td>Caudal thickness (cm)</td>
<td>1.12abc</td>
<td>1.01bcd</td>
<td>0.98f</td>
<td>1.20a</td>
<td>1.02bcd</td>
<td>0.94def</td>
<td>1.13ab</td>
<td>1.00de</td>
<td>0.91ef</td>
<td>0.01</td>
</tr>
</tbody>
</table>

\[ a–f \] Values within a row lacking a common superscript differ \( P < 0.05 \).

\[ 1 \] Data combined across feeding regimen and sex for strain by hour comparison; n = 120 per mean.
During rigor development, muscle pH declines due to an accumulation of lactic acid in the muscle (Lawrie, 1991). As expected, there were significant decreases in pH for all strains from 2 to 4 h and from 4 to 6 h PM (Table 5), similar to results reported by Mehaffey et al. (2006). Strains A and C progressed through rigor at a similar pace, as indicated by no significant difference in pH (between strains) at any given debone time. However, strain B had a significantly higher pH at 2 h PM than the other strains, but pH values at 4 and 6 h PM were similar among the 3 strains. When measuring pH at 24 h PM, there were no significant differences in pH attributed to strain or debone hour, with the exception of strain A that had a slight difference in pH at 24 h PM between fillets deboned at 4 and 6 h PM. López et al. (2011) also found no difference in 24 h pH when comparing 2 strains. Males in this study progressed through rigor at a slower pace than females, as indicated by pH. At 2 and 4 h PM, males had a significantly higher pH than females; however, by 6 h PM, there was no difference in pH, which is similar to the sex differences previously reported by Lyon et al. (1992).

The MORS energy was measured in this study as an indication of meat tenderness (Table 5). Previous research has led to recommendations of aging carcasses at least 4 h to prevent toughening (Stewart et al., 1984; Lyon et al., 1985; Dawson et al., 1987). In this study, this recommendation was confirmed with 2 strains, but in one strain, deboning before 4 h PM (at 2 h PM) did not affect tenderness. At 2 h PM, fillets of strains B and C were significantly tougher (higher MORS energy) than their 4 and 6 h PM counterparts. Fillets deboned at 2 h PM from strains B and C would be considered slightly tender or neither tough nor tender (strain B and C, respectively) by consumers, whereas those deboned at 4 and 6 h were deemed slightly tender or moderately tender by consumers according to sensory equivalency scales developed by Cavitt et al. (2005). Within strain A, however, there was no difference in MORS energy between the debone hours, and fillets deboned at 2, 4, or 6 h PM would be considered slightly tender (Cavitt et al., 2005). Thus, tender-ness was not significantly affected by deboning time in strain A in this study, suggesting that this strain may be more suitable for prerigor deboning than the other 2 strains. At 2 h PM, fillets from strain C had significantly greater MORS energy than strain B, which was also significantly higher in MORS energy than strain A. Therefore, deboning at 2 h PM affected strain C more than the other strains used in this study, resulting in greater MORS energy or toughness. The differences in MORS energy of fillets deboned at 2 h PM among strains in this study did not seem to be related to muscle pH at the time of deboning, an indicator of rigor development. Therefore, factors other than rigor development (e.g., fiber characteristics) may also be involved in tenderness of the meat from young poultry. For all strains, fillets deboned at 4 and 6 h PM had similar MORS energy values. Mehaffey et al. (2006) reported variation in MORS energy among 5 common genetic strains (6 wk of age) deboned at 2 h PM, where some strains were in the neither tough nor tender category and some were in the slightly tough category, suggesting that strains may have different responses in terms

### Table 4. Fillet weight and dimensions from male and female broilers deboned at 2, 4, or 6 h post-mortem

<table>
<thead>
<tr>
<th>Item</th>
<th>2 h</th>
<th>4 h</th>
<th>6 h</th>
<th>2 h</th>
<th>4 h</th>
<th>6 h</th>
<th>Pooled SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet weight (g)</td>
<td>342d</td>
<td>326e</td>
<td>324e</td>
<td>401a</td>
<td>389b</td>
<td>378c</td>
<td>0.001</td>
</tr>
<tr>
<td>Fillet length (cm)</td>
<td>16.78</td>
<td>16.38</td>
<td>16.55</td>
<td>16.73</td>
<td>16.95</td>
<td>17.16</td>
<td>0.15</td>
</tr>
<tr>
<td>Fillet width (cm)</td>
<td>8.375</td>
<td>8.596</td>
<td>8.625</td>
<td>8.665</td>
<td>8.764</td>
<td>8.77a</td>
<td>0.02</td>
</tr>
<tr>
<td>Cranial thickness (cm)</td>
<td>2.43b</td>
<td>2.32bc</td>
<td>2.15c</td>
<td>2.67a</td>
<td>2.45b</td>
<td>2.36b</td>
<td>0.03</td>
</tr>
<tr>
<td>Caudal thickness (cm)</td>
<td>1.00b</td>
<td>0.91d</td>
<td>0.82e</td>
<td>1.30b</td>
<td>1.12c</td>
<td>1.01c</td>
<td>0.01</td>
</tr>
</tbody>
</table>

*Values within a row lacking a common superscript differ (*P < 0.05).*

### Table 5. Meat quality of breast meat from 3 broiler strains deboned at 2, 4, or 6 h postmortem

<table>
<thead>
<tr>
<th>Item</th>
<th>Strain A</th>
<th>Strain B</th>
<th>Strain C</th>
<th>Pooled SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH at debone</td>
<td>6.17b</td>
<td>5.90c</td>
<td>5.81d</td>
<td>5.01</td>
</tr>
<tr>
<td>pH at 24 h</td>
<td>5.82ab</td>
<td>5.83b</td>
<td>5.76b</td>
<td>0.01</td>
</tr>
<tr>
<td>L* value at debone</td>
<td>47.9b</td>
<td>48.2ab</td>
<td>48.9a</td>
<td>47.4b</td>
</tr>
<tr>
<td>L* value at 24 h</td>
<td>47.9b</td>
<td>47.9b</td>
<td>48.7ab</td>
<td>47.9b</td>
</tr>
<tr>
<td>MORS² energy (N × mm)</td>
<td>144c</td>
<td>144c</td>
<td>141c</td>
<td>163d</td>
</tr>
</tbody>
</table>

*Values within a row lacking a common superscript differ (*P < 0.05).*

*Data combined across feeding regimen and strain for sex comparison; n = 120 per mean.*

*MORS² = Meullenet-Owens Razor shear.*
of tenderness when deboned early. In addition, sex did not affect fillet MORS energy, regardless of debone hour. However, in a similar study conducted using high-yielding broilers for a big-bird program, males had significantly greater MORS energy than females (Brewer et al., 2009). The fact that sex did not have an effect in this study may be attributed to the young flock age at the time of processing. Similarly, Poole et al. (1999) demonstrated 1.7 and 0% of the male and female birds, respectively, processed at 5 wk of age would have been considered slightly tender to moderately tough by a consumer sensory panel. In contrast, when birds were processed at 7 wk, 19% of males would have been considered slightly tender to slightly tough compared with 6.9% of females.

Water-holding capacity is an important consideration for meat quality because it can affect many attributes of fillets, such as color, texture, and yield (Jeffery, 1983). In this study, there were no differences in cook loss due to strain or debone hour (Table 5). Mehaffey et al. (2006) reported similar trends in cook loss of fillets from 6-wk-old broilers (no difference due to strain). There were also no differences in cook loss for males and females of any strain (Table 6), which concurs with Poole et al. (1999), who reported no difference in cook loss between male and female broilers.

Color can be an important measure because it can effect consumer acceptability as well as be an indicator of problems in muscle quality, like PSE, for example (Owens et al., 2000). Sex had no effect on instrumental color in this study (Table 6); however, differences due to strain and PM time were significant (Table 5). The L* values measured at the time of debone generally increased the longer the fillets were aged on the carcass before deboning (i.e., 2 to 6 h PM); however, there was not a significant increase with fillets from strain C (Table 5). This may be due to possible sarcomere shortening due to early deboning, causing the muscle to be more dense. Fillets deboned early in this study also had higher MORS energy, which is probably indicative of reductions in sarcomere length. Mehaffey et al. (2006) reported similar trends. The L* values measured at 24 h PM also follow the same trend observed immediately after deboning (increase in L* value with increasing aging times), thereby suggesting that the increases in L* values (with deboning time) were more likely related to the physical structure of the muscle and not necessarily attributed to a decrease in muscle pH over time.

### Conclusion

In conclusion, PF did not effect meat quality in this study. Strain and sex had some effect on yield and meat quality, but deboning time had the greatest effect on meat quality with small birds in this study. There were differences in fillet dimensions, specifically length and width, due to sex and strain, whereas deboning time had the greatest effect on fillet thickness. As expected, yield was improved by deboning the carcasses at 2 h PM for all strains used in the current study, and pH declined over time in all strains. The L* values at the time of deboning generally increased as the deboning time increased. Tenderness, as measured by MORS, was negatively affected in most strains by deboning early at 2 h PM. However, one strain in this study (strain A) did not produce a tougher fillet when deboned early. Results suggest that strain can effect tenderness of breast fillets when deboned prerigor. If companies continue to trend toward deboning prerigor because of the economic benefits (improved yield and processing efficiency), it may become more important to select strains more suitable for early deboning. However, more research is needed to determine causes of the strain effect on tenderness of fillets deboned early postmortem.

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### REFERENCES


