The Development of Pale, Exudative Meat in Two Genetic Lines of Turkeys Subjected to Heat Stress and Its Prediction by Halothane Screening

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ABSTRACT

Previous research has indicated that seasonal-type heat stress (HS) can contribute to the development of pale, soft, exudative (PSE) meat in fast-growing turkeys and that halothane exposure may identify stress-susceptible animals. This study evaluated the ability of halothane screening to identify stress-susceptible birds prone to developing pale, exudative meat when reared to market age. Two lines of turkeys (n = 292), one selected for rapid overall growth (BODY) and the other for large breast muscle yield (BREAST), were exposed to 3% halothane for 5 min at 2 to 4 wk of age and were raised together until 16 wk of age. Approximately 10% of both BODY and BREAST birds were sensitive to halothane. Between 16 and 20 wk, all of the halothane sensitive (HAL+) and half of the halothane nonresponders (HAL–) were exposed to an HS environment of 30 to 36°C (night/day), whereas the other half of the HAL– birds were kept at an ambient temperature of 13 to 21°C (night/day). All birds were slaughtered at 20 wk of age, and samples were collected for pH, L* value, drip loss, cooking loss, and shear value. The BREAST strain had 5% greater breast percentage than the BODY strain, and there were no differences in ready-to-cook yields between any treatments. The HAL+ HS birds had significantly lower muscle pH (0 h) and significantly higher L* values at 2 h postmortem compared with HAL– HS birds in the BREAST strain; however, there was no difference in L* value at 24 h postmortem. The HAL– HS birds had significantly lower muscle pH (0 h and 2 h) and significantly higher L* values at 2 h postmortem compared with HAL– controls in the BODY strain. The HAL– HS BREAST birds had significantly higher drip loss than HAL– controls. No differences in shear value were found among any treatments. The incidence of PSE (2-h L* values >52) was significantly higher in HAL+ HS birds (34.7%) compared with HAL– HS birds (13.4%). These results suggest that halothane sensitivity early in life is associated with HS susceptibility and the development of pale meat when birds are slaughtered at market age. These results also suggest that halothane screening may be better at predicting the development of PSE meat during HS in the strain selected for large breast yield rather than rapid overall growth.

(Key words: pale, soft, exudative, halothane, heat stress, turkey, rigor)

INTRODUCTION

The occurrence of pale, soft, exudative (PSE) meat has become a growing problem for the turkey industry. This condition has been extensively studied in swine, but much is still unknown about the problem in poultry.

Pale, soft, exudative meat in swine has been associated with rapid growth and antemortem and postmortem stressors, including environmental temperatures (too hot or cold), transportation, preslaughter handling practices, stunning methods, and chilling regimes (Cassens et al., 1975; Honikel, 1987; Offer, 1991; Backstrom and Kauffman, 1995; D’Souza et al., 1998; Maribo et al., 1998). Pale, soft, exudative meat is the result of accelerated postmortem glycolysis, which results in a rapid postmortem decline in pH while carcass temperatures are still high. This combination can result in portein denaturation of the muscle that leads to pale meat color, decreased water-holding capacity, and poor texture (Penny, 1969; Warriss and Brown, 1987; Santos et al., 1994).

In swine, PSE is associated with Porcine Stress Syndrome (PSS), which is similar to malignant hyperthermia (MH) in humans (Hall et al., 1966; Mitchell and Heffron, 1982; Harrison, 1994). Porcine Stress Syndrome and MH are inherited disorders caused by a defect in the calcium-release channel (ryanodine receptor) in the sarcoplasmic reticulum (O’Brien, 1986). Porcine Stress Syndrome and
MH can be induced by stressful conditions as well as with anesthetics such as halothane or depolarizing agents such as succinylcholine in swine that are homozygous for the recessive PSS/MH gene (also known as the halothane gene). Muscle rigidity, increased body temperature, and increased lactic acid production can characterize the response to halothane (Michelson and Louis, 1993). Animals with PSS are prone to developing PSE meat. The swine industry has used halothane as a screening method for PSS to remove stress-susceptible animals from breeder populations, thereby reducing the incidence of PSE meat (Webb and Jordan, 1978).

The halothane screening test has been successful in identifying pigs that are susceptible to stress and are prone to developing PSE. In addition, previous research has indicated that seasonal-type heat stress (HS) can contribute to the development of PSE in swine and turkeys (Santos et al., 1994; McKee and Sams, 1997). Therefore, the objective of this study was to evaluate the ability of halothane screening to identify stress-susceptible birds prone to developing PSE meat when reared to market age. Because rapid growth can increase stress susceptibility and the incidence of PSE (Ferket and Foegeding, 1994), two genetic lines of turkeys, selected for either rapid overall growth or large breast muscle yield, were evaluated to determine if they differed in the incidence of halothane sensitivity or PSE meat.

**MATERIALS AND METHODS**

Two genetic lines of turkeys from Nicholas Turkey Breeding Farms were used in this study. One line was selected for overall rapid growth (BOD) and the other for large breast yield (BREAST). Hatching eggs were set and incubated for 28 d to hatch at the university’s poultry research farm. After hatching, poult’s were vent-sexed, wing-banded, and toe- and beak-trimmed. Poult’s were raised under normal brooding practices in brooder cages until 2 to 4 wk of age. Two hundred ninety-two 1- to 4-wk old birds in two trials were challenged with halothane gas (Wheeler et al., 1997). After exposure, turkeys were quickly removed and placed in an air-tight chamber (four to eight birds per group, depending on size) and were exposed to halothane gas at 3% for 5 min. All birds were reared together until 2 wks of age. Two hundred ninety-two 1- to 4-wk old birds in two trials were challenged with halothane gas (Wheeler et al., 1997). After exposure, turkeys were quickly removed and placed in an air-tight chamber (four to eight birds per group, depending on size) and were exposed to halothane gas at 3% for 5 min. At 20 wk, HAL− males and females of each strain from the HS treatment (HS) (n = 67) and control treatment (n = 75) and all HAL+ HS (n = 23) were slaughtered at the university’s pilot processing plant. Feed was withdrawn from turkeys for 12 h, and then they were transported to the holding room 1 h prior to slaughter. Preslaughter stunning was not used as it is not required for commercial poultry slaughter (Humane Slaughter Act of 1958). Furthermore, it is not universally practiced by commercial processors and has been shown to interfere with rigor mortis development (Murphy et al., 1988; Papinaho and Fletcher, 1995; Poole and Fletcher, 1998). Birds were killed by bleeding through a unilateral neck cut for 3 min. Birds were then individually subscalded (61 C, 45 s) and picked (rotary drum picker); 30 s). Birds were manually eviscerated, and carcasses were chilled using a two-stage chilling system (12 C for 30 min the 4 C for 75 min). Breast fillets were deboned at 2 h postmortem and then aged on ice until 24 h postmortem.

Muscle samples were collected from left fillets at 0, 2, and 24 h postmortem for pH determination using the iodoacetate method described by Jeacocke (1977) as modified by Sams and Janky (1986). After sample collection at 0 h (collected immediately after feather removal), breast skin surrounding the sample area was clipped together to prevent water in the chiller from contacting the breast muscle (McKee and Sams, 1997). Muscle samples were immediately frozen in liquid nitrogen and stored at −76 C until further analysis. Color (L* value) was measured on the cut surface of the left fillets at 2 and 24 h postmortem using a Minolta colorimeter. After deboning (2 h), fillets were placed in closed-top sealable bags and stored in a 4 C cooler overnight on ice. After 24 h postmortem, right fillets were placed in pans on raised wire racks, covered with aluminum foil and then cooked to an internal temperature of 76 C in a convection oven. Allo-Kramer shear analysis was conducted using the methods

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3Model SP3055, Brower Corp., Haughton, IA 52631.
4Model CR-200, Minolta Corp., Ramsey, NJ 07446.
described by Sams (1990) and McKee and Sams (1998) using an Instron Universal Testing machine.\(^6\) Weights of fillets before and after cooking were measured to determine cooking loss.

Data were subjected to analysis of variance using the general linear model procedures of SAS (1985). Differences between means were determined using the least squares means procedure of SAS (1985) and a significance level of \(P < 0.05\). The percentages of pale fillets (\(L^* < 52\)) in each treatment group were subjected to chi-square analysis to determine differences (\(P < 0.05\)). The effect of applied HS was analyzed by comparing HAL– control birds to HAL– HS birds. To determine if the halothane screening was effective in predicting birds prone to developing PSE meat, HAL+ HS birds were compared with HAL– HS birds. Because of an interaction in some parameters between strain and treatment, the strains were analyzed and are presented separately. The sexes were pooled within strain as there was no interaction or sex effect.

### RESULTS AND DISCUSSION

**Halothane Response and Live Performance**

Approximately 10% of the turkeys screened with halothane responded to the treatment by showing signs of muscle rigidity in the legs. There was no significant difference in halothane response between the two strains (data not shown). In swine, the frequencies of halothane-positive reactions vary from 0 to 88%; however, most breeds range from 0 to 20% (Webb et al., 1982). Wheeler et al. (1997) reported that 2 to 15% of young turkeys challenged with halothane showed some response. Therefore, the 10% response in this study was consistent with this previous report. The BREAST strain had a greater (\(P < 0.05\)) breast percentage (29% vs. 24%) than the BODY strain. However, HS significantly reduced breast percentage in the BODY strain but not in the BREAST strain (Table 1).

In addition, there were no significant effects of halothane response on breast percentages in either strain (Table 2).

### Rigor Mortis Development

Postmortem decline in muscle pH is due to an accumulation of lactic acid in the muscle during postmortem glycolysis (Khan and Nakamura, 1970). The application of HS accelerated rigor development in the BODY strain, as indicated by significantly lower pH values at 0 and 2 h postmortem, but caused no difference in muscle pH in the BREAST strain (Table 1). McKee and Sams (1997) reported that HS application 4 wk prior to slaughter accelerated rigor development in a fast-growing commercial strain of turkeys. Howe et al. (1968) reported that growing swine in an environment with fluctuating temperatures (21 and 32 C; 3 d at each temperature) resulted in a more rapid decline in postmortem pH compared with growing animals in an environment with a constant temperature of 27 C. In the BREAST strain, the HAL+ HS birds had significantly lower pH values at 0 h when compared with HAL– HS birds (Table 2). An acceleration of rigor development in halothane-positive swine is a common characteristic of these animals compared with halothane-negative animals (De Smet et al., 1993; Cheah et al., 1994; Klont and Lambooy, 1995). This finding suggests that the heat treatment caused a more rapid decline in muscle pH and that halothane was able to identify those animals (BREAST strain) susceptible to the accelerated rigor development. The fact that there was a difference in muscle pH of the BREAST strain between HAL+ HS and HAL– HS, but that there was no difference due to HS application (in the BREAST strain) suggests that halothane screening may be useful in identifying birds that are prone to accelerated rigor development when stressed.

### Color

Acceleration of rigor development, or rapid decline in pH, while carcass temperatures are still high can result in protein denaturation (Bendall and Wismer-Pedersen, 1973).
than the percentage of HAL+ (HAL+) heat-stressed (HS) or halothane–(HAL−) heat-stressed (HS) turkeys.

Table 2: Muscle pH (0, 2, 24 h) and L* value (2, 24 h) of Pectoralis from two genetic lines (BODY or BREAST) of halothane + (HAL+) heat-stressed (HS) or halothane–(HAL−) heat-stressed (HS) turkeys.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>BODY</th>
<th>BREAST</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HAL+1</td>
<td>HAL−2</td>
<td></td>
</tr>
<tr>
<td>Breast percentage pH</td>
<td>23.74</td>
<td>23.72</td>
<td></td>
</tr>
<tr>
<td>0 h</td>
<td>6.11</td>
<td>6.07</td>
<td></td>
</tr>
<tr>
<td>2 h</td>
<td>5.92</td>
<td>5.89</td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>5.80</td>
<td>5.84</td>
<td></td>
</tr>
<tr>
<td>L* Value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 h</td>
<td>51.07</td>
<td>50.55</td>
<td></td>
</tr>
<tr>
<td>24 h</td>
<td>53.23</td>
<td>53.71</td>
<td></td>
</tr>
<tr>
<td>Cooking loss percentage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear value (kg/g)</td>
<td>7.88</td>
<td>7.56</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>BODY</td>
<td>BREAST</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SEM</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a,bMeans within BODY strain within sample time with no common superscript differ significantly (P < 0.05).

TABLE 3: Incidence of pale meat (L* value >52) from halothane + heat-stressed (HS), halothane – heat-stressed (HS), or halothane–nonheat-stressed (non-HS) turkeys.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>L* Value &gt;52</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BODY</td>
<td>BREAST</td>
</tr>
<tr>
<td>Halothane + HS</td>
<td>5/7</td>
<td>3/8</td>
</tr>
<tr>
<td>Halothane – HS</td>
<td>5/30</td>
<td>4/28</td>
</tr>
<tr>
<td>Halothane – Non-HS</td>
<td>2/34</td>
<td>4/35</td>
</tr>
</tbody>
</table>

a,bMeans within columns with no common superscript differ significantly (P < 0.05).
The bimodal frequency histogram of 2-h L* values from the HAL+ turkeys suggests that there are two distinct subpopulations of birds with differing potentials for developing pale meat (Figure 1). The frequency of L* values from HAL–HS turkeys has an expected normal distribution.

Water-Holding Capacity

Water-holding capacity is another important aspect of PSE meat and can be evaluated with cooking loss. No significant difference was observed in cooking loss in either strain due to HS (Table 1). There was no significant difference in cooking loss between HAL+ HS and HAL–HS turkeys in either strain (Table 2). Heat stress has been previously reported to increase drip loss and cooking loss (McKee and Sams, 1997). McKee and Sams (1998) reported increases in cooking loss only when carcasses were chilled above 20 C. It may be possible that the fast or long chilling system used in this study may have prevented some denaturation of the muscle proteins, resulting in little or no effect on cooking loss of the meat. Ma and Addis (1973) reported that cooking losses were not affected by muscle pH. Struggling turkeys (at time of slaughter) had significantly lower muscle pH than restrained turkeys, but there was no difference in cooking loss. Other factors, such as fillet size, surface exposure, and chilling water uptake can influence cooking loss. These factors may have contributed to the unexpected lack of differences in cooking loss observed in this study.

Texture

Because texture is another quality of meat that can be affected in PSE meat, tenderness of turkey breast fillets was evaluated in this study. There were no differences in shear value when comparing HAL–HS with non-NS birds or HAL+ HS to HAL–HS in either strain (Tables 1 and 2). All shear values in this study were at or below 8 kg/g, which would be low enough to be considered moderately tender by consumers (Lyon and Lyon, 1990). This lack of a shear value difference is consistent with the results of McKee and Sams (1998) using a 0 or 20 C chilling temperature. Froning et al. (1978) also reported no difference in shear values between HS and non-HS turkeys. Fox et al. (1980) reported that PSE pork chops had lower Warner-Bratzler shear values, although there was no difference in tenderness scores from a tasting panel compared with normal chops. Fox et al. (1980) also reported inconsistency among researchers in texture characteristics of PSE meat in which higher shear values and lower taste panel scores for tenderness have also been observed in PSE pork.

These results indicate that the HS affected muscle pH and color of the halothane-positive birds more than the halothane-negative birds in the strain selected for large breast yield (BREAST). Therefore, these results suggest that the halothane sensitivity early in life may be associated with HS susceptibility and the development of PSE meat when birds are slaughtered at market age. These results also suggest that halothane may be better able to predict the development of PSE meat during HS in the strain selected for large breast yield rather than the strain selected for rapid overall growth.

ACKNOWLEDGMENTS

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