The Use of Halothane and Succinylcholine to Identify Broilers Prone to Developing Pale, Soft, Exudative Meat

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ABSTRACT Within the last several years, the poultry industry has seen a dramatic increase in the occurrence of pale, soft, and exudative (PSE) meat. This problem is known to be associated with a rapid decline in postmortem (PM) muscle pH, which results in inferior protein functionality similar to that found in PSE pork. Many factors such as seasonal changes have been known to influence the occurrence of PSE meat in poultry and swine. Halothane and succinylcholine have been used within the pork industry to identify animals susceptible to stress and prone to developing PSE meat. The mechanism for the triggering of the PSE gene in poultry has not been fully understood. Therefore, a study was conducted to determine the effectiveness of screening broilers with halothane to identify those prone to developing PSE meat. Succinylcholine was used before slaughter to serve as a triggering agent for the PSE condition. At 4 wk of age, broilers from 4 commercial strains (n = 1,000) were subjected to 3% halothane gas and classified as either halothane positive (HAL+) or negative (HAL−) based on muscle rigidity within the legs. Although halothane sensitivity varied slightly among the strains, approximately 14% of the birds overall were classified as HAL+. All HAL− birds (n = 163) and an equal number of HAL− birds (n = 163) in each strain were grown to market age (7 wk) and were commercially processed. At the time of processing, half of the HAL+ and HAL− birds were injected intravenously with succinylcholine and were slaughtered at 0.25 h postinjection. Pectoralis muscle samples were collected at 0.25, 2, 5, and 24 h PM for the evaluation of rigor development (muscle pH) and meat quality (L* value, moisture, drip loss, and cook loss). Halothane sensitivity had no effect on rigor development, muscle color, or water-holding capacity in the 4 broiler strains. Although birds exhibited reactions to the halothane gas, the halothane sensitivity, along with the use of succinylcholine, was not able to identify birds prone to developing PSE meat.

(Key words: pale, soft, exudative meat; halothane sensitivity; succinylcholine; broiler meat quality)

INTRODUCTION

The modern poultry industry has experienced dramatic growth within the last 20 yr, primarily to meet the consumer demand for lean, cost efficient and convenient meat products. With the use of genetic selection, the industry has selected for birds that exhibit efficient growth and heavy muscling. Consequently, within the last several years, the poultry industry has experienced an increase in the occurrence of pale, soft, and exudative (PSE) meat. This problem has been known to be associated with a rapid decline in postmortem (PM) muscle pH, which results in inferior protein functionality similar to that found in PSE pork (Greaser, 1986; Sosnicki, 1995). This problem results in substantial economic losses to the poultry industry.

Antemortem factors such as seasonal changes have been known to influence the occurrence of PSE meat in pork and poultry (Cassens et al., 1975; McKee and Sams, 1997a,b). In pork, the ultimate cause of porcine stress syndrome (PSS), which results in PSE meat, has been identified as an Arg615 to Cys615 substitution in the skeletal muscle of the sarcoplasmic reticulum Ca2+-channel protein, the ryanodine receptor (Fujii et al., 1991). This mutation leads to an alteration in Ca2+ homeostasis, hypermetabolism, and malignant hyperthermia in stressed PSS-susceptible pigs (Wang et al., 1999). The striking similarity of factors leading to development of PSE meat in poultry to that in pork suggests that there may be a genetic basis for this syndrome in poultry (Pietrzak et al., 1997). However, to date, the mutation has not been identified in poultry.

Succinylcholine, a neuromuscular depolarizing muscle relaxant, and certain anesthetics such as halothane

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Abbreviation Key: HAL− = halothane negative; HAL+ = halothane positive; PM = postmortem; PSE = pale, soft, exudative; PSS = porcine stress syndrome.
have been successfully used to screen pigs for the presence of the genetic mutation that results in PSE meat (Webb and Jordan, 1978).

These drugs are able to induce PSS and subsequently the PSE condition by triggering calcium release from the ryanodine receptor in the muscle. Although successful in the swine industry, the use of these drugs in poultry has been limited. McKee et al. (1998) reported a higher incidence of PSE meat in turkeys treated with succinylcholine and researchers have used halothane screening in turkeys, but with limited success (Wheeler et al., 1999; Owens et al., 2000a,b).

Unlike PSS, the mechanism for triggering the PSE condition in poultry has not been attributed fully to genetic causes. Therefore, this study was conducted to determine the effectiveness of screening commercial market-age broilers with halothane gas and succinylcholine to identify those prone to developing PSE meat.

MATERIALS AND METHODS

A total of 1,000 male broilers from 4 commercial strains (A, B, C, and D; n = 250 each strain) were obtained from commercial hatcheries at day of hatch and transported to the University of Arkansas Poultry Science Research Farm. Birds from each strain were evenly divided and housed on soft pine wood shavings in 24 floor pens (each strain in separate pens; 6 replications) under constant lighting. Birds were fed a commercial diet ad libitum, according to NRC guidelines, until processing. At 4 wk of age, birds were tested for halothane sensitivity over a 6-d period based on the procedures of Wheeler et al. (1999) and Owens et al. (2000b). Birds were placed in an airtight chamber (5 birds per group) and exposed to 3% halothane gas in oxygen for 5 min using an oxygen flow rate of 6 L/min. All birds were anesthetized within 2 to 3 min of exposure to halothane. Following exposure, birds were promptly removed from the chamber and subjectively evaluated for muscle rigidity within the legs while still anesthetized, similar to the halothane evaluation procedures of Wheeler et al. (1999) and Owens et al. (2000b) in turkey, and Eikelboom et al. (1978) and Webb and Jordan (1978) in swine. Birds that exhibited muscle rigidity were classified as halothane positive (HAL+), and birds that exhibited flaccid leg muscles were classified as halothane negative (HAL−). A panel consisting of the same 2 responders in each strain, the seventh pen only contained birds from strains C and D (HAL+/-), whereas the first 6 pens contained all strains (HAL+/-). Birds were housed at ambient temperatures, and fed a commercial ration that met NRC (1994) recommendations. At 7 wk of age, broilers were processed at the University of Arkansas Poultry Processing Pilot Plant. Feed was withdrawn 10 h before slaughter; however, birds were allowed free access to water during the period. One hour before slaughter, birds were transported in coops on a flatbed truck to the pilot processing plant. Following transport, half of the HAL+ (n = 82) and HAL− (n = 82) birds were injected with the depolarizing agent. Succinylcholine (60 µg) was administered intravenously in 0.2 mL of physiological saline solution in a procedure similar to that described by McKee et al. (1998). After succinylcholine administration, all birds exhibited signs of muscle rigidity, but fully recovered within 15 min. Following a 15-min recovery period, all birds were hung on a shackles line and commercially processed. Birds were electrically stunned (11 V, 11 mA, 10 s), manually cut (severed left carotid artery and jugular vein), bled (1.5 min), scalded (55°C, 2 min), and picked inline using commercial equipment. Birds were eviscerated and placed in a prechill for 15 min (12°C) and a chill tank for 45 min (2°C). Carcasses were stored on ice in a 4°C cooler until 5 h PM when breast fillets were deboned. Muscle tissue samples were obtained from the right pectoralis muscle at 0.25 h PM (prechill), 2 h (postchill), 5 h, and 24 h PM, immediately frozen in liquid nitrogen, and stored at −76°C for pH determination using the iodoacetate method (Jeacocke, 1977; Sams and Janky, 1986). The L* value, a color measurement of lightness, was measured on the posterior region of the left breast fillet at 5 and 24 h PM using a Minolta colorimeter. Three readings per fillet were taken and an average reading was recorded. Left fillets were weighed at the time of deboning and at 24 h PM for determination of drip loss. Percentage moisture was determined in duplicate using the oven dry method (AOAC, 1990) at 24 h PM. To determine cook loss, the left fillets were placed in pans on raised wire racks, covered with aluminum foil, and cooked to an internal temperature of 76°C in a convection oven according to the method of Sams (1990). Pre- and postcook weights were recorded for cook loss determination.

All data were subjected to ANOVA using the GLM procedure of SAS (SAS Institute, 1999) testing treatment and replication as well as the interaction term using the residual error. Because no significant differences in rigor and meat quality parameters were observed due to strain, strain data were pooled and only treatment effects were reported. Therefore, a total of 326 birds (over 4 treatments) were used in this study in 7 replications. Duncan’s Multiple Range test was used to separate means. Significance was determined using P < 0.05.

2Model CR-300; Minolta Corp., Ramsey, NJ.
RESULTS AND DISCUSSION

Sensitivity to halothane varied from 13.2 to 22.9% depending upon the strain tested (Figure 1). Strain D had a significantly higher response to halothane compared with strains A and B, but strain C was similar to strains A, B, and D. Similar results of halothane sensitivity have been reported in turkeys, ranging from 2 to 15% (Wheeler et al., 1999; Owens et al., 2000b), and in swine, ranging from 0 to 20% (Webb and Jordan, 1978).

Rate of pH decline has been shown to influence the development of PSE meat; therefore, PM metabolism was monitored in this study by measuring muscle pH at various times (Table 1). The response to halothane had no influence on the pH decline of pectoralis muscle, as indicated by no significant differences in muscle pH at 0.25, 2, 5, or 24 h PM between the HAL+ or HAL− noninjected birds. There have been inconsistent results of the ability of halothane to identify birds prone to PSE development. Owens et al. (2000b) reported that HAL+ heat-stressed turkeys had significantly lower muscle pH early PM but in only one strain, concluding that the halothane screening may not be useful in all turkey strains. Furthermore, Owens et al. (2000a) stated that either halothane is a limited predictor of PSE meat in turkeys or the appropriate stressor had not been identified to induce the condition. Therefore, in this study, succinylcholine, a depolarizing muscle relaxant known to induce PSS in pork, was injected before processing to induce the PSE condition in broilers upon processing. The injection of succinylcholine resulted in no significant effect on the pH decline of pectoralis muscle compared with noninjected birds in either the HAL+ or HAL− groups. Similarly, McKee et al. (1998) reported no significant difference in muscle pH for turkeys injected with succinylcholine compared with the control. These results suggest that the injection of succinylcholine did not have a significant influence on muscle pH decline nor was halothane screening predictive for identifying birds prone to accelerated rigor development.

Factors such as an acceleration of rigor development or a rapid decline in muscle pH while carcass temperatures are still elevated have been known to result in protein denaturation, which can lead to meat that is light in color and has a reduced water-holding capacity (Warriss and Brown, 1987), which are the primary characteristics of PSE meat. The paleness of the meat is attributed to denaturing of sarcoplasmic proteins, which results in a scattering of light (Bendall, 1973; Swatland, 1993). Injection of succinylcholine had no significant effect on lightness of meat (L* value) for either HAL+ or HAL− treatments, nor was the halothane screening predictive of pale fillets (L* > 54) as indicated by no significant differences in L* values in any of the treatments (Table 1). McKee et al. (1998) reported that turkeys treated with succinylcholine had a higher incidence of PSE meat although treatment means were not significantly different. In the current study, succinylcholine and halothane sensitivity had no effect on the incidence of pale meat; the incidence of pale meat (L* > 54) was

<table>
<thead>
<tr>
<th>TABLE 1. Muscle pH and L* value of pectoralis muscle from halothane-positive broilers (HAL+) and halothane-negative broilers (HAL−) injected with succinylcholine (SC)</th>
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<tr>
<td>SC injected¹</td>
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<tr>
<td>Muscle pH⁴</td>
</tr>
<tr>
<td>0.25 h</td>
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<tr>
<td>2.00 h</td>
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<tr>
<td>5.00 h</td>
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<td>24.00 h</td>
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<tr>
<td>L* value⁵</td>
</tr>
<tr>
<td>5.00 h</td>
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<tr>
<td>24.00 h</td>
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</tbody>
</table>

¹n = 82 per mean.
²n = 81 per mean.
³Pooled SEM.
⁴Pectoralis muscle pH measured from 0.25 to 24 h postmortem.
⁵L* value (lightness of color) measured at 5 and 24 h postmortem.
approximately 30% for all treatments. Therefore, these findings indicate that halothane sensitivity along with succinylcholine injection had no significant influence on the prediction of the lightness of meat at both time points of 5 and 24 h PM.

Water-holding capacity is another meat quality factor that is affected with the development of PSE meat. Therefore, percentage moisture, drip loss, and cook loss values of the different treatments were measured, and the results are presented in Table 2. Data indicate no significant differences in percentage moisture, drip loss, and cook loss for all treatments. Based on muscle pH and color data, it was not expected that water-holding capacity would be affected. This data is consistent with McKee et al. (1998) who reported no significant differences in drip loss or cook loss for turkeys injected with succinylcholine. Owens et al. (2000b) also reported no significant differences in cook loss for HAL+ and HAL− treatment groups in turkeys. Ma and Addis (1973) reported no differences in cook loss for birds exhibiting different rates of PM metabolism. These results suggest that the injection of succinylcholine in conjunction with halothane screening was not predictive of fillets exhibiting a poor water-holding capacity.

In conclusion, although birds exhibited reactions to the halothane gas, our results demonstrate that the halothane screening test in conjunction with succinylcholine injection was not predictive of detecting 4-wk-old broilers prone to developing PSE meat when processed at 7 wk. Further studies are needed to test a variety of influences such as halothane exposure, bird age at exposure or slaughter, and type of stress being administered.

ACKNOWLEDGMENTS

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REFERENCES


TABLE 2. Percentage moisture, drip loss, and cook loss of pectoralis muscle from halothane-positive broilers (HAL+) and halothane-negative broilers (HAL−) injected with succinylcholine (SC)

<table>
<thead>
<tr>
<th></th>
<th>SC injected</th>
<th>Noninjected</th>
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<tr>
<td>Moisture (%)</td>
<td>24.90</td>
<td>24.29</td>
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<tr>
<td>Drip loss (%)</td>
<td>8.84</td>
<td>8.76</td>
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<tr>
<td>Cook loss (%)</td>
<td>20.00</td>
<td>20.23</td>
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<tr>
<td></td>
<td>SC injected</td>
<td>Noninjected</td>
</tr>
<tr>
<td>Moisture (%)</td>
<td>24.36</td>
<td>24.12</td>
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<tr>
<td>Drip loss (%)</td>
<td>7.96</td>
<td>7.59</td>
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<tr>
<td>Cook loss (%)</td>
<td>20.37</td>
<td>19.38</td>
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</table>

1n = 82 per mean.
2n = 81 per mean.
3Pooled SEM.


