Meat quality of heat stressed broilers: Effects of thermal conditioning at pre- and -postnatal stages

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Summary

This study was conducted to investigate the effects of exposure of eggs to heat during incubation and heat conditioning chicks at 5 d on the meat quality of broilers reared under heat stress. The 1,000 eggs used in this experiment were obtained from younger (YBB, 28 wks) and older (OBB, 58 wks) broiler breeders from the same genetic stock. Eggs were randomly divided into two incubation temperature groups. 1). Standard (SInc) where eggs were incubated at 37.8ºC from d 1 to 18 of incubation; 2). High (HInc) where eggs were heated at 39.6ºC for 6 h daily from d 10 to 18 of incubation. At hatch, chicks were placed into 36 floor pens and chicks from 12 pens (3 pens/parent age/incubation temperature) were heat-conditioned (Cond) at 5 d of age for 24 h. At 21 d of age, 3 pens/parent age/incubation temperature were kept as controls (C), and the remaining broilers (including group Cond) were heat stressed (HS) daily from 21 to 49 d and then slaughtered. After postchilling, samples of pectoralis muscle were taken and pH, colour, thawing, and cooking loss and shear force were measured.

Breeder age interacted with incubation and rearing temperatures and influenced meat quality. Age of breeder was significant for meat colour and pH, with meat from YBB broilers less light, redder, and less yellow with higher pH. HInc increased L* and b* values but decreased a* values in meats from OBB broilers. In the YBB group, pH was lower for HS broilers and the pH of meats of Cond and C broilers were similar. Although incubation temperature had no effect on cooking loss from YBB broilers, cooking loss from OBB broilers was decreased by HInc. Rearing temperature affected cooking loss with meat from YBB broilers being lower than that for broilers reared at HS.

Introduction

There is considerable evidence for the effects of heat stress on body weight, carcass, and breast yield of broilers (Howlider and Rose, 1989; Whiting *et al.*, 1992; Yalçın *et al.*, 1995; 2001). McKee and Sams (1997) reported that breast meat of heat stressed turkeys exhibited accelerated post-mortem glycolysis and had pale colour, increased drip loss, and cooking loss. Sandercook *et al.* (2001) also found that acute heat stress lowered breast muscle pH and increased water loss.

To reduce detrimental effects of heat stress, one approach is to improve thermotolerance of broilers at the pre -or postnatal stage (Yahav and Hurwitz, 1996, Yalçın *et al.*, 2001; Yahav *et al.*, 2004). However, Northcutt *et al.* (1994) reported that thermal conditioning at early ages posthatch did not prevent the loss in water holding properties of broiler meat and preconditioned broilers had pale, soft, and exudative breast meat. Although incubation temperature influences the proportion of fibre types of 10 d old chicks (Boleli *et al.*, 2000), no information is available on its effect at slaughter age. Also broilers from older breeder flocks appear to be more sensitive to heat stress than those from younger breeder flocks (Weytjens *et al.*, 1999). Therefore the objective of the present study was to determine the effect of pre- and –postnatal thermal conditioning on breast meat quality of broilers from younger and older breeders.

Materials and methods

ANIMAL MATERIAL

The 1,000 eggs used in this experiment were obtained from younger (YBB, 28 wks) and older (OBB, 58 wks) broiler breeders from the same genetic stock. From each flock, 500 eggs were randomly divided into two incubation temperature groups. 1). Standard (SInc) where eggs were incubated at 37.8ºC from d 1 to 18 of incubation; 2). High (HInc) where eggs were heated at 39.6º C for 6 h daily from d 10 to 18 of incubation. Incubation temperature was maintained at 37.8ºC for the remainder of the time. Relative humidity was maintained at 60%. On d 18, eggs were transferred to hatching baskets where temperature and RH was 37.5ºC and 85%, respectively.

At hatch, all chicks were placed into 36 floor pens and standard brooding temperatures were used from 1 to 21 d, except that chicks from 12 pens (3 pens/parent age/incubation temperature) were heat-conditioned (Cond) at 5 d posthatch for 24 h in a room where the temperature was 36ºC, after which they returned to their original pens. At 21 d of age, 3 pens/parent age/incubation temperature remained at control (C) rearing temperatures of 22 to 24°C. From d 22 to 49 the remaining broilers (including group Cond.) were heat stressed (HS) daily (32 to 35°C from 10:00 to 17:00 h and 24 to 26°C from 17:00 to 10:00 h, RH was 60 to 72%). Thus, there were 3 groups from 21 to 49 d including C, H, and Cond+H for each parent age and incubation temperature. Feed and water were available for ad libitum consumption. Photoperiod for all treatments were 23L:1D.

MEASUREMENTS

A total of 18 male and female broilers from each treatment were weighed and slaughtered at 49 d in a commercial processing plant after 1-h of transport . The birds were electrically stunned before being killed by neck cutting. Breast muscles were deboned manually from each carcass after air chilling, skin was removed, and samples were placed in plastic bags on ice and moved to the laboratory.

PH AND COLOUR

After 24 h storage at 4°C, pH of the left of breast muscle was measured (Hanna Instrument Model 8314) using a penetration electrode (FC-200). Then, samples were sliced into 2 pieces. Slice “1” (3 cm thick) was used for colour measurement, slice “2” (grand piece) was used for thawing loss, cook loss, and assessment of shear force. Colour (Hunter L*, a* and b* values) was measured on the medial surface of the left breast muscle using a Minolta colorimeter. Three readings per muscle were taken and averaged. To measure colour stability, samples were placed in a styrofoam tray and overwrapped with an oxygen permeable film and stored for 4 d at 4 ^{0}C.

THAWING, COOKING LOSS, AND SHEAR FORCE

Samples to be used for thawing and cooking loss were frozen in plastic bags at –18 ^{0}C for 7 d. Thawing loss was obtained after samples were thawed in water for 4 h at 15 to 17^{0}C after which they were removed from the bags, dried with paper, and weighed. To obtain cooking loss, samples were cooked individually in heat-and-seal bags immersed in 75^{o}C water to internal temperature of 70^{o}C. Samples were weighed before and after cooking to determine cooking loss. Weight loss was expressed as a percentage of initial weight for thawing and cooking loss.

After cooling to room temperature, five 1 cm diameter cores were removed paralleled to muscle fibres from each sample. Shear force was measured using Instron Universal Testing Machine, fitted with Warner Bratzler (WB) shear attachment. Full-scale load was set at 10 kg and chart drive and crosshead speeds were 200 mm/min (Bourne, 1982).

STATISTICAL ANALYSIS

All data were subjected to ANOVA using GLM procedure of SAS (SAS Institute, 1999) testing breeder age, incubation temperature, and rearing temperature effects as well 2 and 3 ways interactions among them. Significance was considered as $P<0.05$. Correlation coefficients were generated using correlation coefficient option of SAS (SAS Institute, 1999)

Results and discussion

The pH of breast meat from YBB was greater (5.95) than that from OBB (5.89). A breeder age by incubation temperature interaction (P=0.004) for pH showed that although breast meat of broilers from OBB had a lower pH when eggs were incubated at HInc, incubation temperature had no effect on breast meat of broilers from YBB (Table 1).

McKee and Sams (1997) reported heat stressed birds had higher L* and lower pH than controls. In the present study, an interaction effect was present for age of breeder and rearing temperature for pH. Rearing temperature did not effect pH of breast meats of broilers from OBB. For YBB, pH was lower for HS broilers whereas for Cond broilers it was similar to C. Lower pH in meat from OBB and incubated at HInc or reared at HS may be the consequence of elevated rate of muscle post-mortem glycolytic metabolism (McKee and Sams, 1997) however, the rate of pH decline was not determined in our study.

Table 1 Effect of incubation temperatures[1] and rearing temperatures[2] on pH and colour of breast meat of broilers from younger and older breeders at 24 h after slaughter.

	pH		L*		a*		b*	
	Breeders							
	Younger	Older	Younger	Older	Younger	Older	Younger	Older
Incubation temperature								
SInc	5.93	5.93[a]	55.99	56.49[b]	2.51	2.38[a]	2.18	1.57[b]
HInc	5.97	5.85[b]	56.56	58.30[a]	2.48	1.95[b]	1.80	2.62[a]
Rearing temperature								
C	5.99[a]	5.89	55.96	57.25	2.47	2.24	1.90	2.54[a]
HS	5.88[b]	5.86	56.92	58.13	2.37	2.19	2.11	2.49[a]
Cond+HS	5.97[a]	5.91	55.92	56.74	2.63	2.06	1.98	1.25[b]

[a,b] Means in the same column within a parent age with no common superscript differ significantly (P<0.05).

[1] Incubation temperature: Sinc: incubated at 37.8ºC throughout; HInc: exposed to heating at 39.6ºC 6 hours/day from 10 to 18 d of incubation.

[2]Rearing temperature**:** C: Chicks were reared under standard ambient temperature from 0 to 49 days of age; 2. HS: Broilers were exposed to high ambient temperatures from 21 to 49 days 3. Cond+HS: On day 5, chicks were exposed to 36 °C for 24 hour and broilers were exposed to high ambient temperatures from 21 to 49 day.

Age of breeder had a significant effect on meat colour, with meat from YBB one unit less light, redder, and less yellow than meat from OBB (Table 1). Petracci *et al.* (2004) reported that breast muscle fillets of broilers reared in summer exhibit higher lightness, lower redness and yellowness than those reared in winter. In our study, although there was no effect of incubation temperature on colour of breast meat from YBB, HInc resulted in increased L* and b* and decreased a* values in meats from OBB. Indeed, the percentage of meat with L*values lower than 53 was similar for SInc meat (average 26.4%) regardless of parent age but it decreased by HInc for broilers from OBB being 4.76% vs 18.4% for YBB broilers. There was no rearing temperature effect on colour of meat from YBB, however, conditioning decreased b* values of meat from OBB. Although body weights at slaughter age are not presented here, the results may be explained by body weights of broilers. This is because, body weights were negatively correlated with L* (r=-0.16, P=0.02) and b* (r=-0.288, P<0.01) which in consistent with the results obtained in turkeys by Le Bihan-Duval (2003) indicating that heavier body weight decreased lightness and yellowness.

Table 2 Effect of incubation temperatures[1] and rearing temperatures[2] colour of breast meat of broilers from younger and older breeders at 4 d after slaughter.

	L*		a*		b*	
	Breeders					
	Younger	Older	Younger	Older	Younger	Older
Incubation temperature						
SInc	52.06[b]	54.20[b]	1.93	1.95[a]	3.49	3.50[b]
HInc	54.68[a]	56.10[a]	1.84	1.30[b]	3.63	4.28[a]
Rearing temperature						
C	52.83[b]	55.28	1.97	1.70	3.20	4.39[a]
HS	55.27[a]	55.91	1.61	1.47	3.81	4.12[a]
Cond+HS	52.01[b]	54.31	2.09	1.71	3.65	3.14[b]

[a,b] Means in the same column within a parent age with no common superscript differ significantly (P<0.05).

[1] Incubation temperature: Sinc: incubated at 37.8ºC throughout; HInc: exposed to heating at 39.6ºC 6 hours/day from 10 to 18 d of incubation.

[2]Rearing temperature**:** C: Chicks were reared under standard ambient temperature from 0 to 49 days of age; 2. HS: Broilers were exposed to high ambient temperatures from 21 to 49 days 3. Cond+HS: On day 5, chicks were exposed to 36 °C for 24 hour and broilers were exposed to high ambient temperatures from 21 to 49 day.

High L* and b* values persisted 4 d after slaughter for meat from OBB (Table 2). Le Bihan-Duval et al (1999) observed significant increases in L* and a* values 6 and 10 d after slaughter. Although not statistically analysed, L* and a* values decreased and b* values increased after 4 d of storage. Sante *et al.* (1991) reported that b* increased in turkey meats stored for 7 d which is in agreement with our data.

The correlation between pH and L* values was -0.64 (P<0.001). Correlations (P<0.001) for pH with a* and b* values were 0.29 and -0.54, respectively. These results are consistent with those reported by Allen *et al.* (1997) and Barbut (1997) indicating that pH is major determinant of colour. The correlation between pH and thawing loss was -0.24 (P=0.003) while the correlation (r=0.12) between pH and cooking loss was not significant.

Age of breeder and incubation temperature had no effect on thawing loss. However, the interaction between breeder age and rearing temperature showed that thawing loss was greater from YBB broilers and those reared at HS (Table 3).

Table 3 Effect of incubation temperatures[1] and rearing temperatures[2] on percent thawing and cooking loss of breast meat of broilers from younger and older breeders.

	Thawing loss		Cooking loss	
	Breeders			
	Younger	Older	Younger	Older
Incubation temperature				
SInc	3.4	4.7	13.3	12.2[a]
HInc	5.1	4.8	13.6	10.7[b]
Rearing temperature				
C	3.4[b]	4.5	14.6[a]	11.7
HS	6.0[a]	5.0	12.5[b]	11.3
Cond+HS	4.8[b]	4.7	13.3[ab]	11.2

[a,b] Means in the same column within a parent age with no common superscript differ significantly (P<0.05).

[1] Incubation temperature: Sinc: incubated at 37.8ºC throughout; HInc: exposed to heating at 39.6ºC 6 hours/day from 10 to 18 d of incubation.

[2]Rearing temperature**:** C: Chicks were reared under standard ambient temperature from 0 to 49 days of age; 2. HS: Broilers were exposed to high ambient temperatures from 21 to 49 days 3. Cond+HS: On day 5, chicks were exposed to 36 °C for 24 hour and broilers were exposed to high ambient temperatures from 21 to 49 day.

Breeder age was significant for cooking loss, being lower in meat from OBB than YBB. The breeder age by incubation temperature interaction was significant for cooking loss. While incubation temperature had no effect on cooking loss of breast meat of broilers from YBB, cooking loss from OBB was significantly decreased by HInc. Rearing temperature affected cook lossing with meat from YBB being lower from broilers reared at HS. This result indicated that meat from HS broilers lost more water at thawing which, in terms, may contribute to lower cooking loss.

Table 4 Effect of incubation temperatures[1] and rearing temperatures[2] on shear force of breast meat of broilers from younger and older breeders.

	Younger		Older	
	Incubation temperature			
Rearing temperature	SInc	HInc	SInc	HInc
C	2.32[a]	3.30[a]	1.70	1.28
HS	2.18[a]	1.68[b]	1.72	1.39
Cond+HS	1.71[b]	3.40[a]	1.66	1.20
Mean	2.07[y]	2.79[x]	2.69[x]	1.29[y]

[a,b] Means in the same column within a parent age with no common superscript differ significantly (P<0.05).

[xy] Means in the same row within a parent age with no common superscript differ significantly (P<0.05)

[1] Incubation temperature: Sinc: incubated at 37.8ºC throughout; HInc: exposed to heating at 39.6ºC 6 hours/day from 10 to 18 d of incubation.

[2]Rearing temperature**:** C: Chicks were reared under standard ambient temperature from 0 to 49 days of age; 2. HS: Broilers were exposed to high ambient temperatures from 21 to 49 days 3. Cond+HS: On day 5, chicks were exposed to 36 °C for 24 hour and broilers were exposed to high ambient temperatures from 21 to 49 day.

Shear force was lower in breast muscle from OBB than YBB (Table 4). This difference may be a consequence of greater cooking loss in broilers from YBB indicating higher water retention ability which cause tight structure (Anadon, 2002). Shear force was increased by HInc in YBB and decreased in OBB (Table 4). Rearing temperature had no effect on tenderness of breast meat from OBB. A significant incubation temperature by rearing temperature interaction was observed for shear value of meat from YBB. This interaction showed that Cond+HS broilers had lower tender force than those C and HS broilers when SInc applied whereas under HInc, HS broilers had lower shear force than those C and Cond+HS.

In summary, we found that breeder age interacted with incubation and rearing temperatures and had an effect on meat quality. The results suggest that poultry industry should take into consideration heat conditioning of broilers to obtain better meat quality of broilers reared during hot weather in open sided poultry houses. Additional studies concerning the effects of prenatal adaptation on meat quality are needed.

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