EFFECT OF DIFFERENT DEGREES OF ACUTE HEAT STRESS ON BROILER MEAT QUALITY

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Abstract - This experiment focused on the effect of different pre-slaughter acute heat stress levels on chicken meat color and water holding capacity (WHC). Broilers were randomly divided into 7 groups to receive heat stress (HS) for different temperatures and times: (1) 36℃ for 1 h, (2) 36℃ for 2 h, (3) 38℃for 1 h, (4) 38℃ for 2 h, (5) 40℃ for 1 h (6) 40℃ for 2 h, and (7) unstressed control (C). Results indicated that pre-slaughter acute heat stress had significant effect on initial temperature, lightness （*L）, redness（*a**） and cooking loss (*P* < 0.05). But the heat treatment time and its' interaction with temperature had no significant effect on meat color or WHC (*P* > 0.05). Compared to the control group, heat treatment at 36℃ increased *L**-value and decreased *a** value（*P* < 0.05）, and improved cooking loss （*P* < 0.05）. However, as the temperature increased to 38 or 40℃, the significant difference in *L** value and cooking loss disappeared, compared to the control group (*P* > 0.05). So, high levels of heat stress before slaughter do not always lead to PSE chicken meat.**

Key Words - acute heat stress, broiler, meat quality

I. INTRODUCTION

Heat stress has long been recognized as one of the prominent environmental elements influencing chicken meat quality [1]. In recent years, many scholars have pointed out that heat stress has negative effects on broiler meat color and WHC [2]. Sams (1997) found that turkey under heat stress (38/32°C, night/day) had higher *L** and lower WHC [3]. Sandercock (2001) showed that acute heat stress (32℃, 2h) increased broiler meat drip loss, and decreased color score and chicken flavor intensity[4].

Birds with stress syndrome may exhibit a rapid decline in postmortem muscle pH while the meat temperature remains high [5, 6]. Under this condition, light scattering by precipitated sarcoplasmic proteins increases meat paleness, and the shrinkage of the myofilament lattice at a low pH increases reflection at myofibrillar surfaces, increasing *L** [7, 8, 9], and decreasing WHC. So, heat stress may lead to higher incidence of PSE chicken meat [3, 4].

However, there are also a few reports indicating that acute heat stress has no effect on meat quality. Northcutt et al., (1994) found broilers subjected to acute pre-slaughter heat stress (40℃, 1h) had no significant change on chicken meat drip loss or cooking loss (*P* >0.05) [10]. Pan (2007) also found that acute heat stress (30 days of age, 40℃) could increase broiler breast *L** and decrease a* when treated for 1 to 5 h, but these effects were less pronounced at 10 h [11]. Regretfully, there are no further studies concerning this phenomenon. Our earlier work also suggested that broiler meat *L** increased significantly (*P* < 0.05) with pre-slaughter HS at 36℃, but had no significant change of L* at 38 or 40℃, compared to the control group.

Thus, this study was conducted in order to further investigate the changes in chicken meat color and WHC in response to different heat stress levels before slaughter.

II. MATERIALS AND METHODS

A. Birds and experimental design

All animal experiments were reviewed and approved by the Institutional Animal Care and Use Committee of Shandong Agricultural University (No. 2001002, Figure S1) and performed in accordance with the "Guidelines for Experimental Animals" of the Ministry of Science and Technology (Beijing, China).

One hundred male broiler chickens (Arbor Acres, AA), 6 weeks of age, were used in the current study. The chickens were randomly divided into 7 groups (14 birds in each group), including 6 heat stress (HS) groups and one control group (C). The HS treatment was conducted in an environmentally

controlled room. The birds in the 6 HS groups were received different HS treatment respectively with different temperatures and times: (1) 36 ℃ for 1 h, (2) 36 ℃ for 2 h, (3) 38 ℃for 1 h, (4) 38 ℃ for 2 h, (5) 40 ℃ for 1 h and (6) 40 ℃ for 2 h. The control group did not receive the HS treatment, and remained at normal growing temperature of 25 ℃. Water was offered throughout the heat stress procedure. After treatment, 12 broilers of each group were randomly selected for slaughter and analysis. The boneless breast of broilers was removed by knife cutting immediately after bleeding, without scalding or defeathering, and then stored at 4 °C for aging and analysis.

At 5 min and 24 h postmortem, the color value was recorded on the left breast. The core temperature was also recorded at 5 min. The right breast was used for water holding capability (WHC) analysis.

B. Meat Quality Measurements

Color

Color was measured at 5 min and 24 hours postmortem with a colorimeter (SP62-Xrite, USA, 8 mm diameter measuring aperture, illuminant D65). The color was described as coordinates (L^*, a^*, and b^*), representing lightness, redness, and yellowness, respectively; CIE, 1986). Color values at six different locations of the pectoralis muscle were averaged and recorded [12].

Drip loss and Cooking loss

At 5 min postmortem, a cube of muscle fillet (about 50 g) from the right pectoralis muscle was collected and weighed. Subsequently, the fillets were suspended in paper cups covered with plastic film and stored at 4 °C for 24 h. Samples were reweighed, and drip loss (%) was calculated as:

[(sample weight - sample weight after 24 h) / sample weight] × 100 %.

At 24 h postmortem, after the fillets were reweighed, the fillets were cooked individually in plastic bags immersed in a water bath at 75 °C to an internal temperature of 70 °C [13]. During cooking, the core temperature of samples was tracked with a digital thermometer (DM6801A, Shenzhen Victor Hi-tech Co. Ltd., China). The cooked samples were chilled and stored in a refrigerator overnight, then reweighed. Cooking loss was calculated as: (weight of water loss before and after cooking / weight before cooking) × 100%.

C. Statistical analysis

Two-way analysis of variance (ANOVA) was done, followed by Tukey's HSD test for multiple comparisons, considering the time of acute heat stress and heat stress temperature. Statistical analysis was performed with Statistical Product and Service Solutions (IBM SPSS Statistics 19) using the General Linear Model procedure. Significant differences are indicated, and the *P*-value is given.

III. RESULTS AND DISCUSSION

A. Temperature

Heat stress significantly increased the breast core temperature ($P < 0.05$) at 5 min (after scalding and before chilling) (Table 1). The core temperature increased with increasing ambient temperature, but there was no significant difference among the 3 treatment groups ($P > 0.05$). Heat stress time and the interaction with temperature had no effect on the initial temperature ($P > 0.05$).

B. Color

Pale meat is often associated with a PSE-like condition as described in pork [14]. In this study, HS had no significant effect on L^*_{5min} ($P > 0.05$). But it significantly affected the lightness at 24h postmortem ($P < 0.05$). L^*_{24h} in the 36℃ group increased to 53.15, which was significantly higher than controls ($P < 0.05$; Table 2). It was reported in many previous studies that $L^*_{24h} > 53.0$ may be used as a cut-off value indicating PSE-like chicken meat (Fraqueza et al., 2006; Petracci et al., 2010; Ziober et al., 2010). So according to this cut-off value, heat stress under 36℃ caused PSE-like chicken meat [6, 15].

However, opposite to our expectation, with an increase in HS temperature to 38 or 40℃, the L^*_{24h} began to decline. The significant difference between control group and HS group disappeared. There was no significant difference between control group and heat stress groups at 38 or 40℃ ($P > 0.05$), and the L^*_{24h} was also lower than 53. Pre-slaughter HS significantly decreased both a^*_{5min} and a^*_{24h}, in agreement with many previous studies ($P < 0.05$) [13]. But there was no significant difference within HS groups due to temperature differences ($P > 0.05$). HS time and their interaction with temperature had no effect on color values ($P > 0.05$).

C. Drip Loss and Cooking Loss

Processing plants are becoming more concerned about meat quality, especially to improve water-holding capacity (WHC), and therefore increase product yields.

In this study, there was no significant difference in WHC between HS and C groups ($P > 0.05$). Other studies have reported different results. Zhu et al. (2011) found that the muscles in the HS group had higher drip loss compared to non-HS controls [16]. However, Northcutt (1994) reported that the drip loss in their heat stress (40℃) group was significantly lower than the control group ($P < 0.05$) [10]. The different HS conditions between studies may account for the different results.

Different from drip loss, cooking loss was affected by HS temperature ($P < 0.05$, Table 2). It was significantly increased to 16.08 %, compared to 13.33% for the C group ($P < 0.05$). Cook loss also tended to increase in 38 and 40℃ groups, but not significantly, compared to the C group ($P > 0.05$). HS time and their interaction with temperature also had no effect on WHC ($P > 0.05$).

IV. CONCLUSION

HS under 36 ℃ caused broiler chicken breasts to have lighter color and higher cooking loss, which led to more PSE-like chicken meat. However, as the HS temperature increased to 38 and 40℃, this phenomenon weakened or disappeared. Thus, high temperature heat stress before slaughter does not always lead to PSE-like chicken meat. Further work is necessary to explain the changes of chicken meat quality under higher HS temperatures.

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Table1. Effects of heat stress temperature and heat stress time on the the core temperature of muscles (n = 12)

Heat Stress Temperature					Heat Stress Time			Significance		
C[1]	36°	38°	40°	SE[3]	1h	2h	SE	Temp[4]	Time	Temp×Time
41.57b	43.86a	44.14a	44.52a	0.19-0.22	43.40a	43.64a	0.14-0.15	***	N.S.[2]	N.S.

[1] C = control, no heat stress. [2] N.S: no significance. [3] Standard error [4]Temp: Temperature. *: P<0.05 ***: P<0.01

a-b Means in a row within a treatment with a different letter differ.

Table 2. Effects of heat stress temperature and time on the color and WHC of muscles (n = 12).

Item	Temperature					Time			Significance		
	C[1]	36°	38°	40°	SE[3]	1h	2h	SE	Temp	Time	Temp×Time[4]
$L^*_{5\ min}$	49.01a	48.86a	48.67a	48.15a	0.43-0.45	48.48a	48.86a	0.30-0.32	N.S.[2]	N.S.	N.S.
a^*_{5min}	8.16a	7.05b	6.57b	7.06b	0.26-0.30	7.14a	7.28a	0.18-0.20	***	N.S.	N.S.
b^*_{5min}	14.92a	13.61a	13.61a	13.88a	0.37-0.43	13.95a	14.01a	0.27-0.28	N.S	N.S	N.S.
L^*_{24h}	50.56b	53.15a	52.02ab	50.89ab	0.35	52.26a	51.77a	0.25	***	N.S.	N.S.
a^*_{24h}	9.85a	8.48ab	8.14b	9.38ab	0.40	8.88a	9.04a	0.28	*	N.S.	N.S.
b^*_{24h}	16.39a	15.82a	15.45a	15.75a	0.39	15.90a	15.81a	0.28	N.S.	N.S.	N.S.
Drip loss (%)	1.10a	1.40a	1.20a	1.17a	0.12	1.22a	1.21a	0.08	N.S.	N.S.	N.S.
Cook loss (%)	13.33b	16.08a	14.15ab	13.79ab	0.61-0.66	13.94a	14.72a	0.44	*	N.S.	N.S.

[1] C = control, no heat stress. [2] N.S: no significance. [3] Standard error [4]Temp: Temperature. *: $P < 0.05$ ***: $P < 0.01$

a-b Means in a row within a treatment with a different letter differ.