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Physical and Chemical Properties of Meat in Relation to Wooden Breast Myopathies in Male Broiler Chickens Raised in Evaporative Cooling Systems

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ABSTRACT

Background: There are few scientific reports of the occurrence of wooden breast (WB) in Thailand. This study aimed to evaluate the incidence and effect of WB on the physical and chemical properties of meat from chickens reared under an evaporative cooling system (EVAP).

Methods: A total 124 broiler chickens (BW = 2721.27±273.40 g) were selected from a group of 588 male broiler chickens (at 36 days of age). The WB meat (left site) score of each chicken was identified as being normal, moderate or severe. In order to compare the effect of the WB score on meat quality, based on the number of chickens in the normal group, the number of chickens in the moderate and severe groups were equalised (19 birds/group). The effects of the WB score on pH, colour, drip loss, thawing loss and cooking loss of the meat were observed.

Result: The body weight of normal meat, moderate WB and severe WB was 2525.26±221.49, 2683.53±273.17 and 2883.78±211.90 g, respectively. The severe WB score occurred when the body weight (g) was heavier than the normal meat group for 14.19% (P<0.01). At 24 hours, the pH, drip loss, cooking loss and water content of the severe WB group was significantly higher, while the protein content in the severe WB group was lower than the normal meat group (P<0.01). Moreover, the severe WB group presented higher lightness, redness and yellowness values compared to the normal meat group (P<0.01). In conclusion, a larger body of broiler chickens, greater than 14% of the strain's recommendation induced a severe WB score, which caused poor meat quality.

Key words: Broilers, Chicken breast meat, Meat quality, Wooden breast.

INTRODUCTION

The problem of meat quality due to wooden breast in the broiler industry causes severe economic losses (Kuttappan *et al*., 2013; Mudalal *et al*., 2015; Kuttappan *et al*., 2016; Zhao *et al*., 2020). The incidence of WB has increased significantly from 1.4 to 8.7% in the United States (Kuttappan *et al*., 2012; Petracci *et al*., 2013), from 25.7 to 32.3% in Italy (Tijare *et al*., 2016) and from 48 to 73% in Finland (Sihvo *et al*., 2017). Recently, in Ontario Canada, Che *et al*. (2022) estimated that 11.9-82.4% of commercial broilers had WB.

Several factors affect the incidence of WB including gender, genotype, growth rate, dietary energy, slaughter weight, early dietary restriction and breast yield/size (Kuttappan *et al*., 2012; Kuttappan *et al*., 2016). It is known that an environmental temperature above 30°C induces heat stress in poultry (Malila *et al*., 2021; Rajkumar *et al*., 2021). Consequently, the adverse impact on meat quality *via* oxidative damage (Reddy *et al*., 2018) reduces the process of muscle regeneration and the resulting WB (Aslam *et al*., 2021). Therefore, to improve the productive performance of broilers in tropical countries, there is an increasing trend of raising broilers in sheds with EVAP installed, which are capable of maintaining the shed temperature at 28°C or less during the hot season (Wasti *et al*., 2020). Although Thailand is a major exporter of chicken meat in the world, unfortunately, there are only few scientific reports on the situation of WB in broilers raised in EVAP. Therefore, this study aimed to evaluate the incidence of WB in chicken rearing under an EVAP in Thailand and its impact on meat quality parameters.

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MATERIALS AND METHODS

Animals and management

The experiment was conducted session of 2022 (total research period was around 5 months) at research farm of

Kasetsart University and all parameters were measure at Valaya Alongkorn Rajabhat University Under the Royal Patronage. Under licence number U1-07385-256, 588 male broiler chickens (Ross 308) were reared in an EVAP from age day 1 to day 36 (11.66 birds/m^2 or 31.7 kg/m^2) at the research farm of Kasetsart University, Bangkok, Thailand. The chickens were managed and vaccinated according to commercial practices. Water and feed were provided *ad libitum*. At one week of age, the temperature was maintained around 33°C and then gradually reduced to 25-28°C until the end of experiment; the relative humidity was around 75-80%.

At 36 days of age, a total 124 broiler chickens, having a body weight close to the mean of the flock, were selected (2,721.27±273.40 g), then the outer breast meat (left site) of each bird was collected and classified according to the WB score.

WB scoring

Briefly, to minimise variation, only one trained person was assigned to scoring the WB (Kuttappan *et al*., 2012). Whole breast meat (*Pectoralis major* muscle) was immediately scored for hardness based on the physical assessment scale by Oliveira *et al*. (2021): normal = flexible throughout the meat; moderate = flexible in the mid to caudal region; and severe = extremely hard throughout from the cranial region to caudal tip. After determination of the WB, the pH of the meat was immediately measured (Instruments, Wilmington, MA, USA) as reported by Xing *et al*. (2019). The samples were kept in a refrigerator at -20°C for further analyses.

After classification of the WB score, the percentage of normal, moderate and severe scores was 14.82 (19 birds), 53.12 (68 birds) and 28.91 (37 birds) and the average body weight of each group was 2525.26±221.49, 2683.53±273.17 and 2883.78±211.90 g, respectively. To evaluate the effects of WB score on meat quality, the number of birds in each group were equalised into 19 birds per group. The birds in the moderate and severe groups having a body weight close to the group mean were selected. Therefore, the body weight of normal, moderate and severe groups used for the evaluation of the meat quality was 2525.26±221.49, 2640.53 ±229.81 and 2834.74±185.48 g, respectively. Subsequently, the meat quality (physical and chemical properties) was analysed.

Physical analysis

Meat colour and pH measurements

At 45 min and 24 h post-slaughtering, the colour was evaluated as L* (lightness), a* (redness) and b* (yellowness) using a colorimeter (CR-400, Konica Minolta Sensing, Inc., Japan) with a D65 illuminant and 10 mm and 8 mm apertures in the observer mode. The colour difference (ΔE) between non-WB and WB was calculated from the following equation:

$$\Delta E = [(\Delta L^*)^2+(\Delta a^*)^2 +(\Delta b^*)^2]^{1/2}$$ (Thanatsang *et al*., 2020).

Water holding capacity (WHC)

Water holding capacity of meat was assessed on the basis of drip loss, thaw loss and cooking loss. The raw breast meat samples were individually packed in plastic bags and kept at 4°C for 24 h. The drip loss was calculated as the percentage difference between the initial and final weights. For assessment of thaw loss, each breast meat sample was individually packed in a plastic bag and frozen (-20°C). Breast meat samples were thawed at 4°C for 24 h, then kept at room temperature until they reached 4°C. Thawing losses (%) were calculated according to Tasoniero *et al*. (2016). Cooking loss was measured using the whole breast, according to Brambila *et al*. (2018). The meat samples were cooked in a water bath at 80°C until the temperature of the meat reached 75°C. Then, the samples were cooled at room temperature, before weighing to calculate the percentage of cooking loss.

Chemical analyses

The samples of meat were evaluated in triplicate for water and protein contents following the AOAC (2011). The water content was measured by oven-drying the samples at 100°C for 16 hr and the Kjeldahl method was used to determine the protein content.

Statistical analysis

A completely randomised design was used according to the General Linear Model (GLM) procedure, with one-way Analysis of Variance (ANOVA) and Tukey's studentised range (Honestly Significant Difference; HSD) (SAS Institute Inc., Cary, NC). A significant difference was considered at $P<0.05$. The correlation coefficient between body weight and WB score was evaluated using Pearson correlation coefficient.

RESULTS AND DISCUSSION

General data on the 588 broiler breasts (*pectoralis major* muscle) are presented in Fig 1. The average body weight and breast meat of the broilers was 2,721.21±273.40 and 526.94±76.79 g, respectively. The effects of WB score on body weight, breast meat weight and meat quality are presented in Table 1. It was found that the body and breast meat weight (g) of the severe WB group was significantly heavier than the normal meat and moderate WB groups ($P<0.01$), whereas the breast meat weight expressed as a percentage of body weight did not differ significantly ($P>0.05$).

Within the total samples (124 samples), the breast meat score was identified as normal meat (14.82%), moderate WB (53.12%) and severe WB (28.91%). The incidence of WB in the current study seems to be higher than recent reports from Finland (48-73%) (Sihvo *et al*., 2017), Italy (53.2%) (Dalle Zotte *et al*., 2017) and China (61.91%) (Xing *et al*., 2019).

Compared to the standard of the male ROSS 308 strain's recommendation (2021) at 36 days of age, the average body weight in the current study was 2,721.27 g; higher than the standard (2,522 g). After classification of the WB score, the body weight of the normal meat group was 2,525.26 g, while the moderate WB (2,683.52 g) and severe WB (2,883.78 g) groups were heavier than the normal meat group for 6.27% and 14.19%, respectively. Moreover,

it was found that there was positive correlation between the body weight and WB score (r= 0.52; P<0.01). Since the body weight of the normal meat group was near the recommendation, it can be implied that body weight greater than the recommendation induced the occurrence of WB. In particular, when the body weight was heavier than the standard by 14.19%, it caused severe WB.

Since the broiler chickens that are raised under tropical conditions always present low productive performance, using an EVAP can prevent these negative effects. However, the high growth rate of broiler chickens raised under this system also induces WB myopathy problems. Therefore, we suggest that the body weight should be kept near the standard of the strain's recommendation to avoid the incidence of WB.

At 24 h post-mortem, the pH, drip loss, cooking loss and water content of the severe WB group were significantly higher than the normal and moderate WB meat groups (P<0.01). On the other hand, the protein content in the breast meat of the severe WB group was significantly lower than the normal meat group (P<0.01).

It is clear that the greater size of body and breast meat weight, around 14% (normal meat vs severe WB group), significantly reduced the quality of breast meat due to WB myopathy. In terms of meat quality, it was noted that there were no significant differences between normal meat and moderate WB groups. This may be due to the body weight being heavier than the normal meat group for 6.27% only. This is in agreement with Kuttappan *et al*. (2017), who reported that increased weight and age of broilers enhanced the incidence of severe WB and Petracci *et al*. (2013) who found a high pH at 24 h in WB meat. Tasoniero *et al*. (2016) also found a positive correlation between breast meat weight and pH of the meat. An increase in this value can cause high degeneration of the meat (Mudalal *et al*., 2015; Tasoniero *et al*., 2016), with a subsequent reduction in meat quality. A high pH in WB meat may be due to a low

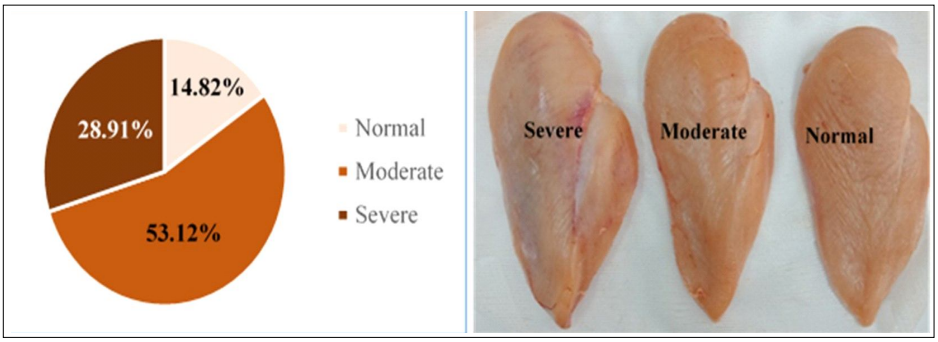

Fig 1: Incidence and scoring examples of WB.

Table 1: Effects of level of WB myopathy on weight, pH, WHC and proximate chemical composition of meat fillets.

Item	Severity of wooden breast			P-value	SEM
	Normal (N=19)	Moderate (N=19)	Severe (N=19)		
Live weight (g)*	2,525.26^{C}	2683.52 ^{B}	2883.78 ^{A}	<0.01	24.69
% CV of body weight*	8.77	10.20	7.35	-	-
Number of scored birds from 124 birds*	19 (14.82%)	68 (53.12%)	37 (28.91%)	-	-
Live weight (g)(Equalised N of birds;19 birds)	2,525.26^{B}	2,640.53^{B}	2,834.74^{A}	<0.01	32.55
% CV of body weight (N=19 birds)	8.77	8.70	6.54	-	-
Breast (g)	477.78^{B}	482.89^{B}	542.10^{A}	<0.01	8.54
Breast (%)	18.93	18.24	19.11	0.17	0.19
pH at 45 min	6.88	6.83	6.84	0.80	0.02
pH at 24 h	5.95^{B}	6.04^{AB}	6.12^{A}	0.01	0.02
Drip loss (%)	2.73^{B}	2.80^{B}	3.64^{A}	0.01	0.12
Thawing loss (%)	6.56	6.10	6.62	0.75	0.30
Cooking loss (%)	19.69^{B}	21.36^{B}	23.61^{A}	<0.01	0.40
Protein (%)	86.86^{A}	85.29^{AB}	82.90^{B}	<0.01	0.52
Water (%)	73.60^{B}	74.25^{B}	75.69^{A}	<0.01	0.20

*Number of birds in each group: Normal= 19; Moderate= 68; Severe= 37.

Number of birds in each group for measurement of meat qualities= 19 birds.

CV= Coefficient of variation (%).

SEM= Mean standard error; ^{A,B,C} Mean values of same parameter followed by different uppercase superscripts differ significantly (P<0.05).

Table 2: Effects of level of WB myopathy on colour of meat fillets.

Item	Normal	Moderate	Severe	P-value	SEM
			At 45 min		
L*	48.44^{B}	49.99^{B}	52.35^{A}	<0.01	0.36
a*	1.67^{B}	2.08^{AB}	3.00^{A}	0.01	0.18
b*	6.14^{A}	6.79^{B}	7.76^{B}	<0.01	0.16
ΔE*	0	1.73	4.46	-	-
			At 24 h		
L*	51.01^{C}	52.91^{B}	55.26^{A}	<0.01	0.33
a*	2.41^{B}	2.53^{B}	3.48^{A}	<0.01	0.13
b*	7.58	7.88	8.17	0.3	0.15
ΔE*	0	1.92	4.42	-	-

SEM, mean standard error; ΔE*, total colour difference between the control group; ^{A,B,C} Mean values of same parameter followed by different uppercase superscripts differ significantly (P<0.05).

accumulation of glycogen in the meat, since Tasoniero *et al*. (2016) found a negative correlation between glycogen content and breast meat weight.

In the present study, high drip loss and cooking loss were recorded for the severe WB meat. These phenomena may be due to degradation of muscle fibres (decreased myofibrillar and sarcoplasmic proteins) according to Sirin (2018). Mudalal *et al*. (2015) and Tijare *et al*. (2016) showed that WB resulted in a higher cooking loss, lower flavouring pick-ups, reduced tenderness and poor cohesion (tendency for separation of muscle fibre bundles). Furthermore, we also found that a severe WB meat score meant a high amount of water and a low protein content compared to normal meat. Similarly, Kuttappan *et al*. (2013) demonstrated that severe WB had a low protein content and high myopathic lesions. A reduction in muscle fibre number significantly reduces the WHC in breast meat affected by WB (Sihvo *et al*., 2014). The present study confirms that WB resulted in downgrading of the meat quality in agreement with Tijare *et al*. (2016) and Petracci *et al*. (2019). Thus, although rearing broiler chickens in an EVAP can avoid heat stress, a high incidence of severe WB also occurs if the growth body weight and/or breast meat are in excess of the recommendations for the strain.

The effects of WB on meat colour are presented in Table 2. At 45 min. and 24 h, severe WB samples had highly significantly greater values for L* (lightness), a* (redness) and b* (yellowness) than the normal meat (P<0.01), except at 24 h for b*, which was not significantly different among the WB scores. There was a visible total colour difference (ΔE*) between the normal and WB meat samples, although not significant.

Meat colour is an important benchmark for consumer decisions. The poor physical and chemical properties of WB and the higher the L* value may be related to changes in the structure of the muscle (Oliveira *et al*., 2021). In addition, Sihvo *et al*. (2014) and Trocino *et al*. (2015) found that a high cooking loss in WB was related to a high accumulation of intramuscular fat that resulted in a higher b* value for meat in the severe WB class. Higher a* and b* values indicate a reduction in the pigment content of WB meat (Velleman *et al*., 2017). Therefore, it can be said that WB negatively affects the appearance of meat and would influence customer acceptability.

CONCLUSION

It seems that WB could be a problem of tropical countries using EVAP, if the growth rate is higher than the strain's recommendations. The WB directed deterioration of meat quality and incidence of WB was related to the 14% excess body weight at the time of slaughter. Therefore, the broilers can be raised up to a target body weight according to strain's recommendations without the problem of WB, while maintaining breast meat quality.

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Conflict of interest

All authors declare that they have no conflict of interest.

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