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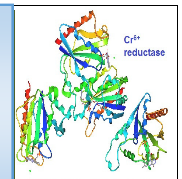

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Effects of Shackling and Cone Restraining on Meat Quality of Broiler Chickens Slaughtered at Two Categories of Live Weight

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ABSTRACT

A study was conducted to determine the effects of shackling and cone restraining methods on meat quality of broiler chickens slaughtered at two categories of live weight. Fourty Cobb 400 male broilers were randomly assigned to a 2 × 2 factorial arrangement in a completely randomized design with 10 birds of each treatment group. The birds were slaughtered at ≤2 kg and ≥2.5 kg live weights using shackling or cone restraining methods. Neither cone nor shackle restraining methods affected the pH change of both slaughter weights. Birds weighing ≤2 kg subjected to cone method had higher ($P<0.05$) a*, b* and lower ($p<0.05$) L*, drip loss, cooking loss and shear force than those subjected to shackle method. Birds weighing ≥2.5 kg subjected to cone method had higher ($p<0.05$) b* and lower ($p<0.05$) L* and cooking loss than those restrained with a shackle method. Results of shear force values, L*, a*, b*, and pH change were significantly higher ($p<0.05$) in ≥2.5 kg chickens compared with those ≤2 kg chickens using shackling restraining method.

INTRODUCTION

Environmental conditions existed shortly before an animal is slaughtered have been known to be stressful for broiler chickens and could even affect the meat quality [1]. Restraining methods and slaughter weight for example had been reported to have impacts on the pre and post slaughter physiological responses in broiler chickens [2,3,4]. While the most common broiler restraining method used under commercial practice is shackling, this method has been recognised to have a negative impact on the welfare of broilers [5,6,3] and their meat quality [7,8,9]. Struggling or wing flapping during shackling has been reported to fasten the initial rate of pH drop and increased the redness of breast meat [9]. Therefore, it is suggested that limiting this behaviour in shackled broilers could help to improve their meat quality [10].

Apart from the aforementioned factors, behavioural response to shackling may also vary among chicken types where the slow-growing line (lighter) being more reactive than the fast growing line (heavier) [6]. According to a report by authors in [11], broilers slaughtered at a target carcass weight of 1.2 kg exhibited a lower pH and higher redness compared with broilers slaughtered for 1.8 and 2.4 kg carcass weight. Darker meat was observed in broiler slaughtered above 3.3 kg when compared to broilers lighter than 3 kg. After a short transport distance, broilers slaughtered at below 2 kg were seen to have a lower ultimate pH than those slaughtered at more than 2.4 kg weight. Meanwhile, it has been discovered that cone restraining can reduce the movement in birds either pre slaughter, during slaughter or early post slaughter [12.13]. Authors in [12] considered that placing broilers in a cone during stunning and exsanguination reduce convulsion as compared to shackle restraining.

It was also discovered that placing birds in cone followed by stunning successfully reduces struggling in chicken [12,13] as well as improves the carcass quality [2]. However, there is a dearth of information on how cone restraining, in comparison to shackling, affects the meat quality of broiler chickens slaughtered at different slaughter weights. Hence, the present study was conducted to determine the effects of shackling and cone restraining methods on breast meat quality in broiler chickens slaughtered at ≤2 kg and ≥2.5 kg live weights.

MATERIALS AND METHODS

Experimental design, animals, restraining and slaughter

The study was conducted on 40 male Cobb 400 broiler chickens. They were randomly assigned to a 2 x 2 factorial arrangement in a completely randomized design with 10 birds in each treatment group. The birds were subjected into shackle and cone restraining methods and slaughtered at ≤2.0 kg and ≥2.5 kg live weights. Chicks of 0 day old were obtained from a commercial farm located at Rembau, Negeri Sembilan, Malaysia and reared in a semi closed pen at Farm 2, Universiti Putra Malaysia. Birds were provided with commercial broiler chicken starter and finisher feed and *ad libitum* amounts of drinking water. After 35 days of rearing period, 20 birds were randomly picked and assigned to the ≤2 kg group before being crated and transported to a slaughter house located at the Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, for restraining and slaughtering. At day 42, another 20 birds were randomly picked, assigned to the ≥2.5 kg group, crated and transported to the same slaughter house for restraining and slaughtering. In the slaughter house, birds were restrained for 30 s using either shackle or cone restraint method and humanely slaughtered following the Halal slaughtering procedure as outlined in [14].

Muscle pH determination

Approximately 0.5 g of pulverised right *pectoralis major* muscle was homogenised in 5 ml of ice cold distilled water and the pH was measured using a pH meter (Mettler Toledo, USA). Changes of pH over 24 h post mortem storage was calculated based on the differences between pH value at 45 min and 24 h post mortem [15].

Colour determination

Meat for colour analysis was sampled from the right *pectoralis major* muscle at 24 h post mortem and objectively measured using Colour Flex® (HunterLab, USA). Samples of approximately 10 mm of thickness [16] were exposed to the ambient for 30 min at room temperature to allow blooming. Colour was determined in triplicate using Colour Flex spectrophotometer (Hunter Lab Reston, VA, USA). Lightness (L*), redness (a*) and yellowness (b*) were measured using D56 illumination and 10° standard observer, tristimulus values (X,Y,Z) and reflectance at a specific wavelength (400 - 700 nm) to express the meat colour data [17].

Drip loss

The meat samples collected from the left *pectoralis major* muscle at 7 min post mortem were weighed and recorded as W1 before being placed in a plastic bag, vacuum packed and stored at 4ºC for 24 h. After 24 h, samples were removed from the plastic bag. The surface of samples was dried gently using a tissue paper before weighing and recording as W2. The following equation was used in determining the percentage of drip loss 24 h of post chilled muscle [18] (Eqn. 1).

$$\text{Drip loss } (\%) = \frac{W1 - W2}{W1} \times 100 \qquad (1)$$

Where,
W1 = Initial weight
W2 = Final weight

Cooking loss

Samples were collected from the left *pectoralis major* muscle at 24 h of post mortem for the determination of cooking loss. Samples were weighed and recorded as W1. The samples were placed in plastic bags and cooked in a water bath at 80ºC for 30 min. The cooked samples were removed from the plastic bags, cooled, gently dried, weighed and recorded as W2. Cooking loss percentage were calculated based on the difference between W1 and W2 using the following equation [18] (Eqn. 2).

$$\text{Cooking loss } (\%) = \frac{W1 - W2}{W1} \times 100 \qquad (2)$$

Where,
W1 = Initial weight
W2 = Final weight

Shear force measurement

Samples used for cooking loss determination were used to measure the shear force values. Each sample was divided into three sub-samples for the measurement with 1 cm × 1 cm× 2 cm thicknesses. Shape and fiber orientation based on the protocols outlined by [19]. Each sample was sheared once perpendicularly to the fibers at a speed of 1.0 mm/sec with a Volodkovitch bite jaw attached to a texture analyser fitted with a 5 kg load cell.

Statistical analysis

Data were analysed using the GLM procedure of Statistical Analysis System package (SAS) Version 9.4 software [20]. Means were separated using Tukey's multiple range test option and the P value was set at 0.05. The correlations between meat quality parameters were calculated using the CORR procedure of the SAS.

RESULTS AND DISCUSSION

Muscle pH

It appears that greater pH fall are caused by higher rate of post mortem glycolysis [21] which leads to higher production of lactate and lower the ultimate pH in meat of broilers [22]. As presented in **Table** 1, the change in pH over 24 h post mortem periods was found to not be affected by restraining method but affected by slaughter weights. In shackle group, the change in pH was found to be greater ($p<0.05$) in samples from birds weighing ≤2 kg than samples from birds weighing ≥2.5kg. Similar trend was found in the group subjected to cone restrain although no significant ($p>0.05$) differences were observed.

Authors in [23] found broilers slaughtered at 32 days (lighter) had significantly lower pH values at 24 h post mortem compared those slaughtered after 42 days (heavier). Authors in [24] observed lower muscle pH at 4 h post mortem in birds slaughtered at 42 days compared to those slaughtered at 53 days. Authors in [25] reported lower plasma glucose in younger (lighter) broilers than in older (heavier) broilers. According to authors in [26] heavy chickens have more energy stores to prevent changes in blood glucose level, suggesting why the pH change in the present study was lower in heavy chicken than in lighter chickens. Meanwhile, struggling and free wing flapping during shackling was reported to cause an increase in breast muscle lactate concentration and lower the muscle pH after 15 min of post mortem aging [1]. In the present study, significant differences in pH change were only observed in group restrained by shackling could be because the free wing flapping only happens in shackled birds, and not in cone restrained birds.

Table 1. Effects of restraining method and slaughter weight on meat quality of broiler chickens.

Traits	Slaughter weight (W)	Restraining method (R)		SEM	P value	
		Shackle	Cone		R	R x W
p**H** change	≤2kg	0.20^{x}	0.24	0.03	0.3943	0.8975
	≥2.5kg	0.12^{y}	0.15	0.04	0.5807	
	sem	0.02	0.04			
	p value	0.0379	0.1648			
lightness (l*)	≤2kg	51.03^{ax}	48.70^{bx}	0.53	0.0060	0.2521
	≥2.5kg	47.34^{ay}	43.67^{by}	0.63	0.0006	
	sem	0.57	0.58			
	p value	0.0003	<.0001			
redness (a*)	≤2kg	6.13^{bx}	7.49^{ax}	0.20	0.0002	0.0033
	≥2.5kg	4.46^{y}	4.47^{y}	0.23	0.9923	
	sem	0.19	0.23			
	p value	<.0001	<.0001			
yellowness (b*)	≤2kg	19.44^{bx}	22.71^{ax}	0.67	0.0032	0.6910
	≥2.5kg	14.60^{by}	17.33^{ay}	0.68	0.0108	
	sem	0.53	0.80			
	p value	<.0001	0.0002			
drip loss (%)	≤2kg	2.01^{a}	1.27^{b}	0.25	0.0470	0.9745
	≥2.5kg	2.20	1.43	0.33	0.1188	
	sem	0.28	0.30			
	p value	0.6497	0.6974			
cooking loss (%)	≤2kg	22.06^{a}	19.30^{b}	0.60	0.0041	0.9417
	≥2.5kg	23.01^{a}	20.33^{b}	0.66	0.0105	
	sem	0.57	0.68			
	p value	0.2571	0.2984			
shear force (kg)	≤2kg	1.88^{ax}	1.13^{b}	0.01	0.0121	0.1217
	≥2.5kg	1.23^{y}	1.16	0.04	0.5485	
	sem	0.02	0.04			
	p value	0.0429	0.5677			

^{a,b}Means within a row with no common superscripts are significantly different ($p<0.05$).
^{x,y}Means within a column with no common superscripts are significantly different ($p<0.05$).
SEM, Standard error of means

Colour

Colour is a major factor influencing consumer's acceptability of meat and it is a useful tool for assessing meat at purchase [27]. The result of colour parameters is shown in Table 1. Restraining methods affected meat lightness, redness and yellowness. Meat from birds restrained using shackle method was significantly ($p<0.05$) higher in L* and lower in a* and b* than meat from birds restrained using the cone. Results on correlation found positive correlation between a* and b* values. There was a positive correlation between redness and yellowness in previous report by authors in [28]. According to authors in [29] the redness and yellowness of meat are linked, where meat with higher a* tends to have higher levels of b*. Meanwhile, breast meat colour has often been related to the post mortem kinetics of muscle pH decline. Lightest breast meat was characterised by the least decline in pH [30]. Broiler breast muscles with lower pH appear less red than those with higher pH [31]. However, in the present study, positive correlation was found between meat a* and pH change, suggesting that meat with lower pH was redder than those with higher pH (**Table** 2).

This is not in agreement with reports by authors in [32] and [28] who reported a positive correlation between pH and a* values obtained after 24 h post mortem breast muscle of broilers. While ultimate pH are mostly associated with rate of post mortem glycolysis, glycogen reserve in muscle at death were also the key factors associated with the onset and extent of post mortem pH decline and the quality of broiler breast meat [1]. Slaughter weights affect the L*, a* and b* of meat in all treatments. In shackle and cone methods, birds weighing ≤2 kg showed higher ($p<0.05$) L*, a*, and b* values than those from birds weighing ≥2.5kg. [33] reported that meat a* in broilers decreased with age. According to authors in [30], breast muscle hypertrophy occurs as birds age, causing myofibers to enlarge and reduce the density of capillary peripheral to the myofiber [34]. This could have contributed to the reduction in meat a* value.

Table 2. Correlation coefficient among quality measurements of *pectoralis major* muscle in broiler chicken

Traits	L*	a*	b*	Drip Loss	Cooking Loss	Shear Force
pH change	0.14	0.41	0.24	-0.01	-0.33	0.05
p value	0.40	0.01	0.14	0.97	0.04	0.76
L*		0.41	0.36	0.12	0.43	0.19
P value		0.01	0.02	0.47	0.01	0.25
a*			0.71	-0.10	-0.40	-0.02
P value			0.00	0.53	0.01	0.91
b*				-0.15	-0.21	0.06
P value				0.35	0.19	0.73
Drip loss					0.25	0.19
P value					0.13	0.23
Cooking loss						0.31
P value						0.05

L* = lightness; a* = redness; b* = yellowness.

Drip loss and cooking loss

Birds weighing ≤2 kg shackled had significantly higher ($p<0.05$) drip loss than birds ≤2 kg restrained in a cone (Table 1). There is no effect ($p>0.05$) on restraining methods on meat drip loss for birds weighing ≥2.5kg. Cooking loss in birds restrained using a shackle appear to be higher ($p<0.05$) than those restrained with a cone at both slaughter weights. Struggle at slaughter significantly decrease water holding capacity in broiler chicken [35]. This could be due to the struggling happened during shackling which promotes the production of lactate in muscle. Lower meat pH lead to denaturation of protein and reduced the water holding capacity of meat [36]. This is also supported by the positive correlation found between pH changes and cooking loss in meat (**Table** 2).

Shear force

Breast meat from birds weighing ≤2 kg exposed to cone method appear to be more tender (lower shear force) than meat from shackled birds ($p<0.05$). Wing restraint treatment stretches the breast muscles and prevents contraction, resulted in longer sarcomeres thus improving the tenderness of the meat [37]. In shackle method, shear force values in birds weighing ≤2 kg were higher ($p<0.05$) than ≥2.5 kg birds. These results were in agreement with those reported by authors in [23] who reported that the shear force values of lighter birds slaughtered at 32 days were significantly higher than shear force values of heavier birds slaughtered at 42 days. It has been reported that the muscle fiber cross-sectional area increases with age [38]. Larger fiber diameters may allow lower packing density and reduce the toughness of muscles [23,39]. A positive correlation between cooking loss and shear force shows that meat with lower water holding capacity has a lower tenderness (**Table** 2). According to [40], the texture of the meat is closely related to the amount of intramuscular water and the water retention capacity of the meat. Therefore, meat with higher water content fixed in the muscle would be more tender than meat with less water content

CONCLUSION

Overall findings indicate that restraining methods and slaughter weights did affect the observed quality traits in broiler. In terms of effect on restraining methods, the result demonstrated that cone method improved the meat colour, drip loss, cooking loss, and tenderness of birds weighing ≤2 kg. Cone method also improved the colour and cooking loss birds weighing ≥2.5kg. Neither cone nor shackle restraining methods affects the pH change of both lighter and heavier broiler chickens. The shackle was found to have better effect on heavier weight chicken than those of lighter chicken as regards pH change and meat tenderness but caused pale meat appearance in heavier birds. It can be concluded that the use of cone restraint can improve the meat quality of both light and heavy weight chicken. It can also be suggested that shackling method is best to be used in birds weighing ≥2.5 kg than in birds weighing ≤2 kg in terms of their meat tenderness.

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