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Influence of age on the incidence of wooden breast and white striping, carcass composition, meat physicochemical property, texture profile, and chemical composition of broiler chickens

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Abstract The effects of the age at 43 and 51 days on the incidence of wooden breast (WB) and white striping (WS), carcass composition, meat physicochemical property, textural profile, and chemical composition of broiler chickens were investigated. The frequency and percentage of WB and severity of WS did not differ between age groups. Live weight and carcass weight were affected by age, except the carcass composition percentages. Breast, thigh, wing, and leg weights were not differences between groups. However, the percentage of the thigh was higher in broilers at 51 days of age than at 43 days of age. The percentage of meat physicochemical properties; pH_3 and pH_{24} of broilers at 43 days of age were higher than those at 51 days of age ($P<0.01$). Broiler meat at 51 days of age had statistically significant higher a* value, while L*, b*, chroma, and hue values were not significant differences. There were not significant differences in drip loss percentage, cooking loss percentage, and shear force value. Hardness, gumminess, and chewiness were higher in 51-day-old broilers than 43-day-old broilers ($P<0.05$), except the cohesiveness of cooked meat of 51-day-old broilers was higher than that of 43-day-old broilers ($P>0.05$). For meat chemical composition, the different age groups did not affect the chemical composition, but only the percentage fat content of 51-day-old broilers tended to be higher than that of 43-day-old broilers.

Keywords: wooden breast, white striping, physicochemical property, texture profile

Introduction

Nowadays, consumer demand for chicken meat has increased significantly because chicken meat contains less total fat and more protein than other meats; pork and beef, 3.57 g/100g and 31 g/100g, 20.8 g/100g and 25.7 g/100g and 6.36 g/100g and 27.7 g/100g, respectively (USDA, 2018). Poultry

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meat consumption has risen from 15 million tons in 1970 to 122.3 million tons in 2017 (FAO, 2019). To meet chicken broiler meat demand, poultry industry has attempted to select broilers with a high growth rate and carcass yield, resulting in broilers with larger body weight at younger age. The average market weight of broiler chickens at 112 days in 1925 was 1.1 kg, while it was 2.8 kg at 48 days in 2015 (National Chicken Council, 2015). And in line with the consumer demands and preferences, broiler meat has begun to offer in the form of cut-up into parts: breast, leg, drumstick, and thigh instead of whole carcasses.

Age, feed, and genetic are among the most important factors affecting the growth rate of broiler chickens. Moreover, age has a significant effect on the carcass and meat quality changes that occur in fast growing broilers (Lyon *et al.*, 1984; Young *et al.*, 2001; Baéza *et al.*, 2012; Coban *et al.*, 2014; Glamoclija *et al.*, 2015). Increasing slaughter age also affected the yield of meatier parts (Young *et al.*, 2001), pH (Glamoclija *et al.*, 2015), shear force (Baéza *et al.*, 2012), texture profile (Lyon *et al.*, 1984), and chemical composition (Baéza *et al.*, 2012) of meat. According to Young *et al.* (2001), the percentage of cutting parts of broilers increased with age at slaughter, especially after 42 days. Glamoclija *et al.* (2015) reported that age affected the pH in the breast muscles of broilers with the older broilers having lower pH values than younger broilers. The older the chicken were the lower the moisture content and the higher the lipids content in the meat (Glamoclija *et al.*, 2015). Baéza *et al.* (2012) discovered that the moisture content of raw breast muscle decreased with age, while the fat and protein content increased when they were older. In addition, they found that the meat of younger broilers was lighter and more yellow but less red than that of older broilers. The drip loss and cooking loss of chicken breast meat decreased when the chicken was older (Coban *et al.*, 2014).

New muscle defects emerged in the poultry industry more than a decade ago, and their incidence has increased since then. A number of studies have been published linking increased growth rate in poultry to various muscle defects, particularly in the pectoral muscle (Radaelli *et al.*, 2017; Sihvo *et al.*, 2017; Malila *et al.*, 2018). Among muscle myopathies, there are two predominant myopathies: white striping (WS) and wooden breast (WB). In white striping, white stripes grow parallel to the muscle fibers of the breast, while wooden breast is a hard and ridge-like protrusion of the raw breast. The incidence of WS in commercial slaughter ranges from 9.8% of broilers slaughtered at 42 days of age and 3.2 kg live weight (Ferreira *et al.*, 2014) to 55.8% in chickens slaughtered at 59 to 63 days of age (Kuttappan *et al.*, 2013) or 86.7% in chickens slaughtered at 46 days of age (Trocino *et al.*, 2015).

Radaelli *et al*. (2017) and Malila *et al*. (2018) investigated the influence of different ages on the prevalence of WB and WS and found that as chickens grew older, the severity of WB and WS also increased.

The commercial practice of broiler rearing in Thailand, farmers raised broilers at 42 days of age with an average body weight more than 2.5 kg (Baéza *et al.*, 2012). However, some special Thai dishes prefer larger carcasses of broilers, which are about 3 kg carcass weight or about 4 kg live weight (Baéza *et al.*, 2012). Therefore, a longer rearing period was required to produce broilers with a larger carcass to meet consumer demand. Based on the information on myopathies, the carcass and meat characteristics of broilers one week older than normal commercial practice are limited. Therefore, the objective of this study was to investigate the effects of age on breast meat myopathies, carcass composition and meat quality of broilers.

Materials and methods

Animals and samples

A total of 181 Ross 308 male broilers were raised at Bangkok Animal Research Center Co., Ltd. (BARC), Thailand. They were fed ad libitum with a three-phase broiler industry feeding regimen, with corn-soy diets as the basal diet for each phase. The NRC-recommened corn-soy basal diet is shown in Table 1. Fifty-six chickens were randomly slaughtered at 43 days of age and the rest at 51 days of age. The birds were fasted for 12 hours before slaughter. After slaughter, deboned breast muscles were taken for visualisation and classification based on the scores WB and WS: 0 = normal, 1 = mild, 2 = moderate, and 3 = severe (Kuttapan *et al*., 2013). After classification by WB and WS, the right and left pectoral muscles were taken from each chicken to measure meat quality and texture profile.

Meat quality evaluation

The pH of the left pectoral muscle was determined at 3 and 24 hours postmortem using a portable pH meter (Model SG2- ELK Seven GoTM, Mettler Toledo International Inc., China). A Chroma Meter was used to quantify the color of skinless samples using the CIE L* (lightness), a* (redness), b* (yellowness), c (chroma), and h (hue angle) systems (MiniScan®EZ 45/0 LAV, Hunter Associates Laboratory Inc., Virginia, USA). To assess drip loss, 50 g of left breast muscle was placed in a plastic bag and hung on a hanger for 48 hours at 4 ℃. After hanging, the sample was carefully dried with paper and weighed again to calculate the percentage of drip loss relative to the initial weight. For determination of cooking loss, the right breast muscle was weighed and placed in a plastic bag, cooked in a water bath (Memmert, Germany) using a portable thermometer to measure meat temperature until an internal temperature of 70 ℃ was reached (approximately 25 minutes), then cooled to room temperature, carefully wiped with paper, and reweighed. Cooking loss was calculated as a percentage of cooked weight relative to raw weight. Six cooked muscle slices of 1x2x1 cm width x length x thickness was cut parallel to the fiber orientation through the thickest part of the cooked muscle. A Texture Analyzer Machine was used to determine the shear force (kg-force) of the cooked breast specimens (Model EZSX, Shimadzu, Japan). A 50-kg load cell was connected to an instrument, and tests were performed at a cross head speed of 50 mm/min. Tapezium software suite was used to process the signals.

Table 1. Composition (%) of the experimental diets

Item	Starter (0-10 day)	Grower (10-24 day)	Finisher (24-50 day)
Ingredeint (%)			
Corn	51.460	56.630	61.660
Soybean meal, 48 %CP	39.460	34.050	28.670
Soybean oil	4.070	4.660	5.280
Mono-Di-Ca-P	1.770	1.600	1.430
Limestone (CaCO3)	1.330	1.200	1.120
Salt (NaCl)	0.350	0.350	0.350
DL-Methionine	0.340	0.310	0.290
Premix Blank	0.200	0.200	0.200
L-Lys-HCl	0.170	0.170	0.180
Sodium bicarbonate	0.100	0.100	0.110
L-threonine	0.110	0.090	0.090
Choline Cloride 60%	0.100	0.090	0.100
Pellet binder (Pelex Dry)	0.300	0.300	0.300
Cocidiostat (sacox)	0.050	0.050	0.050
Antimold (Propimpex)	0.200	0.200	0.200
Nutrient and energy level (% calculated)			
Protein	23.42	21.22	19.04
Crude fiber	3.53	3.32	3.11
Fat	6.76	7.44	8.15
ME (kcal/kg)	3000.00	3100.00	3200.00
Calcium	0.96	0.87	0.79
Total Phosphorus	0.77	0.71	0.65
Available Phosphorus	0.48	0.44	0.40
Lysine	1.41	1.26	1.13
Methionine+cyctein	1.04	0.95	0.87
Threonine	0.99	0.89	0.80
Tryptophane	0.28	0.25	0.22

Texture profile analysis

Raw and cooked muscles were cut into three 1.5x1.5x1.5 cm wide x long x thick slices parallel to the fiber orientation. A Texture Analyzer Machine (Model EZSX, Shimadzu, Japan) was used to evaluate the texture profiles of the raw and cooked breast samples. The samples were placed under a cylindrical probe with a diameter of 36 mm. The probe descended at a constant rate of 127 mm/min. The probe returned to the original point of contact with the sample after penetrating a predefined proportion (50 percent) of the sample thickness. Before starting the second compression cycle, the probe was stopped for a specified time (1 s). The force of the sample was measured every 0.01 s during the test and recorded in a force-time diagram. Tapezium software was used to process the signals.

Analysis of chemical composition

Meat chemical composition was determined from the right breats muscle according to the AOAC (2000) methods. The dry matter content was estimated by drying in a 100 ℃ oven, and the ash content was determined by burning in a 550 ℃ furnace. The extraction with petroleum ether in a Soxtec 416 apparatus (Model Gerhardt analytical system, Königswinter, Germany) was used to determine the fat content. The crude protein content was determined using a Speed digester (Model K-439, Buchi. Thailand) and Distillation Unit apparatus (Model B-324, Buchi. Thailand).

Statistical analysis

The independent chi-square test was used to determine the distributions of frequency (n) and percent severity of WB or WS at 43 or 51 days of age. The assumed significance level was $P < 0.05$.

Analysis of variance (ANOVA) was performed and comparison of means between age groups was done using a two-tailed independent t-test for carcass and meat quality parameters at 95% confidence level. Statistical analysis was performed using SPSS statistical software version 26 (SPSS Inc, Chicago, IL, USA).

Results

The results of frequency and probability distribution for each WB and WS scores of broiler chickens at 43 and 51 days of age are shown in Table 2.

The results show that there is no significant relationship between the proportion of individual WB or WS scores of broiler chickens aged 43 and 51 days (p=0.885 and p=0.437, respectively). The proportion of individual WB or WS values was probably the same at 43 and 51 days of age. However, the incidence of severe WS at score 2 and 3 was slightly increased by 3.2 and 5.4%, respectively, at 51 days of age compared to 43 days of age, while the incidence of normal pectorals decreased. Age seems to influence WS more than WB.

Table 2. Frequency and percentage of breast muscles with different severities of wooden breast (WB) and white stripping (WS) in 43 and 51 day-old broilers

Age		**WB**				**Chi-square**	**WS**				**Chi-square**
		0	1	2	3		0	1	2	3	
43	N1	21	15	4	16		17	25	13	1	
	(%)	37.5	26.8	7.1	28.6	0.649	30.4	44.6	23.2	1.8	2.721
51	N	52	34	10	29	(p= 0.885)	36	47	33	9	(p=0.437)
	(%)	41.6	27.2	8.0	23.2		28.8	37.6	26.4	7.2	

[1] N = number of chickens

The live and carcass weight of chickens of different ages are shown in Table 3. The weight of broilers at different ages differed significantly ($p < 0.01$), but not the carcass percentage. Chickens slaughtered at 51 days of age had higher live and carcass weights than chickens slaughtered at 43 days of age. There were differences in carcass composition weight of breast, thigh, drumstick and wing between groups ($p < 0.05$). However, only the percentage of thigh was higher in 51-day-old broilers than in 43-day-old broilers ($p < 0.05$).

Table 3. Carcass composition traits of 43 and 51 day-old broilers

Traits	**Age** 43 days	**Age** 51 days	**p-value**
Live weight (g)	3124.55±241.70b	3563.56±619.40a	0.000
Carcass weight (g)	2580.68±172.57b	2935.00±510.50a	0.000
Carcass (%)	82.68±1.93	82.38±1.69	0.291
Carcass composition			
Breast (g)	778.26±88.29b	886.69±184.47a	0.000
Thigh (g)	467.52±44.06b	555.36±102.33a	0.000
Drumstick (g)	336.22±31.51b	383.33±68.27a	0.000
Wing (g)	256.86±18.17b	290.47±42.19a	0.000
Breast (%)	30.06±2.05	30.06±2.27	0.991
Thigh (%)	18.31±0.90b	18.94±1.70a	0.000
Drumstick (%)	13.05±0.62	13.09±1.12	0.783
Wing (%)	9.89±0.51	9.98±0.84	0.373

[a, b] Different letters in the same row within main effect differed (P<0.05)

The physicochemical properties measured in broilers of different ages are shown in Table 4. The pH_3, pH_{24} and a* values were statistically significantly different between the ages of 43 and 51 days ($p < 0.05$). Breast meat at 43 days of age had higher pH_3 and pH_{24} but lower a* values than meat at 51 days of age. While L*, b*, chroma and hue did not show statistically significant differences ($p > 0.05$), shear force value and percentage of drip loss and cooking loss were also not significant.

Table 4. Physicochemical property traits of breast muscle of 43- and 51-day-old broilers

Traits	**Age**		**p-value**
	43 days	51 days	
pH3	6.32±0.10a	6.17±0.15b	0.000
pH24	6.16±0.11a	5.98±0.10b	0.000
L* (Lightness)	52.97±4.44	53.59±4.29	0.376
a* (Redness)	1.30±0.71b	1.64±1.01a	0.015
b* (Yellowness)	12.29±3.01	12.62±2.93	0.483
c* (Chroma)	12.39±3.07	12.86±3.20	0.365
h (Hue angle)	84.99±4.25	83.53±5.83	0.063
Drip loss (%)	1.63±0.67	1.73±0.85	0.428
Cooking loss (%)	14.50±4.11	15.83±5.51	0.140
Shear force (kg)	4.26±1.09	4.50±1.28	0.264

[a, b] Different letters in the same row within main effect differed (P<0.05)

Table 5. Texture profile traits of raw and cooked breast meat from 43 and 51 day-old broilers

Traits	**Age**		**p-value**
	43 days	51 days	
Raw breast			
Hardness (N/cm2)	31.47±19.34b	45.95±29.39a	0.005
Springiness (cm)	1.00±0.00	1.00±0.01	0.278
Gumminess (N/cm2)	13.45±8.39b	18.53±12.58a	0.018
Chewiness (N/cm2)	13.44±8.39b	18.36±12.19a	0.019
Cohesiveness	0.42±0.08	0.38±0.15	0.057
Cooked breast			
Hardness (N/cm2)	43.75±13.39	39.35±14.38	0.105
Springiness (cm)	1.00±0.00	1.00±0.00	0.259
Gumminess (N/cm2)	20.79±6.82	21.41±7.38	0.647
Chewiness (N/cm2)	20.79±6.82	21.41±7.38	0.647
Cohesiveness	0.46±0.07b	0.55±0.09a	0.000

[a, b] Different letters in the same row within main effect differed (P<0.05)

Table 5 shows the characteristics of the texture profile of raw and cooked breast meat of broilers at different ages. The different ages of broilers significantly affected the hardness, gumminess and chewiness ($p < 0.05$) of the raw meat, but not the cooked meat, except for cohesiveness. The breast muscle at 51 days of age had higher hardness, gumminess and chewiness than that at 43 days of age. The cooked breast meat of older chickens had higher cohesiveness than that of younger chickens.

The results of the chemical composition of meat from broilers of different ages are presented in Table 6. There were no significant differences ($p < 0.05$) in chemical composition between the meat of broilers aged 43 and 51 days. However, it was found that fat content tended to be higher at 51 days of age ($p = 0.093$).

Table 6. Chemical composition traits of breast meat of 43 and 51 day-old broilers

Traits	**Age**		**p-value**
	43 days	51 days	
Ash (%)	1.08±0.11	1.13±0.10	0.183
Moisture (%)	76.34±1.73	75.67±2.01	0.238
Protein (%)	20.98±2.00	21.81±1.67	0.140
Fat (%)	1.88±0.83	2.36±1.01	0.093

[a, b] Different letters in the same row within main effect differed (P<0.05)

Discussion

There were no significant differences ($p > 0.05$) in the occurrence of WB and WS in broiler chickens at 43 and 51 days of age in this study. However, the occurrence of moderate and severe WS scores slightly increased at 51 days of age compared to 43 days of age, while the occurrence of normal breast muscle slightly decreased, which is in agreement with Radaelli *et al.* (2017) and Malila *et al.* (2018) who reported that the frequency of chickens with WB and WS increased with age. According to Radaelli *et al.* (2017), the frequency of chickens with muscle fibre degeneration (MFD) increased with age (18.8%, 28.1%, 75.1%, 96.9%, and 96.9% at 14, 21, 28, 35, and 46 days, respectively). Malila *et al.* (2018) observed that 179 breasts of broilers age 42 and 49 days and live weight ≥ 2.5 kg exhibited WS deficiency in varying degrees of severity with 102 (55.7%), 71 (39.0%) and 6 (3.3%) classified as mild, moderate and severe respectively with WB present in 6.6% of the total samples. Broiler chickens with higher proportion of breast mass to body weight were more prone to have WS and WB abnormalities (Malila *et al.*, 2018). Sihvo *et al.* (2017) studied the occurrence of WB and discovered that the first cases of WB occurred at 18 days of age and that the WB lesion had more severe diffuse features in the older age groups, which was related to a mild macroscopic lesion that formed in the caudal part of the breast at 35 to 42 days of age.

In this study, age difference affected live, carcass, and cut weight of broilers, which is consistent with Young *et al.* (2001), and Coban *et al.* (2014), who reported that live, carcass, and cut weight increased when broilers were older. In addition, Young *et al.* (2001) found that the yield of cuts, except legs and wings, increased with the age of broilers.

In this study, postmortem pH_3 and pH_{24} values were found to be lower at 51 days than at 43 days, which is in agreement with Glamoclija *et al.* (2015) who reported that lower pH values were found in older chickens. The muscle of broiler chickens at 51 days of age accumulated metabolites due to inadequate muscular vascularization. These were lactic acid, which remained in the muscle and resulted in lower pH of the meat (Malila *et al.*, 2018).

In this study, it was found that a* increased when the age of broilers increased. This is in contradiction with the findings of Coban *et al.* (2014) who demonstrated that the a* value of chicken breast meat decreased in carcasses killed after 56 days. Kurnoth *et al.* (1994) discovered that as muscle size increased, capillary density decreased, similar to Papinaho *et al.* (1996) who found a correlation coefficient of 0.275 between a* value and capillary density. It is hypothesized that as chickens age increases, a* values decrease due to decreased color intensity caused by increasing muscle width, which corresponds with decreasing capillary density. There were no significant differences in drip loss, cooking loss, shear force, and chemical composition of breast meat due to age differences in this study. These results do not agree with those of Baéza *et al.* (2012) who reported that drip loss, cooking loss and moisture content of breast meat decreased with age, while protein and lipid content increased. Baéza *et al.* (2012) said there is a positive relationship between meat pH and age, and variations in muscle pH affect various fresh meat characteristics such as drip loss, which decreases with age. The effects of age on the chemical composition of meat were unclear, but white cured-cooked meat had less water and more proteins and lipids as slaughter age increased (Baéza *et al.*, 2012). Analysis of the texture profile of raw breast meat was influenced by age, as this study found that hardness increased and gumminess and chewiness decreased in older broilers. A possible explanation for this could be that maturation of connective tissue is a process of chemical cross-linking of collagen in muscle, which increases with age, resulting in tough meat in older chickens (Mir *et al.*, 2017). In the current study, there was no significant effect of age on the texture profile of the cooked meat. This is in agreement with Lyon *et al*. (1984) who studied the texture profile of cooked breast meat of broilers aged 7 to 11 weeks. They found no significant difference in hardness and chewiness of broilers less than 10 weeks of age, which were significantly lower compared to 11 weeks. They also found that springiness increased with age but cohesiveness decreased.

In conclusion, from the results of this study the occurrence of WB and WS were not significant affected by age of 43 and 51 days. However, age seemed to affect WS more than WB. Age increasing affected live and carcass weight, cutting part weight, but cutting part percentages were not affected, except thigh yield. Meat quality such as postmortem pH, some color attributes especially the redness of chicken breast meat were significant differences between age at 43 and 51 days, as well as texture profiles especially raw breast meat.

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