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Influence of slaughter age on the occurrence and quality characteristics of white striping and wooden muscle abnormalities

Abstract

The aim of this study was to assess the occurrence of white striping (WS), wooden (WB), and white striping combined with wooden (WS/WB) muscle abnormalities in broilers (Ross 500) at different slaughter ages (34, 41, and 48 days). In addition, the influence of these muscle abnormalities at different slaughter ages on quality characteristics (physical dimensions, pH, color index, and chemical composition) was studied. Overall occurrence of muscle abnormalities was 45%, 92%, and 100% at slaughter ages of 34, 41, and 48 days, respectively. It was found that about 39% from the occurrence of muscle abnormalities was not similar in the same bird (left and right fillets). Breast fillets affected by muscle abnormalities had significantly ($p<0.05$) higher weight than normal fillets. At slaughter age of 34 days, normal fillets had significantly higher L*-values (67.37 vs. 61.73 and 63.05, $p<0.05$), lower a*- values (3.25 vs. 4.87 and 5.18, $p<0.05$) and b*-values (4.02 vs. 5.20 and 5.99, $p<0.05$) than white striping and white striping combined with wooden fillets; respectively. The changes in chemical composition due to muscle abnormalities were more significant at high slaughter age than at low slaughter age. In conclusion, the occurrence of muscle abnormalities was strongly influenced by slaughter age. Moreover, breast fillets affected by muscle abnormalities had different quality characteristics (proximate composition, color traits, and dimensions) in comparison to normal fillets.

Keywords: White striping, wooden, occurrence, quality, slaughtering age.

Introduction

Optimization of housing conditions and genetic selection have resulted in dramatic improvements in broiler growth rates in recent decades. This success has been effective in increasing of poultry meat production and meeting the growing demand for poultry meat (Petracci et al., 2019). On the other hand, genetic selection to improve growth rate has been associated with occurrence of several muscle abnormalities (Dransfield and Sosnicki, 1999; Mahon, 1999). Deep pectoral muscle disease, PSE-like meat (pale, soft, and exudative-like condition), white striping (WS), wooden breast (WB), and spaghetti meat (SM) are good examples of these muscle abnormalities (Bianchi et al., 2006; Petracci et al., 2019).

White striping and wooden breasts are considered the newest muscle abnormalities threatening the poultry industry because of their effect on meat quality. White striping was first studied by Bauermeister et al. (2009) and Kuttappan et al. (2009) and identified by the appearance of white striation on the surface of chicken fillets parallel to the fiber directions. Wooden breast abnormality was described by the appearance of hardened and pale areas in the caudal part of the pectoral muscles in combination with polyphasic myodegeneration with fibrosis (Sihvo et al., 2014).

Previous studies generally agreed that white striping and wooden breast muscle abnormalities have negative effects on meat quality, such as a reduction in water holding capacity, color changes, a reduction in sensory perception, changes in chemical composition, and changes in texture characteristics (Kuttappan et al., 2009; Sihvo et al., 2014; Mudalal et al., 2014, 2015; Tasoniero et al., 2016; Kato et al., 2019).

The incidence of white striping varied depending on different farming factors such as genotype, gender, growth rate, feed composition, and slaughter age. Petracci et al. (2013) found that high-breast yield hybrids exhibited higher incidence of white striping than standard-breast yield hybrids. Birds fed with high energy diet had higher incidence of white striping than birds fed with standard diet while male broilers had higher incidence of white striping than females (Kuttappan et al., 2013b). Several studies evaluated the incidence of white striping and wooden breast abnormalities under different farming conditions. In this context, Petracci et al. (2013) found that the incidence of white striping in some slaughterhouses in Italy was 12%. Alnahhas et al. (2016) showed that the average incidence of white striping was about 50% in examined birds' population. Ahsan and Cengiz (2020) revealed that the incidence of white striping was lowered by reducing the level of lysine in the grower feed. It was found that low level of lysine in the feed lowered the feed intake as well as the growth rate of the birds, therefore, the severity and incidence of white striping reduced.

Several researchers investigated the possibility of using different tools and instruments to distinguish between normal and abnormal meat. It was found that visible/near infrared spectroscopy was able to differentiate between normal and white striped meat (Zaid et al., 2020). Kato et al. (2019) found that there was possibility to classify muscle abnormalities based on a computer vision system (CVS), exploring different machine learning (ML) algorithms and the most important image features. Hyperspectral imaging in visible and near-infrared range (400-1000 nm) was a good tool to differentiate between normal and white striped meat (Jiang et al., 2019).

Even white striping and wooden breasts were investigated by several researchers. Further studies are needed to evaluate the effect and complications of these muscle abnormalities on the quality traits of meat under different farming conditions. There is limited knowledge about the effect of slaughter age on the incidence and the quality traits of white striping and wooden muscle abnormalities at different slaughter ages as well as for different commercial chicken breeds. This study aims to evaluate the occurrence and the effect of white striping and wooden breast muscle abnormalities on quality characteristics of chicken breast fillets at different slaughter ages.

Materials and Methods

A total of approximately 600 one-day old male chicks (Ross 500) were purchased from a local hatchery. The chicks were reared under continuous lighting throughout period. The internal temperature of the farm was gradually lowered from 32 ℃ on day 1 to 7 ℃ to 24 ℃ on day 21 and then kept constant.

The chemical composition of the feed is shown in Table 1. In the first three weeks, chicks were fed with the starter diets and for the remaining time (48 days), they were fed with the grower diet.

At 34 days of age, 200 broilers were slaughtered and the same number of birds were slaughtered at 41 and 48 days of age. After approximately 6 hours of slaughter, chicken fillets were classified into several levels of muscle abnormalities based on criteria previously described by Kuttappan et al. (2012) and Sihvo et al. (2014). The total number of fillets that exposed to muscle abnormalities assessment at each slaughtering time was 400 fillets (200 birds * 2 fillets/bird). Fillets were classified into four levels of muscle abnormalities (Normal (N), white striping (WS), wooden (WB) and white striping/wooden (WS/WB)). Fillets were classified as normal when there were no any white striations or hardened areas over the surface. Fillets that showed white striations (thin to thick striations) on the surface, were classified as white striped fillet (WS). When fillets had pale ridge-like bulges and diffuse hardened areas, they were classified as wooden (WB) breasts. Fillets were classified as white striping combined with wooden when they had pale ridge-like bulges and diffuse hardened areas, combined with white striations in different thickness. For each pair of breast fillets in the same bird, they were classified as similar when both fillets are normal or abnormal (either both WS or WB or WS/WB) and when both fillets are N/WS or WS/WB or WS/WS+WB, they were classified as different.

At each slaughter age, 36 fillets were selected and divided into 3 groups: normal (n=12), white striping (n=12), and white striping combined with wooden breast (n=12) to evaluate the quality characteristics (pH, physical dimensions (length, width, and height at three points), color index (L*a*b*), and chemical composition (moisture, protein, fat, ash, and collagen)). Meat pH was measured using a calibrated handheld pH/temperature meter (ISFET, model # IQ150, IQ Scientific Instruments, San Diego, USA) according to the method described by Jeacocke (1977).

The longest dimension of the fillet was measured and recorded as Length (L). The longest distance from side to side in the middle of fillet was measured and recorded the width (W). The first height (H3) was measured as vertical distance far from the end of caudal part by 1 cm toward dorsal direction. At the half distance of the breast length (L), the second height (H2) was measured. At the highest point in the cranial part, the third height (H1) was measured.

Color characteristics (L*, a*, b*) were measured using the Minolta Chroma Meter (CR-410, Osaka, Japan). Color values were recorded according to the Commission International de l'Eclairage (CIE) system. The system consists of three dimensions: one for luminance (L*-lightness) and two for color (a*-green to red; b*-blue to yellow). The color values for each meat type were measured at three different locations (at the top of cranial part, middle, and peripheral of caudal part), and the mean value was considered. Any abnormal area (containing blood splash, or connective tissues, or visible fat tissues) was excluded during measuring the color values.

Twelve samples were selected to determine proximate composition (moisture, protein, ash and lipid contents) for each meat type according to official methods of AOAC (AOAC, 1999). The moisture content was determined based on weight differences due to losses during air oven drying. The Kjeldahl method was used to determine total crude protein content. In addition, fat content was determined using the solvent extraction method. For ash content, dry ashing technique by employing muffle furnace has been used. Collagen content was determined by measuring hydroxyl proline content using a colorimetric method (Kolar, 1990).

Statistical analysis

The results of the study were analyzed using the ANOVA (GLM procedure SPSS Statistical Analysis Software, 2002). It was used to evaluate the influence of slaughter age on the occurrence and the quality properties of white striping and wooden breast muscle abnormalities. Duncan test was used to separate the means of the dependent variables in case of statistical differences ($P < 0.05$).

Results and Discussions

The incidence of muscle abnormalities (normal, white striping, and wooden) at different slaughter ages of 34, 41, and 48 days is shown in Table 2. At slaughter age of 34 day, it was found that 55% of fillets were normal while 29% were white striping. Moreover, about 14% of chicken fillets were affected by white striping combined with wooden breast. A small proportion (about 2%) of chicken fillets had wooden breast abnormality. In general, the incidence of muscle abnormalities at this age was relatively high, but to some extent, it was in consistent with previous studies. In this context, Lorenzi et al. (2014) found that the incidence of white striping in medium- sized birds (1.5-2 kg) was 24.3% in females and 33.9% in males. Mudalal et al. (2021) found that the incidence of white striping in broilers fed standard feed was 38.5% while it was 28-30% in broiler fed herb extract enriched feed at slaughter age of 34 days.

At slaughter age of 41 days, the percentage of normal fillets at this age was 8%, which is considered relatively low compared with previous studies. The percentage of normal fillets decreased by 47% (55% from 8%) when the slaughter age was increased to 41 days. The proportion of fillet with white striping in combination with wooden breast was 66% while the proportion of wooden breast fillet was 4%. In addition, 22% of fillets were affected by white striping abnormality. Lorenzi et al. (2014) found that broiler flocks slaughtered at 41-50 days of age had average of 43% white striping. Malila et al. (2018) found that broilers slaughtered at 42 days (>2.5kg) of age had 3% normal fillets, 89% white striped fillets, and 7% wooden breast combined with white striping fillets.

At slaughter age of 48 days, there were no normal cases of chicken fillets. Chicken fillets had 26% white striping and 74% white striping combined with wooden breast. Similar results were obtained by Trocino et al. (2015). At slaughter 46 days of age, it was found that overall incidence of white striping was about 75%. Lorenzi et al. (2014) revealed that the incidence of moderate and severe white striping in heavy flocks slaughtered at 3.0-4.2 kg live weight (50 to 58 days old) was 46.9% and 9.5%, respectively. In other studies, it was found that the incidence of white striping was in range 50.7-55.8% at slaughter 59-63 days of age (Kuttappan et al., 2009; Kuttappan et al., 2013a). Oral Toplu et al. (2021) showed that the incidence of normal, moderate, and severe white striping in broiler fed with standard diet and slaughtered at 49 days of age were 2.5, 40, 57.5%, respectively. At slaughter 49 day of age (weight >2.5 kg), Malila et al. (2018) showed that there were no normal fillets. In the same study, the incidence of white striping (mild, moderate, and severe) was 92% while white striping combined with wooden breast reached to 8%. About 5 to 10% of produced chicken fillets by industry had wooden breast abnormality (Gee, 2016). In the United States, it was found that 98% of chicken breasts obtained from 9-weeks-old birds were found to be affected by white striping (Kuttappan et al., 2017).

The incidence of muscle abnormalities in both fillets (left and right) of the same bird at different slaughter ages (34, 41, 48 days) is shown in Table. 3. This part of the results was used to understand whether the two fillets of the same bird have the same pattern of occurrence of muscle abnormalities or not. It was observed that at the same slaughter age, not all fillets (left and right) of the same bird showed the same type of muscle abnormalities. The study showed that the percentage of fillets (left and right) that had similar abnormalities increased with age. At 34 days of age, about 39.2% of fillets had different muscle abnormalities between left and right. About 13.5% of the left and right fillets of the same bird exhibited normal and white striping combined with wooden breast. At 48 days of age, it was clear that the differences in muscle abnormalities in the same pairs of fillets was related to white striping and white striping combined with wooden breast.

The weights, physical dimensions (Length-L, width-W and height at three points, T1, T2, and T3), color traits (L*a*b*), and pH of chicken fillets affected by different muscle abnormalities at slaughter 34 days of age are shown in Table 4. The incidence of muscle abnormalities had no effect on T3 and T2. Normal fillets had significantly lower T1 (5.99 vs. 8.56 and 8.43, $p<0.05$) compared to white striping and white striping combined with wooden breast fillets, respectively. There were no significant differences in T1 between white striping and white striping combined with wooden breast fillets. Fillets affected by white striping combined with wooden breast showed significantly higher width than normal and white striped fillets. White striped fillets had significantly higher length when compared normal fillets and fillets affected by white striping combined with wooden breast. Normal fillets had significantly higher L*-values (67.37 vs. 61.73 and 63.05, $p<0.05$) and lower a*- values (3.25 vs. 4.87 and 5.18, $p<0.05$) and b*- values (4.02 vs. 5.20 and 5.99, $p<0.05$) than white striping and white striping combined with wooden breast fillets; respectively. Moreover, the weight of fillets affected by muscle abnormalities were higher than normal fillets. Normal fillets had significantly lower pH-values than fillets affected by white striping or both abnormalities. Fillets affected by white striping had significantly lower pH than fillets affected by both muscle abnormalities.

The physical and chemical characteristics of the chicken breast affected by different muscle abnormalities at slaughter 41 days of age are shown in Table 5. In contrast to age 34 days, there were no significant differences between muscle abnormalities in height at T1. Normal fillets had significantly lower T3 values (23.28 vs. 26.41 and 26.75, $p<0.05$) and T2 values (17.17 vs. 21.25 and 22.22; $p<0.05$) than white striping and white striping combined with wooden breast fillets; respectively. The incidence of muscle abnormalities at both levels did not affect the width of the fillets. Fillets affected by both abnormalities had significantly higher length (74.97 vs. 71.88, $p<0.05$) than normal fillets while white striped fillets exhibited moderate values. In contrast to the results obtained at age 34, the incidence of muscle abnormalities did not show any effect on color characteristics (L*a*b*). Similar to the results obtained at age 34, normal fillet had a lower pH-value than fillets affected by white striping or fillets affected by both muscle abnormalities. Fillets affected by white striping or by both abnormalities had significantly higher fillet weights than normal fillets.

The quality characteristics of normal and abnormal chicken breasts obtained at slaughter age of 48 days are shown in Table 6. Normal fillets had significantly lower T3-values (24.78 vs. 28.87, $p<0.05$) and T1-values (7.97 vs. 11.88; $p<0.05$) than white striping combined with wooden breast fillets; respectively. There were no significant differences in T2, width, and length between groups.

Normal fillets had significantly lower L*-values than fillets affected by both abnormalities while white striping exhibited moderate values. Muscle abnormalities did not show any effect on a*-values and b*-values. Normal fillets exhibited lower pH-values than fillet affected by muscle abnormalities. Moreover, normal fillets had lower weight when compared to white striped fillets or fillets affected by both abnormalities

The high ultimate pH of abnormal fillets in comparison to normal fillets may be attributed due to the strong negative correlation between glycogen storage and breast muscle weight (Le Bihan-Duval et al., 2008). Abnormal and high weighed fillets may exhibit low glycolytic potential resulting in a higher pH than normal fillets (Soglia et al., 2016a). Mudalal (2019) found that white striped turkey breast had a higher pH than normal turkey breast.

Mudalal et al. (2014, 2015) showed that there were no differences in the length of normal and white striped fillets while Baldi et al. (2018) found differences. There were no significant differences in the length of fillets between normal and wooden breast fillets or white striping combined with wooden breast (Mudalal et al., 2015; Zambonelli et al., 2016). Several studies revealed that the width of normal fillets was not significantly different from the width of white striping and wooden breast fillets (Mudalal et al., 2014, 2015; Baldi et al., 2018). On the other hand, fillets affected by both striping and wooden breast abnormalities had a greater width than normal fillets (Zambonelli et al., 2016).

The proximate composition (moisture, proteins, fat, ash, and collagen) of normal, white striped, and white striped combined with wooden breast chicken fillets at different slaughter ages is shown in Table 7. In general, there were significant differences in proximate compositions due to the incidence of muscle abnormalities. Overall, the results showed that chicken fillets affected by muscle abnormalities had higher fat content and lower protein content than normal fillets. At slaughter ages of 34 and 48 days, there were no significant differences in ash and collagen content between normal and abnormal fillets. Chicken fillets affected by both muscle abnormalities (white striping and wooden breast) had higher moisture content compared to normal and white striped fillets. There were no significant differences in protein, ash and collagen content between normal and abnormal fillets at slaughtering age 34 days. Moreover, white striped meat had higher fat content (1.99 vs. 1.75 and 1.65%, $p<0.05$) when compared to normal and meat affected by both abnormalities. Our results suggest that the effect of muscle abnormalities on the proximate composition became more evident with increasing slaughter age.

Several researchers investigated the effect of white striping and wooden breast muscle abnormalities (either separately or combined) on proximate chemical composition (moisture, protein, fat, collagen, and ash), mineral profile, fatty acids profile, and protein functionality. Zambonelli et al. (2016) found that meat affected by white striping and wooden breast had higher moisture, fat, and collagen contents as well as lower contents of proteins and ash if compared to normal meat. In another study, there were significant differences in the proximate composition between normal and white striped meat (Petracci et al., 2015). Chicken fillet affected by severe white striping exhibited significantly higher fat content and lower protein content than normal chicken fillets (Mudalal et al., 2020). Soglia et al. (2016b) showed that the presence of both muscle abnormalities (white striping and wooden breast) had greater effect on the chemical composition than the presence of single muscle abnormality. This result was consistent with our results in particular at slaughtering age 41 days. Our study showed that meat affected by both muscle abnormalities (wooden and white striping breast) had significantly lower protein content (22.73 vs. 22.93%, $p<0.05$) and higher fat content (2.25 vs. 1.95, $p<0.05$) in comparison to meat affected only by white striping. In general, the studies agreed on the effect of muscle abnormalities on protein and fat content.

Several authors showed that there were no significant differences in moisture content between normal and white striped fillets (Kuttappan et al., 2012b; Petracci et al., 2014; Soglia et al., 2016a, b; Baldi et al., 2018; Soglia et al., 2018b). In contrast, several studies showed that wooden breast fillets had significantly higher moisture content than normal (Soglia et al., 2016a, b; Wold et al., 2017; Cai et al., 2018). Most of studies agreed that white striped meat had lower protein content than normal meat (Kuttappan et al., 2012b; Mudalal et al., 2014; Petracci et al., 2014; Soglia et al., 2016b; Baldi et al., 2018). On the contrary, Soglia et al (2018b) revealed that there were no significant differences in protein content between white striped and normal fillets. Wooden breast fillets and white striping combined with wooden breast fillets had significantly lower protein contents than normal fillets (Soglia et al., 2016a, b; Wold et al., 2017; Cai et al., 2018). For the effect of muscle abnormalities (white striping and wooden breasts) on lipid content, most of studies were generally in agreement. Meat affected by severe cases of white striping or wooden or white striping combined with wooden breasts exhibited higher fat content than normal meat (Kuttappan et al., 2012b; Soglia et al., 2016a, b; Wold et al., 2017; Cai et al., 2018; Baldi et al., 2018; Soglia et al., 2018b). Some researchers indicated that in moderate cases of white striping and wooden breast muscle abnormalities, there were no significant differences in fat content in comparison to normal (Kuttappan et al., 2012b; Wold et al., 2017; Soglia et al., 2018b). In respect to ash content, Kuttappan et al. (2012b) and Baldi et al. (2018) did not find any significant effect for white striping while Soglia et al. (2018b) found that white striped meat had lower ash content than normal.

In conclusion, the incidence of white striping and wooden breast muscle abnormalities was highly affected by slaughtering age. The muscle abnormalities did not occur in the same pattern at left and right fillets of the same bird. The effect of muscle abnormalities on quality characteristics was stronger at high slaughter age. Accordingly, it is important to differentiate between slaughter age for fillets dedicated for fresh retail use and for fillets dedicated for processing in order to mitigate the implications of muscle abnormalities on consumer perception.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Table 1. Composition of the basal diets fed to broilers in feeding trial, g/kg

Ingredient	Starter	Grower
Yellow corn	560	620
Soybean meal	360	306
Oil	40	40
DCP1	15	12
Limestone	15	15
NaCl	3.5	3.5
Premix	5	5
DL-methionine	1	1
L- lysine	0.5	0.5
Calculate analysis		
Crude protein	220	200
Lysine	110	110
Methionine	55	56
Calcium	100	110
Available P	46	47
ME, MJ/ kg ration	704	718

[1]Dicalcium phosphate. [2] Vitamin premix/kg diet: vitamin A, 12,000 IU; vitamin D3,1500 IU; vitamin E, 50 mg; vitamin K3, 5 mg; vitamin B1, 3 mg; vitamin B2, 6 mg; vitamin B6, 5 mg; vitamin B12, 0.03 mg; niacin, 25 mg; Ca-D-pantothenate, 12 mg; folic acid, 1 mg; D-biotin, 0.05 mg; apo-carotenoic acid ester, 2.5 mg; choline chloride, 400 mg.

Table 2. The incidence of muscle abnormalities (Normal, white striping, and wooden) in chicken fillets at different slaughter ages of 34, 41, and 48 days

	Normal		White striping		WS/WB		WB	
Slaughtering age	**Incidence%**	**n**	**Incidence%**	**n**	**Incidence%**	**n**	**Incidence%**	**n**
34 Days (N=400)	55	219	29	114	14	58	2	8
41 Days (N=400)	8	31	22	87	66	264	5	18
48 Days (N=400)	0	0	26	104	74	296	0	0

N: normal, WS: white striping, WB: wooden

Table 3. The incidence of muscle abnormalities in each individual pairs of breast fillets in the same bird at different slaughtering ages (34, 41, 48 days).

Age	Similar[1]	Different[2]	Distribution of muscle abnormalities in breast pairs with different abnormalities between left and right breast					
			WS/WS+WB	WB/WS+WB	N/WB	N/WS	WS/WB	N/WS+WB
34	60.81	39.19	6.08	2.03	2.03	15.54	0.00	13.51
41	63.56	36.44	21.19	5.93	0.85	3.39	0.85	4.24
48	68.71	31.29	29.93	1.36	0.00	0.00	0.00	0.00

[1] This result represents the percentage of breast fillet pairs (left and right) that had the same muscle abnormalities

[2] This result represents the percentage of breast fillet pairs (left and right) that had the different muscle abnormalities

N: normal, WS: white striping, WB: wooden

Table 4. Weights, physical dimensions (Length-L, Width-W and Height at three locations, T1, T2, and T3), color traits (L*a*b*), pH of chicken breast fillets affected by different muscle abnormalities at slaughtering age 34 days.

Muscle abnormalities	Normal	WS	WS/WB	P
T3 (mm)[1]	21.02±3.07	24.18±6.51	22.38±1.49	0.136
T2 (mm)[2]	13.74±3.81	15.74±6.72	16.50±2.21	0.253
T1 (mm)[3]	5.99±1.17^{b}	8.56±4.55^{a}	8.43±2.25^{a}	<0.05
Width (mm)[4]	67.17±5.17^{b}	66.78±6.22^{b}	73.83±7.42^{a}	<0.05
Length (mm)[5]	141.53±10.54^{b}	154.40±14.62^{a}	144.20±13.87^{b}	<0.05
L*	67.37±4.09^{a}	61.73±3.32^{b}	63.05±2.91^{b}	<0.05
a*	3.25±1.18^{b}	4.87±1.77^{a}	5.18±2.34^{a}	<0.05
b*	4.02±1.97^{b}	5.20±2.28^{a}	5.99±1.13^{a}	<0.05
pH	5.67±0.09^{c}	5.74±0.08^{b}	5.84±0.09^{a}	<0.05
Weight (g)	106.16±22.85^{b}	123.48±27.90^{a}	135.47±21.04^{a}	<0.05

[1] T3: is the height at the highest point of cranial part.

[2]T2: is the height at the mid of breast length

[3]T1: is the height measured from 1 cm far a way of the end of caudal part.

[4]Width: is the distance of widest area in the middle of breast

[5]Length: represents the longest distance of the breast.

Table 5. Weights, physical dimensions (Length-L, Width-W and Height at three locations, T1, T2, and T3), color traits (L*a*b*), pH of chicken breast affected by different muscle abnormalities at slaughtering age 41 days.

Muscle abnormalities	Normal	WS	WS/WB	P
T3 (mm)[1]	23.28±2.23^{b}	26.41±6.51^{a}	26.75±3.47^{a}	<0.05
T2 (mm)[2]	17.17±3.81^{b}	21.25±4.83^{a}	22.22±3.40^{a}	<0.05
T1 (mm)[3]	10.52±3.90	11.59±4.65	12.64±3.42	0.337
Width (mm)[4]	71.88±7.81	75.64±6.	74.97±5.52	0.09
Length (mm)[5]	141.16±11.00^{b}	147.60±10.14^{ab}	152.53±14.23^{a}	<0.05
L*	64.71±2.13	65.51±2.29	65.45±2.57	0.40
a*	1.88±1.01	2.33±1.44	2.75±2.36	0.20
b*	5.76±1.44	6.03±1.61	6.08±1.75	0.76
pH	5.73±0.09^{b}	5.83±0.11^{a}	5.88±0.12^{a}	<0.05
Weight (g)	132.49±26.25^{b}	168.90±40.90^{a}	156.26±22.68^{a}	<0.05

[1] T3: is the height at the highest point of cranial part.

[2]T2: is the height at the mid of breast length

[3]T1: is the height measured from 1 cm far a way of the end of caudal part.

[4]Width: is the distance of widest area in the middle of breast

[5]Length: represents the longest distance of the breast.

Table 6. Weights, physical dimensions (Length-L, Width-W and Height at three locations, T1, T2, and T3), color traits (L*a*b*), pH of chicken breast affected by different muscle abnormalities at slaughtering age 48 days.

Muscle abnormalities	Normal	WS	WS/WB	P
T3 (mm)[1]	24.78±1.47^{b}	27.14±5.14^{ab}	28.87±3.83^{a}	<0.05
T2 (mm)[2]	20.31±2.43	20.53±5.76	23.24±3.60	0.10
T1 (mm)[3]	7.97±2.88^{b}	9.02±2.77^{b}	11.88±3.94^{a}	<0.05
Width (mm)[4]	78.56±5.65	83.89±9.20	82.83±6.42	0.10
Length (mm)[5]	161.26±12.74	166.40±10.55	167.86±16.91	0.37
L*	62.79±3.73^{b}	64.64±3.98^{ab}	65.57±3.47^{a}	<0.05
a*	1.51±1.19	2.18±1.28	1.94±1.18	0.43
b*	5.67±1.44^{b}	6.48±1.63^{ab}	6.69±1.90^{a}	0.76
pH	5.73±1.07^{b}	5.80±0.09^{a}	5.86±0.12^{a}	<0.05
Weight (g)	176.57±23.78^{b}	215.870±38.56^{a}	220.28±41.55^{a}	<0.05

[1] T3: is the height at the highest point of cranial part.

[2]T2: is the height at the mid of breast length

[3]T1: is the height measured from 1 cm far a way of the end of caudal part.

[4]Width: is the distance of widest area in the middle of breast

[5]Length: represents the longest distance of the breast.

Table 7. Proximate composition (Moisture, proteins, fat, ash, and collagen) of normal, white striped, and white striped combined with wooden chicken fillets at different slaughtering ages (34, 41, and 48 days).

Muscle abnormalities	Normal	WS	WS/WB	P
	Slaughtering age 34 d	Slaughtering age 34 d	Slaughtering age 34 d	
Moisture	73.46±0.19^{b}	73.47±0.16^{b}	74.31±0.42^{a}	<0.05
Proteins	24.20±0.14	24.23±0.22	24.02±0.37	0.21
Fat	1.76±0.17^{b}	1.99±0.10^{a}	1.65±0.14^{b}	<0.05
Ash	1.44±0.03	1.45±0.07	1.43±0.5	0.58
Collagen	0.82±0.16	0.78±0.16	0.66±0.13	0.11
	Slaughtering age 41 d	Slaughtering age 41 d	Slaughtering age 41 d	
Moisture	74.46±0.23	74.47±0.18	74.27±0.21	0.09
Proteins	23.83±0.2^{a}	22.93±0.14^{b}	22.73±0.17^{c}	<0.05
Fat	1.40±0.12^{c}	1.95±0.30^{b}	2.25±0.19^{a}	<0.05
Ash	1.31±0.04^{b}	1.36±0.06^{ab}	1.39±0.07^{a}	<0.05
Collagen	0.55±0.10	0.72±0.20	0.64±0.22	0.17
	Slaughtering age 48 d	Slaughtering age 48 d	Slaughtering age 48 d	
Moisture	73.62±0.19^{c}	74.11±0.19^{a}	73.83±0.29^{b}	<0.05
Proteins	24.07±0.8^{a}	22.92±0.05^{c}	23.29±0.11^{b}	<0.05
Fat	1.55±0.08^{b}	2.10±0.18^{a}	2.02±0.15^{a}	<0.05
Ash	1.42±0.04	1.44±0.07	1.41±0.07	0.52
Collagen	0.84±0.22	0.87±.08	0.87±0.22	0.89