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Original Article

Correlations Between Muscle Fibers Characteristics and Meat Quality Attributes of Biceps Femoris Muscle: a Comparative Study of 2 Distinctive Broiler Breeds

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ABSTRACT

The current study was conducted to develop the correlations between muscle fiber characteristics and meat quality attributes in the *biceps femoris* muscle of Arbor Acres (AA) and Yellow-feathered chicken (YFC). A total of fourty pure breed birds of AA (n=20) and YFC (n=20) were used in the experiment. After slaughtering at their respective market age of slaughtering: AA 40 d and YFC 120 d, samples were collected for meat quality attributes and myosin ATPase staining for fiber types analyses. Meat quality attributes and muscle fiber characteristics i-e; diameter, cross-sectional area (CSA) and density of AA were significantly different from the YFC (p<0.05). Type I fibers number percentage was significantly higher in YFC than AA, whereas CSA and fiber diameter were higher in AA (p<0.05). Negative correlations were obtained between lightness (L*) and type I fiber number percentage in AA (p<0.05). In YFC fiber number percentage, CSA and diameter of type IIA were negatively correlated with Warner-Bratzler Shear Force. Taken together, muscle fibers characteristics of AA and YFC differ in both breeds and have influenced the meat quality attributes.

INTRODUCTION

In China the demands for poultry meat are mainly satisfied by the consumption of Arbor Acres (AA) and Yellow-feathered chicken (YFC). YFC is a famous native Chinese breed of chicken raised for meat and egg purposes (Wang *et al.*, 2017). The meat of YFC has its distinctive color, flavor and texture, therefore, it is more liked among the consumers than AA (Wang *et al.*, 2017; Fan *et al.*, 2018;). AA is a commercial broiler breed which has its relative abundance in population heads and meat production in China (Zhao *et al.*, 2011).

In each breed of birds muscle fiber number established before hatching, their diameter and size is dependent on the environment and genetic pre-disposition (Tumova & Teimouri, 2009). Chicken *biceps femoris* muscle is composed of type I, type IIA and type IIB fibers (Papinaho *et al.*, 1996). The proportions of these fiber types are highly dependent on the breed differences based on location and function of specific muscle in the body (Hwang *et al.*, 2010). Meat quality mainly relies on the muscle's fiber number, cross-sectional area (CSA) and fiber types. In chicken *biceps femoris* muscle has significant contribution for meat production and quality cut (Wattanachant *et al.*, 2004). Previous literatures have explored the Thai indigenous chicken *biceps femoris* muscle characteristics and found significant differences among the breeds as well as individual's muscles (Wattanachant *et al.*, 2004; Wattanachant *et al.*, 2005). However, the characteristics of *biceps femoris* muscle of YFC and their comparison with AA have not been explored yet.

Existing literature have also compared the breed differences with respect to muscle fiber characteristics and their relationship with meat quality in pork (Ryu *et al.*, 2008), sheep (Şirin *et al.*, 2017) and chicken (Zhao *et al.*, 2011), and found significant results. But there is little literature found in the *biceps femoris* meat quality attributes and their correlations with the muscle fibers characteristics in AA and YFC. Furthermore, comparison of these two breeds provides quality insights to the consumers and meat industry. Hence, the current study was aimed to compare and establish the correlations between *biceps femoris* muscle fiber types and meat quality attributes of AA and YFC.

MATERIAL AND METHODS

Samples

For the current experiment female AA (n=20) and YFC (n=20) were supplied by Taikun Company Limited, China. Birds from both breeds were reared separately and entered the experiments at the same time. Feed and water were supplied *ad libitum.* The birds were fed in accordance with their nutritional requirements (NRC, 1994). Environmentally controlled housing were provided to the birds with multiple floor (up to 8) pens. Twenty birds with similar weight of each breed were selected for the collection of *biceps femoris* muscle. Birds were slaughtered at their respective market age: AA 40 d and YFC 120 d. The feed was withdrawn 12 h before slaughtering. Electrical stunning was given in water bath with 240mA and 120V to birds before slaughtering. Slaughtering was performed by neck cutting. Then exsanguinations, plucking and evisceration were carried out. Post eviscerations 2 h of chilling of carcasses was ensured at 2 °C. The *biceps femoris* muscle was excised from the right thigh for histochemical analyses, whereas left side muscle were used for meat quality analyses. The same anatomical position was used to collect all samples. All experiments were performed in the Institute of foodscience and technology, Chinese Academy of Agricultural Science, Beijing, China. The study was approved by animal welfare and the ethics committee (approval no. IFSTCAAS-AE20161001).

Histochemical Analyses

Following postmortem muscle blocks oriented in the direction of muscle fibers (0.5 × 0.5 × 1.0 cm) were excised from the *biceps femoris* muscle of AA and YFC. The samples were chilled in isopentane cooled by liquid nitrogen (-176 °C) and then stored at -80 °C for further analysis. Thin slices of 10 µm were produced by microtome (HM525, MicromGmbHGermany) after equilibration for 2 h at -25 °C. Thin slices were mounted on glass slides and air dried at 25 °C. Then staining was performed by the method developed by Brooke & Kaiser (1970) and Sen *et al.* (2016). Histological sections demonstrated the ATPase activity following pre-incubation in pH 4.6. Fiber differentiation were performed in accordance to Brooke & Kaiser (1970). Photomicrographs were acquired and analyzed by Image J software (Abràmoff *et al.*, 2004). The measurements were computed as: fiber numbers of each type (type I, IIA and IIB), fiber density (number of fibers/computed field) and cross-sectional area (CSA) of different fiber types in μm^2. One hundred fibers, as representative of the whole sample from each slide field were computed. Three representative field areas were selected from every slide. Each field area measured $280 \times 10^3 \mu m^2$.

Meat Quality attributes Analyses

The pH_{24h} of *biceps femoris* muscle was measured by preparing muscle slurries with 5 g meat and 45 mL of distilled water using a pH meter (Shanghai Scientific Instrument Co., Ltd., Shanghai, China). The color of muscle samples was measured with a portable colorimeter (Minolta Osaka, Japan). Following parameters for CIELAB were set: illuminance was D65 with 0° viewing angle and aperture size was 8 mm for color determination. Calibration of instrument was done by ceramic tile provided by the company before measurements. Each value was a sum of triplicate measurements taken from different sites of muscle. Fresh samples were allowed to bloom for 30 min at room temperature in the open air. Cooking loss was measured by cooking the samples at 100 °C for 30 min with internal temperature of 70 °C. Afterwards, cooking samples were allowed to cool for 40 min to calculate the cooking loss percentage. This was calculated by finding the difference of raw and cooked samples relative to the raw sample weight by following Eq. (1):

Cooking loss (%) = {(raw sample weight – cooked sample weight) / raw sample weight} *100 (1)

The drip loss of *biceps femoris* muscle was determined by the method of Honikel (1998) with slight modifications. Drip loss percentage was calculated by the difference in weight between raw and hanged relative to raw sample weight as following Eq. (2):

Drip loss (%) = (Wi-Wf) / Wi * 100 (2)

Where Wi and Wf represent the initial and final weight of samples before and after storage, respectively.

Warner-Bratzler Shear Force (WBSF) was measured by the protocol developed by Lindahl *et al.* (2010) with minor modifications. Approximately 1.3cm thick raw chicken samples were prepared from both breeds and cooked in the individual cooking bags at 80 °C with internal temperature of 72 °C. Afterwards, the cooking samples were allowed to cool until room temperature was achieved. The testing parameters were adjusted as follows: 5 mm/sec as pre-test speed, 10mm/sec penetration speed and probe lowered 25 mm from the resistance point. The results were denoted as kg/cm^2.

Low-field nuclear magneticresonance (LF-NMR) measurements were carried out by the NMRAnalyzer (NiumagCo., Ltd.,Shanghai, China) to analyze the water distribution. Two g of muscle piece was excised from the *biceps femoris* and placed into the MNR probe. A τ-value of 150 μs and data from 3000 echoes were taken. All measurements were carried out at 32 °C. Data were analyzed by MultiExp Inv Analysissoftware (NiumagCo., Ltd., Shanghai, China). Water populations in three states (bound, immobilized and free water) were calculated by Bertram & Andersen (2007). The values of bound water peak area (P_{21}), immobilized water peak area (P_{22}) and free water peak area (P_{23}) were used to denote the percentages of T_{21}, T_{22} and T_{23} respectively. Following mathematical Eq. (3) was used to acquire the relaxation curves.

$$A(t) = \sum_{i} A_{0i} \exp(-t/T_{2i}) \quad (3)$$

Where A (*t*) represents the ~~the~~ amplitude size when attenuation to t; A_{0i} is the amplitude size; t is decay time and T_{2i} is the relaxation time.

Scanning electron microscopy

The microstructure of *biceps femoris* muscle of AA and YFC were carried out using a SEM (scanning electronmicroscope). The detailed procedure was explained by Li *et al.* (2014). Briefly, the chicken samples (3×3×5 mm^3, excised with a scalpel) were fixed with 3% glutaraldehyde for 3h and later rinsed for 1h with distilled water prior to dehydration with graded ethanol. Finally, mounting of dried samples on a bronze stub and sputter-coated with gold (EikoIB-5, Hitachi Tokyo, Japan) was performed. Scanning electron microscope (Quanta 200FEG, FEI, Netherlands) at magnification of ×300 was used to observe the cross sections of muscle fibers.

Statistical Analysis

Meat quality attributes and muscle fiber characteristics of both breeds were analysed by independent sample t-test. The relationship among the meat quality traits and muscle fibers characteristics were obtained by the Pearson's correlation coefficient (r). All the data were analysed using SPSS version 19.0 with the significant difference of 0.05.

RESULTS

Representative micrographs of the histochemical results of *biceps femoris* muscle of AA and YFC are presented in the Fig. 1. Muscle fibers were distinctively divided into type I, type IIA and type IIB in compliance with method of Brooke & Kaiser (1970). Fiber type number percentage of both breeds is presented in the Fig. 2. AA had a lower number percentage of type I fiber (13.93 %) and higher proportion of type IIB (50.55%) than YFC. Interestingly, the proportion of type IIA fibers (35.23% vs 36.31%) was almost similar in both breeds of chicken. The mean values of fiber density, CSA and diameter are presented in the Table 1. The overall results have shown that fiber density was significantly lower in the AA than YFC, however,

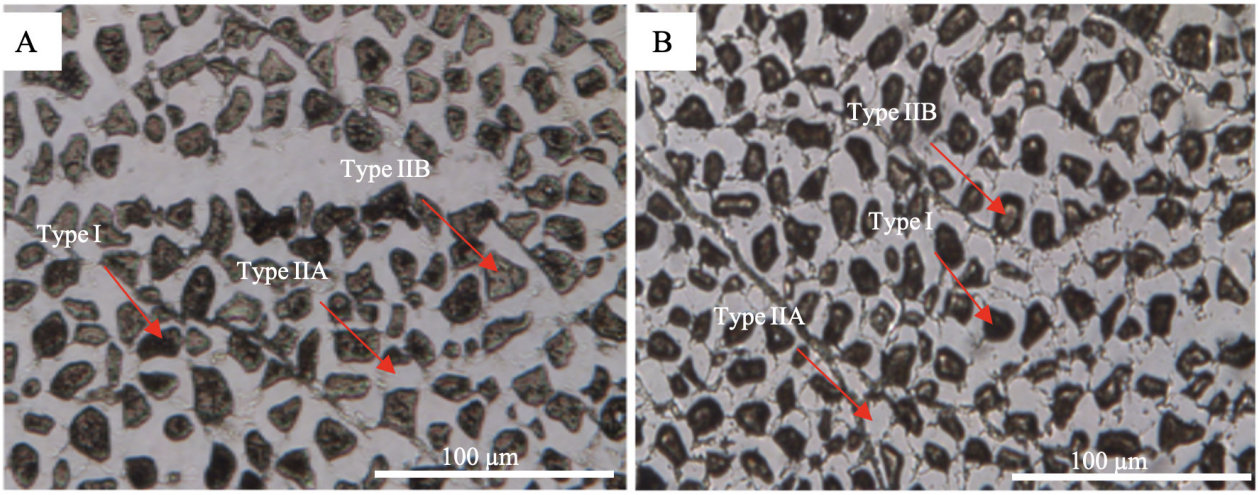

Figure 1 – Serial sections of *biceps femoris* muscle staining with myosine ATPase reactivity after pre-incubation at pH 4.2. Magnification of 100× was used (Bar=100 μm). A: Arbor Acres; B: YFC: Yellow-feathered chicken.

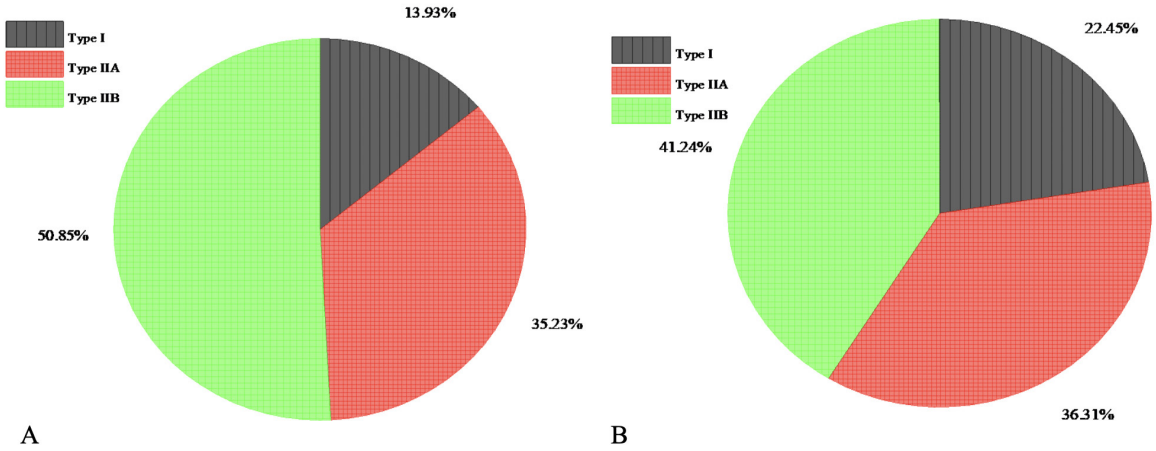

Figure 2 – Fiber number distribution of fiber types (I, IIA, IIB) in *Biceps femoris* of AA (A) and YFC (B). AA: Arbor Acres; YFC: Yellow-feathered chicken.

fiber CSA and diameter were higher in the AA (Table 1). Highly significant differences in fiber density were found between type I fiber of AA and YFC (p<0.05). Fiber CSA and diameter were significantly higher in AA than YFC (p<0.05).

Table 1 – Least squares means of fiber characteristics of *biceps femoris* muscle of AA and YFC.

Measurements	Chicken breeds		
	AA	YFC	*p* -Value
Fiber density			
Type I	23.10[b]	41.10[a]	< 0.001
Type IIA	58.60[b]	66.80[a]	0.007
Type IIB	86.55[a]	81.00[b]	0.042
Fiber CSA (μm²)			
Type I	2523.38[a]	2106.20[b]	0.003
Type IIA	2653.42[a]	2190.01[b]	< 0.001
Type IIB	3493.96[a]	2819.00[b]	< 0.001
Fiber diameter (μm)			
Type I	55.60[a]	50.08[b]	0.008
Type IIA	57.33[a]	49.62[b]	< 0.001
Type IIB	66.22[a]	59.53[b]	< 0.001

[a, b] Means with different letters (n=20×100) in the same row are significantly different at p< 0.05.

Fiber density= fibers numbers/given field; CSA= cross-sectional area (μm²). AA: Arbor Acres; YFC: yellow-feathered chicken.

Meat quality attributes of *biceps femoris* muscle of AA and YFC are presented in Table 2. The pH_{24h} was significantly higher in YFC than AA (p<0.05). Meat lightness (L*) values were significantly higher in AA than YFC (p<0.05), however, the redness(a*) and yellowness(b*) values were significantly higher in YFC. There were no significant differences found in the drip loss of both breeds (p>0.05). WBSF was significantly higher in YFC than AA (p<0.05). The cooking loss percentage was significantly higher in AA than YFC (p<0.05). There were significantly less immobilized water (P_{22}) and more free water populations (P_{23}) were found in AA than YFC (p<0.05).

Table 2 – Meat quality attributes of *Biceps femoris* muscles of AA and YFC.

Traits	AA	YFC	*p*-Value
pH_{24h}	5.60 ± 0.10[b]	6.10 ± 0.15[a]	0.001
Lightness (L*)	59.61 ± 5.00[a]	52.07 ± 4.04[b]	0.002
Redness (a*)	38.27 ± 6.13[b]	45.45 ± 2.50[a]	0.003
Yellowness (b*)	25.28 ± 4.00[b]	30.16 ± 1.77[a]	0.020
Drip loss (%)	2.40 ± 0.80[a]	2.37 ± 0.88[a]	0.438
WBSF[1](Kg/cm²)	2.99 ± 0.11[b]	4.51 ± 0.11[a]	0.001
Cooking loss (%)	38.12 ± 1.05[a]	24.00 ± 0.90[b]	0.001
p_{23} (%)	4.59 ± 2.08[a]	2.63 ± 0.60[b]	0.032
p_{22} (%)	95.06 ± 1.60[b]	97.37 ± 0.60[a]	0.063
p_{21} (%)	0.36 ± 0.62[a]	0.31 ± 0.62[a]	1.000

[a,b] Mean ± SD (n=6) with different superscripts in the same row are significantly different (p<0.05);[1]Warner Bratzler shear force; p_{21}: Bound water peak area; p_{22}: Immobilized water peak area; p_{23}: Free water peak area; AA: Arbor Acres; YFC: Yellow-feathered chicken.

The Pearson's correlation coefficients (r) and their probabilities between some of the meat quality attributes and muscles fiber number percentage in the *biceps femoris* muscle of both breeds are presented in Table 3. There were significant positive correlations (r=0.855) obtained between the muscle fiber number percentage of IIA and pH_{24h} (p<0.05) in AA. L* values and type I fiber number percentage was significantly negatively correlated (r=-854: p<0.05). Positive correlations (r=0.741) were found between type I fiber number percentage and a* values of AA. There were no significant correlations found in YFC except the negative correlations (r=-0.857) between muscle fibers type IIA and WBSF (p<0.05).

The relationship between CSA of fibers and meat quality attributes of the both breeds is presented in the Table 4. In AA cooking loss has significant negative and positive correlations (r=-0.731 and 0.731) with type IIA and IIB respectively. P_{22} has significant negative correlations (r = -0.553 and -0.868) with CSA of type I and type IIB (p<0.05). In YFC CSA of type IIA and pH_{24h} were significantly positively correlated (r= 0.796). The

Table 3 – Correlation coefficients (r) and their probabilities (*p*) within fibers number percentage and meat quality attributes of *biceps femoris* muscle of AA and YFC.

Measurements	AA fiber types			YFC fiber types		
	Type I	Type IIA	Type IIB	Type I	Type IIA	Type IIB
pH24h	0.055 (0.918)	0.855* (0.030)	-0.613 (0.196)	0.383 (0.453)	-0.047 (0.930)	-0.016 (0.976)
Lightness (L*)	-0.854* (0.031)	0.129 (0.807)	-0.593 (0.215)	0.481 (0.334)	0.357 (0.488)	-0.012 (0.982)
Redness (a*)	0.741* (0.042)	0.385 (0.451)	0.178 (0.736)	-0.117 (0.825)	-0.312 (0.548)	0.001 (0.999)
Yellowness (b*)	0.005 (0.992)	0.055 (0.917)	-0.041 (0.939)	-0.727 (0.101)	-0.095 (0.858)	0.473 (0.343)
WBSFa	0.207 (0.693)	0.607 (0.201)	-0.535 (0.274)	-0.729 (0.100)	-0.857* (0.029)	-0.001 (0.998)
Cooking loss (%)	-0.731 (0.099)	0.309 (0.551)	0.223 (0.671)	-0.004 (0.994)	-0.561 (0.246)	-0.649 (0.163)
Drip loss (%)	-0.269 (0.606)	-0.187 (0.723)	0.286 (0.582)	-0.325 (0.494)	-0.151 (0.776)	0.180 (0.732)
*p*23 (%)	0.514 (0.297)	-0.132 (0.802)	-0.214 (0.683)	-0.347 (0.501)	-0.539 (0.270)	-0.377 (0.461)
*p*22 (%)	-0.506 (0.306)	0.123 (0.816)	0.216 (0.681)	0.339 (0.511)	-0.004 (0.995)	0.379 (0.459)
*p*21 (%)	-0.594 (0.214)	-0.005 (0.993)	0.355 (0.490)	-0.030 (0.955)	-0.442 (0.380)	0.210 (0.690)

*$p<0.05$, [a]Warner-Bratzler shear force); p_{21}: Bound water peak area; p_{22}: Immobilized water peak area; p_{23}: Free water peak area; AA: Arbor Acres; YFC: Yellow-feathered chicken.

Table 4 – Correlation coefficients (r) and their probabilities (*p*) within fibers CSA and meat quality attributes of *biceps femoris* muscle of AA and YFC.

Measurements	AA fiber types			YFC fiber types		
	Type I	Type IIA	Type IIB	Type I	Type IIA	Type IIB
pH24h	0.003 (0.995)	0.551 (0.257)	-0.325 (0.530)	0.136 (0.797)	0.796* (0.048)	0.176 (0.739)
Lightness (L*)	0.199 (0.705)	0.727 (0.102)	0.243 (0.643)	0.333 (0.519)	0.670 (0.146)	0.064 (0.904)
Redness (a*)	-0.370 (0.470)	-0.408 (0.423)	-0.580 (0.227)	0.543 (0.265)	-0.307 (0.554)	-0.140 (0.792)
Yellowness (b*)	0.656 (0.159)	-0.111 (0.834)	-0.697 (0.124)	-0.724 (0.104)	0.084 (0.875)	0.484 (0.331)
WBSFa	-0.027 (0.960)	0.713 (0.112)	-0.285 (0.584)	-0.483 (0.332)	-0.774* (0.041)	0.345 (0.503)
Cooking loss (%)	-0.521 (0.289)	-0.731* (0.048)	0.731* (0.049)	-0.270 (0.604)	-0.468 (0.350)	0.385 (0.451)
Drip loss (%)	0.172 (0.745)	-0.137 (0.795)	0.171 (0.746)	0.106 (0.841)	-0.358 (0.486)	-0.380 (0.457)
*p*23 (%)	0.656 (0.157)	0.258 (0.621)	0.798* (0.048)	-0.577 (0.231)	-0.738* (0.044)	0.508 (0.303)
*p*22 (%)	-0.553* (0.045)	-0.255 (0.626)	-0.868* (0.025)	0.577 (0.231)	0.732 (0.098)	-0.506 (0.306)
*p*21 (%)	-0.124 (0.815)	-0.245 (0.639)	-0.205 (0.697)	0.128 (0.809)	0.491 (0.322)	0.101 (0.845)

*$p< 0.05$, [a]Warner-Bratzler shear force); CSA: cross-sectional area; p_{21}: Bound water peak area; p_{22}: Immobilized water peak area; p_{23}: Free water peak area; AA: Arbor Acres; YFC: Yellow-feathered chicken.

CSA of type IIA had significant negative correlations (r=-0.774 and -0.738) with WBSF and P_{23} ($p<0.05$), respectively.

Results of correlations between muscle fiber diameter and meat quality attributes are summarized in Table 5. In AA chicken, diameter of fiber type IIA, L* and P_{23} showed significant positive correlations ($p<0.05$). In YFC fiber diameter of type IIA and pH_{24h} demonstrated significant positive correlations (r=0.797) ($p<0.05$). Moreover, fiber diameters of type IIA and WBSF were significantly negatively correlated (r=-0.776).

The current study has highlighted the microstructures of the muscle fibres of *biceps femoris* of AA and YFC

Table 5 – Correlation coefficients (r) and their probabilities (*p*) within fiber diameter and meat quality attributes of *biceps femoris* muscle of AA and YFC.

Measurements	AA fiber types			YFC fiber types		
	Type I	Type IIA	Type IIB	Type I	Type IIA	Type IIB
pH24h	0.002 (0.997)	0.524 (0.284)	-0.325 (0.530)	0.125 (0.813)	0.797* (0.048)	0.169 (0.749)
Lightness (L*)	0.294 (0.572)	0.713* (0.011)	0.268 (0.607)	0.326 (0.528)	0.677 (0.140)	0.064 (0.904)
Redness (a*)	-0.399 (0.434)	-0.440 (0.383)	-0.582 (0.226)	0.538 (0.271)	-0.321 (0.535)	-0.165 (0.754)
Yellowness (b*)	0.675 (0.141)	-0.089 (0.867)	-0.706 (0.117)	-0.726 (0.101)	0.095 (0.857)	0.457 (0.362)
WBSFa	-0.027 (0.960)	0.706 (0.117)	-0.291 (0.576)	-0.480 (0.336)	-0.776* (0.040)	0.327 (0.527)
Cooking loss (%)	-0.532 (0.278)	-0.316 (0.541)	-0.732* (0.048)	-0.274 (0.600)	-0.479 (0.337)	0.389 (0.445)
Drip loss (%)	0.071 (0.894)	-0.086 (0.871)	0.134 (0.800)	0.107 (0.840)	-0.380 (0.458)	-0.394 (0.439)
P23 (%)	0.614 (0.195)	0.308 (0.553)	0.751* (0.046)	-0.571 (0.237)	-0.729 (0.101)	0.516 (0.295)
P22 (%)	-0.719 (0.107)	-0.308 (0.553)	-0.854 (0.031)	0.571 (0.237)	0.723 (0.105)	-0.514 (0.297)
P21 (%)	-0.126 (0.812)	-0.239 (0.648)	-0.208 (0.693)	0.117 (0.825)	0.485 (0.329)	0.077 (0.885)

*$p < 0.05$, [a](Warner-Bratzler shear force); p_{21}: Bound water peak area; p_{22}: Immobilized water peak area; p_{23}: Free water peak area; AA: Arbor Acres; YFC: Yellow-feathered chicken.

at 24 h of postmortem at 4 °C by SEM (Fig. 3). Muscle fibers in AA demonstrated loose structures with cracks, whereas YFC muscles are more dense and compacted shown by arrows. Muscle fibers in AA were more wide in comparison to YFC. Therefore, it is plausible that YFC muscles have more WBSF compared to AA.

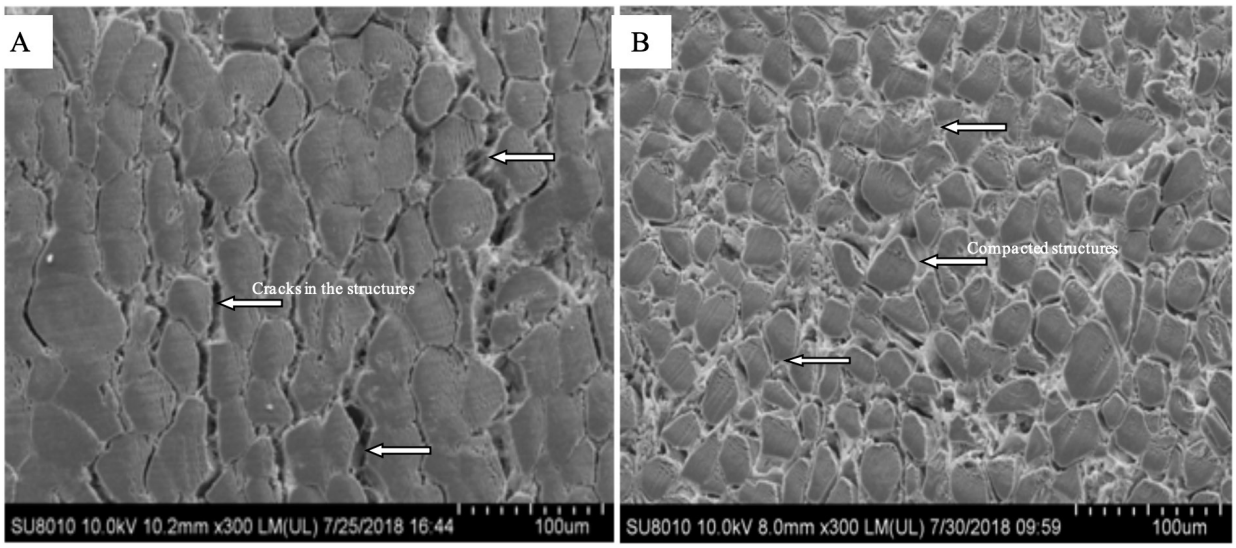

Figure 3 – SEM images of *biceps femoris* muscle 24 h of postmortem at 4 °C of AA (A) and YFC (B) at magnification ×300. AA: Arbor Acres; YFC: Yellow-feathered chicken.

DISCUSSION

The current study compared the muscle fibers characteristics and their correlations with some of the meat quality attributes of *biceps femoris* muscle of AA and YFC. Results have shown that muscle fiber characteristics and meat attributes of both breeds were significantly different. Muscle fibers characteristics (number, CSA and density) were highly variable in both breeds of chicken. However, little is known on the muscle fibers comparative characteristics of *biceps femoris* muscle of AA and YFC. Previous literatures have confirmed that chicken *biceps femoris* muscle is composed of type I, type IIA and type IIB fibers (Suzuki *et al.*, 1985; Papinaho *et al.*, 1996; Zikic *et al.*, 2016). Another study has termed these fibers in *biceps femoris* muscle of chicken as oxidative fibers (Type I), intermediate oxidative glycolytic fibers (Type IIA) and

glycolytic fiber (Type IIB) (Gošnak *et al.*, 2010). Our results have shown the similar trend with the existing studies which compared the meat quality attributes of commercial broilers and indigenous chicken breeds, and found the significant differences (Wattanachant *et al.*, 2004, 2005). YFC had higher number percentage of type I fibers than AA because of breed difference and higher slaughter age. This result is consistent with the previous study on chicken which suggested that breed differences have impact of fiber types distribution and size in chicken (Fu *et al.*, 2015; Gošnak *et al.*, 2010). Similar trend was observed in the Berkshire pigs which have more type I fibers than the Yorkshire and Landrace in the *longissimus dorsi* muscle (Ryu *et al.*, 2008). Fiber density of YFC was higher than AA because of lower CSA and diameter of fibers (Table 1), meanwhile, the CSA and diameter of AA fibers were significantly (p<0.05) higher than YFC. Hence, the muscle fiber number percentage was inversely related with the CSA and fiber diameter. As seen in Fig. 1 the muscle fibers of YFC are more compacted than AA because of breed difference which makes it distinctive in meat properties. Moreover, it is elsewhere reported that sex of chicken has no significant effect on the muscle fiber characteristics (Tejeda *et al.*, 2019). Meat quality attributes of both breeds were significantly different (p<0.05). AA has lower pH_{24h} which leads to lower water holding capacity (Lefaucheur, 2001). Therefore, AA has higher cooking and drip loss percentages (Table 2). YFC has higher values of a* and b* and lower L* than AA, this might be the presence of higher type I fibers giving more dark color. This is in agreement with the previous study which showed that AA has lower L* values as compared to YFC(Zhao *et al.*, 2012). Another study has also indicated that type I muscle fibers number percentage is inversely proportional to the meat color stability by producing dark color (Renerre, 1990). Type I fiber have higher amount of lipids and myoglobin contents (Essén-Gustavsson *et al.*, 1992). Cooking loss and drip was higher in AA than YFC because of the bigger fiber size of AA. Compactness of YFC muscles was more pronounced which resulted in higher values of WBSF. YFC retained more water, which was represented in the form of P_{21}, P_{22} and P_{23} than AA. This result is consistent with previously reported data (Şirin *et al.*, 2017) as the size of fiber type IIA and IIB increases the lightness and water holding capcity decreases. Our study suggested that AA has higher tendencies towards undesirable changes than YFC because of the breed difference (Joo *et al.*, 2013).

The present study demonstrated the positive correlation between fiber number percentage of type IIA fibers and pH_{24h}. A negative correlation was obtained between type I fiber number percentage and L* in AA. As type I fibers numbers are responsible for generating dark color in meat. In AA as the CSA of fiber type IIB increases the cooking loss will tend to increase and ultimately water content will be decreased (Table 4). Increase in the CSA of fiber type IIA will lead to production of more tougher meat. In AA as the diameter of type IIA increases the L* value will tend to increase because the type IIA fibers have white color. In YFC the diameter of type IIA fibers has an inverse relation with WBSF. A positive correlation between type IIA fibers and WBSF of muscle of YFC was obtained which is consistent with a previous study where the direct relationship has been established in type II fibers and meat tenderness (Totland *et al.*, 1988). On contrary to that diameter of the fibre type IIA has positive correlation because AA posses higher diameter as result of that WBSF decreases. The free water content (P_{23}) of meat increases as the diameter of fiber type IIB increases. Previous literature has shown the correlation between muscle fiber characteristics and meat quality attributes (Fu *et al.*, 2015; Mazzoni *et al.*, 2014; Ryu *et al.*, 2008). Moreover, post hatch production of hyperplasia and hypertrophy of muscle fibers of these breeds and their impact on meat quality needs further attention.

SEM results have unraveled that muscle fiber bundles of AA were wider and loose as compared to YFC. These results are consistent with the histological examined data. Expanded and loose structures of muscle fibers lead to decline in water holding capacity, which results in deterioration of muscle structures and exaggerated drip loss. The muscles of AA have more gaps and unstable structural integrity which might lead to more drip loss. This result is consistent with the drip loss and cooking loss data.

CONCLUSION

The results of the current study indicated that breed differences have pronounced effect on the skeletal muscle fiber characteristics and meat quality attributes of AA and YFC. Type I fibers were higher in YFC which have an impact on the color of meat. Muscle fiber density, CSA and number percentage have correlations with the meat quality attributes. Further study is needed to explore the fiber changing trends with respect to progression of age in chicks during different growth periods of AA and YFC.

CONFLICTS OF INTEREST

The authors declared no conflict of interest.

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REFERENCES

Abràmoff MD, Magalhães PJ, Ram SJ. Image processing with Image J. Biophotonics International 2004;11(7):36–42.

Bertram HC, Andersen HJ. NMR and the water-holding issue of pork. Journal of Animal Breeding and Genetics 2007;124:35–42.

Brooke MH, Kaiser KK. Muscle fiber types:how many and what kind? Archives of Neurology 1970;23(4):369–379.

Essén-Gustavsson B, Karlström K, Lundström K. Muscle fibre characteristics and metabolic response at slaughter in pigs of different halothane genotypes and their relation to meat quality. Meat Science 1992;31(1):1–11.

Fan M, Xiao Q, Xie J, Cheng J, Sun B, Du W, *et al.* Aroma compounds in chicken broths of beijing youji and commercial broilers. Journal of Agricultural and Food Chemistry 2018;66(39):10242–10251.

Fu D, Zhang D, Xu G, Li K, Wang Q, Zhang Z, *et al.* Effects of different rearing systems on meat production traits and meat fiber microstructure of Beijing-you chicken. Animal Science Journal 2015;86(7):729–735.

Gošnak RD, Eržen I, Holcman A, Škorjanc D. Effects of divergent selection for 8-week body weight on postnatal enzyme activity pattern of 3 fiber types in fast muscles of male broilers (Gallus gallus domesticus). Poultry Science 2010;89(12):2651–2659.

Honikel KO. Reference methods for the assessment of physical characteristics of meat. Meat Science 1998;49(4):447–457.

Hwang Y-H, Kim G-D, Jeong J-Y, Hur S-J, Joo S-T. The relationship between muscle fiber characteristics and meat quality traits of highly marbled Hanwoo (Korean native cattle) steers. Meat Science 2010;86(2):456–461.

Joo ST, Kim GD, Hwang YH, Ryu YC. Control of fresh meat quality through manipulation of muscle fiber characteristics. Meat Science 2013;95(4):828–836.

Lefaucheur L. Myofiber typing and pig meat production. Slovenian Veterinary Research 2001;38(1):5–28.

Li Y, Li X, Wang J, Zhang C, Sun H, Wang C, *et al.* Effects of oxidation on water distribution and physicochemical properties of porcine myofibrillar protein gel. Food Biophysics 2014;9(2):169–178.

Lindahl G, Lagerstedt Å, Ertbjerg P, Sampels S, Lundström K. Ageing of large cuts of beef loin in vacuum or high oxygen modified atmosphere–Effect on shear force, calpain activity, desmin degradation and protein oxidation. Meat Science 2010;85(1):160–166.

Mazzoni M, Petracci M, Meluzzi A, Cavani C, Clavenzani P, Sirri F. Relationship between pectoralis major muscle histology and quality traits of chicken meat. Poultry Science 2014;94(1):123–130.

NRC – National Research Council. Nutrient requirements of poultry. Washington: National Academies Press; 1994.

Papinaho PA, Ruusunen MH, Suuronen T, Fletcher DL. Relationship between muscle biochemical and meat quality properties of early deboned broiler breasts. Journal of Applied Poultry Research 1996;5(2):126–133.

Renerre M. Factors involved in the discoloration of beef meat. International Journal of Food Science & Technology 1990;25(6):613–630.

Ryu YC, Choi YM, Lee SH, Shin HG, Choe JH, Kim JM, *et al.* Comparing the histochemical characteristics and meat quality traits of different pig breeds. Meat Science 2008;80(2):363–369.

Şirin E, Aksoy Y, Uğurlu M, Çiçek Ü, Önenç A, Ulutaş Z, *et al.* The relationship between muscle fiber characteristics and some meat quality parameters in Turkish native sheep breeds. Small Ruminant Research 2017;150:46–51.

Suzuki A, Tsuchiya T, Ohwada S, Tamate H. Distribution of myofiber types in thigh muscles of chickens. Journal of Morphology 1985;185(2):145–154.

Tejeda OJ, Calderon AJ, Arana JA, Meloche KJ, Starkey JD. Broiler chicken myofiber morphometrics and myogenic stem cell population heterogeneity1,2. Poultry Science 2019;4123–4130.

Totland GK, Kryvi H, Slinde E. Composition of muscle fibre types and connective tissue in bovine M. semitendinosus and its relation to tenderness. Meat Science 1988;23(4):303–315.

Tumova E, Teimouri A. Chicken muscle fibres characteristics and meat quality:a review. Scientia Agriculturae Bohemica, 2009;4:253–258.

Wang H, Zhang X, Wang G, Jia K, Xu X, Cesare AD. Bacterial community and spoilage profiles shift in response to packaging in yellow-feather broiler , a highly popular meat in Asia. Frontiers in Microbiology 2017;8(12):1–12.

Wattanachant S, Benjakul S, Ledward DA. Composition, color, and texture of thai indigenous and broiler chicken muscles. Poultry Science 2004;83(1):123–128.

Wattanachant S, Benjakul S, Ledward DA. Microstructure and thermal characteristics of Thai indigenous and broiler chicken muscles. Poultry Science 2005;84(2):328–336.

Zhao GP, Cui HX, Liu RR, Zheng MQ, Chen JL, Wen J. Comparison of breast muscle meat quality in 2 broiler breeds. Poultry Science 2011;90(10):2355–2359.

Zhao JP, Zhao GP, Jiang RR, Zheng MQ, Chen JL, Liu RR, *et al.* Effects of diet-induced differences in growth rate on metabolic, histological, and meat-quality properties of 2 muscles in male chickens of 2 distinct broiler breeds. Poultry Science 2012;91(1):237–247.

Zikic D, Stojanovic S, Djukic-Stojcic M, Kanacki Z, Milosevic V, Uscebrka G. Morphological characteristics of breast and thigh muscles of slow- and medium growing strains of chickens. Biotechnology in Animal HusbandryBiotehnologija u Stocarstvu 2016;32(1):27–35.