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Kaiqi Weng
Yangzhou University
Weiran Huo
Yangzhou University
Tiantian Gu
Yangzhou University
Qiang Bao
Yangzhou University
Li-e Hou
Yangzhou University
Yu Zhang
Yangzhou University
Yang Zhang
Yangzhou University
Qi Xu
Yangzhou University
Guohong Chen (ghchen2019@yzu.edu.cn)
Yangzhou University https://orcid.org/0000-0003-3795-2585

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Effect of marketable ages on meat quality through fiber characteristics in goose

Kaiqi Weng[1], Weiran Huo[1], Tiantian Gu[1], Qiang bao[1], Li-e Hou[1], Yu Zhang[1], Yang Zhang[1], Qi Xu[1]*, Guohong Chen[1,2]*

1. Jiangsu Key Laboratory for Animal Genetic, Breeding and Molecular Design, Yangzhou University, Yangzhou, Jiangsu, China.
2. Joint International Research Laboratory of Agriculture and Agri-Product Safety, the Ministry of Education of China, Yangzhou University, Jiangsu Yangzhou, China.

*Correspondence authors.
Qi Xu, E-mail address: xuqi@yzu.edu.cn

Guohong Chen, E-mail address: ghchen2019@yzu.edu.cn

Abstract

Background: Goose meat is more and more popular among consumers because of its good quality. The fiber characteristics, as a key determinant factor, contributing to meat quality has been well demonstrated, and the marketable ages are also closely related to meat quality in livestock and chicken. However, little is known about the effect of different marketable ages on the meat quality through fiber characteristics in goose.

Results: Here, 1-day, 28-day and three market-age old (70, 90 & 120 days) Yangzhou geese were selected and their fiber characteristics were investigated. The results showed that only fast-twitch fibers were observed in the breast muscle irrespective of the ages, while little slow-twitch fibers could be identified in leg muscle in three marketable ages, especially in gastrocnemius and extensor digitorum longus. As for the fiber diameter, a rapid upward trend was observed in breast muscle from 70 days to 90 days, and the corresponding values were 19.88 to 26.27μm, respectively, and it remained stable 90d thereafter. While the diameter and cross-sectional area of muscle fiber in leg muscle increased with ages. In addition, the proximate composition and physical properties was measured at different ages. 120-day-old geese had richer intramuscular fat and protein content both in breast and leg meat, as well as lower moisture content among three marketable ages. The higher lightness and pressing loss and the lower redness and shear force was observed in the breast and leg meat of 70-day-old geese compared with the 90 and 120-day-old geese.

Conclusions: Taken together, although longer marketable age did not affect muscle fiber type in geese, it resulted in a thicker muscle fiber area, richer intramuscular fat and protein content, redder and chewier meat. As a result, the reasonable marketable age should be taken into account to improve the meat quality in the goose production.

Key words: Goose, Muscle fibers, Marketable ages, Meat quality

Background

Meat quality has become a major concern to consumers with the preferences for better quality and healthier meat products in the poultry market. Meat quality traits are complex and are influenced by many internal and external factors. Age, as a key external factor, has been confirmed that it was closely related to meat qualities in broiler and duck. The very early marketable age of chicken may relate to the meat with poor cohesiveness, color and water holding properties [1], while the meat of favorable color and tenderness (firm, but not tough) were observed in the older broilers [2]. Also, it believed that the chemical or metabolite composition of duck meat can differ with age and the flavor increases with aging time [3]. However, the effect of goose age at slaughter or market on meat quality remain unclear.

In the meat production, the muscle fiber, as an internal factor, plays a key role in meat quantity and quality. Skeletal muscle is the main component of meat, accounting for about 50% ~ 60% of animal carcasses. Morphology traits such as total number of fibers and cross-sectional area of fibers are major determinant factors of muscle mass [4]. Pushing muscle fibers to their maximum functional size constraints is the way of the selection for rapid growth and high breast and leg yield in broilers [5]. In addition, muscle fiber characteristics contribute to meat quality. The meat with different types of muscle fibers displays different meat color, tenderness and water holding capacity. Increasing the proportion of slow-twitch oxidative muscle fibers is known to increase the redness and Mb content of meat [6]. The composition of fast-twitch glycolytic fibers is related to higher lightness and lower water holding capacity in pork [7] and tougher meat in beef [8]. However, the muscle fiber characteristics of goose in different ages and the effect of muscle fibers on goose meat quality has not been well documented.

As two important factors affecting meat quality, age and muscle fiber have been attracted extensive attention in the production and breeding of livestock and poultry. In fact, there are some relationships between them. It has been documented that muscle fiber compositions of different muscle types depended on the age in mutton [9]. Also, L. Li et al reported that the older birds exhibited larger myofiber diameter and area, and lower myofiber density for the older birds than the younger birds [10]. Therefore, unveiling the age-related influences of muscle fiber characteristics can provide a feasible solution for improving the meat quality.

Goose is a herbivorous poultry, it owns a good adaption to different environment and has a high dietary meat quality [11, 12]. However, little is known about the internal and external determinant of meat quality in goose. In present study, the 1-day, 28-day and three market-age old (70, 90 & 120 days) Yangzhou geese were selected and their fiber characteristics were investigated. In addition, the proximate composition and physical properties were detected in goose of different market-age old. Also, the relationships between meat quality traits and muscle fiber characteristics were analyzed. These data could find out the effect of marketable ages on meat quality through fiber characteristics in goose, which might provide alternatives to further improve the meat quality in the goose production.

Methods

Experiments, animals handling and slaughtering

The experiment was conducted at the Tiange Goose Industry Co. Ltd (Yangzhou, China). All experimental procedures performed in this study were approved by the Institutional Animal Committee of Yangzhou University (Permit Number: YZUDWSY, Government of Jiangsu Province, China).The total 120 healthy Yangzhou goslings (Anser cygnoides)—28 day old with similar body weight were selected and assigned to three groups. Each group of geese was kept for 70 days, 90 days and 120 days respectively. During the experiment, the geese of each group were kept in separate pens (5 individuals per square meter) that included a playground and pool. The geese were exposed to natural lighting and temperature. The feed and water were given during the daytime when the geese were released to an open area outside the house. The geese were fed with the same commercial diets and the ingredient and chemical composition of diets were showed in Table 1. On day 1, 28, 70, 90 and 120 (Fig. 1A), the geese were carefully caught and transported within 1h to the laboratory. Before the transport, the geese were fasted for 12 h and had free access to water. The birds were weighed individually (Fig. 1B) and slaughtered by manual exsanguination after anesthetizing them with sodium pentobarbital.

Sample collection

After the slaughter, the carcasses were cooled in the chilling room (4 °C). Within 45 min postmortem, carcasses were split into the left and the right sides. The breast muscle and the leg muscle were taken. The gastrocnemius muscle, soleus muscle and extensor digitorum longus muscle from the thigh muscle of 6 carcasses were separated (Fig. 1C). Five pieces (0.5×0.5×1.0 cm) were taken from the breast muscle, gastrocnemius muscle, soleus muscle and extensor digitorum longus muscle of each carcass for histochemical analysis and molecular biology experiment. The samples for paraffin section were stored in 4% paraformaldehyde and the other samples were promptly frozen in liquid nitrogen and stored at −80 °C until subsequent analyses. After 24 h chilling, the breast muscle and the leg muscle from the 12 carcasses were taken to carry out meat quality experiments. The collection of all muscle samples and meat quality measurements were done at the right side of each carcass.

Physical properties and proximate composition of meat

The physical properties (pH, meat color, pressing loss and shear force) and the proximate composition (moisture, intramuscular fat, protein and collagen content) of meat were measured.

The pH value was recorded at 45 min and 24 h post-mortem using a pH meter (DELTA 320, Mettler Toledo). The pH meter was first calibrated at chilling temperature using pH 4.00 and pH 7.00 buffers. Then, the pH was measured in the breast muscle and the leg muscle (using the upper, middle and lower spots inserted 10 mm into the muscle). The three measurements within each carcass were averaged for statistical analyses.

For determination of the initial meat color, the Minolta colorimeter (Minolta CR400, Konica Minolta, Japan) was used. The meat color was measured at 6 randomly selected positions of the breast muscle and the leg muscle. The results were collected under the CIE-LAB system L* (lightness), a* (redness), and b* (yellowness).

The shear force analysis according to Tang et al. (2009) was conducted on a digital tenderness meter (C-LM3B, Tenovo, Beijing, China). Cores with a diameter of 1 cm were removed from the breast muscle and leg muscle at different positions parallel to fiber orientation. Each value was an average of 6 measurements.

The pressing loss analysis was carried out with a dilatometer (C-LM3B, Tenovo, Beijing, China). Samples (about 1g, W1) of the breast muscle and the leg muscle was weighed at 24 h post-mortem. Then put 16 layers of filter paper on the top and bottom of the sample. Add a hard plastic plate to the lowest and the top layer and put it on the platform of the dilatometer. Pressurize (68.66 kPa) the sample for 5min and weigh the meat sample (W2). The pressing loss was then calculated using the following equation.

Pressing water loss (%) = (W1-W2) / W1×100%

The proximate composition was subjected to a FoodScan™ Meat Analyzer (Foss, Denmark)[13]. The meat samples of the breast muscle and the leg muscle were removed from tendons and muscle membranes. Then cut into pieces, ground into meat mud by high-speed universal crusher and put into sample cups. The moisture, intramuscular fat, protein and collagen contents were analyzed by the FoodScan™ Meat Analyzer. Measurements were taken on the mixture of three individual geese in the same group and repeated three times.

H&E staining and immunohistochemistry

Each muscle sample was fixed in 4% paraformaldehyde for 24 h, paraffin-embedded, and a microtome (Leica, Germany) was used to prepare 5-μm-thick sections. After drying overnight at 40°C, the sections were stained with H&E using a Leica Autostainer XL (Leica, Germany).

For immunohistochemistry, the slides were immersed in xylene three times for 15 min each, anhydrous ethanol twice for 5 min each, 95% ethanol twice for 5 min each, and 80% ethanol twice for 5 min each, and then incubated in 3% methanol-H_2O_2 for 10 min. The slides were incubated with the primary antibody Anti-Fast (1:1200, ab51263, Abcam, Cambridge, UK) and antibody Anti-Slow(1:4000, ab11083, Abcam, Cambridge, UK). After overnight incubation at 4°C, the slides was washed in PBS three times for 5 min each, reacted with the secondary antibody (rabbit anti-mouse, ab6728, Abcam, Cambridge, UK) for 30 min, and then washed again with PBS three times for 5 min each, and finally stained with DAB for 10 s.

The samples were scanned by a NanoZommer scanner (Humamatsu, Sydney, Australia). The image analysis system (Image-Pro Plus, Media Cybernetics, Silver Springs, USA) was used for the calculation of fiber diameter, cross-sectional area, and fiber density.

RNA extraction and real-time quantitative PCR (RT-qRCR)

Total RNA was extracted from each muscle sample using a RNA kit (Tiangen, China) according to the manufacturer’s protocol. The first strand cDNA was synthesized from 1 μg RNA with RevertAid™ First Strand cDNA Synthesis Kit (MBI Fermentas, Tiangen). The synthesized cDNA then served as a template for real-time PCR using SYBR PCR Mix(Takara Biotechnology Co. Ltd., Japan) and data were collected in an ABI 7500 Real-Time PCR System (Applied Biosystems, Foster City, CA, USA). Real time PCR was performed at 98 °C for 30 sec, and 40 cycles of 98°C for 10 s and 60°C for 30 sec. β-actin was used as the reference gene to normalize the expression data and calculated with the $2^{-\Delta\Delta Ct}$ method [14]. The primers designed for real-time PCR were listed in Table 2.

Statistical analysis

The comparisons among different marketable ages and different muscular tissues were fulfilled using repeated measures in SPSS statistical software (SPSS, Ver. 18.0). All data were evaluated as mean ± standard error (SE) including Gene expression levels from RT-qPCR, fiber histological characteristics and meat quality traits. Duncan's multiple range test was used to analysis of the main effect. A level of $P \leq 0.05$ was set as the criterion for statistical significance.

Results

Comparison on myosin heavy chain-based fiber characteristics among goose of different ages

To investigate the fiber type composition in the goose muscle of different ages, relative protein expressions of fast myosin heavy-chain and slow myosin heavy-chain were detected by immunohistochemistry. As shown in Fig. 2, there were completely fast-twitch fibers and no slow-twitch fibers in breast muscle regardless of the tested ages. To understand the muscle fiber composition of the leg muscle in detail, the GAS, SOL &EDL of the leg muscle were dissected, we found that the GAS muscle had significantly higher distribution of slow-twitch fiber than that in SOL muscle (16.69% VS 4.74%) at birth, while the EDL muscle did fast-twitch fiber. At 28 day, a great transition from fast-twitch fiber to slow-twitch fiber was observed in the SOL muscle and the corresponding area percentage of slow-twitch fiber was 85.11%, while the GAS muscle showed the opposite trend, and turned to the pure fast-twitch fibers. With the arrival of the marketable ages (70, 90 & 120 days), little slow-twitch fibers could be observed in leg muscle (Fig. 2). In addition, the mRNA expression of MyHC isoform MYH7B (type I slow-twitch), MYH1A (type IIb fast-twitch) and MYH1B (type IIa fast-twitch) in goose of different ages were detected by qRT-PCR. The results were in agreement with the immunohistochemistry. There was little expression of MYH7B and no significant difference in all detected muscular tissues of marketable ages ($P > 0.05$) (Fig. 3C). In addition, 90 and 120-day-old geese exhibited higher expressions of MYH1A and MYH1B than those in the 70-day-old geese ($P < 0.05$) and the relative expression of MYH1B was lower in the breast muscle than that in the leg muscle (Fig. 3A, B). Together, these data indicate that the variations of muscle fiber types primarily occur at the early growth stage. With the arrival of marketable ages, there were little differences in fiber types and the muscular tissues mainly consist of fast-twitch fibers.

Comparison on muscle fiber morphology traits during the growth of goose

To compare the morphology traits of muscle fibers in geese, representative characteristics (fiber diameter, cross-sectional area and fiber density) of four muscular tissues (Fig. 4A) were investigated. Some significant main effects were observed for marketable ages and muscular tissues on the contents of fiber diameter and cross-sectional area (Fig. 4B and 4C, Table S1). The largest muscle fiber cross-sectional area was observed in the EDL muscle, while the breast muscle owned the smallest one (51.93 vs 24.23μm). From 70 days to 90 days, the fiber diameter in breast muscle showed a sharp rise from 19.88 to 26.27μm while it remained stable 90d thereafter. As to leg muscle (GAS, SOL, EDL), the diameter and cross-sectional area of muscle fiber increased with advancing ages ($P < 0.05$). In addition, there was a significant interaction between factors (marketable ages and muscular tissues) for the fiber density. As expected, it showed an opposite trend from the fiber diameter and the cross-sectional area results. Interestingly, the breast muscle had considerable amounts of intramuscular adipocytes between muscle fibers while it could not be found in the leg muscle in 28-day-old geese (Fig. 4A and 4S). Collectively, these findings clearly indicated that the fiber cross-sectional area increased with advancing ages in leg muscle while in breast muscle, it continued growing till 90d and remained stable thereafter.

Comparison on physical properties among goose meat of different marketable ages

Comparing the physical properties among goose meat of different marketable ages, certain meat quality traits, including pH_{45min}, pH_{24h}, the meat color, the pressing loss and the shear force were detected. Some significant main effects were observed for different breeds and muscular tissues on the contents of the shear force and pH_{45min} (Table 3). The leg meat is tougher than breast meat measured by shear force values (43.25 vs. 26.41, $P < 0.05$) in all three marketable ages. The breast meat showed higher pH_{45min} value than the leg meat in three marketable ages (6.05 vs. 5.90, $P < 0.05$) and the higher pH_{45min} value tended to be present in 90-day-old geese. Compared with pH_{45min}, pH measured at 24h postmortem declined. In 90-day-old geese and 120-day-old geese, pH_{24h} was lower in breast meat compared to the leg meat which revealed that there was a greater pH value decrease in breast meat than the leg meat during the meat maturation after slaughter. Besides, there was a significant interaction between factors (marketable ages and muscular tissues) for the meat color (L*, a*) and pressing loss. Significant higher lightness value was observed in 70-day-old goose breast meat compared with the 90 and 120-day-old goose breast meat. Also, the lowest redness value was observed in 70-day-old goose breast meat while there were no significant differences among other groups ($P > 0.05$). In terms of water holding capacity, the highest pressing loss was found in 70-day-old goose leg meat, while the lowest was observed in 120-day-old goose leg meat. Together, the higher lightness and pressing loss but the lower redness and shear force was observed in the breast and leg meat of 70-day-old geese compared with the 90 and 120-day-old geese.

Comparison on proximate composition among goose meat of different marketable ages

To compare the proximate composition among goose meat of different marketable ages, the content of moisture, protein, intramuscular fat and collagen was detected (Table 4). It was shown that all determined indexes were significantly different among the groups and there was a significant interaction between factors (marketable ages and muscular tissues). The moisture content of breast meat and leg meat of 120-day geese was significantly lower than that of 70-day geese ($P < 0.01$) and it decreased gradually with the increase of marketable ages. The protein content in breast meat of 120-day geese was higher than that in 70-day geese but lower than 90-day geese ($P < 0.05$). While in leg meat, the protein content was not significantly different in 70-day geese and 90-day geese. The intramuscular fat content showed an upward trend with the increase of the marketable age ($P<0.05$). Surprisingly, in 90-day and 120-day geese, the intramuscular fat content in breast meat was considerably higher than that in leg meat ($P<0.05$). The content of collagen fluctuated between 1.10~1.53 and it was consistently higher in breast meat than that in leg meat ($P < 0.05$). To sum up, compared with 70-day-old geese and 90-day-old geese, 120-day-old geese had richer intramuscular fat and protein content and lower moisture content.

Discussion

Goose meat is more and more popular among consumers for its good quality which can be characterized as high content of protein, lysine and unsaturated fatty acid as well as low fat [15]. Some researchers have confirmed the fiber characteristics are key determinant factor for meat quality and the marketable ages are also closely related to it.

Here, we investigated the muscle fiber characteristics of four muscular tissues in Yangzhou goose of different ages (1, 28, 70, 90 & 120 days). In general, the muscle fiber increased regularly with advancing age which was in agreement with the previous studies in birds and livestock [10, 16]. In breast muscle, it stopped growth from 90 day thereafter. Tilki et al. stated that the native Turkish geese at the age of 63 days have actually achieved only 70% to 80% of their adult weight and leg muscle reach their final proportion at the age of 70 days, whereas the intensive growth of breast continues until 16 wk of age [17]. These results had some differences with our present study mainly because of the different goose breeds.

Numerous studies have reported the relationships between fiber types and meat quality traits in livestock and chickens [8, 18, 19]. However, little research on fiber types in geese had been done. We investigated the expression of myosin heavy chain-related genes (MYH1A, MYH1B & MYH7B) and the myosin heavy chain-related proteins. Our results showed that the variations of muscle fiber types primarily occur at the early growth stage and little slow-twitch fibers existed in geese muscle fibers in all three marketable ages. Picard et al stated that the muscle is composed of oxidative (slow-twitch) fibers at birth and the proportion of oxidative fibers decreases while the proportion of glycolytic (fast-twitch) fibers increases during growth. The decrease in type I and IIA fibers and an increase in type IIB fibers are due to the increasing carcass weight [20] . We also found that the highest percentage of type I fiber was existed in the soleus muscle at 28 day, which accounted the major proportion (85.11%) and the breast muscle was pure type IIB fibers all the time. The results were consistent with the results obtained by several authors, who reported that the soleus muscle mainly composed of red slow-twitch myofibers in chickens [21, 22] and the chicken breast contained 100% type IIB muscle [23]. However, till the Yangzhou goose marketable ages, the slow-twitch myofibers could not be detected in both of the breast muscle and leg muscle. Therefore, we speculated that the muscle fiber morphology traits had greater impacts on meat quality traits compared to the fiber types.

Meat color is the most important meat appearance quality traits because it is the first factor seen by the consumer and is used as an indication of freshness and wholesomeness while tenderness is the most important eating quality traits because it strongly influences consumer's perceptions of acceptability [24]. In the present study, significant brighter (higher L* values) and lighter red (lower a* values) meat was observed in 70-d goose breast muscle compared with the 90 and 120-d goose breast muscle. Also, the 70-d goose leg muscles shower higher L* values than those in other ages. The similar experimental results were reported by Baéza et al. that breast meat of broilers slaughtered at 35 days of age was lighter than that of older broilers [25]. Moreover, Fletcher et al. reported that poultry breast meat tended to become darker and redder as bird’s age increased [26]. Purslow et al. highlighted the key mechanisms contributing to variations in the lightness of meat. A 20% increase in lightness (L* value) between muscles with ultimate pH of 6.1 versus 5.4 is accompanied by a 17% change in muscle fiber diameter [27]. In addition, we found that the shear force increased with advancing age in both the breast muscle and leg muscle. The age-related findings in this study were consistent with those of L. Li and Uhlířová et al. in chicken and geese [10, 28]. Also, the shear force was positively correlated with the muscle fibers. Owens stated that the contractile state of the muscle (myofibrillar component) is probably the most important influence in meat tenderness in marketable aged (6-8 weeks) broilers [29]. Meat tenderness varies with the rate of glycolysis, the rigor onset post-slaughter and the extent of glycolysis, which are all related to muscle fiber characteristics [30]. These findings were consistent with our results. Compared with beef and pork, goose meat is softer. Therefore, consumers preferred chewier (firm, but not tough) goose meat in China. Also, the older geese had greater water holding capacity (less pressing loss) in leg muscle. To concluded, we found that the 90 and 120-d geese had greater performances in meat quality traits than 70-d geese.

The proximate composition of goose meat was affected mainly by age and muscular tissues. The 120-d geese had richer intramuscular fat (IMF) and protein content, as well as lower moisture content than 90 and 70-d geese. Results of the present study were in agreement with the previous findings. Baeza et al observed a significantly lower water content and higher lipid content in 11-wk-old ducks than in 8-wk-old ducks [31]. Uhlířová et al. stated that the lipid content of the breast increases with age at the expense of the water content which can explain our results [28]. IMF is often recognized as a key factor due to its positive correlation with tenderness, juiciness, and flavor [32, 33]. It not only tends to increase with advancing age until the muscle growth has been completed, but also correlates with muscle fiber characteristics [8]. The relationships between muscle fibers and IMF in goose meat deserves further research.

In view of the studies above, we concluded that the 90 or 120 d but not 70 d as the marketable age of Yangzhou goose may be a good choice for better meat quantities and qualities. Our continued researches will focus on manipulating muscle fiber characteristics to improve meat quality traits based on different marketable ages in Yangzhou goose. Further study will benefit both the consumers and farmers.

Conclusion

It is concluded that breast muscle only included fast-twitch fibers in the geese of all tested ages and little slow-twitch fibers could be identified in leg muscle of the geese in three marketable ages. As for the fiber diameter, a rapid upward trend was observed in breast muscle from 70 days to 90 days and it remained stable 90d thereafter. The diameter and cross-sectional area of muscle fiber in leg muscle increased with ages. In addition, 120-day-old geese had richer intramuscular fat and protein content both in breast and leg meat, as well as lower moisture content among three marketable ages. The higher lightness and pressing loss and the lower redness and shear force was observed in the breast and leg meat of 70-day-old geese compared with the 90 and 120-day-old geese. The reasonable marketable age should be taken into account to improve the meat quality in the goose production. The 90 or 120 d but not 70 d as the marketable age of Yangzhou goose may be a good choice for better meat quantities and qualities.

Abbreviations

BM: breast muscle, SOL: soleus muscle, GAS: gastrocnemius muscle, EDL: extensor digitorum longus muscle, MyHC: myosin heavy-chain, IMF: intramuscular fat.

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Authors' contributions

KW, QX and GC designed and managed the project. YY, YP, ZF analyzed the data. WH, TG, QB, LH, YZ performed all animal works and collected biological samples. KW and QX wrote the manuscript. YZ and GC revised the paper. All authors approved the final version of the manuscript.

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Availability of data and materials

All data generated or analyzed during this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

All experimental procedures performed in this study were approved by the Institutional Animal Committee of Yangzhou University (Permit Number: YZUDWSY, Government of Jiangsu Province, China).

Consent for publication

Not applicable.

Competing interests

All authors have no declared conflict of interest.

References

1. Petracci M, Claudio C: **Muscle Growth and Poultry Meat Quality Issues**. *Nutrients* 2012, **4**:1-12.
2. Janisch S, Krischek C, Wicke M: **Color values and other meat quality characteristics of breast muscles collected from 3 broiler genetic lines slaughtered at 2 ages**. *Poultry science* 2011, **90**:1774-1781.
3. Liu C, Pan D, Ye Y, Cao J: **H-1 NMR and multivariate data analysis of the relationship between the age and quality of duck meat**. *Food chemistry* 2013, **141**:1281-1286.
4. Lee S-H, Joo S-T, Ryu YC: **Skeletal muscle fiber type and myofibrillar proteins in relation to meat quality**. *Meat science* 2010, **86**:166-170.
5. Macrae V, Mahon M, Gilpin S, Sandercock D, Mitchell M: **Skeletal muscle fibre growth and growth associated myopathy in the domestic chicken (Gallus domesticus)**. *British poultry science* 2006, **47**:264-272.
6. Kim G-D, Jeong J-Y, Hur S, Yang H-S, Jeon J-T, Joo S-T: **The Relationship between Meat Color (CIE L* and a*), Myoglobin Content, and Their Influence on Muscle Fiber Characteristics and Pork Quality**. *Korean journal for food science of animal resources* 2010, **30**.
7. Kim G-D, Jeong J-Y, Jung E, Yang H-S, Lim H-T, Joo S-T: **The influence of fiber size distribution of type IIB on carcass traits and meat quality in pigs**. *Meat science* 2013, **94**:267-273.
8. Hwang Y, Kim G, Jeong J, Hur SJ, Joo SJMS: **The relationship between muscle fiber characteristics and meat quality traits of highly marbled Hanwoo (Korean native cattle) steers**. 2010, **86**(2):456-461.
9. Hwang Y-H, Bakhsh A, Lee J-G, Joo S-T: **Differences in Muscle Fiber Characteristics and Meat Quality by Muscle Type and Age of Korean Native Black Goat**. *food science of animal resources* 2019, **39**.
10. Li L, Yang J, Peng, Yin J-H, Wang Z, Wu Z, Luo Y-F, Jiang J-T, du d, Liu X-B: **Effects of Slaughter Age on Muscle Characteristics and Meat Quality Traits of Da-Heng Meat Type Birds**. *Animals* 2019, **10**:69.
11. Hamadani H, Khan A, Salahudin M, Sofi AH, Banday MTJIjops: **Slaughter and carcass characteristics, sensory attributes and consumer acceptability of geese meat**. 2013, **48**(2):223-227.
12. Liu H, Zhou D: **Influence of pasture intake on meat quality, lipid oxidation, and fatty acid composition of geese**. *Journal of animal science* 2013, **91**.
13. Anderson S: **Determination of fat, moisture, and protein in meat and meat products by using**

the FOSS FoodScan Near-Infrared Spectrophotometer with FOSS Artificial Neural Network Calibration Model and Associated Database: collaborative study. *Journal of AOAC International* 2007, **90**:1073-1083.

14. Livak KJ, Schmittgen TD: **Analysis of Relative Gene Expression Data Using Real-Time Quantitative PCR and the 2−ΔΔCT Method**. *Methods* 2001, **25**(4):402-408.
15. Oz F, Kızıl M, Çelık T: **Effects of Different Cooking Methods on the Formation of Heterocyclic Aromatic Amines in Goose Meat**. *Journal of Food Processing and Preservation* 2016, **40**(5):1047-1053.
16. Johnson DD, Huffman RD, Williams SE, Hargrove DDJJoAS: **Effects of percentage Brahman and Angus breeding, age-season of feeding and slaughter end point on meat palatability and muscle characteristics**. 1990, **68**(7):1980-1986.
17. Tilki M, Saatci M, Kirmizibayrak T, Aksoy A: **Effect of age on growth and carcass composition of Native Turkish Geese**. *Archiv fur Geflugelkunde* 2005, **69**:77-83.
18. Choe JH, Kim BC: **Association of blood glucose, blood lactate, serum cortisol levels, muscle metabolites, muscle fiber type composition, and pork quality traits**. *Meat Science* 2014, **97**:137–142.
19. Ishamri I, Joo S-T: **Poultry Meat Quality in Relation to Muscle Growth and Muscle Fiber Characteristics**. *Korean journal for food science of animal resources* 2017, **37**:873-883.
20. Picard B, Jurie C, Duris M, Renand G: **Consequences of selection for higher growth rate on muscle fibre properties in cattle**. *Livestock Science - LIVEST SCI* 2006, **102**:107-120.
21. Shan Y-j, Xu W-j, Shu J-t, Zhang M, Song W-t, Tao Z-y, Zhu C-h, Li H-f: **Differentiation of expression profiles of two calcineurin subunit genes in chicken skeletal muscles during early postnatal growth depending on anatomical location of muscles and breed**. *Journal of Integrative Agriculture* 2016, **15**(5):1085-1094.
22. Du YF, Ding QL, Li YM, Fang WR: **Identification of Differentially Expressed Genes and Pathways for Myofiber Characteristics in Soleus Muscles between Chicken Breeds Differing in Meat Quality**. *Animal biotechnology* 2017, **28**(2):83-93.
23. Kim GD, Jeong, J. Y., Moon, S. H., Hwang, Y. H., Park, G. B., Joo, S. T. : **Effects of muscle fiber type on meat characteristics of chicken and duck breast muscle**. *54th International Congress of Meat Science and Technology* 2008.
24. 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.
25. Baéza E, Arnould C, Jlali M, Chartrin P, Gigaud V, Mercerand F, Durand C, Méteau K, Le Bihan-Duval E, Berri C: **Influence of increasing slaughter age of chickens on meat quality, welfare, and technical and economic results**. *Journal of animal science* 2012, **90**(6):2003-2013.
26. Fletcher DL: **Poultry meat quality**. *World's Poultry Science Journal* 2002, **58**(2):131-145.
27. Purslow P, Warner R, Clarke F, Hughes J: **Variations in meat colour due to factors other than myoglobin chemistry; a synthesis of recent findings (invited review)**. *Meat Science* 2019, **159**:107941.
28. Uhlířová L, Tůmová E, Chodová D, Vlčková J, Ketta M, Volek Z, Skřivanová V: **The effect of age, genotype and sex on carcass traits, meat quality and sensory attributes of geese**. *Asian-Australasian journal of animal sciences* 2018, **31**(3):421-428.
29. Owens CM: **Identifying quality defects in poultry processing**. *Watt Poultry Usa* 2014.
30. Ali MS, Yang HS, Jeong JY, Moon SH, Hwang YH, Park GB, Joo ST: **Effect of chilling temperature**

of carcass on breast meat quality of duck. *Poult Sci* 2008, **87**(9):1860-1867.
31. Baeza E, Salichon MR, Marche G, Wacrenier N, Dominguez B, Culioli JJBPS: **Effects of age and sex on the structural, chemical and technological characteristics of mule duck meat**. 2000, **41**(3):300-307.
32. Madeira M, Costa P, Alfaia C, Lopes P, Bessa R, Cardoso Lemos JP, Prates J: **The increased intramuscular fat promoted by dietary lysine restriction in lean but not in fatty pig genotypes improves pork sensory attributes**. *Journal of animal science* 2013, **91**.
33. Hocquette J-F, Gondret F, Baeza E, Médale F, Jurie C, Pethick D: **Intramuscular fat content in meat-producing animals: Development, genetic and nutritional control, and identification of putative markers**. *Animal : an international journal of animal bioscience* 2010, **4**:303-319.

Figure captions

Fig. 1 The body weight and different muscular tissues of Yangzhou geese.

A. 1-d, 28-d, marketable age geese. B. The body weight during the growth of Yangzhou geese from 1d to 120d. C. Schematic diagram of breast muscle and different muscular tissues in leg muscle. BM, breast muscle. SOL, soleus muscle. GAS, gastrocnemius muscle. EDL, extensor digitorum longus muscle.

Fig. 2 The fiber type composition in the goose muscle of different ages.

Immunohistochemical for four muscular tissues using anti-fast and anti-slow myosin skeletal heavy chain in geese at different ages. Magnification of 200× was used (Bar=100 μm).

Fig. 3 Relative mRNA expressions of myosin heavy-chain (MyHC) isoform genes in the goose muscle of different ages.

A. MYH1A, type IIb, fast-twitch. B. MYH1B, type IIa, fast-twitch. C. MYH7B, type I, slow-twitch. A–C mRNA expression was normalized to β-actin gene expression. Mean values within different letters were significantly different ($p<0.05$).

Fig. 4 Muscle fiber morphology traits during the growth of goose.

A. Hematoxylin and eosin staining. Magnification of 200× was used (Bar=100 μm). B. Muscle fiber diameter. C. Muscle fiber cross-sectional area. D. Muscle fiber density. Mean values within different letters were significantly different ($p<0.05$).

Fig. 4S Intramuscular adipocytes between breast muscle fibers in the 28-day-old goose. Magnification of 900× was used (Bar=20 μm).

Figures

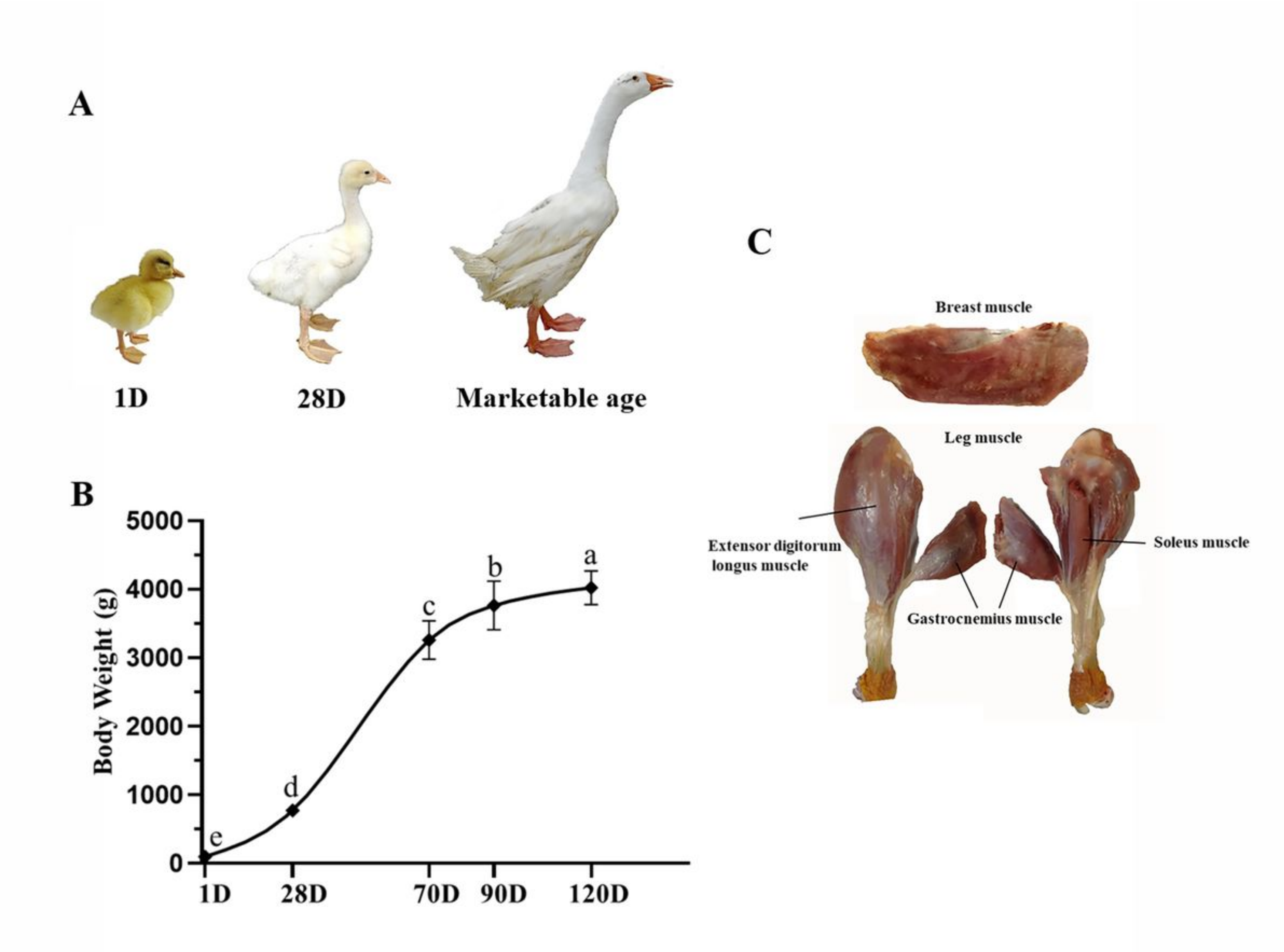

Figure 1

The body weight and different muscular tissues of Yangzhou geese. A.1 d, 28 d, marketable age geese. B. The body weight during the growth of Yangzhou geese from 1d to 120d. C. Schematic diagram of breast muscle and different muscular tissues in leg muscle. BM, breast muscle. SOL, soleus muscle. GAS, gastrocnemius muscle. EDL, extensor digitorum longus muscle.

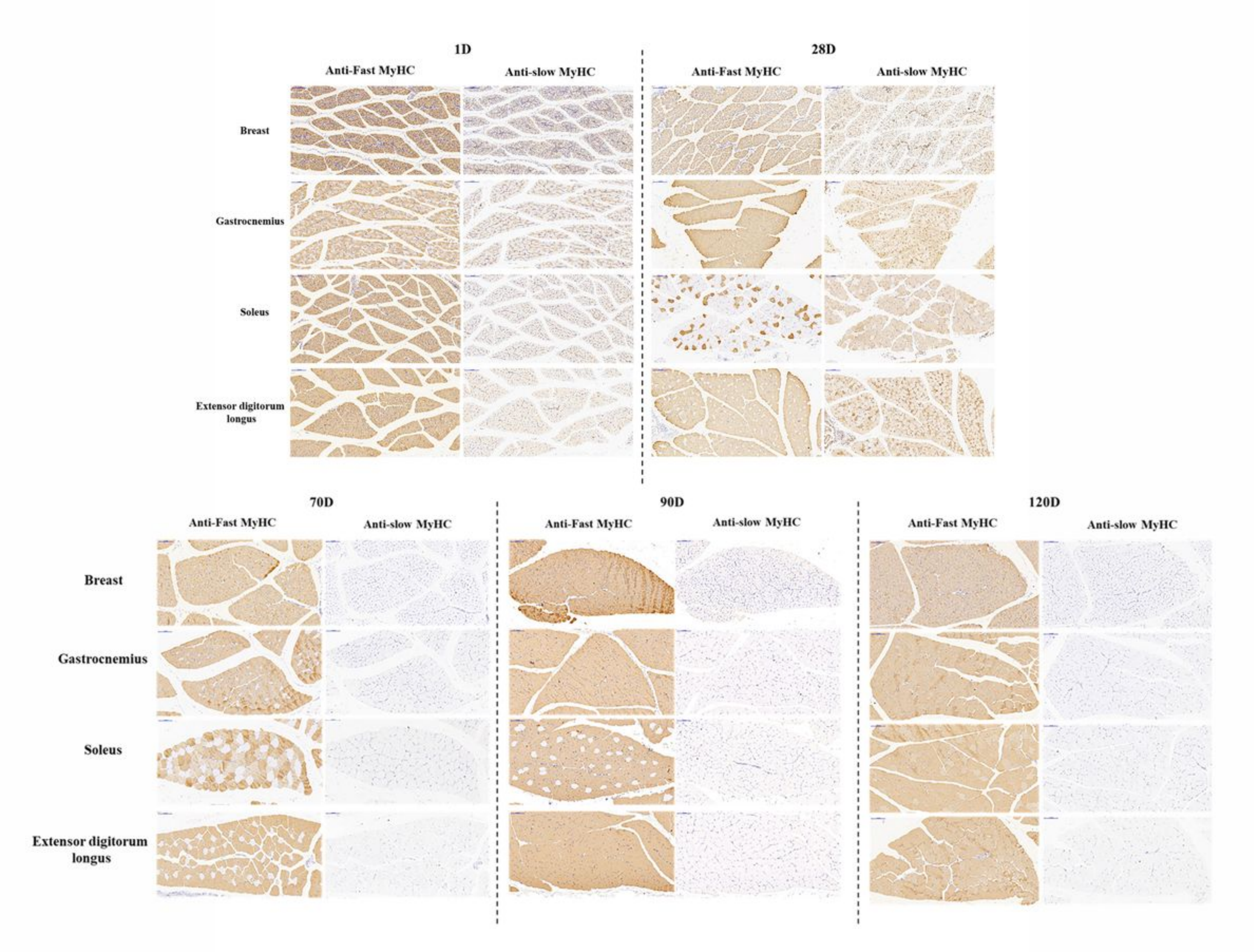

Figure 2

T he fiber type composition in the goose muscle of different ages Immunohistochemical for four muscular tissues using antifast and anti slow myosin skeletal heavy chain in geese at different ages. Magnification of 200× was used (Bar=100 μm).

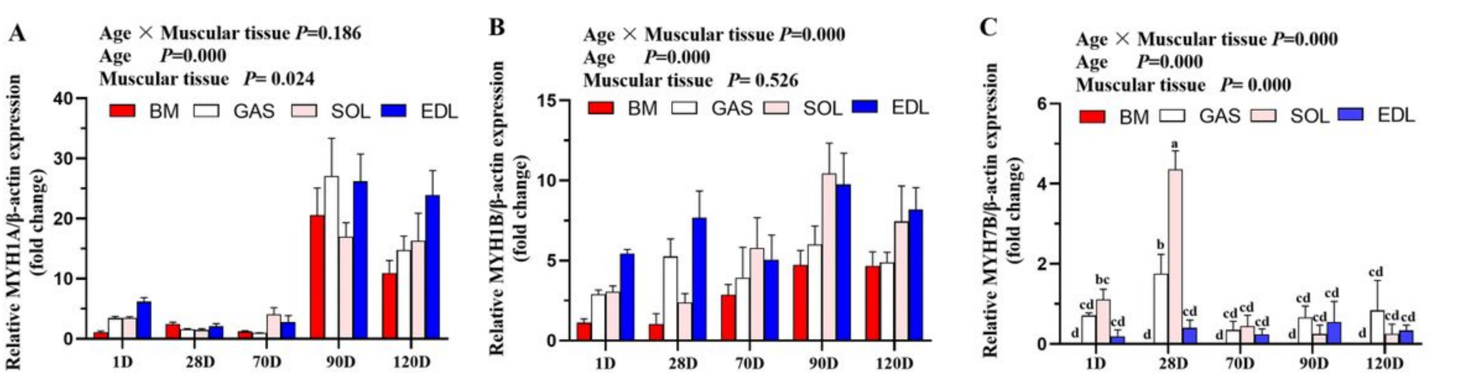

Figure 3

Relative mRNA expressions of myosin heavy chain (MyHC) isoform genes in 513 the goose muscle of different ages. A. MYH1A, type IIb, fast twitch. B. MYH1B, type IIa, fast twitch. C. MYH7B, type I, slow twitch. A C mRNA expression was normalized to β actin ge ne expression. Mean values within different letters were significantly different (p<0.05).

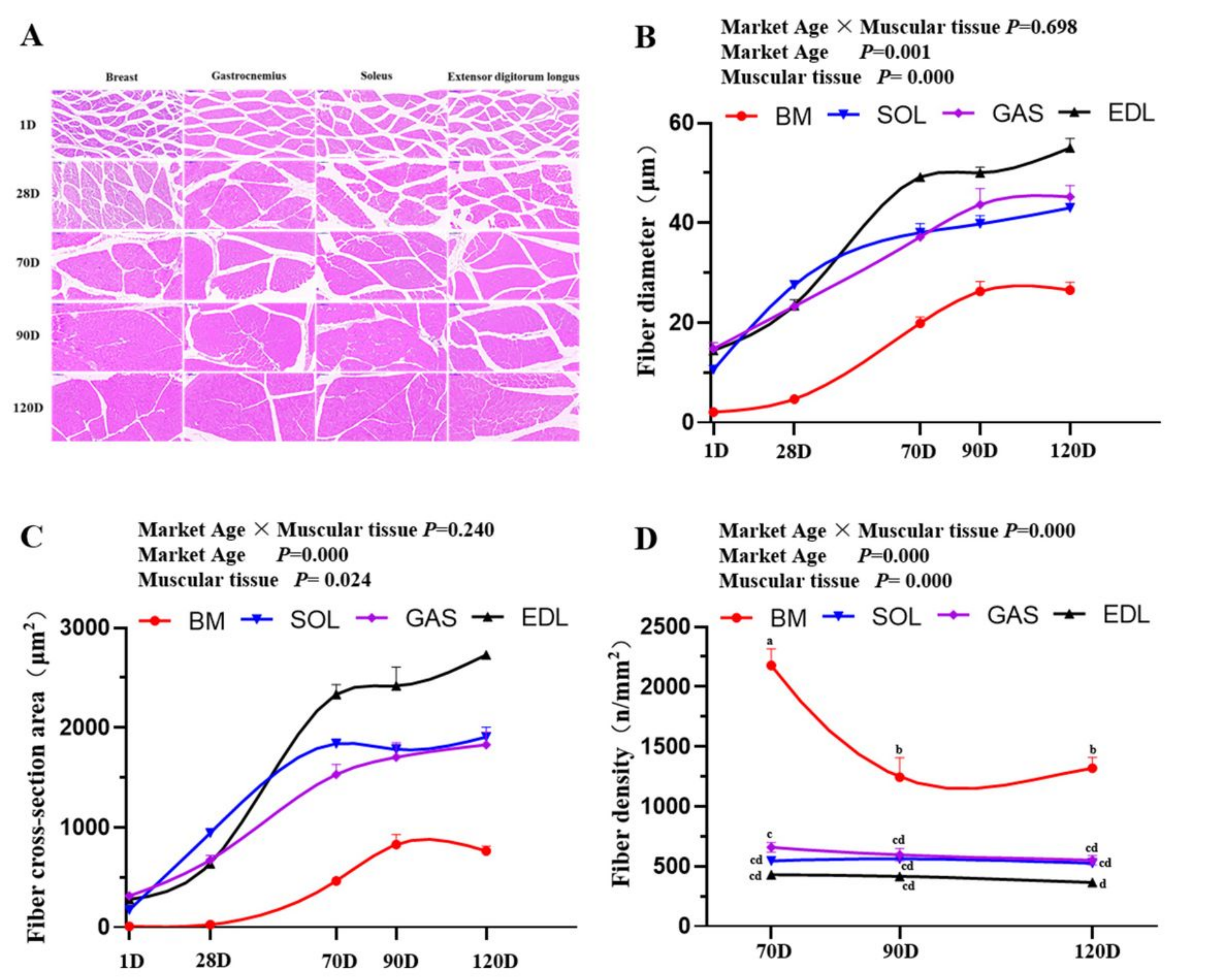

Figure 4

Muscle fiber morphology traits during the growth of goose. A. Hematoxylin and eosin staining. Magnification of 200× was used (Bar=100 μm). B.Muscle fiber diameter. C. Muscle fiber cross sectional area. D. Muscle fiber density. Mean values within different letters were significantly different (p<0.05).

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