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Original Article

Comparison of Some Biomechanical Properties of Tibiotarsus in Four Different Feather Color Lines of 60-Day Old Female Quails

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ABSTRACT

This study aimed to compare some morphological and mechanical measurements of four different color female quails to contribute to the formation of the morphological database.

Quails are the smallest farmed avian species which are becoming more important for the poultry industry. They are also used as experimental animals and are valuable birds for researches. Genetic factors are important determinants of bone strength. Thus, skeletal disorders may be reduced by breeding selection in quails. Forty female quails with four different feather colors, including wild, white, yellow, and black, were compared at 60 days of age. Each quail group contained ten individuals. A three-point bending test was performed with a custom-made testing machine designed for low strength materials. No significant difference was found between the groups in terms of body weight. The tibiotarsus weight in wild and black (0,665±0,055g and 0,687±0,025g, respectively) was significantly lower than in the others but, the significant highest value was in white quails (0,758±0,063g) (p=0.001). Significantly shorter tibiotarsus was observed in the black quails (51,286±1,374mm), while the tibiotarsi of the white and yellow quails were the tallest (53,216±1,796mm and 53,083±1,092mm, respectively) (p=0.005). There were no significant differences among the groups in the biomechanical properties of tibiotarsus, except stiffness. Stiffness was the highest in the white quails (109,500±3,807 N/mm) and the lowest in the black quails (99,000±9,498 N/mm) (p=0.042). In conclusion, white quails have been observed to have relatively better bone biomechanical properties compared to the other color groups at 60 days of age.

INTRODUCTION

Different poultry species are being used for food production and protecting genetic resources, although egg and meat production in the world is based mainly on chicken production (Hassan, 2013). One of those species, quail, is the smallest farmed avian species which is becoming more significant for egg and meat production industries (Minvielle, 2004).

Besides breeding for egg or meat production, quails are also used as an experimental animal and is a valuable bird for researches. The use of Japanese quails in biomedical research is becoming widespread (Minvielle, 2004) and has been widely used for biological and genetic studies. Quails are useful sources for researchers because of their high egg production rates, intensive growth rate, early sexual maturity, short generation interval, low maintenance costs as well as their small body size and resistance to diseases (Yildiz & Kesici, 1999; Minvielle *et al*., 2007; Tarhyel *et al*., 2012; Hassan, 2013).

Genetic factors are important determinants of bone strength (Rath *et al*., 2000). The effects of genetic factors on bone strength have been tested by several studies on rats, mice and laying hens (Bishop *et al*., 2000; Szumska *et al*., 2007; Alam *et al*., 2011). Since 30% to 80% of the variance in tibia breaking strength is genetically determined for broiler chickens (Mandour *et al*., 1989; de Verdal *et al*., 2013) and White Leghorn hens (Bishop *et al*., 2000), skeletal system disorders may be reduced by genetic selection (Bishop *et al*., 2000) that seems to be effective behind nutrition to improve bone strength (Fleming, 2008). There are some studies on skeletal formation, including effects of age and sex on bone development, and effects of feed additives on performance traits and bone tissue properties of pelvic limb bones (Kara *et al*., 2012; Kolas & Kara, 2013; Tufan *et al*., 2014). Further, quails with different colors attracted the attention of the researchers. Several researchers have studied several feather color mutations such as rusty (Minvielle *et al*., 2005), white (Petek *et al*., 2004; Inci *et al*., 2015, Taha *et al.,* 2019), dark brown, golden (Inci *et al*., 2015, Taha *et al.,* 2019), roux (Minvielle *et al*., 1999), lavender (Bed'hom *et al*., 2012) and wild-type (Petek *et al*., 2004; Minvielle *et al*., 2005; Bed'hom *et al*., 2012; Inci *et al*., 2015) and their effects on some growth performance parameters. However, there is no study comparing bone biomechanical studies of quail with different feather colors.

In the present study, wild, white, yellow, and black color quails were compared in some basic morphological and mechanical traits. To date, morphological and biomechanical properties of tibiotarsus of selected quails have not been compared. Therefore, this study aimed to compare some morphological and mechanical measurements of four different colored female quails to contribute to the formation of the morphological database.

MATERIALS AND METHODS

Animals and collection of bones

The study was performed on the tibiotarsi of four different breeds of quails. The tibiotarsi bones were obtained from quail raised for production at Bursa Uludag University Animal Production Research and Application Center Quail Production Unit including one pure line stocks as 'wild' and their recessive white variety 'white' quail of the Pharaoh strain (*Coturnix coturnix pharaoh*) and two cross-line stocks of yellow and black color quail. The white line was set up from mutant birds, which appeared spontaneously in a wild-type quail colony, and after initial crossing, they were fixed. The crosslines ('yellow' and 'black' colored) were obtained from pure line stocks of *Coturnix coturnix japonica* and pure line stocks of Bob White. The visual properties of each line were presented in Figure 1. Each quail group contained ten individuals. All birds were kept in the same feeding conditions and living environment and were slaughtered on 60 days of age. Birds in all groups were reared at 31-33 °C in week 1, 27-31 °C in week 2, 23-26 °C in week 3, 20-23 °C in week 4 and 18-21 ° C in weeks 5 to 6. Newly hatched chicks in all groups were housed in the same environmental conditions (floor space, bird density, feeder, and drinker space) in a multitier cage during the growing period. Birds on all groups consumed ad libitum a commercial maize-based grower ration from 1 to 45 d of age (ME = 12·50 MJ/kg, 220 g/kg total protein) and a finisher ration from 45 to 60 d of age (ME = 12·70 MJ/kg, 200 g/kg total protein). Quails received continuous light, including natural daylight during daytime and artificial light during the night. Chick weight at hatch and final bodyweight of the birds in the groups were measured individually, and weight gain during the growing period was calculated. The right tibiotarsi were collected from each bird, dissected surrounding soft tissues, and then frozen in plastic bags at -20 °C until mechanical tests and cortical area analysis were conducted (Swiatkiewicz & Arczewska-Wlosek, 2012).

Biomechanical tests

Tibiotarsi were thawed in room temperature, and then they were weighed with a Precisa XB4200C digital scale (Precisa Instruments Ltd., Switzerland). Length measurements were applied with Mitutoyo CDN-20C digital caliper (Mitutoyo Corp., Kawasaki, Japan).

Figure 1 – Visual properties of the quails used in the experiment. a: Wild-type 'wild', b: Recessive white, 'white', c: Yellow, 'yellow', d: Black, 'black'

Three-point bending tests were performed with a custom-made testing machine, which was designed for low strength materials at the Mechanical Engineering Department of Suleyman Demirel University in Isparta, Turkey (Tufekci *et al*., 2014). A load-cell (50 kg, Tedea Huntleigh Malvern, USA) and a Linear Variable Differential Transformer (LVDT) (10-mm stroke, Novotechnik Tr10, Germany) were used to measure force and corresponding displacement during tests, respectively. A four-channel oscilloscope (100 data/sec, Nicholet-Oddysey XE, USA) was used to record the measured data from both transducers. The oscilloscope has its own software and gives the load-cell and LVDT data in the dimension of voltages. These data were converted to Newton and mm using the formulations presented by the manufacturer in Microsoft Excel. The experimental results could be affected by loading head speed rate. Therefore, all tests were performed at a constant loading head speed of 10 mm/min, as suggested by a previous study (Lopez & Markel, 2000). The average length of the whole bone tested was 50 mm, so the span between support was set to 20 mm, which is 40% of the total bone length, and the force was applied at the middle of the span (Figure 2). Three-point bending test provided ultimate strength, stiffness, displacement, and work-to-fracture.

Statistical analysis

Data for the measured parameters were normally distributed and met the assumptions for homogeneity of variance. For each measured parameter, the mean for each experimental group and the standard errors were calculated in SPSS (SPSS, Version 23.0, Chicago, IL). Data were presented as mean±standard error of the mean. For statistical evaluation, one-way ANOVA test was used. Differences were accepted as $p \leq 0.05$ significant. When the differences between the groups were significant ($p \leq 0.05$), data were assessed by Tukey HSD to determine groups that the difference originated from (Snedecor & Cochran, 1989).

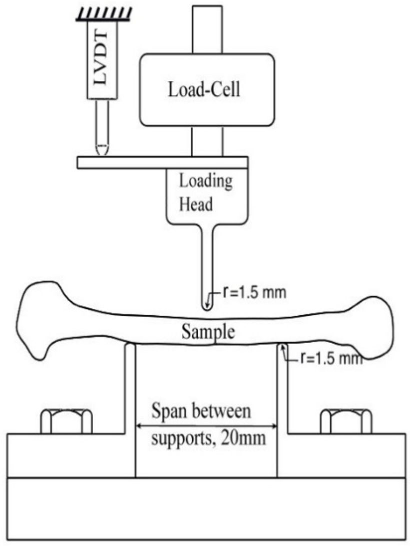

Figure 2 – Schematic drawing of the three-point bend fixture.

*LVDT: Linear Variable Differential Transformer, r: Radius of crosshead and supports.

RESULTS

Chick weight, final body weight, and morphological and mechanical measurements of quails tibiotarsus were presented in Table 1. There were no significant differences between the groups in terms of chick weight at the beginning of the study (p=0.883). At the end of 60 days period, no significant difference was found between the groups in terms of body weight (p=0.160). White quails had the heaviest tibiotarsus (0.758±0.063 g) significantly compared to other groups. But, the weight of tibiotarsus in wild and black quails was remarkably lower than the others (p=0.001), and the tibiotarsus weight for wild and black quails was 0.665±0.055 g and 0.687±0.025 g, respectively. There was no difference in tibiotarsus weight between yellow quails (0.719±0.038 g) and the other quails. With the 51.286±1.374 mm tibiotarsus length, black quails had significantly shorter tibiotarsus length than other quails, whereas white, and yellow quails had the tallest tibiotarsus (p=0.005) with the length of 53.216±1.796

Table 1 – Chick weight, final body weight, and morphological and biomechanical measurements of tibiotarsus of quails.

	Chick weight (g)	Final Body weight (g)	Bone weight (g)	Bone length (mm)	Ultimate strength (N)	Stiffness (N/mm)	Displacement (mm)	Work-to-fracture (Nmm)
Wild (n=10)	7.77±0.14	181.20±22.82	0.687±0.008[a]	51.76±0.29[ab]	43.01±2.45	99.000 ±3.00[a]	0,513±0.02	12,948±0.76
Recessive white (n=10)	7.91±0.24	180.92±22.90	0.758±0.020[b]	53.21±0.56[b]	41.59±0.94	109.500±1.20[b]	0,463±0.02	11,164±0.92
Yellow (n=10)	8.02±0.22	169.98±21.63	0.719±0.012[ab]	53.08±0.34[b]	43.14±1.41	103.500±3.62[ab]	0,524±0.02	13,364±0.70
Black (n=10)	7.91±0.23	165.81±23.95	0.665±0.017[a]	51.28±0.43[a]	44.72±1.38	103.600±2.29[a]	0,525±0.01	12,818±0.53
p-value	0.883	0.160	0.001	0.005	0.615	0.042	0.293	0.407

*Data were presented as mean±standard error of the mean. Differences were accepted as $p \leq 0.05$ significant.

mm and 53.083±1.092 mm, respectively. Wild quails had 51.762±0.924 mm tibiotarsal length but showed no difference with other quails.

No statistically significant differences were observed among the groups in ultimate strength, displacement, and work-to-fracture (p=0.615, p=0.293, p=0.407, respectively). In the biomechanical properties, only stiffness showed a statistical difference (p=0.042), and this value was the highest in the white quails (109.500±3.807 N/mm) and the lowest in the black quails (99.000±9.498 N/mm).

DISCUSSION

In the present study, we compare some morphological and mechanical characteristics of female quails with different colors, including wild, white and yellow.

Several researchers documented many quails with different feather colors in the world. Some of them were white, brown, roux, yellow, rusty, and wild type (Minvielle *et al*., 2005). In general, researchers have focused on and compared the effects of different feather color and type on growth performance (Minvielle *et al*., 1999; Petek *et al*., 2004; Minvielle *et al*., 2005; Bed'hom *et al*., 2012; Inci *et al*., 2015). However, there is a lack of information on the biomechanical comparisons of these quails.

In our study, live weight for wild, white, yellow, and black quails were 181.20±22.82, 180.92±22.90, 169.98±21.63 and 165.81±23.95, respectively. Although black and white quails were observed numerically to be heavier than others, the difference was not statistically significant. In contrast to our study, Minvielle *et al*. (1999) and Inci *et al*. (2015) stated that feather color had a significant effect on live bodyweight and that the wild-type quails had a higher body weight. Some studies have also observed that white quails had less body weight than wild-type quails (Petek *et al*., 2004; Minvielle *et al*., 2005; Yilmaz & Caglayan, 2008). Petek *et al*. (2004) and Minvielle *et al*. (2007) have reported that recessive white color has a depressive effect on quail body weight. But we did not observe this depressive effect on the body weight of white quails. Because no difference was found between wild and white quails, the scarcity of previous morphological and mechanical comparison studies in the quails was a handicap to make the biomechanical comparisons. Several studies suggested that tibiotarsus may serve as model bones in studies on the quality of the skeleton of poultry (Church & Johnson 1964; Tatara *et al*., 2005; Charuta *et al*., 2013). Also, tibial length has been used as an indicator of linear growth (Masoud *et al*., 1986; Fritton *et al*., 2005). In the present study, the significantly higher values in tibiotarsal length and weight of white quails compared to other color quails showed that the growth rate of white quails was better than others. Tibiotarsi of white quails were also stiffer than others. With higher stiffness value in white quails, greater ultimate strength and lower displacement values are expected because stiffer structures deform less for a certain load than more compliant structures (Jepsen *et al*., 2015). But the ultimate strength and displacement values were not statistically significant among the groups. Stiffness depends on bone geometry and bone material properties (Jepsen *et al*., 2015). Therefore, the increase of the stiffness in white quails may be a result of better morphology of the tibiotarsus due to higher weight and length of white quails. Also, in poultry, medullary bone formation increases with the onset of the laying period (Whitehead & Wilson 1992). It is stated that the bone strength increases with the increase of the medullary bone formation (Fleming *et al*., 1998). Kaczanowska-Taraszkiewicz (2001) also reported that Pharaoh quails have started to lay at the age of 8 weeks, and due to the presence of medullary bone, the mechanical properties of the bones were higher in females than males. According to Kaczanowska-Taraszkiewicz (2001), the quails in our study were also 60 days old, and they were around the starting of laying period. We did not collect data about egg production in our experiment. But quails with different colors might start to lay at different periods. This situation may also affect the amount of medullary bone on the day of the experiment. Various amounts of medullary bone formation may cause differences in biomechanical values. Therefore, further studies are required to evaluate the laying age, feather color and their effects on bone properties in quails.

CONCLUSION

In conclusion, none of the color groups seem superior to the others when all biomechanical properties were considered. There was no difference in biomechanical characteristics of tibiotarsus except stiffness in female quails with different feather colors including wild, white, yellow and black at 60 days of age. According to these results, white quail has been observed to have relatively better bone biomechanical properties. Furthermore, we concluded that more comprehensive studies are required to determine the relationship between feather color and some morphometric and mechanical measurements in quails.

CONFLICTS OF INTEREST

The authors hereby declare that we do not have any conflict of interest in regard to the information provided in this study.

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