MANAGEMENT AND PRODUCTION

Effect of housing system and age on products and bone properties of Taihang chickens

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ABSTRACT The aim of this study was to compare egg quality, carcass, meat characteristics, and bone properties of Taihang chickens in 2 different housing systems at various ages. A total of 168 birds were selected and randomly allocated to 2 groups at 23 wks and raised in conventional cage (**CC**) or flattening on floor (**FF**) housing system, respectively. FF hens' egg weight, albumen height, and Haugh unit were higher ($P < 0.05$), and yolk weight was lower ($P < 0.001$) than those of the CC hens. Egg quantity of FF hens was higher than that of the CC hens ($P < 0.01$). The FF hens' weight ($P < 0.05$) and breast meat percent ($P < 0.01$) were higher than those of the CC hens. The highest live body and carcass weight were observed at 57 wk (both $P < 0.01$), whereas the highest semieviscerated percentage ($P < 0.01$) and meat weight of breast and thigh ($P < 0.05$) were shown at 49 wk. The highest eviscerated percentage and thigh meat were displayed at 41 and 32 wk, respectively ($P < 0.01$). For meat color, the lightness of both breast and thigh meat in the FF group was significantly reduced compared with those of the CC group ($P < 0.01$ and $P < 0.05$). FF hens' humerus weight and breaking strength (both $P < 0.01$) and tibia breaking strength ($P < 0.05$) were significantly higher than those of the CC hens. Femur breaking strength was significantly affected by hens' age ($P < 0.01$). Egg weight, albumen height, Haugh unit, yolk color (all $P < 0.01$), pH of thigh meat, semieviscerated, and eviscerated weight (all $P < 0.05$) were influenced by the interaction of housing system and age, whereas no change in moisture loss rate, meat color, shearing force, and bone quality was found ($P > 0.05$). In summary, in the 2 housing systems, hens' age and their interaction could affect slaughter performance, quality of egg, meat, and bone of Taihang chickens. In addition, the results of the present study support a theoretical basis for the development and utilization of Taihang chickens in accordance with the FF system.

Key words: Taihang chicken, housing system, bone quality, egg quality, meat quality

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INTRODUCTION

Over the past few years, poultry farming systems have been transformed around the world, as more attention is being paid to animal welfare. Following the growing concern of animal welfare, consumers are more sensitive to the economic and ethical aspects of food from animals, and consumers prefer to purchase the eggs produced in free-range systems (Kouba, 2003; Miao, et al., 2005) because the quality of eggs is guaranteed in animal-friendly systems. The conventional cage systems were banned by the European Union in 2012, which provided new ideas for laying hens around the world. It has been reported that the free-range system led to better chicken welfare (Heier BT, 2002; Pettersson, et al., 2016).

Alternative housing systems, such as free-range systems, could affect some quality features of eggs (Kucukyilmaz, et al., 2012; Dong, et al., 2017). Recent studies indicated that a free-range system contributes to better product quality, but it resulted in poorer production performance (Xiang, et al., 2018). However, other reports suggested egg production performance of modern layers was not significantly affected by the rearing systems (Ahammed, et al., 2014). Conflicting reports were likely due to some variables such as age, genotypes, environment, housing systems, and nutrition, affecting

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Table 1. Ingredients and chemical composition of basal diet.

Ingredients	Content, %
Corn	60.80
Soybean meal	22.90
Zeolite powder	2.60
Limestone	8.60
$CaHPO_4$	1.53
Peanut meal	1.00
Hydrolyzed feather meal	1.00
Plant oil	0.80
NaCl	0.30
Trace elements[1]	0.20
Met	0.17
Lys	0.06
Multivitamin[2]	0.03
Bacillus subtilis	0.01
Total	100.00
Nutrient level[3]	
ME/(MJ/kg)	10.88
CP	15.98
CF	2.37
Ca	3.66
TP	0.56
AP	0.32

[1]The trace elements provided the following per kg of diets: Cu (as copper sulfate), 0.8 g; Fe (as ferrous sulfate), 6 g; Mn (as manganese sulfate), 9 g; Zn (as zinc sulfate), 6 g; I, 90 mg; Se (as sodium selenite), 21 mg.

[2]The multivitamin provided the following per kg of diets: vitamin A, 330,000 IU; vitamin B_1, 20 mg; vitamin B_2, 500 mg; D-pantothenate calcium, 1,200 mg; vitamin B_6, 300 mg; vitamin D_3, 82,500 IU; vitamin E, 2,000 IU; vitamin K, 180 mg; biotin, 14 mg; folic acid, 55 mg; niacin, 2,300 mg; choline, 45 g.

[3]The nutrient levels were calculated.

the performance and egg quality of birds (Rakonjac, et al., 2014; Steenfeldt and Hammershøj, 2015). It is well known that exercising could improve meat quality. There were differences in meat quality with how birds are reared with or without outdoor access (Fanatico, et al., 2005). In addition, free-range housing systems lead to more cooking and drip loss in meat, which results in healthier and less-fat meat, in comparison with the cage systems (Xiang, et al., 2018).

The decline of bone quality can lead to progressive weakening of bones and to fractures because of unbalancing of bone formation and absorption. The ability of bone formation in hens to maintain better bone quality can be enhanced with more exercise, while caged birds could accelerate structural bone resorption resulting in poor quality (Whitehead and Fleming, 2000). And the causes of bone fractures are likely multifactorial and influenced by age, diet, genetic line, restricted movement, lack of exercise, and other factors (Toscano, et al., 2018). Twenty-nine percent of hens in the conventional cages in the UK have one or more broken bones in their lifetime (Gregory and Wilkins, 1989). Another research illustrated that the environment had a secondary effect on bone status after genetics (Fleming, et al., 2006). Apparently, hens in free-range systems had stronger bones and walking ability; exercise had a positive effect on bone mineral content of tibias and humeri (Fanatico, et al., 2008; Enneking, et al., 2012).

Taihang chicken is a famous indigenous chicken breed for both meat and egg production in Hebei Province. The chickens, with crude feed tolerance, high disease resistance, cold resistance, and other good characteristics, are generally raised in free-range systems and remote mountainous regions in northern China. More number of Taihang chickens is required because of the great demand of the high-quality product. The conventional 3-tier cage system is also used for breeding the birds for more production of products. In the present study, the egg quality, slaughtering performance, meat quality, and bone quality of Taihang chickens at 4 ages were evaluated to compare the product and bone properties in the 2 housing systems. This study helped clarify how the housing systems influence the egg and meat of the chickens and provided more information to choose appropriate housing systems and a theoretical basis for the development and utilization of Taihang chickens.

MATERIALS AND METHODS

Ethics Statement

Practices regarding the care and use of animals for research purposes were in accordance with the institutional and national guidelines and were approved by the Animal Use and Ethics Committee of the Agricultural University of Hebei (University Identification Number: HB/2019/03). Every effort was made to minimize animal pain, suffering, and distress.

Animals and Experimental Design

The 2 different housing systems were installed in parallel in the same building. Taihang chicken, a local breed in China, was selected as the experimental bird. Briefly, 400 one-day-old pullets were reared in cages under the same conditions of temperature (near 35°C) a and light period of 22 to 24 h until the age of 8 wk in Songshi Poultry Company (Cangzhou County, Hebei Province, China). All birds at 9 wk of age were transferred to Liuwangchuan Ecological Aquaculture Co. Ltd. (Laiyuan County, Hebei Province, China). The pullets were raised indoor on floor, where the temperature was 20 ± 2°C and the photoperiod was 10 h from 9 wk to 21 wk. No difference between the 2 groups at the beginning of the experiment was guaranteed. At 22 wk, 168 birds were randomly assigned to be raised in conventional cages (**CC**) or flattening on floor (**FF**) until 57 wk. Thus, there were 84 birds in the FF group allotted to 3 pens, with 28 birds per pen, allowing for 3,890 cm^2/bird. Three birds per cage with a space allowance of 507 cm^2/bird were assigned to the CC housing system. All birds of different stages were given an equal amount of normal poultry food based on the feeding standards of China (China's Ministry of Agriculture, 2004) for laying hens. Ingredients and chemical composition of the basal diet during the experiment are shown in Table 1. Both groups were housed in the same conditions of temperature (near 20°C) and light cycle (16-h/8-h light/dark cycle).

Egg Quality and Quantity Assessment

Thirty eggs from each group were randomly selected, and egg quality parameters were measured within 48 h. Eggs were collected at the age of 32, 41, 49, and 57 wk throughout the experimental period. The egg shape index was measured using an egg form coefficient measuring instrument (NFN385, FHK Corp., Tokyo, Japan) and calculated by dividing the short diameter by the long diameter of each egg and multiplying by 100. All the eggs of both groups were weighed individually by an egg multitester (EA-01, ORKA FOOD TECHNOLOGY LTD., Bountiful, UT); albumen height, Haugh unit, and yolk color score were also evaluated. Egg shell breaking strength was determined by an egg force reader (EFR-01, ORKA FOOD TECHNOLOGY LTD., Bountiful, UT), and then the egg shell was broken to determine other quality parameters. The shells of the broken eggs were cleaned and weighed using an electronic balance to an accuracy of 0.01 g. Yolks were separated and weighed using an electronic balance to an accuracy of 0.01 g. The number of eggs was recorded every day.

Slaughtering Traits Assessment

Five birds from each group were randomly selected at 32, 41, 49, and 57 wk of age. All birds were weighed before they were euthanized, strictly following the recommendations of the relevant national and/or local animal welfare bodies. Then, carcasses were removed and weighed. After that, the tracheoesophageal crop, intestine, spleen, pancreas, bile, and reproductive organs were removed, and the semieviscerated weight was recorded. Then, the heart, liver, gizzard, and proventriculus and fat (perivisceral and abdominal) were removed to obtain the eviscerated weight. The semieviscerated weight, eviscerated weight, and breast and thigh meat weight were recorded using an electronic balance to an accuracy of 0.1 g. The proportion of carcass weight, semieviscerated weight, and eviscerated weight was calculated with divided by live body weight. The ratio of breast to thigh meat was recorded as percentages of eviscerated weight.

Meat Quality Assessment

The moisture loss of breast and thigh meat was calculated as follows: [weight of initial sample] − [sample weight after pressuring with 35-kg force for 5 min] (MAEC18, Mingao Instrument Corp., Nanjing, China). The results were expressed as the percentage of weight difference divided by the initial sample weight. The breast and thigh meat color profile (lightness-L*, redness-a*, and yellowness-b*) was measured within 10 min postmortem using a color reader (CR 10, Konica Minolta Corp., Tokyo, Japan). Shearing force was measured using a shear force meter (TA. XTPlus, Stable Micro System Corp., Surrey, UK). The pH of meat samples (breast and thigh) was analyzed using a pH meter (UB-7, Denver Instrument Corp., Bohemia, NY). The pH of each meat sample was analyzed 3 times, and thus, the average pH value of meat samples was used.

Bone Quality Assessment

The left wing and leg bones of each hen were removed and dissected. The bones were coded and kept frozen at −20°C until measurement and analysis. No effect of freezing and thawing bones on its breaking strength had been reported (Seldin and Hirsch, 1966). Weights of the humerus, femur, and tibia were measured using an electronic balance to an accuracy of 0.01 g. To assess biomechanical properties of the humerus, femur, and tibia, each bone was loaded on 2 fulcrum points (4.8 cm apart for the humerus, 6.0 cm apart for femur, and 6.4 cm apart for tibia) and a constant force was applied using a texture analyzer (TA. XTPlus, Stable Micro System Corp., Surrey, UK), with 30-kg cell load until the bones fractured. The breaking strength (in kg) was read using the connected software as the peak of the curve produced, following suitable calibration, and was corrected by live body weight of each hen.

Statistical Analysis

All data were tested for normality using the UNIVARIATE procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC). The means were calculated and statistically analyzed using the GLM procedure of SAS (version 9.4; SAS Institute Inc., Cary, NC).

The housing system and age were the fixed factor. The housing system and age, as well as their interactions, were also included in the model. Comparisons among means were made using the Tukey test. The results were expressed as the least square mean and standard error of mean with a P value < 0.05 considered statistically significant.

RESULTS

Effect of Housing System and Age on Egg Quality and Quantity

Different types of housing systems had no significant effect on the shape index, shell weight, shell breaking strength, and yolk color (Table 2). Compared with the quality of eggs in the CC group, weight, albumen height, and Haugh unit were higher in the FF group ($P \leq 0.05$), while the yolk weight was lower ($P < 0.05$). FF hens' egg quantity was higher than that of CC hens ($P < 0.01$). The effect of age on egg quality traits was significant ($P < 0.05$), except for shape index. The highest egg weight, albumen height, shell weight, yolk weight ($P < 0.001$), and Haugh unit ($P < 0.05$) were found at 57 wk. The highest shell breaking strength ($P < 0.05$) and the highest yolk color ($P < 0.001$) were found at 32 and 49 wk, respectively, and the maximum egg quantity was shown at 41 and 49 wk ($P < 0.01$). There was an interaction effect between the housing system and age on egg quality, egg weight, albumen height, Haugh unit, yolk color, and egg quantity ($P < 0.01$). However, no

Table 2. Effect of housing system, age, and their interaction on egg quality and quantity.

HS	Egg weight (g)	Shape index	Albumen height (mm)	Shell weight (g)	Yolk weight (g)	Haugh unit	Breaking strength (kg)	Yolk color	Egg quantity
CC	45.50^{b}	1.32	4.08^{b}	6.00	15.00^{A}	64.79^{b}	38.93	10.68	32.78^{B}
FF	46.33^{a}	1.31	4.37^{a}	5.98	14.60^{B}	68.33^{a}	40.38	10.46	49.06^{A}
SEM	0.296	0.003	0.098	0.047	0.110	1.027	0.660	0.084	0.852
Age									
32 wk	42.70^{C}	1.31	4.22^{B}	$5.69^{C,c}$	12.51^{D}	$67.55^{B,a,b}$	$41.82^{A,a}$	$10.17^{B,C,b}$	35.26^{B}
41 wk	43.73^{C}	1.32	3.92^{B}	$6.12^{A,B,a}$	14.52^{C}	63.76^{B}	$39.37^{a,b}$	10.13^{C}	50.36^{A}
49 wk	47.53^{B}	1.31	4.05^{B}	$5.92^{B,C,b}$	15.70^{B}	64.93^{b}	$37.75^{B,b}$	11.40^{A}	49.32^{A}
57 wk	49.70^{A}	1.33	4.73^{A}	$6.23^{A,a}$	16.45^{A}	$69.99^{A,a}$	$39.69^{a,b}$	$10.58^{B,a}$	28.75^{B}
SEM	0.419	0.005	0.138	0.066	0.156	1.452	0.934	0.119	1.098
HS	0.050	NS	0.034	NS	0.009	0.016	NS	NS	<0.001
Age	<0.001	NS	<0.001	<0.001	<0.001	0.013	0.024	<0.001	<0.001
HS × age	0.004	NS	<0.001	NS	NS	0.001	NS	<0.001	0.016

Means within a column followed by different superscript letters differ significantly; NS: $P > 0.05$; $^{A,B,C,D}P < 0.01$; $^{a,b}P < 0.05$.
Abbreviations: CC, conventional cage; FF, flatting on the floor; HS, housing system.

interaction between housing systems and age was observed for shape index, shell weight, yolk color, and shell breaking strength ($P > 0.05$).

Effect of Housing System and Age on Slaughtering Performance

Different types of housing systems had a significant effect only on the breast meat weight and percentage; however, there was no significant effect on other slaughtering performances (Table 3). The breast meat weight and percentage were higher in the FF group (140.93 g and 17.62%, respectively) than those in the CC group (128.68 g and 15.17%, respectively). For slaughtering performance, the heaviest live body weight and carcass weight were found at 57 wk of age ($P < 0.01$). The highest semieviscerated weight percentage ($P < 0.01$), eviscerated weight ($P < 0.05$), and breast and thigh meat weight ($P < 0.05$) were observed at the age of 49 wk. The highest eviscerated weight percentage and thigh meat were observed at the age of 41 wk and 32 wk, respectively ($P < 0.01$). The interaction (housing system × hen age) was only significant in the semieviscerated weight percentage ($P < 0.05$) and eviscerated weight percentage ($P < 0.05$, Table 3).

Effect of Housing System and Age on Meat Quality

Results of breast meat quality characteristics are provided in Table 4. Only the L* parameter ($P < 0.01$) of the breast was lower in the FF group than in the CC group. The moisture loss rate, shearing force, pH, a* value, and b* value had no significant difference between the 2 housing systems ($P > 0.05$). The overall mean moisture loss rate measured in the experimental period was very similar in 49 and 57 wk, which was lower than that in 32 wk ($P < 0.05$) and significantly lower than that in 41 wk ($P < 0.01$). The lowest L* value was found at 32 wk ($P < 0.01$), and the lowest value of b* and shearing force was observed at 49 and 41 wk (both $P < 0.01$), respectively. The highest value of a* and pH was shown at 49 and 57 wk (both $P < 0.01$), respectively. It is clear that none of the breast meat quality characteristics were influenced by the interaction of housing systems and hen's age ($P > 0.05$).

The effects of the housing system and hen's age on thigh meat quality are shown in Table 5. Only the FF hens' L* value was higher than CC hens' ($P < 0.05$). The moisture loss rate, shearing force, pH, and a* and b* value had no significant difference between the

Table 3. Effect of housing system, age, and their interaction on slaughtering performance.

HS	LW (kg)	CW (kg)	SEW (kg)	SEP (%)	EW (kg)	EP (%)	BMW (g)	BMP (%)	TMW (g)	TMP (%)
CC	1.40	1.29	1.06	78.64	0.86	66.11	128.68^{b}	15.17^{B}	169.13	19.82
FF	1.35	1.23	1.03	79.99	0.83	66.73	140.93^{a}	17.62^{A}	160.67	19.82
SEM	0.037	0.032	0.030	0.852	0.024	1.034	4.840	0.334	5.117	0.285
Age										
32 wk	$1.20^{B,b}$	1.08^{B}	0.95	$79.18^{A,b}$	$0.80^{b,c}$	$66.64^{A,b}$	$131.01^{a,b}$	16.47	$165.18^{a,b}$	$20.71^{A,a}$
41 wk	1.40^{a}	1.27^{A}	1.03	81.34^{A}	$0.78^{B,c}$	$70.54^{A,a}$	125.12^{b}	16.10	146.64^{b}	$18.90^{B,b}$
49 wk	$1.41^{A,a}$	1.31^{A}	1.09	$83.60^{A,a}$	$0.91^{A,a}$	69.51^{A}	148.28^{a}	16.37	182.89^{a}	20.12^{a}
57 wk	$1.50^{A,a}$	1.39^{A}	1.10	73.16^{B}	$0.89^{a,b}$	59.02^{B}	147.27^{a}	16.65	174.25^{a}	$19.55^{a,b}$
SEM	0.052	0.047	0.043	1.205	0.033	1.034	6.724	0.473	7.970	0.404
HS	NS	NS	NS	NS	NS	NS	0.026	<0.001	NS	NS
Age	0.002	0.001	NS	<0.001	0.018	<0.001	0.045	NS	0.020	0.024
HS × Age	NS	NS	NS	0.044	NS	0.021	NS	NS	NS	NS

Means within a column followed by different superscript letters differ significantly; NS: $P > 0.05$; $^{A,B}P < 0.01$; $^{a,b,c}P < 0.05$.
Abbreviations: BMP, breast meat percentage; BMW, breast meat weight; CW, carcass weight; CP, carcass percentage; EW, eviscerated weight; EP, eviscerated percentage; LW, live weight; SEW, semieviscerated weight; SEP, semieviscerated percentage; TMP, thigh meat percentage; TMW, thigh meat weight.

Table 4. Effect of housing system, age, and their interaction on breast meat quality.

HS	Moisture loss rate (%)	L*	a*	b*	Shearing force (N)	pH
CC	24.15	51.79^{A}	0.82	8.73	31.71	5.89
FF	24.81	49.19^{B}	1.46	7.65	33.56	5.92
SEM	0.747	0.589	0.391	0.530	3.434	0.056
Age						
32 wk	$23.08^{B,a}$	48.13^{B}	0.007^{B}	9.74^{A}	48.58^{A}	-
41 wk	35.76^{A}	-	-	-	18.61^{C}	5.72^{B}
49 wk	19.27^{C}	51.24^{A}	4.05^{A}	6.14^{B}	-	5.66^{B}
57 wk	$20.17^{B,C,b}$	52.10^{A}	-0.65^{B}	8.69^{A}	30.71^{B}	6.31^{A}
SEM	1.000	0.721	0.479	0.649	4.206	0.068
HS	NS	0.005	NS	NS	NS	NS
Age	<0.001	0.002	<0.001	0.002	<0.001	<0.001
HS × age	NS	NS	NS	NS	NS	NS

Means within a column followed by different superscript letters differ significantly; NS: $P > 0.05$; $^{A,B,C}P < 0.01$; $^{a,b}P < 0.05$.

- = Data were not measured.

Abbreviations: a*, redness; b*, yellowness; CC, conventional cage; FF, flattening on floor; HS, housing system; L*, lightness.

2 housing systems ($P > 0.05$). The moisture loss rate evaluated in the period of 41 wk was significantly higher than that in the other 3 ages ($P < 0.01$). L* values at 49 wk and 57 wk were similar and lower than that at 32 wk ($P < 0.01$). The lowest shearing force was observed at the age of 41 wk ($P < 0.05$), and the highest value of a* was observed at the age of 49 wk ($P < 0.01$). The pH at 57 wk was higher than that at 41 wk. However, the b* parameter was not affected by hens' age ($P > 0.05$). The interaction of housing systems with hens' age had a significant effect on pH only ($P < 0.05$). On the contrary, the interaction had no significant effect on other traits of thigh meat quality ($P > 0.05$).

Effect of Housing Systems and Age on Bone Quality

Femur weight, tibia weight, and femur breaking strength of FF hens were similar to those of CC hens ($P > 0.05$, Table 6), while FF hens had higher humerus weight ($P < 0.01$), greater humerus breaking strength ($P < 0.01$), and greater tibia breaking strength ($P < 0.05$). The breaking strength of femur was affected by hens' age ($P < 0.05$). Meanwhile, the highest femur breaking strength was found at 32 and 57 wk of age ($P < 0.05$). However, the effect of interaction between housing systems and hen age on bone quality was not significant ($P > 0.05$).

DISCUSSION

Egg weight, an important trait of egg quality and grading, is determined without breaking eggs. In the present study, egg weight quantity of birds kept on the floor was higher than that of caged birds, which is consistent with the finding of the previous studies (Vits, et al., 2005; Hidalgo, et al., 2008; Singh, et al., 2009). However, no significant difference of egg weight among backyard systems, organic systems, and intensive cultivation systems indicated that egg weight is not always higher for FF systems (Krawczyk, 2009). This study showed that egg production performance of FF hens was higher than CC hens. No remarkable differences in egg production and hen egg production were seen for Lohmann Brown hens (Ahammed, et al., 2014) and Shaver White hens (Neijat et al., 2014),

Table 5. Effect of housing system, age, and their interaction on thigh meat quality.

HS	Moisture loss rate (%)	L*	a*	b*	Shearing force (N)	pH
CC	19.86	41.86^{b}	16.30	8.26	33.60	6.07
FF	22.01	45.78^{a}	15.24	8.60	38.74	6.01
SEM	1.037	1.004	0.766	0.464	2.362	0.059
Age						
32 wk	20.13^{B}	50.81^{A}	7.33^{B}	7.99	$36.30^{a,b}$	-
41 wk	28.62^{A}	-	-	-	30.61^{b}	5.89^{b}
49 wk	16.64^{B}	41.59^{B}	$21.62^{A,a}$	8.08	-	$6.06^{a,b}$
57 wk	18.28^{B}	39.06^{B}	$18.36^{A,b}$	9.21	41.61^{a}	6.17^{a}
SEM	1.445	1.230	0.938	0.569	2.893	0.073
HS	NS	0.011	NS	NS	NS	NS
Age	<0.001	<0.001	<0.001	NS	0.042	0.020
HS × age	NS	NS	NS	NS	NS	0.012

Means within a column followed by different superscript letters differ significantly; NS: $P > 0.05$; $^{A,B}P < 0.01$; $^{a,b}P < 0.05$.

- = Data were not measured.

Abbreviations: a*, redness; b*, yellowness; CC, conventional cage; FF, flattening on floor; HS, housing system; L*, lightness.

Table 6. Effect of housing system, age, and their interaction on bone quality.

HS	Humerus weight (g)	Femur weight (g)	Tibia weight (g)	Humerus breaking strength (kg/kg)	Femur breaking strength (kg/kg)	Tibia breaking strength (kg/kg)
CC	3.52^{B}	7.13	8.53	8.85^{B}	13.11	13.67^{b}
FF	4.49^{A}	7.28	8.62	15.75^{A}	15.42	16.76^{a}
SEM	0.240	0.237	0.237	0.724	0.878	0.875
Age						
32 wk	-	-	-	13.73	16.41^{a}	17.41
41 wk	4.23	7.09	8.65	12.71	12.02^{b}	13.95
49 wk	4.02	7.46	8.94	11.27	11.88^{b}	13.10
57 wk	3.76	7.06	8.14	11.48	16.75^{a}	16.39
SEM	0.294	0.290	0.291	1.024	1.242	1.238
HS	0.009	NS	NS	<0.001	NS	0.018
Age	NS	NS	NS	NS	0.008	NS
HS × age	NS	NS	NS	NS	NS	NS

Means within a column followed by different superscript letters differ significantly; NS: $P > 0.05$; $^{A,B}P < 0.01$; $^{a,b}P < 0.05$.
- = Data were not measured.
Abbreviations: CC, conventional cage; FF, flattening on floor; HS, housing system.

whereas some researchers have reported that egg quantity was higher in CC systems than in alternative systems (Mugnai et al., 2009, Anderson, 2010). This different response of laying hens might be partly due to the breeds of indigenous or commercial chickens, and the present results clarified the Taihang chickens were more suitable for FF systems. In addition, yolk weight was significantly affected by housing systems and increased significantly over time, while no significant difference was found for the interaction of these 2 factors. Similarly, a common conclusion was found for yolk weight of white Babcock layers reared in conventional caged systems (Basmacioglu and Ergul, 2005). Contrastingly, free-range systems showed the highest level of yolk weight in Xianju chickens (Dong, et al., 2017). Different responses of yolk weight probably due to housing systems might be caused by the enrichment of alfalfa and trifolium mixture in the free-range system open area. Albumen height and Haugh unit were greater for eggs produced in the FF housing system than for those produced in the CC housing system. Conversely, as previously reported, albumen height of hens reared in cages was higher than that of hens reared in floor systems (Singh, et al., 2009; Jones, et al., 2014).

In the present small-scale study, almost all slaughtering traits except for breast meat weight and percentage were not influenced by housing systems, in accordance with the previous studies (Jiang, et al., 2011; Chen, et al., 2013) that included yellow-feathered chickens and Chinese yellow broilers as their experimental animals. However, the age had significant effects on slaughtering performance ($P < 0.05$ or less) except for carcass weight and breast meat percentage. Previous research observed that aviary rearing systems had better effect on breast weight than conventional cage systems (Casey-Trott, et al., 2017a); the conclusion is probably due to the permission of flight, flapping the wings, and running with the wings assisted in FF systems. In contrast, the weight and percentage of breast meat of Ross 708 broilers decreased when birds had outdoor access (Funaro, et al., 2014); the opposite conclusion reflected the differences of genetics in breeds.

Color is an important indicator of meat product. The present study revealed that the FF system contributed to better L* value of breast meat, whereas the L* value of the thigh meat was better in the CC system. Many researchers reported that the chicken meat from free-range systems showed peculiar meat characteristics in comparison with industrially reared chicken meat and that the L* of breast meat was lower in the free-range system than in the conventional cage system (Funaro et al., 2014; da Silva, et al., 2017). A probable reason was that the FF system increased the opportunity for birds to flap their wings. In addition, all traits of meat quality were affected by the age of chickens, and only the pH of the thigh was affected by the interaction of both housing system and hens' age ($P < 0.05$). As evidenced by other studies, free-range systems had no effect on meat quality including water-holding capacity, shear force, or pH (Wang, 2009).

A large number of studies have shown that laying hens are prone to have osteoporosis when kept in cages, which can directly result in loss of bone mass and lower bone strength. Bone weakness is an important issue for the egg layer industry because of the negative influence on the egg production performance and the economic profit (Gregory and Wilkins, 1989; Webster, 2004). In the present study, hens in the FF system had a higher humerus breaking strength and tibia breaking strength than hens in the CC system. The result indicated that exercises during the rearing phase could enhance bone quality. Similarly, hens kept in free-range systems had shorter tibia length, more tibia weight, and higher breaking strength than those that are kept in conventional cage systems (YilmazDikmen, et al., 2016). Similarly, bone breaking strength of hens in conventional cages was poorer than that of hens in aviary rearing systems (Casey-Trott, et al., 2017b).

CONCLUSION

In conclusion, egg quality, egg quantity, breast and thigh weight, and humerus and tibia breaking strength were higher in hens in the FF system than those of hens in the CC housing system. The egg quality, semieviscerated weight percentage, eviscerated weight percentage, and pH of the thigh over a period were affected by interactions between the housing system and age, suggesting that hens' age should be considered when using alternative housing systems. In addition, results of the the present study support a theoretical basis for the development and utilization of Taihang chickens in accordance with its FF system.

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