

GENETICS AND GENOMICS

Research Note

Phenotypic, genetic and environmental parameters for traits related to femur bone integrity and body weight at 42 days of age in a broiler population

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ABSTRACT Intense selection among broilers, especially for performance and carcass traits, currently favors locomotion problems and bone resistance. Conducting studies relating to development and growth of bone tissue in broilers is necessary to minimize losses. Thus, genetic parameters were estimated for a broiler population's phenotypic traits such as BW at 42 d of age (BW42), chilled femur weight (CFW) and its yield (CFY), and femur measurements: calcium, DM, magnesium, phosphorus, and zinc content; breaking strength; rigidity; length; and thickness. Variance components were estimated through multitrait analyses using the restricted maximum likelihood method. The model included a fixed group effect (sex and hatch) and

additive and residual genetic random effects. The heritability estimates we obtained ranged from 0.10 ± 0.05 to 0.50 ± 0.08 for chilled femur yield and BW42, respectively, and indicated that the traits can respond to the selection process, except for CFY, which presented low-magnitude heritability coefficients. Genetic correlation estimates between breaking strength, rigidity, and traits related to mineral content indicated that selection that aims to improve the breaking strength resistance of the femur is highly correlated with mineral content. Given the genetic correlation estimates between BW42 and minerals, it is suggested that in this population, selection for BW42 can be performed with greater intensity without affecting femoral integrity.

Key words: body weight, femur mineral content, genetic correlation, quantitative trait, selection

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INTRODUCTION

The competitiveness of broiler lineages has resulted from intense selection for body performance and carcass traits. However, selection that has favored rapid growth among these broilers has also caused locomotion problems and reduced bone resistance. Skeletal disorders occur because the skeletal system is not supporting the increased BW (Julian, 2005; Dibner et al., 2007). Although skeletal disorders occur from the beginning of the animal's life (when bones begin to undergo mineralization processes), locomotion problems are noticed later, closer to slaughter age (Oviedo-Rondón et al., 2008; Ferket et al., 2009). The poultry industry is concerned with problems related to bone integrity, mainly because poorly developed and fractured carcasses lead to high discard rates at slaughterhouses. The objective

of the present study was to provide support for the selection process by estimating the genetic, phenotypic, and environmental parameters for BW at 42 d of age and traits related to femoral integrity in a broiler population.

MATERIAL AND METHODS

Experimental Population and Data Gathering

The study used the database of the reference population of broilers called TT from the Poultry Breeding program of Embrapa Swine and Poultry in Concórdia, SC, Brazil. The TT reference population originated from the expansion of a paternal broiler line called TT by mating 20 males with 92 females (1:5) in 5 hatches that produced approx. 1,500 progenies, used in this study.

The birds were kept in pens until 35 d of age, and from 35 to 41 d, they were housed in individual cages to

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evaluate feed conversion. The animals were tagged with metal rings for pedigree control. Feeding management consisted of an initial ration from 1 to 21 d (21% CP and 3,150 kcal ME), a growth ration from 22 to 34 d (20% CP and 3,200 kcal ME), and a final ration from 35 to 41 d (18.5% CP and 3,200 kcal ME). At 42 d, 1,453 birds were slaughtered after fasting for 6 h, and femoral bones were collected, weighed, and stored in a freezer at -20°C . This material was measured to assess bone structure traits.

Phenotypic Traits

The following phenotypic traits were evaluated: BW at 42 d of age (**BW42**), chilled femur weight (**CFW**) and its yield (**CFY**), and femur measurements: calcium (**CA**), DM, magnesium (**MG**), phosphorus (**P**), and zinc content (**ZN**); breaking strength (**FEMBS**); rigidity (**RG**); length (**FEML**); and thickness (**FEMT**).

To evaluate femur traits, the broilers' femurs were subjected to a temperature of 0°C for 24 h; en the remaining flesh, fat, and cartilage were manually removed; and the bones were evaluated in relation to their moist weight, length between extremities, and thickness in the middle area. After these measurements were made, the femurs were placed in plastic bags, labeled, and stored at -20°C .

Femurs were kept at 0°C for 48 h and then left at room temperature for approx. an hour to determine flexural strength. The bending test was performed on a TA-XTPlus Texture Analyzer (Texture Technologies Corporation, Hamilton, MA, USA), using the probe 3-point bending rig (HDP/3PB), HDP/90 platform, and 50 kg load cell. The probe touched the sample with a programmed weight force (trigger force) of 5 kg. This force was applied to the central area (diaphysis) to determine the flexural strength and rupture modulus. After breaking, the femoral fragments were placed in plastic bags, labeled, and stored at 0°C for 24 h to determine DM and ash.

To determine DM percent, the femur fragments that had been stored at 0°C were placed at room temperature for approx. an hour. Subsequently, they were placed in preweighed porcelain crucibles, kept in an oven at 105°C for 16 h, placed in a desiccator until they reached room temperature, and weighed. The DM percent was determined as the ratio of the dry over the wet sample weights.

Using the bone fragments, ash was determined immediately after obtaining the DM. The samples were incinerated in a muffle for 6 h. The initial temperature was 350°C for an hour and increased gradually to 450°C for an hour and then 550°C for an hour too, and finally, to 600°C for 3 h. Next, the crucibles with the samples were left in the desiccator until they reached room temperature and then weighed. The ash percent was determined by dividing ash and dry sample weights.

To determine the mineral content, the mineral residue obtained previously from the samples was analyzed. The acid solubilization was made in Anton-Paar

Microwave 3000 (Graz, Austria) fitted with a 48MF50 rotor and M50 pressure/temperature sensor accessory following the equipment manufacturer's recommendations. Initially, a 0.1 g (± 0.0001) sample was weighed in a 50 mL perfluoroalkoxy (PFA) liners, to which was added 6 mL HCl (*aq*) 6 mol/L. The microwave oven was operated at a constant speed with a pressure rating of 0.5 bar/sec and power of 1,200 W. The heating time to reach 170°C was 15 min, and this temperature was held for an additional 15 min. After solubilization by microwave radiation, the sample solution was cooled to room temperature, and the volume was adjusted to 100 mL with ultrapure water. Then the elements were quantified in the sample solution. Quantification was performed by atomic absorption spectrometry in VARIAN SpectrAA 220 (Agilent Technologies, Santa Clara, CA, USA) equipment with spray flame monoelementares equipped with hollow cathode lamps using acetylene gas (AOAC, 1995). For data acquisition, we used the software SpectrAA 220 3.0.

Statistical Analyses

The environmental effects considered in the genetic analysis model were studied through the least squares method. The group effect (sex and hatch) was significant ($P < 0.05$) regarding the traits related to bone integrity and BW at 42 d of age. The residuals distribution and other basic assumptions for conducting the analyses of variance were ascertained using the SAS GLM procedure (Statistical Analysis System, v.9.3, Cary, NC). Standardized residuals above 3.5 or below -3.5 were excluded. Genetic parameter estimates for the traits studied were performed using the restricted maximum likelihood method (REML) in a multitrait animal model using the WOMBAT software described by Meyer (2007).

The animal model proposed for the multitrait analyses was:

$$y = Xb + Za + e$$

Where: y is the vector of the dependent variable; X is the incidence matrix for fixed effects, correlating elements from b and y ; b is the fixed effects vector (groups of animals from the same incubations and sex); Z is the incidence matrix for the direct genetic random effect, correlating elements from a and y ; a is the random effect vector for the direct additive genetic effect; and e is the residual effects vector.

RESULTS AND DISCUSSION

High phenotypic variation in the traits studied was observed through the descriptive statistics (Table 1), especially regarding RG, which presented a high coefficient of variation (41.1%). The mean estimate for BW42 found in the present study was similar (Table 1) to reports by Koiyama et al. (2014) (2.27 kg) in the Cobb 500 lineage. These studies suggest that

Table 1. Numbers of animals (N), means, SD, minimum (Min) and maximum (Max) values, and coefficients of variation (CV [%]) in multitrait analyses, observed for traits related to BW at 42 d of age and femoral integrity in a population of broilers.

Trait	N	Mean	SD	Min	Max	CV (%)
BW42 (g)	1,442	2,229	252.2	1,349	2,971	11
CFW (g)	1,410	8.6	1.4	5.0	14.5	16
CFY (%)	1,423	1.5	0.2	1.0	2.3	12
CA (g/kg)	963	313.2	36.6	181.7	602	12
DM (%)	962	51.7	3.5	36.5	62.9	7
MG (g/kg)	963	7.5	1.9	4.7	60	25
P (g/kg)	963	188.3	34.1	110	1,066	18
ZN (mg/kg)	936	374.2	45.6	159.2	560.8	12
FEMBS (kg)	930	29.5	5.9	13.4	49	20
RG (kg/mm)	906	9.2	3.8	1.1	72.7	41
FEML (cm)	1,411	7.0	0.4	7.3	9.3	5
FEMT (mm)	1,411	9.0	0.80	7.2	11.8	9

Trait: BW at 42 d of age (BW42), chilled femur weight (CFW), chilled femur yield (CFY), and femur measurements: calcium (CA), DM, magnesium (MG), phosphorus (P), and zinc (ZN) content; breaking strength (FEMBS); rigidity (RG); length (FEML); and thickness (FEMT).

Table 2. Genetic variances (σ^2_a), phenotypic variances (σ^2_p), environmental variances (σ^2_e), and heritability estimates (h^2) obtained in multitrait analyses, observed for traits related to BW at 42 d of age and femoral integrity in a population of broilers.

Trait	σ^2_a	σ^2_p	σ^2_e	h^2
BW42 (g)	17,276	34,702	17,427	0.50 (0.08)
P (g/kg)	37,379	99,227	61,848	0.38 (0.01)
DM (%)	49,356	133,949	84,590	0.37 (0.01)
MG (g/kg)	53,707	146,656	92,950	0.37 (0.01)
CA (g/kg)	25,742	70,313	44,572	0.37 (0.01)
ZN (mg/kg)	20,239	60,181	39,942	0.34 (0.02)
FEMT (mm)	1,504	4,400	2,896	0.34 (0.06)
RG (kg/mm)	52,149	164,562	112,413	0.31 (0.03)
FEMBS (kg)	45,651	148,768	103,117	0.30 (0.02)
FEML (cm)	3,811	19,154	15,343	0.19 (0.07)
CFW (g)	4,010	22,312	18,302	0.18 (0.07)
CFY (%)	1,072	9,940	8,868	0.10 (0.05)

Trait: BW at 42 d of age (BW42), chilled femur weight (CFW), chilled femur yield (CFY), and femur measurements: calcium (CA), DM, magnesium (MG), phosphorus (P), and zinc (ZN) content; breaking strength (FEMBS); rigidity (RG); length (FEML); and thickness (FEMT).

selection needs to be directed with greater emphasis on BW42 to obtain better phenotypic performance in comparison with commercial lineages.

The physical traits of the femur were studied by Applegate and Lilburn (2002) in commercial broilers at 43 d of age. They reported means estimates for FEML (7.63 cm) and FEMT (9.43 mm) similar to the ones reported in the present study. Almeida Paz et al. (2007) reported mean DM content (47.11%) closer to that found in the present study ($51.67 \pm 3.50\%$) (Table 1).

The heritability estimates obtained (Table 2) ranged between 0.10 (0.05) for CFY and 0.50 (0.08) for BW42. The heritability estimate for BW42 was higher than the ones reported by Vayego et al. (2008) (0.37 ± 0.06) and by Gaya et al. (2006) (0.24 ± 0.03). FEMBS, RG, FEMT, ZN, MG, DM, CA, and P presented moderate to high magnitude coefficients of heritability, indicating that these traits have an additive genetic component

that is sufficient to respond to the selection process with favorable genetic gains. However, the coefficient of heritability of CFY, CFW, and FEML were low in magnitude (Table 2).

According to Zhong et al. (2012), who studied divergent strains of turkeys, although the correlations between BW and the intrinsic properties of bones are unknown, BW has always been reported as a potential factor that modulates bones. Based on only the (negative) sign of the genetic correlations estimates between BW42 and the mineral content data obtained in this study (Supplementary Table S1), we could conclude that selection for heavier animals could result in lower mineral content in the femur and thus the onset of bone fractures and decreased bone strength. However, the correlations estimates are unreliable because the estimated standard errors were greater than or equal to the genetic correlations estimates.

FEMBS is a paramount trait because not only does it present an active genetic component sufficient to respond to selection (Table 2), it also is an intrinsic quality indicator for bone material and can act as a tool for correcting disorders related to bone integrity. A strong positive and favorable genetic association between FEMBS and RG, and mineral content traits indicates that selecting animals based on bone integrity traits such as FEMBS and RG will lead to animals with higher mineral content in their bones and consequently, animals with stronger bone structures and fewer bone disorders. The results observed in the present study (Supplementary Table S1) contradict results found by Runho et al. (2001), who studied differences in broiler diet P levels and their relationship to tibia breaking resistance and mineral content. They observed that higher ash and P content in bones did not correlate with a higher resistance to bone breaking.

The present study found no evidence that selection for body weight at 42 d of age would lead to mineralization differences in femoral constituent and morphometric traits in this population. Selecting for breaking strength and rigidity instead will result in higher femoral mineral content and consequently animals that are more resistant to bone disorders.

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SUPPLEMENTARY DATA

Supplementary Table S1. Genetic correlations (above diagonal) and environmental correlations (below diagonal) with their respective SE estimated for traits related to BW at 42 d of age and femoral integrity in a broiler population.

Supplementary data is available at [PSA Journal online](#).

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