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EFFECT OF STRAIN AND AGE ON BONE INTEGRITY OF COMMERCIAL BROILER CHICKENS

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Abstract: Skeletal disorders and leg problems cause varying degree of economic losses in broiler birds. This study was aimed at investigating the effect of strain and age on bone integrity of some broiler strains available to poultry farmers in Nigeria using morphometric and mechanical indices. Four hundred (400) one-day old chicks comprising of 100 each of Arbor Acre (AA), Hubbard (HB), Marshal R (MR) and Marshal Y (MY) strains were raised for a period of 42 days. The birds were fed similar diet at the starter and finisher phases. At the end of each week, 4 birds were randomly selected from each of the group and sacrificed, femur and tibiotarsal (left and right) bones were obtained from each of the bird for analyses. Body Weight (BW), Femur Weight (FW), Femur Length (FL), Tibia Weight (TW), Tibia Length (TL), Weight/Length Index (WLI), Diaphysis Diameter (DD), Relative Bone Density (RBD), Robusticity Index (RBT) and Tibiotarsal Index (TI) were recorded each week. Mechanical parameters were evaluated using the universal testing machine: Force, Moment of Inertia (MI), Stress and Modulus of Elasticity (ME). Mean values of Mechanical indices of the femur bone was significant at Day 42 with AA Strain having the least mean value of force and MY Strain with highest value of ME. The results of tibiotarsal bone revealed that MY Strain had highest mean value of force, ME and Stress across the weeks. Conclusively, Marshal Y strain was found to have better bone integrity than the other groups

Key words: Broiler Chicken, Bone integrity, Femur bone, Tibiotarsal bone, Morphometric mechanical

Introduction

In broilers, fast growth rates are generally correlated with musculoskeletal weakness since the development of bone in these animals is not well organized, less dense and more porous than slow growing ones (*Bennett, 2008; Williams et al., 2004*). Thus, tibia bones are strongly loaded by muscles and more prone to various mineralization disorders and even fractures (*Charuta et al., 2011*).Market age poultry often suffer from lameness and bone deformities, which can cause bone breakage during catching and transportation and which create problem during processing. Around one third of broilers that died during transportation to processing plants were found to have died from hemorrhaging associated with femur dislocation (*Gregory and Wilkins, 1992*). In addition, skeletal deformities slow down automatic processing lines and increase the requirement of manual trimming during deboning (*Oviedo-Rondón, 2007*). Another concern that arises from leg disorders at the processing plant is food quality. Bone fragility and porosity are correlated with the incidence of bone fragments in deboned meat products and discolouration of meat adjacent to bone due to the leaching of blood (*Gregory and Wilkins, 1992*). Moreover, lame broilers that spend more time lying in the litter (*Oviedo-Rondón et al., 2009*) have more breast blisters, scratches, inflammatory processes, and muscle atrophy (*Julian, 1998; Vaillancourt and Martinez, 2002*). A secondary consequence of poor leg health is the increment of contaminants carried by lame broilers into the processing plant which threatens food safety (*Oviedo-Rondón, 2007*). All these carcass quality defects plus emaciation originates when broilers cannot walk to feeders and drinkers, which results in increased meat losses due to condemnations of carcasses (*Pattison, 1992; Yogaratnam, 1995*).There are different strains of broiler birds available to commercial poultry farmers in Nigeria, these constitute different broiler genotypes, with implications on differences in their performance characteristics such as growth rate, weight gain, feed utilization and efficiency, liveability, meat quality, skeletal abnormalities and bone integrity even when raised under the same environmental condition. This can be attributed to the differences in animal expression as a result of differences in both their genetic make-up and environmental factors. Therefore this study was aimed at investigating the bone integrity of some strains of broiler chicken available to commercial poultry farmers in Nigeria.

Materials and Methods

Four hundred (400) unsexed One-day-old broiler chickens comprising of 100 each of Arbor Acre, Hubbard, Marshal R and Marshal Y strains were used for this study. The strains were allotted into four different groups to constitute the treatment. Each group consisted of two (2) replicate pens with fifty (50) birds per pen. The experiment lasted for 42 days, during which bone samples (tibia and femur) were collected on weekly basis starting from the Day 21. All the necessary management practices were strictly adhered to. At the end of each week, four (4) birds were randomly selected from each treatment, weighed and sacrificed.

Tibiotarsal and femur (right and left) were removed from individual broilers and de-fleshed by hand, the bone caps were removed by hand and tibial and femur bones without muscles, ligament and tendons were obtained.The right and left tibiae as well as femur were then weighed and total length and bone shaft widths measured by means of a digital caliper with an accuracy of 0.001 mm according to the method described by (*Zhang and Coon, 1997*). The left tibiotarsal and femur bones were individually sealed in plastic bags to minimize moisture loss, and stored in a freezer at -18 ^{0}C until the end of the seventh week for mechanical testing**.** Morphometric measurements were then carried out on the right tibiotarsal and femur bones with the aid of a digital caliper. Parameters measured on the two bones include: Tibia weight (g), femur weight (g), Tibia length (mm), femur length (mm), Tibiotarsi Weight/Length index (g/mm), femur weight/length index (g/mm), Robusticity index, Diaphysis diameter(mm), Tibiotarsal index, relative bone density.

- Robusticity index, tibiotarsal index, relative bone density were calculated using the following formula respectively.
- Robusticity index = bone length/ cube root of bone weight (*Tohid et al., 2014*)
- Tibiotarsal index = diaphysis diameter – medullary canal diameter/diaphysis diameter × 100 (*Tohid et al., 2014*)
- Relative bone density = bone weight/ live body weight x 100 (*Charuta et al., 2013*).

Measurements of the bones mechanical properties were taken by means of the three-point bending test, using a universal testing machine. After breaking, diameter measurements were made inside and outside the mid-shaft of the bone both perpendicular and parallel to the direction of the applied force to calculate the area moment of inertia, stress as well as modulus of elasticity as described by (*Kocabagli, 2001*).

Statistical Analysis: The data on tibia and femur bone parameters were analyzed as a completely randomized design using the analysis of variance procedure of the SAS 9.2. Differences between means were compared using the Duncan Multiple Range Test (DMRT).

Results

The effect of strain on morphometric and mechanical parameters of femur and tibiotarsal bones at Day 42 are presented in Tables 1 and 2 respectively.

Table 1. Morphometric and Mechanical Parameters of Femur Bone at Day 42

Parameters	Arbor Acre	Hubbard	Marshal R	Marshal Y
Body weight(g)	1798.00±167.33	1720.75±113.96	1687.75±24.04	1643.75±108.63
Femur weight(g)	7.73±0.67	7.94±0.76	8.33±0.48	7.78±0.50
Femur length(mm)	65.95±1.10	67.34±1.91	69.69±1.09	67.45±0.69
Weight/length index	0.11±0.009	0.117±0.009	0.119±0.006	0.115±0.007
Robusticity index	33.47±0.69	33.90±0.33	34.44±0.59	34.13±0.83
Diaphysis diameter(mm)	8.12±0.25	8.76±0.14	8.93±0.49	8.63±0.29
Relative bone density	0.43±0.02	0.46±0.02	0.49±0.03	0.48±0.03
Force(Kg)	12.01^{b}±0.34	12.75^{a}±0.06	12.90^{a}±0.16	12.91^{a}±0.07
Moment of inertial	0.02±0.003	0.03±0.005	0.002±0.003	0.02±0.003
Stress (kg/cm^2)	156.17±20.47	196.74±19.75	204.05±25.40	216.54±32.91
Modulus of Elasticity (kg/cm^2)	6213.23^{b}±538.64	7061.11^{ab}±1119.69	8287.79^{ab}±915.02	9459.10^{a}±448.94

a, b Means with the same superscript across the rows were not significantly

Table 2. Morphometric Parameter of Tibia Bone at Day 42

Parameters	Arbor Acre	Hubbard	Marshal R	Marshal Y
Body weight(g)	1798.00±167.33	1720.75±113.96	1687.75±24.04	1643.75±108.63
Femur weight(g)	10.34±0.82	10.25±0.60	10.38±0.53	9.89±0.74
Femur length(mm)	89.30±1.30	91.29±1.67	92.48±2.04	91.36±0.62
Weight/length index	0.12±0.008	0.11±0.007	0.11±0.005	0.11±0.008
Robusticity index	41.12±0.68	42.12±0.95	42.45±0.88	42.73±1.26
Diaphysis diameter(mm)	7.87±0.25	8.43±0.17	8.28±0.28	7.81±0.48
Tibiotarsal index	34.68±1.61	30.24±2.10	26.67±3.92	25.19±2.26
Relative bone density	0.58±0.01	0.60±0.03	0.62±0.04	0.60±0.04
Force(Kg)	11.67d±0.10	12.06c±0.08	12.54b±0.10	13.10a±0.11
Moment of inertial	0.02±0.00	0.02±0.00	0.02±0.00	0.02±0.00
Stress (kg/cm^2)	239.08b±12.10	270.43b±2.47	249.94b±1.89	325.73a±27.05
Modulus of Elasticity (kg/cm^2)	10652.00b±1227.32	12534.99b±415.27	12661.84b±901.45	16655.30a±1289.97

a, b, c, d Means with the same superscript across the rows were not significantly different

Discussion

The bone weight/ bone length index is an index of bone density (*Seedor et al., 1991*), the higher the bone weight/ bone length index, the denser is the bone (*Monteagudo et al., 1997*), on the contrary, low Robusticity index indicates a strong bone structure (*Reisenfeld, 1972*). The results obtained at Day 21, 28 and 35 for both bone types in the parameters of Body Weight, Femur Weight, Femur Length, Weight/Length Index and Relative Bone Density did not reveal any significant differences across all the stains. This implied that the rate of weight gain in all the broiler strains at this stage were similar which resulted in their corresponding tibia and femur weight and length. However, Arbor Acre had the least robusticity index and a slightly higher value of relative bone density in the femur and tibiotarsal bones, this may implied that this strain had a better bone mineralization and density than other strains at this age. This may likely be attributed to the shorter length of the bone of Arbor Acre strain as compared to the other groups. The result of relative bone density revealed that Marshal Y had a slightly denser bone structure as adjudged by its slightly higher value for this parameter. The strain difference was in tandem with the report of (*Vitorović et al., 2008*) who reported strain differences in ninety-one day old Master Gris, Red Bro, Farm Q and Hubbard Classic strains of broiler chickens in the parameters of Weight, Length, Breaking Force, Cross-Sectional Diaphysis Area, Cross-Sectional Medullary Area, Cross-Sectional Cortical Area.

Arbor Acre strain had the least mean value of Robusticity index and relative bone density with Marshal Y having a higher mean value of these parameters in the two bone types. Femur and tibiotarsal bone parameters increased arithmetically as the birds' age suggesting possible positive correlation between the parameters and the age of the bird. This is in tandem with the report of (*Krupski and Tatara, 2007*) that the values of densitometric, morphometric and mechanical bone parameters in mid-tibia increased with the age of the birds.

The values of stress parameters obtained from femur bones revealed that there were no significant differences but Marshal Y Strain had the highest mean value with Arbor Acre Strain having the least across the weeks. The results of tibiotarsal bones however indicated that there were significant differences in the mean value which is consistent with the femur bone, suggesting a better bone integrity of Marshal Y Strain compared to others. According to (*Lott et al., 1980*), bone strength is measured as required force (in Kg) to break a bone. The results of Force parameters revealed that there were no significant differences across the strain in the femur bone at Day 21 and 28 but the Day 42 result showed a significant higher mean value in the Marshal Y Strain compared to others suggesting that more The force required to break the bones of Marshal Y Strain was higher than that required for others, hence strong bone structure of this strain, similar conclusion was achieved for the tibiotarsal bone. *Patterson et al. (1986)* pointed out that stress and modular elasticity are more appropriate terms to describe bone strength with respect to different weight and length measures of bones at different bird species. *Rath et al. (2000)* also reported that modulus of elasticity describes bone hardness and its constitutional materials while yield stress is associated with only bone hardness and more hardness of a bone is related to a greater value of modular elasticity. In line with this postulations, it was observed that significant higher values of Modulus of Elasticity were recorded in the Marshal Y strain with the least value in the Arbor Acre Strain suggesting that the bone of Marshal Y Strain are stronger and less prone to breakage than the other strains.

Conclusion

This study indicated that there were strain differences in the morphometric and mechanical parameters of long bone of pelvic limbs of broiler chickens with

Marshal Y strain displaying a better bone integrity index as evident in all the indices adopted in this study.

Uticaj linije i starosti na integritet kostiju komercijalnih brojlerskih pilića

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Skeletni poremećaji i problemi sa nogama uzrokuju različite stepene ekonomskih gubitaka u odgoju brojlerskih pilića. Ova studija je imala za cilj da ispita uticaj linije i starosti na integritet kosti nekih linija brojlera koje su na raspolaganju odgajivačima živine u Nigeriji, koristeći morfometrijske i mehaničke indekse. Četiri stotine (400) jednodnevnih pilića od kojih je po 100 bilo Arbor Acre (AA), Hubbard (HB), Marshal R (MR) i Marshal I (MI) linija, su odgajani u periodu od 42 dana. Pilići su hranjeni sličnim načinom ishrane u starter i finišer fazi. Na kraju svake nedelje, po 4 pileta je nasumično odabrano iz svake grupe i žrtvovano, kako bi se butne kosti i tibiotarzalne kosti (leva i desna) svakog brojlera koristile za analize. Telesne težine (BW), težina femura (FW), dužina femura (FL), težina tibije (TW), dužina tibije (TL), Indeks težina/dužina (WLI), prečnik dijafize (DD), relativna gustina kostiju (RBD), indeks robustnosti (RBT) i tibiotarzalni indeks (TI) su evidentirani svake nedelje. Mehanički parametri su procenjeni korišćenjem univerzalne mašine za testiranje: sila loma, moment inercije (MI), stresa i modula elastičnosti (ME). Srednje vrednosti mehaničkih indeksa butne kosti su bile značajne u uzrastu od 42 dana sa AA linijom sa najmanjim srednjim vrednostima sile loma i MY linija sa najvećom vrednošću ME. Rezultati za tibiotarzalne kosti otkrili su da je MY linija imala najviše srednje vrednosti sile loma, ME i stresa tokom celog perioda. Konačno, utvrđeno je da je Marshal I linija imala bolji integritet kostiju od ostalih grupa.

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