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Multi-trait animal model analysis of body weight and linear traits in Nigerian local chickens: A selection index approach

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ABSTRACT

This study evaluates the growth performance and linear measurements of Nigerian local chickens, utilizing a multi-trait animal model and selection index approach to enhance breeding strategies and from 6 to 12 weeks of age, focusing on body weight, body length, shank length, and wing length. Data summary statistics include mean, standard deviation, minimum, maximum values, and coefficient of variation (CV%) across various traits. This reveals a consistent growth trend with body weight increasing from 257.98g at 6 weeks to 620.75g at 12 weeks. Low standard deviations at later ages indicate a uniformity in size and weight, influenced by genetic factors and management practices. However, variability in weights, especially at 8 weeks, suggests genetic and nutritional diversity within the flock. Linear measurements similarly show significant growth, with body length rising from 25.91 to 37.45cm. The heritability estimates for body weight and linear traits indicate moderate heritability, suggesting potential for genetic improvement through selective breeding. Variance analyses reveal high additive genetic variance at 6 weeks, reflecting the impact of genetic factors on growth. By 12 weeks, variances decline, suggesting stabilization in growth influences. Correlations between traits remain strong at earlier ages but weaken by 12 weeks, with negative correlations emerging for body weight and body length, indicating potential shifts in resource allocation as the chickens mature. Overall, the findings emphasize the importance of genetic and environmental factors in enhancing the growth and productivity of Nigerian local chickens, providing critical insights for future breeding strategies.

Keywords: Genetic parameters; genetic model; selection index; heritability

INTRODUCTION

Most Nigerians have an acute shortage of animal protein in their diets. This has been caused by the low supply and high cost of conventional animal proteins such as beef, pork, goat meat, poultry, egg, and milk due to unstable exchange rates, unfavorable government economic decisions, and lack of accountability in the implementation of government policies have made livestock products more expensive in recent times and animal products do not reach consumers at affordable and reasonable prices (Ade *et al.*,2023). This resulted in the

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inability to consume the recommended 63 g of domestic animal protein per capita recommended by FAO (2022). Nigerian local chicken has been identified as the cheapest source of animal protein among farm animals in Nigeria due to its prolificacy, adaptability, and availability in our environment. Another advantage consumers claim is the good taste and flavor of eggs and meat compared to commercial chickens (Udeh and Ighobesuo 2023). Although the local chicken has been described as a low producer in terms of meat and egg production (40-80 eggs per bird per year under an extensive management system), studies on the development of the local chicken as a potential layer have shown significant improvement in egg production traits of the birds under improved management systems (Nwosu *et al,* 1985; Omeje and Nwosu, 1983; Tule, 2005; Oleforuh-Okoleh 2010). Nwosu and Omeje (1985) noticed that the local chicken was genetically able to produce 128 eggs per bird per year.

Body weight (BW) is defined as a function of the animal's framework or size and condition, which is regarded as the most important element influencing egg size (Robinson and Sheridan, 1982; Abdullah, 2020). Genetic variation and environmental variables affecting individuals can cause BW variance within a flock (Hermiz and Abdullah, 2020). Chicken growth and fitness features, like other economically relevant qualities, are controlled by several genes; therefore, knowing the genetic control of development in chickens will provide an opportunity for genetic enhancement of productive performance and physiology (Khobondo *et al.,* 2015). Growth can be thought of as a direct fitness feature that improves productive efficiency and so lowers production costs (Mohammed, 2020). The poultry producer seeks birds of a minimum dimension and weight to maximize the production of standard-sized eggs at an economical rate while maintaining market carcass value after the production period (Oleforuh-Okoleh, 2010).

Linear body measurements are important features in livestock breeding, particularly poultry because they predict an animal's growth potential, health, and overall performance. These metrics give measurable data that can help influence selection decisions, resulting in increased productivity and profitability. The use of multi-trait animal models is an advanced technique for genetic study, especially when dealing with numerous linked traits (Ayalew *et al.,* 2017). These models account for the intricate interactions between several variables and aid in the simultaneous assessment of genetic parameters for body weight and egg production (Jannoune *et al.,* 2015). By combining data from several traits, these models provide a more thorough understanding of their genetic architecture and allow breeding techniques to be optimized to achieve targeted increases in both traits at the same time (Lippert *et al.,* 2014).

The selection index is an effective tool in genetic improvement programs because it allows for the selection of individuals based on a combination of features rather than a single attribute (Miyumo, 2017). This method combines the genetic and economic weights of numerous variables to maximize overall breeding goals (Sánchez *et al.,* 2016). For Nigerian indigenous chickens, using a selection index that combines body weight and egg production can increase genetic gains more efficiently than choosing each characteristic separately (Ogbu and Nwosu, 2017). It allows breeders to focus on specific breeding goals while considering trait trade-offs and interactions (Oleforuh-Okoleh, 2010). The purpose of this work is to determine genetic factors for body weight and egg production features in Nigerian local chickens using a multi-trait animal model and selection index. By doing so, the study hopes to provide vital insights into the genetic underpinnings of these qualities and develop a robust selection technique for use in breeding programs. The major goal is to increase the productivity and performance of Nigerian local chickens, which would improve the livelihoods of poultry farmers and contribute to the sustainability of poultry farming in Nigeria.

MATERIALS AND METHODS

Description of the Experimental Site

The research was carried out in the poultry unit of Delta State University's Department of Animal Science Teaching and Research Farm in Abraka, Delta State. Abraka town in Ethiope East Local Government Area. It is located in a rainforest agroecology zone. Abraka's average temperature ranges from 23.3 to 37 degrees Celsius. The relative humidity is 68-80%, and the monthly sunlight is 4-8 kWh/m^2/day.

Mating Design and Management

Sixty (60) local sexually matured chickens weighing 1.2kg and four (4) sexually matured cocks measuring 1.6kg were purchased from the local market in Abraka and its surroundings. The birds were divided into two groups upon arrival, with all hens in one pen and four cocks in another, and three weeks of the period used functioned as an acclimation phase for three weeks, during which they were fed commercial feed (grower mash).

After three weeks, they were transferred and arranged into 10 dams per cock, with individual dams kept in a hierarchical battery cage arrangement. The semen was collected from individual cocks using Ade *et al.* (2024) abdominal massage technique, which involves gently pressing on the lower abdomen and cloacal region to induce ejaculation. The semen was then collected with a calibrated collection tube and a microcapillary pipette.

Evaluation and Processing

The collected semen was promptly tested for volume. It was then examined using a light microscope to measure sperm motility, concentration, and viability. A hemocytometer and a CASA (Computer-Assisted Sperm Analysis) system were utilized to precisely measure sperm concentration. Additionally, semen was diluted using an appropriate extender (Beltsville Semen Extender) to ensure viability before insemination.

Equipment Used for Insemination

Using an insemination pipette and micro-syringe, the insemination procedure was done. Semen was carefully and hygienically transferred from the vagina into the oviduct while the hens were carefully restrained.

Time of Collection and Insemination

Semen was collected between 7:00 and 9:00 am when sperm quality is usually at its peak. To maximize sperm viability and fertilization potential, insemination was conducted within 30 to 1 hour of the collection. Eggs were collected from the hens daily for 5-7 days before being placed in an incubator. The eggs for each dam were identified with an indelible marker pen. The still-air turner electric/automatic incubators have a capacity of 1000 eggs.

Daily management procedures included washing the water and feed troughs. When needed, the birds were given antibiotics and anti-coccidia medications through their drinking water supply. The birds had also been dewormed using piperazine.

Feeding: Feeds were given twice daily, at 8.30 a.m. and 2.30 p.m., and were fed *ad libitum* with breeder's mash containing 17% crude protein and 2700kcal ME/kg.

A total of 1,575 eggs were collected and incubated. The three batches of hatch generated a total of 1450 chicks. The chicks were identified with leg tags based on sire groups, brooded for three weeks, and raised to 12 weeks following normal husbandry protocols outlined by Udeh and Ighobesuo (2023). Sexes were separated at 9 weeks of age. The chicks were fed starter mash from the day they were hatch until they were 9 weeks old, and grower mash was fed from 9 to 18 weeks. Daily activities such as washing drinkers, cleaning feeders, and sweeping chicken pens. The birds were vaccinated against Newcastle disease, infectious bursal disease, and fowl pox disease at the proper ages.

Traits Evaluated

The linear body measurement traits considered included the hatch weight (HW0), body weight at 4, 6, 8, 10, and 12 weeks of age (BW4, BW6, BW8, BW10, and BW12), body length at 6-12 weeks of age (BDL6, BDL8, BDL10, and BDL12), shank length at 6-12 weeks of age (SHL6, SHL8, SHL10, and SHL12), and wing length at 6-12 weeks of age (WGL6, WGL8, WGL10, and WGL12).

Genetic Model and Statistical Analysis

The data generated were subjected to descriptive statistics. The effects of batch and sex were examined using analysis of variance. Mrode and Thompson (2005) described the additive genetic relationship matrix that was used. The model is expressed as follows in matrix notation:

$y = Xb + Zs + e$

Where:

y is the vector of observation (BW4, BW6, BW8, BW10 and BW12 etc),

b = is the vector of the fixed effect of batch and sex,

s = vector of random sire effect, and

e = random residual effects.

X and Z are design matrices associating records to fixed effect and random sire effect respectively. It is assumed that $E(y) = Xb$; $E(s) = E(e) = 0$

Where:

E stands for expectation (Mrode and Thompson, 2005). It is also assumed that residual variance, which includes random environmental and gene combination variances, is independently distributed with variance σ^2e.

Therefore,

$var(e) = I\sigma^2e = R$,

$var(s) = A\sigma^2s$ and

$var(y) = ZAZ'\sigma^2s + R$,

where:

A represents the numerator relationship matrix for sires, with σ2s = 0.25σ2a. Estimates of sire components of variance and covariance were utilized to determine genetic and phenotypic relationships.

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The bivariate model in matrix notation is stated as follows:

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} + \begin{bmatrix} Z_1 & 0 \\ 0 & Z_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix}$$

where:
for trait i (i = 1, 2),
yi = vector of observations,
bi = vector of fixed effect of batch and sex,
ai = vector of random direct effect,
ei = vector of random residual effect,
xi and zi are design matrices relating observations to fixed and direct additive genetic effects (Mrode and Thompson, 2005).

Selection Indices

The equations of restricted selection index to maximize the genetic gain in chosen traits and keeping others at a given level (Kempthorne and Nordskog, 1959) and revised by Lin (1985) as follows:

$b^{o} = P^{o-1} G^{o} a^{o}$

$b^{*} = P^{*-1} G^{*} a^{*}$

$$b = G^{-1} \begin{bmatrix} G^0 & 0 \\ 0 & G^* \end{bmatrix} \begin{bmatrix} b^0 \\ b^* \end{bmatrix}$$

Where:
b = vector of the selection index values,
P = phenotypic variance-covariance matrix of the traits,
G = genotypic variance-covariance matrix of the traits,
a = vector of the economic value for each trait, and the symbols “^{o}” and “*” expressed for unrestricted and restricted traits, respectively.

All data analyses were performed using the average information restricted maximum likelihood (AIREMLF90) algorithm from Misztal *et al's* BLUPF90 suite of programs (2019).

RESULTS AND DISCUSSION

Growth and Linear Measurements of Nigerian Local Chickens

Table 1 shows the summary statistics mean, standard deviation (SD), minimum, maximum, and coefficient of variation (CV%) for various growth and linear measurement traits of Nigerian local chickens at different ages. Understanding these metrics is essential for evaluating the growth performance and overall health of these birds, which are critical for poultry production in Nigeria.

The body weight (BWT) shows a clear trend of increasing average weights as the chickens mature from 6 to 12 weeks. The mean body weight at 6 weeks was 257.98g, increasing to 620.75g in 12 weeks. This consistent growth pattern aligns with the natural development of chickens, where rapid growth occurs during the early weeks of life (Huang *et al.*, 2013, Monaghan, 2008).

The low standard deviation observed at 12 weeks (0.18) compared to earlier measurements suggests that by this age, the chickens have reached a more uniform size and weight, possibly due to genetic factors and management practices that enhance growth consistency (Sogunle *et al.*, 2014). However, the increasing coefficient of variation, especially at 8 weeks (13.85%), indicates that while average weights were increasing, individual weights showed considerable variation. This could be attributed to differing genetic backgrounds and nutritional statuses among the birds (Magaia *et al.*, 2019).

Table 1: Mean, standard deviation, minimum, maximum, and coefficient variation of the Nigerian local chickens' body weight, body length, shank length, and wing length

Trait	No. of rec.	Mean	Sdev	Minimum	Maximum	CV%
BWT6, g	814	257.98	9.89	248.31	267.92	3.84
BWT8, g	811	323.70	44.78	281.28	365.83	13.85
BWT10, g	811	482.21	42.42	441.55	522.73	8.80
BWT12, g	811	620.75	0.18	620.48	620.90	0.03
BDL6, cm	812	25.91	1.50	23.88	27.64	5.79
BDL8, cm	811	31.77	2.60	29.20	34.79	8.19
BDL10, cm	811	35.02	0.39	34.52	35.45	1.11
BDL12, cm	811	37.45	0.02	37.43	37.47	0.05
SHL6, cm	812	5.25	0.62	4.61	5.84	11.81
SHL8, cm	811	6.37	0.28	6.11	6.87	4.39
SHL10, cm	811	7.20	0.29	6.92	7.51	4.03
SHL12, cm	811	8.39	0.04	8.34	8.43	0.48
WL6, cm	812	13.03	0.49	12.06	16.90	3.77
WL8, cm	811	14.21	0.32	13.88	14.61	2.25
WL10, cm	811	15.33	0.43	14.92	15.76	2.80
WL12, cm	811	16.53	0.40	15.89	16.90	2.42

No. of rec.—number of data records; Mean—average of growth and egg production traits; SD—standard deviation; Min—minimum values; Max—maximum values; CV—coefficient of variation; BW0—birth weight; BW4—body weight at 4 weeks of age; BW6—body weight at 6 weeks of age; BW8—body weight at 8 weeks of age; BW10—body weight at 10 weeks of age.

Linear measurements, such as body length (BDL), shank length (SHL), and wing length (WL), similar trends of growth are evident. The average body length increases from 25.91 cm at 6 weeks to 37.45 cm at 12 weeks, reflecting the overall growth patterns typical of poultry (Jiang *et al.*, 2016). The standard deviations for these traits are relatively low, indicating that the growth of these linear traits was also consistent among the population.

The shank length at 6 weeks shows a mean of 5.25cm, which increases to 8.39cm by 12 weeks. Shank length is a critical trait in poultry, as it can indicate overall health and growth efficiency (Bourdon, 2000). The increase in shank length relative to body weight suggests that as the birds grow heavier, their skeletal structure also develops adequately, which is essential for their mobility and overall well-being.

The coefficient of variation offers insights into the variability of the traits within the population. A CV% of less than 10% is generally considered low, indicating uniformity in the trait within the population (Woldegiorgiss, 2015). In Table 1, traits such as BWT12, BDL10, and SHL12 exhibit very low CV%, suggesting that these traits were consistently expressed across the individuals in the study. Conversely, the CV% for BWT8 (13.85%) and BDL8 (8.20%) suggests higher variability during these growth stages, which may be due to environmental influences, dietary differences, or genetic diversity within the flock (Mohan *et al.*, 2020).

Table 2 provides insights into the genetic components affecting these traits. The additive genetic variance (σ_a^2) and environmental variance (σ_e^2) for traits at different ages. At 6 weeks of age, the additive genetic variance for body weight (BWT6) was 48.906, which is equal to its environmental variance, also reported as 48.9. This indicates a high level of heritability, as the total phenotypic variance ($\sigma_T^2\sigma$) is substantially influenced by genetic factors (Falconer and Mackay, 1996). The high additive variance suggests that selection based on this trait could lead to significant genetic improvements.

In contrast, by 12 weeks of age (BWT12), both the additive and environmental variances decrease significantly, indicating that factors influencing growth may stabilize or change. This could reflect a plateau in growth potential or the effects of management practices, nutrition, and health interventions (Sogunle *et al.*, 2014). The low variance in later stages might limit the effectiveness of selection if phenotypic variation is reduced.

Table 2: Estimated variance components, heritability (standard error) of body weight, and linear measurements of Nigerian local chickens

Traits	σ^2_a	σ^2_e	σ^2_T	h^2
BWT6, g	48.906	48.9	97.8	0.5(0.35)
BWT8, g	1.003	1.00	2.01	0.5(1.57)
BWT10, g	0.855	0.86	1.71	0.5(1.49)
BWT12, g	0.016	0.02	0.03	0.5(0.01)
BDL6, cm	1.125	1.13	2.25	0.5(0.05)
BDL8, cm	3.38	3.38	6.76	0.5(0.09)
BDL10, cm	0.08	0.08	0.15	0.5(0.01)
BDL12, cm	0.002	0.00	0.00	0.5(0.01)
SHKL6, cm	0.19	0.19	0.38	0.5(0.02)
SHKL8, cm	0.04	0.04	0.08	0.5(0.01)
SHKL10, cm	0.04	0.04	0.08	0.5(0.01)
SHKL12, cm	0.001	0.001	0.00	0.5(0.00)
WL6, cm	0.12	0.12	0.24	0.5(0.02)
WL8, cm	0.05	0.05	0.10	0.5(0.01)
WL10, cm	0.09	0.09	0.19	0.5(0.02)
WL12, cm	0.08	0.08	0.16	0.5(0.01)

additive genetic variance- σ_a^2 environmental variance- σ_e^2: HW0—hatch weight; BW6—body weight at 6 weeks of age; BW8—body weight at 8 weeks of age; BW10—body weight at 10 weeks of age: BW12—body weight at 12 weeks of age; BDL6—body length at 6 weeks of age; BDL6—body length at 6 weeks of ag; BDL8—body length at 8 weeks of age; BDL10—body length at 10 weeks of age; BDL12—body length at 12 weeks of age; SHKL6—body length at 6 weeks of age; SHKL8s—body length at 68weeks of age; SHKL10—body length at 10 weeks of age; SHKL12—body length at 12 weeks of age; WGL6—body length at 6 weeks of age; WGL8—body length at 8 weeks of age; WGL10—body length at 10 weeks of age;WGL12—body length at 12 weeks of age;

The heritability estimates (h²) for body weight and linear measurements indicate moderate heritability, suggesting that these traits are influenced significantly by genetic factors. Heritability of body weight at 6 weeks is estimated at 0.5 (standard error 0.35), which falls within the range reported by Oleforuh-Okoleh, (2010) in her previous studies and highlights the potential for selective breeding programs to enhance growth traits in Nigerian local chickens.

The genetic and phenotypic correlations among the traits, as shown in Table 3, demonstrate strong positive relationships, especially between body weight and shank length (0.998 at 6 weeks). This suggests that selection for increased body weight may also lead to improvements in shank length, a desirable trait for both growth and structural soundness in poultry.

Interestingly, the correlations weaken at 12 weeks, particularly with negative values noted for body weight and body length (-0.254) and shank length (-0.320). This shift may indicate that as the chickens approach maturity, factors such as resource allocation for reproductive traits or increased competition for resources could impact these correlations (Dekkers, 2004, Ogunbameru *et al.*, 2020).

Table 3: Genetic and Phenotypic correlations of performance traits of Nigerian local chickens from 6 to 12 weeks of age

6 weeks	Body weight	Body length	Shank length	Wing length
Body weight	1	0.957	0.998	0.861
Body length	0.957	1	0.980	0.934
Shank length	0.998	0.980	1	0.872
Wing length	0.861	0.934	0.872	1
8 weeks				
Body weight	1	0.957	0.884	0.981
Body length	0.957	1	0.940	0.980
Shank length	0.884	0.940	1	0.923
Wing length	0.981	0.98	0.923	1
10 weeks				
Body weight	1	0.975	0.980	0.99
Body length	0.975	1	0.956	0.972
Shank length	0.980	0.956	1	0.974
Wing length	0.99	0.972	0.974	1
12 weeks				
Body weight	1000	0.495	-0.254	-0.320
Body length	0.495	1000	-0.893	-0.782
Shank length	-0.254	-0.893	1000	0.959
Wing length	-0.320	-0.782	0.959	1000

CONCLUSION

This study has demonstrated the potential of Nigerian local chickens as a viable source of animal protein, particularly through the application of a multi-trait animal model and selection index approach. The findings indicate significant genetic variation in body weight and linear traits, with moderate heritability suggesting that selective breeding can effectively enhance these traits. The positive correlations among traits, especially between body weight and shank length, highlights the interconnected nature of growth metrics, although the diminishing correlations with maturity suggest the need for adaptive management strategies as the chickens develop. Overall, this research underscores the importance of genetic analysis in improving the productivity and performance of local chicken breeds, contributing to food security and the economic well-being of poultry farmers in Nigeria.

Based on the findings of this study, the following recommendations are proposed, thus Selective Breeding: In-between heritability estimates indicate that targeted genetic selection can improve growth attributes in Nigerian chickens. Breeders should target local chickens with desirable body weight and linear attributes to increase productivity; Optimized Nutrition: Variability in body weight at different ages emphasizes the necessity of a balanced diet. Provide regular, high-quality feed to eliminate growth discrepancies and promote flock homogeneity; Early Selection Strategy: Breeding birds at 6 weeks may improve long-term growth performance due to higher genetic variance; Integrated Selection Index: Use a multi-trait selection approach to maximize productivity without affecting other economically important traits; Environmental Management: Management strategies should prioritize housing, health, and disease control to guarantee that genetic potential has been fully achieved; Resource Allocation Consideration: At later phases of growth, the correlations lessen, indicating changes in resource allocation. Future breeding programs should strike a balance between growth rate and other physiological demands to avoid undesirable trade-offs; and additional Genetic study: More study is needed to identify genetic markers related with growth and egg production features in order to improve selection accuracy and efficiency.

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