Agr. Foo. Nat. Res. J. Volume 4, Issue 1, Page 92 - 100
e-ISSN: 1597-7153 | p-ISSN: 3043-5420

Agriculture, Food and Natural Resources Journal
The Official Journal of the Faculty of Agriculture, Nnamdi Azikiwe University, Awka, Nigeria

Journal homepage: https://journals.unizik.edu.ng/afnrj

Original Article

Repeatability of linear body measurements and principal components of body size in crossbred Nigerian local chickens

OPEN ACCESS

Ugwumba Chijioke ISAAC*

Department of Animal Science and Technology, Nnamdi Azikiwe University, Awka, Nigeria

DOI: https://www.doi.org/10.5281/zenodo.15109690

Editor: *Dr Onyekachi Chukwu, Nnamdi Azikiwe University, NIGERIA*

Received: *December 30, 2024*
Accepted: *February 17, 2025*
Available online: *March 31, 2025*

Peer-review: *Externally peer-reviewed*

Conflict of Interest: The authors have no conflicts of interest to declare

Financial Disclosure: *The authors declared that this study has received no financial support*

ABSTRACT

The study aimed at estimating the repeatability of growth traits and principal components of body size (PC1) of crossbred Nigerian local chickens using 5 biweekly records. A total of 123, 49, 116, 137, 42, and 64 chickens of Isa Brown × frizzle feathered (IB×F), Isa Brown × naked neck (IB×Na), Isa Brown × normal feathered (IB×N), frizzled feathered × Isa Brown (F×IB), naked neck × Isa Brown (Na×IB), and normal feathered × Isa Brown (N×IB) genotypes, respectively, were produced at day-old in 12 hatches. Data were taken on body weight (BWT), linear body measurements, and PC1 at 2, 4, 6, 8, and 10 weeks from each individual. The repeatability of body weight (0.27 to 0.49) for the six genotypes was moderately high. Repeatability of PC1 (0.54) was only high in the IB×F genotype. Repeatability of the linear body measurements was high (0.49-0.67), especially in IB×N and N×IB genotypes. The expected relative genetic gain indicated that fewer than 5 records were enough to estimate the repeatability of these traits. It was concluded that considerable genetic improvement in the lifetime average body size of IB×N, N×IB and IB×F genotypes could be realized using fewer than 5 records of the growth traits and PC1 with high repeatability estimates as selection criteria.

KEYWORDS: *Chicken, Growth traits, PC1, Selection, Variance components*

INTRODUCTION

The productivity of the Nigerian local chickens is largely poor due mainly to lack of genetic improvement. Following long-tern selection, local chickens in the select line could be crossed with an improved migrant stock to fix desirable genes (Ibe, 1995). Selection is usually practiced based on the breeding value of animals (Pahdi, 2016). The breeding value for a trait that can be measured more than once in an animal's lifetime depends partly on the repeatability of the trait (Khawaja, 2013). The magnitude of a repeatability estimate indicates the extent to which selection practiced at any stage of growth will affect subsequent performance of animals. It is important to practice selection for early records as it gives the advantage of shortened generation interval and increased genetic progress (Priyce & Daetwyler, 2011).

It is worthy of note that body weight obtained by scale measurement is biased by the animal's gut fill and urine at the time of measurement (Mardhati, 2021). This makes the linear

*Corresponding author: uc.isaac@unizik.edu.ng

body measurements such as shank length and breast width more reliable predictors of body weight. However, the use of these parameters to estimate body weight in some studies like multiple regression has been criticized because of the problem of multicolinearity which reduces accuracy of prediction (Xi *et al*., 2024). Principal components, which are the indices of the linear measurements, eliminate the multicolinearity since they are orthogonal to each other (Gwelo, 2019). Thus, principal components are preferred for estimation of overall body size and conformation (shape) of animals, and their use to obtain repeatability of body size in chickens is justified.

There are hardly any reports on repeatability of scaled body weight and linear body measurements of the crossbred exotic × Nigerian local chickens in literature, l*et al*one that of the principal components of body size. Most repeatability studies on growth traits of chickens in Nigeria were reported in commercial broilers (Sanda *et al*, 2014; Sola-Ojo *et al* 2017; Isaac *et al*. 2022). The available report on repeatability study involving measured growth traits and principal components was done with the local chickens (Ibe, 1995). The aim of this study was to provide estimates of repeatability of body measurements and principal components to aid in selection decisions for improvement of body size of the crosses of Isa Brown and three strains of Nigerian local chickens.

MATERIAL AND METHODS

Experimental Location

The experiment was conducted at the Poultry Unit of the Teaching and Research Farm of Michael Okpara University of Agriculture, Umudike, Abia state, Nigeria. The University is located on Latitude 05029´ North and Longitude 070 33´ East. It is approximately 122 m above sea level. The area is characterized by maximum and minimum daily temperature ranges of 27-36°C and 20-26°C, respectively, average annual rainfall of 2177 mm, monthly ambient temperature range of 22-33°C and relative humidity of 50- 95 %.

Experimental Animals and their Management

The production and management of these birds have been fully described (Isaac, 2021; Isaac & Ezejesi, 2023).

Data Collection and Measured Parameters

Data collected consisted of 5 biweekly records of body weight (BWT), linear body measurements namely shank length (SL), drumstick length (DL), body girth, (BG) breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1) obtained in a 10-week (2-, 4-, 6-, 8- and 10) period from mixed sexes (male and female combined) of crossbred Isa Brown × frizzle feathered (IB×F), Isa Brown × naked neck (IB×Na), Isa Brown × normal feathered (IB×N), frizzled feathered × Isa Brown (FxIB), naked neck × Isa Brown (Na×IB) and normal feathered × Isa Brown (N×IB) chicken genotypes, respectively. The measurements of these parameters are described by Isaac, (2021) and Isaac & Ezejesi (2023). The birds themselves were produced in 12 hatches at weekly intervals.

Principal component measure of body size (PC1) was obtained by weighting standardized values of the seven linear body measurements, namely SL, DL, BG, BW, KL, BL and WL, with principal component coefficients from analysis of the correlation matrix of the linear parameters according to Ibe (1995), as given in expression (1).

$$PC1 = a_1z_1 + a_2z_2 + \ldots + a_iz_j \quad (1)$$

where a_1 to a_i are the derived principal component coefficients, and z_1 to z_j are standardized values of the SL, DL, BG, BW, KL, BL and WL, respectively.

Statistical Model and Analysis

The mixed model in expression (2) was used to generate and analyse the data in each genotype.

$$Y_{ijkl} = \mu + A_i + H_j + I_{jk} + e_{ijkl} \quad (2)$$

where Y_{ijkl} is the l-th record of a response variable (BWT, SL, DL, BG, BW, KL, BL, WL, PC1), μ is overall mean, A_i is fixed effect of i-th age of individual on measurement (i = 2, 4, 6, 8 and 10), H_j is the fixed effect of j-th hatch (j = 1, …, 12), I_{jk} is the random effect of k-th individual within the j-th hatch, and e_{ijkl} is the random error, distributed independently, identically and normally with zero mean and constant variance [iind (0, σ^2)]. IBM SPSS Statistics (2011) computer programme was used to analyse the data. The programme adjusted the data for the non-genetic effects (age and hatch) and thereafter estimated observable components of variance for individual (σ_I^2) and error (σ_e^2) by equating reductions in sums of squares due to fitting different submodels of the full model to their respective expectations, according to Henderson (1953) method of fitting estimates.

Repeatability was then estimated with expression (3) and its standard error with expression (4) as given by Becker (1984).

$$R = \sigma_I^2/(\sigma_I^2+\sigma_e^2) \quad (3)$$

$$SE(R) = \frac{2\,(1-R)2\,[1+(k-1)R]2}{K\,(k-1)(n-1)} \quad (4)$$

where σ_I^2 is the variance component due to differences among individuals and estimates all variations due to permanent components of the record, σ_e^2 is the error variance components and $\sigma_I^2+\sigma_e^2$ is the total phenotypic variance, k is the number of records taken on each individual, n is the number of individuals in each genotype and R is the estimated repeatability of trait. Expression (5) due to Lush (1945) was used to compute the expected relative genetic gain per generation from selection based on repeated records compared with selection on a single record.

$$\Delta G = k/[1+(k-1)\,R] \quad (5)$$

where k is no of records and R is repeatability.

RESULTS AND DISCUSSION

Results

Eigenvalues and Principal Component Weight from Analysis of Linear Body Measurements in Different Genotypes

Tables 1 to 6 present the principal component coefficients (eigenvectors) that were used to obtain values of the trait, PC1 in weeks 2 to 10 according to expression (1). In each of the Tables, eigenvalues or variance ratios were obtained and reported as percentage proportions of variation in body size accounted for by the principal component. The first two principal components (Table 1), PC1 and PC2 explained 69.34, 65.71, 67.82, and 75.67% of the total variation in weeks 2-8 respectively, while PC1 explained 63.03% in week 10 of the total variation in IB×F. The PC1, PC2 and PC3 explained 66.47, 82.8 and 69.04% of the total variation in weeks 2, 4 and 6, respectively, while the PC1 and PC2 explained 72.15 and 72.09% of the total variation in weeks 8 and 10 respectively in IB×Na (Table 2). The PC1 explained 70.02, 69.75, 70.09, 67.9 and 61.88% of the total variation in weeks 2-10, respectively in IB×N (Table 3). The PC1 explained 55.96 % in week 4 whereas PC1 and PC2 explained 72.77, 69.91, 71.45 and 65.26% in weeks 2, 6, 8, 10 respectively in F×IB (Table 4). The PC1 and PC2 explained 68.95, 71.04, 75.75 and 74.82% of the total variation in week 2-8 respectively while the PC1 explained 71.99% of the total variation in week 10 in Na×IB (Table 5). The PC1 and PC2 explained 85.32% of the total variation in week 2 whereas PC1 explained 78.61, 72.33, 75.23 and 85.17% of the total variation in weeks 4 and 10 respectively in N×IB (Table 6).

Table1. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in IB×F

Trait	Week 2		Week 4		Week 6		Week 8		Week 10
	PC1	PC2	PC1	PC2	PC1	PC2	PC1	PC2	PC1
SL	0.52	0.48	0.63	0.34	0.37	0.43	0.47	0.67	0.61
DL	0.45	0.74	0.66	0.51	0.75	-0.49	0.78	-0.48	0.87
BG	0.44	0.69	0.66	0.36	0.83	-0.26	0.75	-0.37	0.85
BW	0.82	-0.33	0.80	-0.39	0.86	0.04	0.89	0.17	0.87
KL	0.76	-0.58	0.63	-0.62	0.62	0.64	0.86	0.20	0.86
BL	0.54	0.40	0.65	0.23	0.66	-0.35	0.78	-0.27	0.65
WL	0.66	-0.59	0.84	-0.28	0.84	0.27	0.85	0.27	0.81
Eigenvalue	37.71	31.63	48.97	16.74	52.13	15.69	61.10	14.57	63.03

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Table 2. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in IB×Na

Trait	Week 2			Week 4			Week 6		Week 8		Week 10	
	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC1	PC2	PC1	PC2
SL	0.76	0.32	0.26	0.79	-0.04	-0.25	0.71	-0.49	0.48	0.68	0.80	0.43
DL	0.69	-0.25	0.32	0.60	0.41	-0.59	0.54	-0.59	0.48	0.71	0.81	0.45
BG	0.56	0.38	-0.67	0.16	0.96	0.17	0.85	0.07	0.85	-0.44	0.79	-0.33
BW	-0.02	0.85	-0.09	0.70	0.48	0.49	0.88	-0.10	0.90	-0.39	0.90	-0.27
KL	-0.48	0.39	-0.22	0.71	-0.30	0.31	0.80	0.24	0.46	0.42	0.54	-0.50
BL	-0.10	0.65	0.62	0.71	-0.46	0.36	0.75	0.38	0.87	-0.39	0.80	-0.23
WL	-0.60	0.01	0.13	0.75	-0.23	-0.40	0.37	0.63	0.56	0.36	0.52	0.49
Eigenvalue	28.07	22.93	15.47	43.78	23.84	15.18	52.01	17.03	46.77	25.38	56.28	15.81

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Table 3. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in IB×N

Trait	Week 2	Week 4	Week 6	Week 8	Week 10
	PC1	PC1	PC1	PC1	PC1
SL	0.67	0.74	0.64	0.72	0.81
DL	0.74	0.83	0.86	0.80	0.89
BG	0.89	0.90	0.92	0.93	0.92
BW	0.87	0.73	0.79	0.86	0.78
KL	0.89	0.89	0.92	0.85	0.84
BL	0.89	0.88	0.82	0.79	0.84
WL	0.88	0.85	0.88	0.81	0.16
Eigenvalue	70.02	69.75	70.09	67.9	61.88

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Table 4. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in F×IB

Trait	Week 2		Week 4	Week 6		Week 8		Week 10	
	PC1	PC2	PC1	PC1	PC2	PC1	PC2	PC1	PC2
SL	0.62	0.40	0.78	0.66	-0.55	0.64	0.68	0.64	0.12
DL	0.47	0.77	0.82	0.73	-0.38	0.75	0.09	0.83	0.07
BG	0.77	-0.42	0.78	0.86	0.16	0.86	-0.25	0.89	-0.01
BW	0.83	-0.46	0.83	0.86	0.21	0.81	-0.38	0.79	-0.11
KL	0.81	0.11	0.59	0.35	0.68	0.69	0.55	0.69	-0.13
BL	0.84	-0.16	0.79	0.81	0.30	0.76	-0.30	0.09	0.98
WL	0.80	0.17	0.62	0.75	-0.22	0.69	-0.18	0.74	-0.06
Eigenvalue	55.49	17.28	55.96	54.00	15.91	55.68	15.77	50.77	14.49

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Table 5. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in Na×IB

Trait	Week 2		Week 4		Week 6		Week 8		Week 10
	PC1	PC2	PC1	PC2	PC1	PC2	Pc1	PC2	PC1
SL	0.53	0.51	0.79	-0.51	0.75	0.53	0.81	0.00	0.94
DL	0.59	0.68	0.82	-0.50	0.79	0.51	0.90	0.03	0.93
BG	0.62	-0.65	0.85	-0.29	0.87	-0.21	0.95	0.03	0.94
BW	0.86	-0.27	0.86	0.38	0.87	-0.36	0.84	-0.23	0.90
KL	0.76	0.14	0.43	0.55	0.21	0.49	0.54	0.70	0.61
BL	0.83	-0.14	0.71	0.53	0.80	-0.46	0.64	-0.67	0.83
WL	0.75	-0.04	0.32	0.35	0.87	-0.06	0.62	0.31	0.72
Eigenvalue	50.98	17.97	50.41	20.63	59.01	16.74	59.34	15.48	71.99

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Table 6. Eigenvalues (as percentage variance) and principal component weight from analysis of linear body measurements in N×IB

Trait	Week 2		Week 4	Week 6	Week 8	Week 10
	PC1	PC2	PC1	PC1	PC1	PC1
SL	0.64	0.73	0.84	0.88	0.94	0.97
DL	0.79	0.54	0.92	0.89	0.93	0.95
BG	0.94	-0.20	0.94	0.94	0.91	0.97
BW	0.92	-0.26	0.94	0.88	0.82	0.97
KL	0.81	-0.08	0.89	0.79	0.80	0.93
BL	0.90	-0.17	0.86	0.85	0.85	0.87
WL	0.82	-0.30	0.80	0.71	0.80	0.77
Eigen value	70.24	15.08	78.61	72.33	75.23	85.17

Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Variance Components and Repeatability of Growth Traits in Different Genotypes

The estimated variance components and the repeatability coefficients for each of the traits in different genotypes are shown in Table 7. Body weight was moderately repeatable in IB×F, IB×Na, F×IB and Na×IB chickens, and highly repeatable in IB×N and N×IB chickens.

All linear body measurements were moderately repeatable in IB×F chickens and lowly to moderately repeatable in IB×Na and Na×IB. The same traits were moderately repeatable in F×IB chickens except for SL which was high. In IB×N, the linear body measurements were highly repeatable except for BL and WL which were low. In N×IB, all linear body measurements were highly repeatable. On the other hand, repeatability for PC1 was high (0.54) in IB×F and moderately low (0.04 to 0.35) in the rest of the genotypes.

Table 7a Variance components and repeatability of traits in different genotypes

*Trait	**IB×F**			**IB×Na**			**IB×N**		
	σ_I^2	σ_e^2	R	σ_I^2	σ_e^2	R	σ_I^2	σ_e^2	R
BWT	480.40	1283.96	0.272 (0.002)	472.27	896.27	0.360 (0.005)	1422.28	1471.20	0.49 (0.002)
SL	0.043	0.102	0.296 (0.002)	0.033	0.095	0.258 (0.005)	0.224	0.222	0.502 (0.002)
DL	0.200	0.368	0.352 (0.002)	0.163	0.387	0.296 (0.005)	1.036	0.594	0.636 (0.001)
BG	0.347	1.151	0.232 (0.002)	0.053	1.891	0.027 (0.002)	2.112	1.689	0.556 (0.002)
BW	0.587	1.653	0.262 (0.002)	0.136	2.487	0.052 (0.003)	2.338	1.712	0.577 (0.002)
KL	0.091	0.181	0.334 (0.002)	0.042	0.253	0.143 (0.004)	0.386	0.304	0.559 (0.002)
BL	0.763	2.285	0.250 (0.002)	0.305	3.805	0.074 (0.003)	4.233	70.978	0.056 (0.001)
WL	0.219	0.434	0.335 (0.002)	0.214	0.798	0.211 (0.004)	1.423	17.783	0.074 (0.001)
PC1	0.010	0.008	0.539 (0.002)	0.004	0.087	0.043 (0.003)	0.003	0.015	0.155 (0.002)

σ_I^2 = Individual variance component, σ_e^2 = error variance component
**Standard errors of repeatability are in parenthesis. See Table 1 for definition of traits*

Table 7b Variance components and repeatability of traits in different genotypes

Trait	F×IB			Na×IB			N×IB		
	σ_I^2	σ_e^2	R	σ_I^2	σ_e^2	R	σ_I^2	σ_e^2	R
BWT	832.31	1823.04	0.313 (0.002)	1155.00	2819.28	0.291 (0.006)	2179.91	2399.51	0.476 (0.004)
SL	0.026	0.026	0.500 (0.002)	0.045	0.107	0.296 (0.006)	0.195	0.115	0.629 (0.003)
DL	0.109	0.433	0.201 (0.002)	0.182	0.445	0.291 (0.006)	1.025	0.514	0.666 (0.002)
BG	0.517	1.139	0.312 (0.002)	0.371	1.121	0.249 (0.005)	1.834	1.201	0.604 (0.003)
BW	0.653	1.345	0.327 (0.002)	0.550	1.610	0.255 (0.006)	3.048	1.921	0.613 (0.003)
KL	0.115	0.386	0.229 (0.002	0.065	0.269	0.194 (0.005)	0.303	0.312	0.493 (0.004)
BL	0.311	73.687	0.004 (0.001)	1.156	2.875	0.287 (0.006)	5.371	3.988	0.574 (0.003)
WL	0.323	0.797	0.289 (0.002)	0.217	0.971	0.182 (0.005)	1.257	1.125	0.528 (0.003)
PC1	0.002	0.023	0.076 (0.001)	0.011	0.021	0.348 (0.006)	0.002	0.004	0.333 (0.004)

σ_I^2 = Individual variance component, σ_e^2 = error variance component

**Standard errors of repeatability are in parenthesis. See Table 1 for definition of traits*

Expected Relative Genetic Gain per Generation of Selection Based on k Records in Different Genotypes

The expected relative genetic gain per generation of selection for different traits (Table 8) increased with increasing number of records on each individual per genotype. The rate of increase, however, varied inversely with repeatability coefficients of the traits. This means that traits with higher repeatability coefficients recorded lower value of expected relative genetic gain per generation.

Table 8. Expected relative genetic gain per generation of selection based on k records for each trait in different genotypes

k	Age	IB×F									IB×Na								
		BWT	SL	DL	BG	BW	KL	BL	WL	PC1	BWT	SL	DL	BG	BW	KL	BL	WL	PC1
1	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	4	1.57	1.54	1.48	1.62	1.58	1.50	1.60	1.50	1.30	1.49	1.59	1.54	1.95	1.90	1.75	1.86	1.65	1.92
3	6	1.94	1.88	1.76	2.05	1.97	1.80	2.00	1.80	1.44	1.78	1.98	1.88	2.85	2.72	2.33	2.61	2.11	2.76
4	8	2.20	2.12	1.95	2.36	2.24	2.00	2.29	2.00	1.53	1.97	2.25	2.12	3.70	3.46	2.80	3.27	2.45	3.54
5	10	2.39	2.29	2.08	2.59	2.44	2.14	2.50	2.14	1.58	2.10	2.46	2.29	4.51	4.14	3.18	3.86	2.71	4.27
6	12	2.54	2.42	2.17	2.78	2.60	2.25	2.67	2.24	1.62	2.20	2.62	2.42	5.29	4.76	3.50	4.38	2.92	4.94
7	14	2.66	2.52	2.25	2.93	2.72	2.33	2.80	2.33	1.65	2.28	2.75	2.52	6.02	5.34	3.77	4.85	3.09	5.56
8	16	2.75	2.60	2.31	3.05	2.82	2.40	2.91	2.39	1.68	2.34	2.85	2.60	6.73	5.87	4.00	5.27	3.23	6.15
9	18	2.83	2.67	2.36	3.15	2.91	2.45	3.00	2.45	1.69	2.39	2.94	2.67	7.40	6.36	4.20	5.65	3.35	6.70
10	20	2.90	2.73	2.40	3.24	2.98	2.50	3.08	2.49	1.71	2.44	3.01	2.73	8.05	6.81	4.37	6.00	3.45	7.21
		IB×N									**F×IB**								
1	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	4	1.34	1.33	1.22	1.29	1.27	1.28	1.89	1.86	1.73	1.52	1.33	1.67	1.52	1.51	1.63	1.99	1.55	1.86
3	6	1.51	1.50	1.32	1.42	1.39	1.42	2.70	2.61	2.29	1.85	1.50	2.14	1.85	1.81	2.06	2.98	1.90	2.60
4	8	1.62	1.60	1.38	1.50	1.46	1.49	3.42	3.27	2.73	2.06	1.60	2.50	2.07	2.02	2.37	3.95	2.14	3.26
5	10	1.68	1.66	1.41	1.55	1.51	1.55	4.08	3.86	3.09	2.22	1.67	2.77	2.22	2.17	2.61	4.92	2.32	3.83
6	12	1.73	1.71	1.44	1.59	1.54	1.58	4.69	4.38	3.38	2.34	1.71	2.99	2.34	2.28	2.80	5.88	2.45	4.35
7	14	1.77	1.74	1.45	1.61	1.57	1.61	5.24	4.85	3.63	2.43	1.75	3.17	2.44	2.36	2.95	6.84	2.56	4.81
8	16	1.80	1.77	1.47	1.64	1.59	1.63	5.75	5.27	3.84	2.51	1.78	3.32	2.51	2.43	3.07	7.78	2.65	5.22
9	18	1.82	1.79	1.48	1.65	1.60	1.64	6.22	5.65	4.02	2.57	1.80	3.45	2.57	2.49	3.18	8.72	2.72	5.60
10	20	1.84	1.81	1.49	1.67	1.61	1.66	6.65	6.00	4.18	2.62	1.82	3.56	2.63	2.54	3.27	9.65	6.00	5.94
		NaxIB									**NxIB**								
1	2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	4	1.55	1.54	1.55	1.60	1.59	1.68	1.55	1.69	1.48	1.36	1.23	1.20	1.25	1.24	1.34	1.27	1.31	1.50
3	6	1.90	1.88	1.90	2.00	1.99	2.16	1.91	2.20	1.77	1.54	1.33	1.29	1.36	1.35	1.51	1.40	1.46	1.80
4	8	2.14	2.12	2.14	2.29	2.27	2.53	2.15	2.59	1.96	1.65	1.39	1.33	1.42	1.41	1.61	1.47	1.55	2.00
5	10	2.31	2.29	2.31	2.51	2.48	2.82	2.33	2.89	2.09	1.72	1.42	1.36	1.46	1.45	1.68	1.52	1.61	2.14
6	12	2.44	2.42	2.44	2.67	2.64	3.05	2.46	3.14	2.19	1.78	1.45	1.39	1.49	1.48	1.73	1.55	1.65	2.25
7	14	2.55	2.52	2.55	2.81	2.77	3.23	2.57	3.35	2.27	1.82	1.47	1.40	1.51	1.50	1.77	1.58	1.68	2.33
8	16	2.63	2.60	2.63	2.92	2.87	3.39	2.66	3.52	2.33	1.85	1.48	1.41	1.53	1.51	1.80	1.59	1.70	2.40
9	18	2.70	2.67	2.70	3.01	2.96	3.53	2.73	3.66	2.38	1.87	1.49	1.42	1.54	1.52	1.82	1.61	1.72	2.45
10	20	2.76	2.73	2.76	3.09	3.03	3.64	2.79	3.79	2.42	1.89	1.50	1.43	1.55	1.53	1.84	1.62	1.74	2.50

k= number of records. Shank length (SL), drumstick length (DL), body girth, (BG), breast width (BW), keel length (KL), body length (BL), wing length (WL) and a principal component of body size (PC1), (PC2) Principal component of conformation (body shape)

Discussion

Based on the percentage of variance (Tables 1-6), PC1 and PC2 explained the largest body size in weeks 8, 2 and 6 in IB×F, F×IB and in Na×IB, respectively. PC1 explained the largest body size in week 6 and 2 in IB×N and N×IB, respectively. The PC1, PC2 and PC3 explained the largest body size in week 4 in IB×Na. The PC1 consists of all positive coefficients (except in week 2 in IB×Na), as expected because it represents a weighted average of the linear measurements. On the other hands, PC2 or PC3 as the case may be, consists of both positive and negative coefficients which indicate contrasts in the various linear measurements. Therefore, PC1 has been regarded as a body size vector while PC2 and PC3 are regarded as a 'conformation' vector (Zarnecki, 1985; Olasege *et al*., 2019). The PC1 is a more accurate measure of body size since weight measurement by scale is often biased by gut fill and feaces (Mardhati *et al*., 2021).

The moderate repeatability coefficients obtained for body weight in IB×F, IB×Na, F×IB and Na×IB chicken genotypes (Table 7) indicate that the animals do not rank consistently high (or low) in the population. This opinion is consistent with previous findings (Ibe, 1995). This implies that selection for 10-week body weight is not expected to result in higher lifetime average body weight in IB×F, IB×Na, F×IB and Na×IB chickens. Selection for improvement of lifetime average body weight may have to be done using more records per individual on biweekly bases. This will result in greater genetic gain than selection based on 10-week body weight with only 5 records per individual as seen in Table 8. However, the economic implications of collecting additional records should be considered. Ibe (1995) obtained low repeatability of 4- week body weight in random-bred population of local chicken of mixed sexes using 2 records, and recommended that selection for improvement of lifetime average body weight may have to be done using 12-week body weight with 6 records for greater genetic gain. On the contrary, the high repeatability for body weight obtained in IB×N and N×IB indicates that selection based on 10-week body weight with 5 records will result in higher lifetime average body weight in these chickens.

PC1, another quantitative measure of body size in animals was highly repeatable in IB×F but lowly to moderately repeatable in other genotypes. The repeatability of this trait indicates that the IB×F chickens ranked consistently high (or low) in a population to the extent that culling the animals with low PC1 values through selection will raise the lifetime average body size of selected animals by an appreciable amount. Therefore, selection based on 10- week PC1, with 5 records per individual (Table 8) in IB×F is expected to result in improvement of body size, measured by PC1, at later ages. This agrees with the findings of Isaac *et al*. (2022), who reported higher repeatability of PC1 than repeatability of measured body weight in broiler chickens. In addition to being a less biased measure of body size than scale body weight (Canaza-Cayo *et al*., 2021), PC1 does not require additional records for significant genetic progress to be made. This makes PC1 a recommended selection criterion for improvement of overall body size. This opinion is supported by previous works (Negash, 2021; Isaac *et al*., 2022). The moderately low repeatability for PC1 obtained in the other genotypes including F×IB, supports the fact that genotype and mating system play a significant role in the performance of an animal (Raidan *et al*., 2015).

The repeatability of SL, DL, BG, BW, KL, BL and WL which ranged from low to moderate in IB×F, IB×Na, F×IB and Na×IB chickens indicate that additional records may not result in a significantly greater genetic gain than with only 5 records, particularly for DL, KL, WL in IB×F and BW and BG in IB×F chickens. Selection based on these linear measurements may not be useful in improving overall body growth of these genotypes. Such selection may be useful when it is desired to alter the shape of animals and to shift the muscle mass toward the portion of the carcass of greater economic importance (Isaac and Ezejesi, 2023). Selection on an index of body size (PC1) and body conformation (PC2 and PC3) (Tables 1 -6) comprising these linear parameters is preferable. The low repeatability coefficients obtained for the linear parameters, especially BG and BW in IB×Na, BL in IB×Na and IB×N and WL in IB×N also indicate that additional records may be needed to improve these traits in these chickens.

The high repeatability of all the linear body measurements in N×IB and those of SL, DL, BG, BW and KL in IB×N chickens indicate that selection for improvement using any of the traits will result in good performance and significant genetic gain throughout the growing period of these chickens. This finding supports the report of Ojedapo (2013), and suggests that normal feathered chickens may be preferred in main and reciprocal crossbreeding with exotic chickens for genetic improvement of meat-type chicken. This is consistent with the findings of other authors (Nwachukwu *et al*. 2006; Isaac & Ezejesi, 2023). The repeatability of these linear parameters, though high, was lower than those reported by Sanda (2014) and Kabir *et al*. (2008) for body weight and body conformation in broilers. This difference may be attributed to the different genetic constitutions and environments to which the animals were exposed. These factors are reported to have significant influence on the performance of animals (Brandit *et al*., 2010; Isaac & Oriaku, 2023).

The expected relative genetic gain per generation of selection (Table 8) indicates that for traits with low repeatability, a large number of records is required to estimate the potential of an individual and to raise a high expected response from selection, while traits with high repeatability require fewer records for same purpose. This is affirmed by other authors (Bourdon, 2000, Akporhuarho & Obodoagwu, 2020; Isaac *et al*., 2022). For instance, with R equals 0.636 for DL in IB×N, the expected response from selection using 5 records compared with that from single record on each individual is 41% [(1.41-1) x 100)]. With R as low as 0.056 for BL in IB×N, the expected response from selection on 5 records compared with that from single record on each individual is 308% [(4.08-1) x 100)]. Thus, the time spent in collecting additional 5 records in order to get this 308% response is justified. The 41% genetic gain obtained for

DL was high enough to estimate repeatability of this trait. This is applicable to most of the traits using 5 records. The implication is that fewer than 5 records are enough to characterize the inherent transmission ability of these chickens. The observed increase in the relative genetic gain as the number of records increased is consistent with the reports of previous authors (Ibe, 1995; Ahmed, 2021; Isaac *et al*., 2022) for different traits in domestic chicken.

CONCLUSION AND RECOMMENDATION

The repeatability coefficients were moderately high for most of the growth traits in different genotypes. Selection for these traits at any stage of growth will significantly improve overall body size and subsequent performance of the chickens. The repeatability of PC1 was higher than repeatability of scaled body weight in IB×F, indicating that appreciable amount of genetic improvement in lifetime average body size of individuals in this genetic group can be achieved using this trait as a selection criterion. Based on the expected relative genetic gain per generation of selection obtained, fewer than 5 records is required to estimate the potential of an individual in each genotype and to raise a high expected response from selection.

The local chickens especially the normal feathered and frizzle feathered strains possess considerable additive genetic variance and are recommended in crossbreeding with exotic Isa Brown chickens for production of hybrids with high repeatability of growth traits. Principal components as orthogonal traits are recommended for estimation of repeatability of body size in chickens.

Acknowledgement

The author is grateful to the college of Animal Science and Animal Production for providing a space in their teaching and research farm where this research was conducted.

Author's Contributions:

The author designed the experiment, collected, analysed and interpreted data, wrote the manuscript and provided all the financial assistance for the study.

Ethical Statement

The research was conducted in line with the regulations guiding animal welfare. The animals were humanely handled in a comfortable environment and fed non-toxic materials.

REFERENCES

Ahmed, L. (2021). Repeatability estimates of egg number and egg weight under various Production periods in three lines of local quail. *Advances in Animal and Veterinary Sciences, 9(12), 2216-2220.* http://dx.doi.org/10.17582/journal.aavs/2021/9.12.2216.2220

Akporhuarho, P. O. & Obodoagwu, E. (2020). Estimates of repeatability for body weight and conformation traits in three breeds of grower pigs. *Nigerian Journal of Animal Production*, 47(1):47 – 52. https://doi.org/10.51791/njap.v47i1.178

Becker, W.A. (1984). Manual of quantitative genetics. 4th ed. Academic Enterprises, Pullman, Washington, U.S.A.

Bourdon, R. M. (2000). Understanding Animal Breeding. 2nd ed. Upper Saddle River, NJ Prentice Hall.

Brandit, H., Werner, D. N., Baulain, U., Brade, W. & Weissman, F. (2010). Genotype–environment interactions for growth and carcass traits in different pig breeds kept under conventional and organic production. Animal, 4 (4), 535-544. https://doi.org/10.1017/S1751731109991509.

Canaza-cayo, A. W., Motab, R. R., Amarilho-Silveira, F., Duarte, D. A. S. & Cobuct, J. A. (2021). Principal component analysis for body weight prediction of Corriedale ewes from southern Peru. *Journal of Animal Health and Production*, 9(4), 417-424. http://dxdoi.org/10.17582/journal.jahp/2021/9.4.417.424

Gwelo, A. S. (2019). Principal components to overcome multicolinearity problem. Oradea *Journal of Business Economic*s, 4(1):79-91. https://doi.org/10.47535/1991ojbe0624.

Henderson, C. R. (1953). Estimation of variance and covariance components. *Biometrics*, 9(2), 226- 252. https://doi.org/10.2307/3001853

Ibe, S. N. (1995). Repeatability of growth traits in Nigerian local chickens using early records. Nigerian *Journal Animal Production*, 22(1): 5-9. https://doi.org/10.51791/njap.v22i1.2014

IBM SPSS Statistics (2011). International Business Machine Statistical Package for Social Sciences. IBM Corp Released 2011. IBM SPSS Statistics for Windows, version 20.0. Armonk, NY. IBM Corp.

Isaac, U. C. (2021). Phenotypic, genetic and environmental correlations between body Weight and linear body traits of chicken genotypes. *Agrobioligical Records*, 4, 32-43. https://doi.org/10.47278/journal.abr/2020.026.

Isaac, U. C. & Ezejesi, H. C. (2023). Genotype impact on body weight and linear body Measurements of main and reciprocal crosses of Isa Brown and local chickens. *Nigerian Journal of Animal Production*, 50(4), 1-9. https://doi.org/10.51791/njap.v50i4.3355

Isaac, U. C., Igbokwe, C. A. , Okafor, N. J., Aniemena, C. F. & Nwachukwu, B. C. (2022). Repeatability of growth traits in three strains of broiler chicken. *Malaysian Animal Husbandry Journal*, 2(2), 29-33. http://doi.org/10.26480/mahj.01.2022.29.33

Isaac, U. C. & Oriaku, J. O. (2023). Genotype × environment interaction: influence on body measurements and growth rates of weaned rabbits. *Malaysian Animal Husbandry Journal*, 3(1):39-45. http://10.26480/mahj.01.2023.39.45.

Kabir, M., Yakudu, H., Akpa, G. N., Jokthan, G. E., Abdul, S. B., Abdulrashid, M. & Adamu, Y. (2008). Repeatability for body weight and body conformation traits in Anak 2000 strains of broilers chickens. *Journal of Applied Breeding and Genetics*, 112: 17-21.

Khawaja, T., Khan, S.H., Mukhtar, N., Paveen, A. & Ahmed, T. (2013). Comparative study of growth performance, meat quality and haematological parameters of three-way crossbred chickens with reciprocal F1crossbred chickens in a subtropical environment. *Journal of Applied Animal Research*, 41 (3), 300-308. https://doi.org/10.1080/09712119.2013.782869

Lush, J. I. (1945). Animal Breeding Plans. 3rd ed. Iowa State College press, Ames, Iowa.

Mardhati, M., González, L. A., Thomson, P. C., Clark, C. E. F. & García, S. C. (2021). Short-term liveweight changes of dairy cows measured by stationary and walk-over weighing scales. *Journal of Dairy Science*, 104 (7), 8202-8213. https://doi.org/10.3168/jds.2020-19912

Nwachukwu, E. N. Ibe, S. N. and Ejekwu, K. & Oke, U. K. (2006). Evaluation of growth Parameters of main and reciprocal crossbred Normal, naked neck and frizzle chickens in a humid tropical environment. *Journal of Animal and Veterinary Advances*, 5 (7), 542- 546.

Negas, F. (2021). Application of principal component analysis for prediction of body weight of Ethiopian indigenous chicken populations. *Tropical Animal Health and Production*, 53(1), 1-15. https://doi.org/10.1007/s11250-020-02526-w

Ojedapo, L. O. (2013). Evaluation of body weight and other linear body parameters of Marshall broiler for repeatability estimates. *International Jo*urnal of Applied *Agricultural and Apicultural Research*, 9(1&2), 175-183.

Olasege, B. S., Zhang, S., Zhao, Q., Liu, D., Sun, H., Wang, Q., Ma, P. & Pan, Y. (2019). Genetic parameter estimates for body conformation traits using composite index, principal component, and factor analysis. *Journal of Dairy Science*, 102(6), 5219-5229. https://doi.org/10.3168/jds.2018-15561

Pahdi, M. K. (2016). Importance of indigenous breeds of chickens for rural economy and their improvements for higher production performance. *Scientifica*, (1): Article ID: 2604687. https://dx.doi.org/10.1155/2016/2604685

Priyce, J. E. & Daetwyler, H. D. (2011). Designing dairy cattle breeding schemes under genomic selection: a review of international research. *Animal Production Science*, 52 (3):107-114. https://doi.org/10.1071/AN11098

Raidan, F. S. S., Passafaro, T. L., Fragomeni, B. O. Josahkian, L. A., Pereira, I. G. & Toral, F. L. B. (2015). Genotype × environment interaction in k performance and progeny tests in beef cattle. *Journal of Animal Science*, 9(3), 920-933. https://doi.org/10.2527/jas.2014-7983.

Sanda, A. J., Olowofeso, O., Adeleke, M. A., Oso, A. O., Durosaro, S. O. & Sanda, M. O. (2014) Heritability and repeatability estimates of some measurable traits in meat type chickens reared for ten weeks in Abeokuta, Nigeria. *International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering*, 8 (7), 170-173.

Sola-Ojo, F. E, Fayeye, T. R., Adedibu, I. I. & Yusuff, A. T. (2017). Repeatability estimates of growth traits in Arbor Acre broiler chickens fed graded level of probiotics enhanced *Moringa oleifera* seed meal diets. Nigerian Journal of Animal Science, 19(2), 8-15.

Tenkle, A. & Mapplle, D. N. (1983). Growth and development of meat animals. *Journal of Animal Science*, 57(Suppl. 2): 273-283. https://doi.org/10.2527/animalsci1983.57Supplement_2273x

Udeh, I., & Ogbu, C. C. (2011). Principal component analysis of body measurements in three strains of broiler chicken. *Science World* Journal, 6(2): 11-14.

Xi, W-F., Jiang, Q-W. & Yang, Ai-M. (2024). Using stepwise regression to address multicollinearity is not appropriate. *International Journal of Surgery*, 110(5), 3122–3123. https://doi.org/10.1097/JS9.0000000000001208

Zarnecki, A., Fimland, E. & Rønningen, K. (1985). Conformational traits and their relation to production in Norwegian Red cattle. *Journal of Animal Breeding and Genetics*, 102(1-5): 271-284. https://doi.org/10.1111/j.1439-0388.1985.tb00695.x