PRINCIPAL COMPONENT AND DISCRIMINANT ANALYSES OF BODY WEIGHT AND CONFORMATION TRAITS OF SASSO, KUROILER AND INDIGENOUS FULANI CHICKENS IN NIGERIA

A. Yakubu* and M. M. Ari

Department of Animal Science, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus, P.M.B. 135, Lafia, Nasarawa State, Nigeria.
*Corresponding author's email address: abdulmojyak@gmail.com

ABSTRACT

This study aimed at evaluating the body weight (BW) and biometric traits [breast girth (BG), neck circumference (NC), Back length (BL), wing length (WL), thigh length (TL), thigh circumference (TC), shank length (SL) and shank circumference (SC)] of two newly introduced and one Nigerian indigenous chicken strains using multivariate principal components (PCs) and to classify the three genotypes using discriminant analysis. A total of one hundred and fifty chickens of both sexes comprising equal number of Sasso, Kuroiler and the local Fulani ecotype were utilized in the study. The birds, which were six weeks old, were managed intensively in a private farm in Nasarawa State, north central Nigeria. General linear model was used to test the fixed effects of genotype and sex including their interaction on the body parameters. With the exception of BG, the univariate analysis showed that Kuroiler birds had higher ($P<0.05$) BW and morphometric traits than Sasso, which in turn, were superior ($P<0.05$) to their Fulani counterparts. Male chickens also had a comparative advantage ($P<0.05$) over their female counterparts in BW and linear body measurements. There was genotype * sex interaction effect on all the body traits, except TC. The phenotypic correlations among the traits were positive and significant ($P<0.05$; $P<0.01$) ranging from 0.41-0.97, 0.47-0.96 and 0.42-0.94 in Sasso, Kuroiler and Fulani chickens, respectively. Factor analysis with varimax rotation of interrelated traits revealed three PCs (Sasso and Kuroiler) and two PCs (Fulani) which accounted for 87.4, 93.9 and 78.9% of the total variance in the genetic groups. The PC-based regression models, which are preferable for selecting birds for optimal balance, accounted for 92, 95 and 88% of the total variation in the BW of Sasso, Kuroiler and Fulani chickens, respectively. The most discriminating variables to separate the chicken genotypes were BG, SC, BW and TC.

Keywords: body traits, chickens, genetic groups, Multivariate, Nigeria

INTRODUCTION

Sciences that have shaped development of innovation in smallholder poultry in the last 30 years include animal health, breeding, feeding, genetics, nutrition, reproduction and socio-economics (Sonaiya, 2016). Indigenous/native chicken breeds play an important role in rural economies in most countries of the World; and are the most popular poultry worldwide irrespective of culture and region (Al-Nasser *et al*., 2007). They contribute largely to the subsidiary income of the rural poor and marginalised including the provision of nutritious chicken egg and meat for their own consumption (Padhi, 2016). The current state of knowledge on indigenous chicken genetic resources of the tropics as regards domestication, distribution, and documentation of information has been reviewed by Dessie *et al*. (2012).

Due to the low production and productivity of African indigenous chickens, efforts are currently being made to introduce some superior tropically adapted genotypes. One of such is the Kuroiler strain: These are dual-purpose scavenger chickens developed in India (Ahuja *et al*., 2008; Mwesigwa *et al*., 2015), but have been adopted in Uganda. The birds are known for superior meat and egg production under rural scavenging or semi-scavenging conditions compared to the natives (Sharma, 2011). Sasso is another improved tropically adapted germplasm, developed in France, and tested in Ghana (Osei-Amponsah *et al*., 2012). Both Kuroiler and Sasso genotypes are newly introduced into the Nigerian tropical environment; hence the dire need for their characterization (Yakubu and Ari, 2016).

The first phase of characterization involves the identification of populations based on morphological descriptors that can also provide useful information on the suitability of breeds for selection (Ajayi *et al*., 2012; N'dri *et al*., 2016). Body weight and linear body measurements are of economic importance in livestock classification, evaluation and improvement (Khargharia *et al*., 2015; Ekka *et al*., 2016; Lukuyu *et al*., 2016). These body parameters are also better assessed using multivariate principal component and discriminant analyses than the univariate approach (Yakubu *et al*., 2009; Malomane *et al*., 2014; Ribeiro *et al*., 2016; Dahloum *et al*., 2016).

While there are few reports on the body weight and morphological traits of Sasso and Kuroiler chicken in Africa, there is no documented information about these strains in Nigeria. The present investigation therefore, was carried out to undertake a systematic phenotypic characterization of Sasso and Kuroiler birds alongside the indigenous Fulani populations in Nigeria using a multivariate approach in order to pave way for subsequent interventions in terms of breeding, utilization and conservation. Body weights of the birds were also predicted from their linear body measurements using orthogonal and non-orthogonal traits.

MATERIALS AND METHODS

Experimental site: Imported eggs of Sasso and Kuroiler and those of the locally sourced Nigerian Fulani chickens were hatched at Fol-Hope Farms Ltd, New Airport Road, Ibadan, Oyo State, Nigeria and the day-old chicks of the three strains arrived Gunduma Integrated Farms, Keffi-Kaduna Road, Keffi LGA, Nasarawa State, Nigeria, on 11th August, 2016. The geographical coordinates of the Farm are 8° 57' 43" North, 7° 53' 33" East.

Birds' management: A total of 150 randomly sampled birds of both sexes comprising equal number of Sasso (25 males + 25 females), Kuroiler (25 males + 25 females) and Fulani (25 males + 25 females) chickens were utilized in the study. The birds were part of a larger flock of each strain. The three strains, which were kept in separate pens, were subjected to similar conditions. They were fed commercial mash from day 1 to 42-day of rearing. Feed and fresh clean water were supplied *ad libitum*. The day-old birds were given intraocular vaccination against Newcastle disease. At days 10 and 25, Gumboro vaccines were administered on the birds while Newcastle Disease Vaccine (Lasota) was administered orally when the birds were 17 and 32 days old. Fowl pox vaccine (wing web) was given on day 36. There was also routine administration of antibiotics, vitamins and coccidiostat (Amprolium) in the drinking water.

Measured traits: At day 42 (six weeks) of rearing, shortly before the distribution of birds to farmers for on-farm testing in the 12 villages under the African Chicken Genetic Gains (ACGG) project in Zone 4, Nasarawa State, Nigeria, certain body parameters were taken. Body weight (BW) and eight biometric traits were measured. The anatomical reference points considered were as described by earlier workers (Yakubu *et al*., 2009; Bett *et al*., 2014) as follows:

Breast girth (BG). It was measured with the tape at the anterior end of the keel bone. The tape was passed under the wings and anterior to the legs;

Neck circumference (NC): Taken at the widest point of the neck

Back length (BL: This was taken when the chicken was on a standing position; the neck curved so that the neck was almost perpendicular to the back. The back was measured from the nadir of the curve to the base of the tail;

Thigh length (TL): Distance between the hock joint and the pelvic joint;

Thigh circumference (TC): Measured as the circumference at the widest point of the thigh;

Wing Length (WL): This was taken from the shoulder joint to the extremity of the terminal phalanx, digit III;

Shank length (SL): Distance from the shank joint to the extremity of the Digitus pedis;

Shank circumference (SC): It was taken at the uppermost part of the shank;

The weight measurement was carried out using a digital scale while the length and circumference measurements were done with a tape. All measurements were taken by the same person to avoid between-individual variations.

Statistical analysis: Data were analyzed using the general linear model (GLM) of SPSS (2010) statistical software to test the fixed effects of breed, sex and age as well as their interactions on BW, BG, NC, BL, WL, TL, TC, SL and SC. Means were separated using Duncan's Multiple Range Test (DMRT) at 95 % confidence interval. The following linear model was employed:

$Y_{ijk} = \mu + G_i + S_j + (GS)_{ijk} + e_{ijk}$

Y_{ijk} = individual observation

μ = overall mean

G_i = fixed effect of i^{th} strain (i = Kuroiler, Sasso, Fulani).

S_j = fixed effect of j^{th} sex (j = male, female)

$(GS)_{ijk}$ = interaction effect of strain and sex

e_{ijk} = random error associated with each record (normally, independently and identically distributed with zero mean and constant variance)

Pearson's coefficients of correlation were first estimated for all the body traits. This was followed by principal component (PC) analysis. Cumulative proportion of variance criterion was employed in determining the number of PCs to extract. The factor matrix was rotated using the varimax criterion for easy interpretation of the PC analysis, which reliability was tested using The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's Test of Sphericity.

A multiple regression procedure using a stepwise variable selection was used to obtain models of estimation of BW from biometric measurements and from established principal components factor scores (Dahloum *et al*., 2016):

$BW = a + b_1X_1 + ... + b_kX_k,$

$BW = c + d_1PC_1 + ... + d_kPC_k,$

where BW is the body weight, a and c are the regression intercepts, b_i and d_i are the i^{th} partial regression

coefficients of the i^{th} linear body measurement or principal component, and X_i and PC_i are the i^{th} morphometric traits or principal component.

In order to identify the combination of variables that best separate the three genetic groups, canonical discriminant analysis was used (Tabachnick and Fidel, 2001). In this wise, BW and the eight biometric traits were introduced as predictor variables in a stepwise manner into the discriminant analysis. The relative importance of the linear body measurements in discriminating the three strains was assessed using the F-to-remove statistic while tolerance statistic was used to detect multicollinearity among the variables used in the discriminant function. The ability of this discriminant model to identify Sasso, Kuroiler and Fulani chickens was indicated as the percentage of individuals correctly classified from the sample that generated the model. Split-sample validation (cross-validation) was used to evaluate the accuracy of the classification.

RESULTS

With the exception of BG in Sasso, the univariate analysis revealed that Kuroiler chickens had significantly ($P<0.05$) higher BW and biometric traits compared to the two other genetic groups. However, Sasso birds had higher ($P<0.05$) body attributes than their Fulani counterparts in all the body parameters estimated (Table 1).

Sex effect on BW and morphometric traits was significant ($P<0.05$) (Table 2). Male chickens had higher body traits compared to their female counterparts.

The analysis of variance showing interaction effect on BW and linear body measurements of chickens is shown in Table 3. There was Genotype * Sex interaction effect ($P<0.05$) on all the size and shape measurements except TC.

Correlation Coefficients of BW and biometric traits of the three genetic groups are presented in Table 3. The phenotypic correlations in Sasso [r= 0.41-0.96 (male) and 0.41-0.97 (female)], Kuroiler [r= 0.61-0.89 (male) and 0.47-0.96 (female)] and Fulani birds [r= 0.43-0.94 (male) and 0.42-0.90 (female)] were positive and significant ($P<0.05$; $P<0.01$). However, BW was more highly correlated with BG (r= 0.96) and TC (r= 0.97) in Sasso male and female, respectively. In Kuroiler birds, the association between BW and WL was greatest in both male and female birds (r = 0.88 and 0.96, respectively). The relationship between BW and WL (r= 0.94) was highest in male Fulani birds, while in the female birds, BW was more associated with TC (r= 0.90).

KMO values (0.865; 0.912 and 0.860 for Sasso, Kuroiler and Fulani birds) were high enough. Bartlett's Test of Sphericity (Chi-square = 344.642; $P<0.01$; 561.083; $P<0.01$ and 279.181; $P<0.01$ for Sasso, Kuroiler and Fulani birds) also provided support for the validity for the application of PC analysis on the data set. The communalities ranged from 0.779-0.964; 0.914-0.980 and 0.734-0.856 in the three genetic groups, respectively. While, three PCs were extracted in Sasso and Kuroiler, two PCs sufficed for Fulani birds and these accounted for 87.4, 93.9 and 78.9% of the total variance in the three genetic groups. PC1 in Sasso accounted for the greatest percentage of the total variation (67.195%). It had its loadings for BG, NC, WL, TC and SL, and was termed general size. BL and SC were more associated with PC2 while TL was the trait of interest in PC3. In Kuroiler, BG, NC, BL, TL and SC greatly influenced PC1 accounting for 86.087% of the total variance. PC2 was determined by WL and SL while PC3 was solely influenced by TC. PC1 in Fulani had its loadings for BG, NC, BL, TC and SC explaining 62.051% of the total variation. PC2 was characterized by WL, TL and SL contributing 16.800% to the total variance.

The inter-dependent original biometric traits and their independent principal component factor scores were used to predict the BW of Sasso, Kuroiler and Fulani chickens (Table 5). The PC-based prediction equations, accounted for 92, 95 and 88% of the total variation in the BW of Sasso, Kuroiler and Fulani birds, respectively.

Results of the stepwise discriminant analysis showing Wilk's Lambda values, F-values, probability and tolerance statistics are presented in Table 6. The discriminant analysis based on significant F-values indicated BG, SC, BW and TC as the linear measures permitting discrimination among the Sasso, Kuroiler and Fulani chickens. Figure 1 showed that the indigenous Fulani type was marked distinct from their exotic counterparts. Similarly, the canonical discriminant function revealed that 84.0%, 82.0%, and 100.0% of Sasso, Kuroiler and Fulani chickens were correctly assigned into their distinct genetic groups (Table 7).

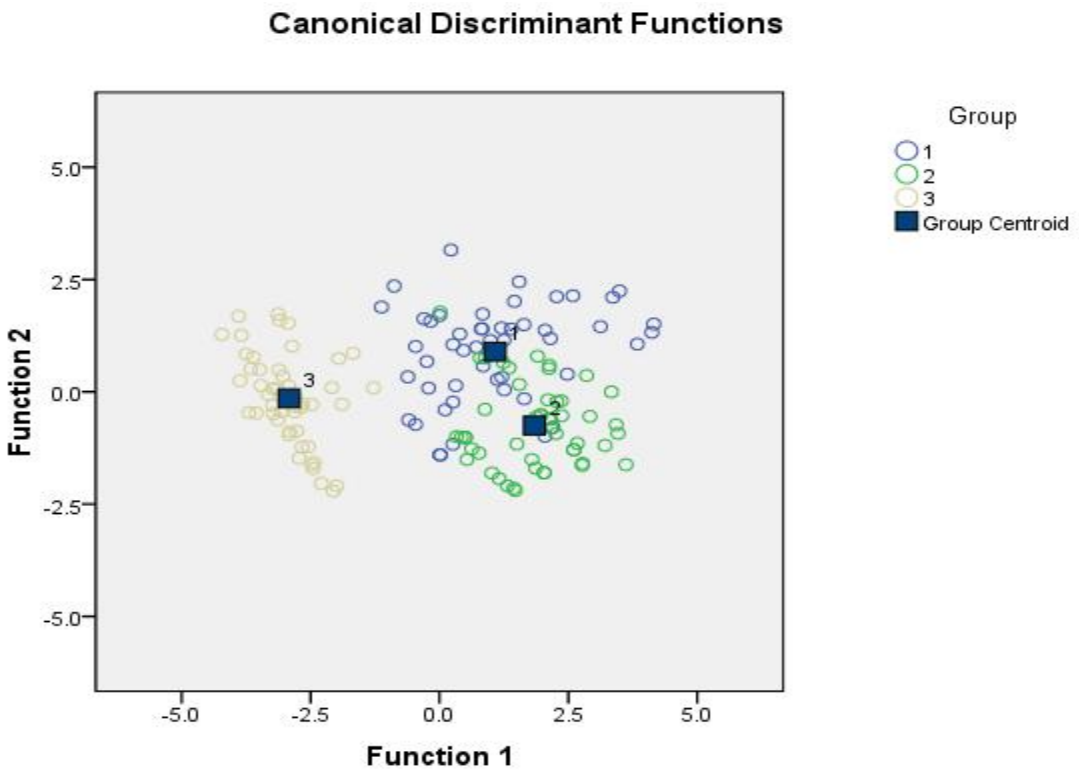

Figure 1. Canonical discriminant function showing the distribution among the three chicken genotypes. 1 represents Sasso, 2 stands for Kuroiler and 3 depicts Fulani chickens.

Table 1. Effects of strain and sex on body weight (grams) and morphometric traits (cm) of chickens.

Traits	Strain			Sex	
	Sasso	Kuroiler	Fulani	Male	Female
	Mean(±SE)	Mean (±SE)	Mean (±SE)	Mean (±SE)	Mean (±SE)
BW	416.82±6.49^{b}	450.86±6.49^{a}	228.66±6.49^{c}	404.07±5.30^{a}	326.83±5.30^{b}
BG	17.72±0.15^{a}	18.116±0.15^{a}	12.66±0.15^{b}	16.96±0.13^{a}	15.37±0.13^{b}
NC	5.82±0.07^{b}	6.11±0.07^{a}	4.03±0.07^{c}	5.69±0.06^{a}	4.95±0.06^{b}
BL	17.68±0.20^{b}	19.25±0.20^{a}	13.28±0.20^{c}	17.79±0.17^{a}	15.68±0.17^{b}
WL	12.48±0.11^{b}	13.02±0.11^{a}	10.80±0.11^{c}	12.47±0.09^{a}	11.74±0.09^{b}
TL	7.52±0.07^{b}	7.76±0.07^{a}	6.34±0.07^{c}	7.32±0.06^{a}	7.09±0.06^{b}
TC	6.15±0.10^{b}	6.92±0.10^{a}	4.55±0.10^{c}	6.47±0.08^{a}	5.28±0.08^{b}
SL	4.66±0.07^{b}	4.93±0.07^{a}	3.46±0.07^{c}	4.58±0.06^{a}	4.12±0.06^{b}
SC	3.42±0.04^{b}	3.87±0.04^{a}	2.98±0.04^{c}	3.61±0.03^{a}	3.24±0.03^{b}

BW= body weight; BG= breast girth; NC= neck circumference; BL= Back length; WL= wing length; TL= thigh length; TC= thigh circumference; SL= shank length; SC= shank circumference

Means in the same row with different superscripts are significantly different (P<0.05)

Table 2. Analysis of variance showing the interaction effect of strain and sex of chickens on body weight and morphometric traits.

SV		Mean squares and level of significance								
	DF	BW	BG	NC	BL	WL	TL	TC	SL	SC
G x S		17479.760	27.729	3.032	75.827	4.555	7.470	0.809	3.775	1.567
Residual		2105.704	1.188	0.271	2.069	0.573	0.274	0.498	0.267	.088

SV= source of variation, G x S= strain by sex interaction, DF= degree of freedom

Table 3. Phenotypic correlations of the body weight and morphometric traits of chickens[**].

Traits	BW	BG	NC	BL	WL	TL	TC	SL	SC
Sasso birds									
BW		0.96	0.82	0.68	0.89	0.41*	0.86	0.88	0.82
BG	0.89		0.78	0.65	0.91	0.42*	0.82	0.89	0.79
NC	0.73	0.72		0.79	0.76	0.58	0.76	0.75	0.71
BL	0.77	0.78	0.60		0.76	0.68	0.75	0.69	0.57
WL	0.73	0.79	0.56	0.78		0.53	0.93	0.94	0.75
TL	0.91	0.79	0.74	0.75	0.76		0.60	0.60	0.44*
TC	0.97	0.84	0.71	0.72	0.70			0.90	0.76
SL	0.71	0.65	0.77	0.47*	0.41*	0.62	0.63		0.79
SC	0.77	0.81	0.53	0.75	0.69	0.72	0.72	0.58	
Kuroiler birds									
BW		0.83	0.82	0.70	0.88	0.83	0.73	0.82	0.87
BG	0.68		0.80	0.61	0.86	0.75	0.89	0.76	0.79
NC	0.84	0.50		0.72	0.83	0.82	0.80	0.71	0.78
BL	0.81	0.73	0.52		0.66	0.86	0.72	0.62	0.56
WL	0.96	0.76	0.80	0.81		0.84	0.77	0.78	0.78
TL	0.88	0.57	0.76	0.74	0.81		0.80	0.70	0.74
TC	0.81	0.47*	0.74	0.62	0.71	0.72		0.71	0.77
SL	0.78	0.83	0.65	0.67	0.84	0.72	0.47*		0.83
SC	0.86	0.55	0.69	0.76	0.82	0.73	0.77	0.65	
Fulani birds									
BW		0.78	0.83	0.87	0.94	0.77	0.74	0.67	0.62
BG	0.85		0.72	0.71	0.74	0.56	0.48*	0.59	0.72
NC	0.78	0.73		0.59	0.86	0.78	0.52	0.66	0.70
BL	0.63	0.61	0.62		0.78	0.67	0.73	0.61	0.62
WL	0.80	0.63	0.50	0.46*		0.80	0.71	0.74	0.60
TL	0.73	0.60	0.72	0.58	0.60		0.72	0.76	0.53
TC	0.90	0.74	0.75	0.59	0.65	0.74		0.51	0.43*
SL	0.85	0.71	0.74	0.59	0.67	0.75	0.80		0.49*
SC	0.79	0.70	0.59	0.42*	0.66	0.54	0.62	0.78	

**Significant at P<0.01 for all correlation coefficients except where otherwise stated; *Significant at P<0.05

Upper matrix: Male chickens

Lower matrix: Female chickens

Table 4. Eigenvalues and share of total variance along with factor loadings after varimax rotation and communalities of the morphometric traits of chickens.

Traits	PC1	PC2	PC3	Communality
Sasso birds				
BG	0.849	0.448	0.079	0.928
NC	0.890	0.015	0.211	0.837
BL	0.053	0.833	0.459	0.907
WL	0.856	0.408	0.117	0.845
TL	0.323	0.371	0.850	0.964
TC	0.907	0.165	0.181	0.882
SL	0.807	0.209	0.290	0.779
SC	0.539	0.734	0.131	0.847
Eigenvalues	5.376	1.171	0.443	
% of total variance	67.195	14.640	5.534	
% cumulative variance	67.195	81.835	87.369	
Kuroiler birds				
BG	0.639	0.631	0.330	0.915

NC	0.592	0.500	0.563	0.917
BL	0.839	0.366	0.346	0.958
WL	0.405	0.719	0.505	0.935
TL	0.785	0.418	0.377	0.933
TC	0.366	0.357	0.847	0.980
SL	0.420	0.818	0.337	0.960
SC	0.590	0.533	0.531	0.914
Eigenvalues	6.887	0.340	0.284	
% of total variance	86.087	4.246	3.552	
% cumulative variance	86.087	90.333	93.885	
Fulani birds				
BG	0.790	0.386		0.773
NC	0.711	0.520		0.776
BL	0.915	0.060		0.840
WL	0.492	0.705		0.739
TL	0.019	0.925		0.856
TC	0.864	0.164		0.773
SL	0.315	0.847		0.816
SC	0.814	0.267		0.734
Eigenvalues	4.964	1.344		
% of total variance	62.051	16.800		
% cumulative variance	62.051	78.851		

Table 5. Stepwise multiple regression of body weight on original body measurements and on their principal component factor scores in chickens.

Model	Significance	R^2	Adjusted R^2	RMSE
Sasso birds				
Original body measurements as predictors				
1. BW= -313.67 + 41.22BG	P<0.01	0.876	0.873	19.92
2. BW= -185.331 + 26.26BG + 22.23TC	P<0.01	0.923	0.920	15.82
3. BW= -185.65 + 23.86BG + 17.891TC + 11.98NC	P<0.01	0.932	0.927	15.08
Principal components as predictors				
1. BW= 416.820 + 50.28PC1	P<0.01	0.810	0.806	24.64
2. BW= 416.820 + 50.28PC1 + 16.93PC2	P<0.01	0.901	0.897	17.93
3. BW= 416.820 + 50.28PC1 + 16.93PC2 + 6.523PC3	P<0.01	0.915	0.909	16.83
Kuroiler birds				
Original body measurements as predictors				
1. BW= -181.525 + 163.289SC	P<0.01	0.887	0.885	27.51
2. BW= -410.32 + 94.75SC + 37.95WL	P<0.01	0.940	0.938	20.22
3. BW= -413.09 + 73.50SC + 30.50WL + 23.48TL	P<0.01	0.952	0.949	18.30
Principal components as predictors				
1. BW= 450.86 + 48.02PC1	P<0.01	0.350	0.337	66.10
2. BW= 450.86 + 48.02PC1 + 47.35PC2	P<0.01	0.691	0.677	46.10
3. BW= 450.86 + 48.02PC1 + 47.35PC2 + 40.90PC3	P<0.01	0.945	0.942	19.73
Fulani birds				
Original body measurements as predictors				
1. BW= 29.98+ 14.959BL	P<0.01	0.821	0.817	17.92
2. BW= -64.06BL+ 34.17NC	P<0.01	0.877	0.872	15.01
3. BW= -70.32 + 8.65 BL + 27.92NC + 15.76TC	P<0.01	0.898	0.892	13.80
Principal components as predictors				
1. BW= 228.66+ 38.80PC1	P<0.01	0.856	0.853	16.08
2. BW= 228.66+ 38.80PC1+ 6.10PC2	P<0.01	0.877	0.872	15.02

Table 6. Body parameters selected by stepwise discriminant analysis to separate Sasso, Kuroiler and Fulani chickens

Traits	Wilk's Lambda	F-remove	P-Level	Tolerance
Breast girth	0.258	16.061	0.001	0.196
Shank circumference	0.147	44.802	0.001	0.279
Body weight	0.136	10.504	0.001	0.114
Thigh circumference	0.125	6.091	0.001	0.269

Table 7. Classification results for the discriminant analysis of three chicken populations.

		Predicted group membership			
	Strains	Sasso	Kuroiler	Fulani	Total
Original count	Sasso	42	8	0	50
	Kuroiler	9	41	0	50
	Fulani	0	0	50	50
%	Sasso	84.0	16.0	0.0	100.0
	Kuroiler	18.0	82.0	0.0	100.0
	Fulani	0.0	0.0	100.0	100.0
Cross-validated count	Sasso	39	11	0	50
	Kuroiler	9	41	0	50
	Fulani	0	0	50	50
%	Sasso	78.0	22.0	0.0	100.0
	Kuroiler	18.0	82.0	0.0	100.0
	Fulani	0.0	0.0	100.0	100.0

88.7% of original grouped cases correctly classified.
86.7% of cross-validated grouped cases correctly classified.

DISCUSSION

There is a global recognition of characterization as an important step towards the sustainable use of animal genetic resources. This is the first report of BW and biometric traits of Sasso, Kuroiler alongside the native Fulani chickens in Nigeria. Sharma *et al*. (2015) reported that Kuroilers gained BW more rapidly and to a higher level than the native birds; although, theirs was at intervals between 11 and 43 weeks of age. In a related study, Osei-Amponsah *et al*. (2012) reported that SASSO T44 chickens had significantly higher weights than the local chickens under improved management practices. The higher body attributes of Kuroiler and Sasso chickens in the present study could be due to their genetic potential. However, the smaller body weights and morphometric traits of the Fulani chickens could be part of the birds' adaptation for survival under the low-inputs tropical environment. According to Fayeye *et al*. (2014), small body parts appeared to have aided the Nigerian indigenous chickens' fitness to the tropical environment and to scavenging rearing conditions. Ahmad and Singh (2007) reported that growth and production traits of birds indicate their genetic constitution and adaptation to the specific environment. In a related study, Ali and Brenøe (2002) opined that genetic and underlying size differences should be considered in breed comparison. The BW of chickens forms the basis for a range of research and management activities which include the evaluation of growth, development, response to the environmental factors and feed efficiency. Considering the importance to identify potential poultry strains, suitable for backyard farming as well as commercial farming in different regions of Nigeria which are easily adaptable to the prevailing tropical environment, the use of Kuroiler and Sasso strains (with established higher BW and morphometric traits) appears promising. These two strains may complement the existing Nigerian indigenous birds especially the Fulani chickens; as indigenous populations of animals have developed unique adaptations to their local environments, which according to (Fleming *et al*., 2016), may include factors such as response to thermal stress, drought, pathogens and suboptimal nutrition. A crossbreeding programme involving the local Fulani birds and the two new strains also appears feasible to boost local production and possibly increase the income of the rural chicken farmers who are predominantly women and youths.

Body weight, body length, chest circumference, shank length, wingspan, thigh length of male chickens were found to be higher than those of the female birds in Southern Highlands of Tanzania (Guni *et al*., 2013). Similarly, Osei-Amponsah *et al*. (2012) reported that male chickens had significantly ($P<0.05$) superior growth rates than females across all genotypes except from the 20^{th} to the 28^{th} week. The superiority of males over

females might not be unconnected with sexual dimorphism, which according to Semakula *et al*. (2011), could be as a result of hormonal differences in both sexes which is responsible for greater muscle development in male than in female chickens. This was substantiated by the submission of Mank (2009) that the evolution of sexual dimorphism is facilitated by sex chromosomes, as these are the only portions of the genome that differ between males and females.

The present findings indicate the separate rankings of the three genotypes under the two sexes investigated. Genotype * sex interaction shows that the strains performed differently in both sexes for the traits that were influenced.

The varying phenotypic correlation coefficients among the three strains suggest differences in the genetic architecture of the birds. The strong relationship existing between BW and biometric traits may be useful as selection criterion where information on heritability is not available. It is also an indication that BW can be predicted from linear body measurements (Fayeye *et al*., 2014).

The present findings are consistent with the reports of earlier workers, where general size was found generally as the main factor of variation and thus constitutive of the first axis of PC analysis in chickens (Udeh and Ogbu, 2011; Ajayi *et al*., 2012; Egena *et al*., 2014; Dahloum *et al*., 2016). The PC analysis allowed for better understanding of the complex correlations among the traits and reduced the number of traits, using only the first two and three PCs, without loss of information in the present study. The PC factors obtained in the present study could be used to define body size and conformation of the three strains; thereby providing information on their skeletal development and identify body measures suitable to be used as ecological indicator for environmental and population changes. Where there is no information on the genetic parameters of chicken, the use of morphometric traits may be a better alternative and may be selected jointly to improve BW in the three strains investigated. BW is an important attribute in poultry production and it's usually estimated using weighing scales. However, under certain circumstances, especially in the rural settings, a scale may not be available. Practical difficulties in measuring BW in the field have led scientists to develop prediction models to estimate live weight from linear body measurements (Dahloum *et al*., 2016). In the presence of multicollinearity, the standard errors of the parameter estimates could be quite high, resulting in unstable estimates of the regression model. Therefore, using the multiple linear regression analysis to investigate the relationships between BW and morphometric traits cannot give reliable results (Mendes, 2011). Alternatively, many researchers have used the independent factor scores derived from multivariate technique of principal component factor analysis to predict BW in chickens (Yakubu *et al*., 2009; Ajayi *et al*., 2012; Dahloum *et al*., 2016).

The performance of a discriminant function analysis in classification is evaluated by estimating the probabilities of misclassification (Aklilu *et al*., 2014). The ability of the discriminant function to successfully classify the three strains can be useful in making general management decisions especially in smallholder farms. This is in consideration of the difficulties in subjective separation of Kuroiler from Sasso based on appearance. For breeding purpose, it is fundamental to better morphologic evaluation through the use of multitrait information (Pinto *et al*., 2008) as discriminant functions can be useful for the selection of breeding stock and to avoid registration of animals not meeting the phenotypic standards of the breed association.

Conclusion: Kuroiler and Sasso birds had a superior advantage over the indigenous Fulani chickens in six-week BW and linear body measurements. The PCs obtained in the present study could be used to define body size and conformation of the three genetic groups while BG, SC, BW and TC were sufficient to assign them into their apriori groups. Information obtained from this study could be useful in appropriate management, breeding programmes for selection and utilization of Nigerian chicken genetic resources.

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REFERENCES

Ahmad, M. and P.K. Singh (2007). Estimates of genetic parameters for some economic traits in White Leghorn. Indian J. Poult. Sci. 42: 311-312.

Ahuja, V., M. Dhawan, M. Punjabi and L. Marse (2008). Poultry based livelihoods of rural poor: Case of Kuroiler in West Bengal. South Asia Pro Poor Livestock Policy Programme (also available at http://sapplpp.org/informationhub/doc012-poultry-livelihoods-rural-poor-kuroiler-west-bengal-study-report).

Ajayi, O.O., M.A. Adeleke, M.T. Sanni, A. Yakubu, S.O. Peters, I.G. Imumorin, C.O.N. Ikeobi, M.O. Ozoje and O.A. Adebambo (2012). Application of principal component and discriminant analyses to morphostructural indices of indigenous and exotic chickens raised under intensive management system. Trop. Anim. Health Prod. 44: 1247-1254.

Aklilu, E., Gebreyesus, G., Kebede, K. and T. Dessie (2014). Morphological traits as a measure of genetic diversity for two indigenous chicken ecotypes in Ethiopia. Proceedings, 10th World Congress of Genetics Applied to Livestock Production.

Ali, K.O. and U.T. Brenøe (2002). Comparing genotypes of different body sizes for growth-related traits in chickens. live weight and growth performance under intensive and feed-restricted extensive systems. Acta Agric. Scand. (Section A-Animal Science) 52: 1-10.

Al-Nasser, A., H. Al-Khalaifa, A. Al-Saffar, F. Khalil, M. Albahouh, G. Ragheb, A. Al-Haddad and M. Mashaly (2007). Overview of chicken taxonomy and domestication. World's Poult. Sci. J. 63: 285–300

Bett, R.C., A.K.F.H. Bhuiyan, M.S. Khan, G.L.L.P. Silva, Le Thi Thuy, F. Islam, M.N.D. Abeykoon, T.H. Nguyen, Sumara Sadef, O. Mwai and M.N.M. Ibrahim (2014). Phenotypic Variation of Native Chicken Populations in the South and South East Asia. Int. J. Poult. Sci. 13: 449-460.

Dahloum, L. N. Moula, M. Halbouche and S. Mignon-Grasteau (2016). Phenotypic characterization of the indigenous chickens (Gallus gallus) in the northwest of Algeria. Arch. Anim. Breed. 59: 79–90.

Dessie, T., N. Dana, W. Ayalew, and O. Hanotte (2012). Current state of knowledge on indigenous chicken genetic resources of the tropics: domestication, distribution and documentation of information on the genetic resources. World's Poult. Sci. J. 68: 11–20.

Egena, S.A., A. T. Ijaiya, D. M. Ogah and V. E. Aya (2014). Principal component analysis of body measurements in a population of indigenous Nigerian chickens raised under extensive management systems. Slovak J. Anim. Sci., 47: 77-82.

Ekka, R., N.C. Behura, L. Samal, G.D. Nayak, P.K. Pati and P.K. Mishra (2016). Growth performance and linear body measurements of Hansli, CSML and Hansli×CSML cross under intensive system of rearing. J. Livest. Sci. 7: 114-121.

Fayeye, T.R., J.K. Hagan and A.R. Obadare (2014). Morphometric traits and correlation between body weight and body size traits in Isa Brown and Ilorin Ecotype chickens. Iran. J. Appl. Anim. Sci. 4: 609-614.

Fleming, D.S., J.E. Koltes, A.D. Markey, C.J. Schmidt, C.M. Ashwell, M.F. Rothschild, M.E. Persia, J.M. Reecy and S.J. Lamont (2016). Genomic analysis of Ugandan and Rwandan chicken ecotypes using a 600 k genotyping array. BMC Genom. 17:407 DOI: 10.1186/s12864-016-2711-5.

Guni, F.S., Katule, A.M. and P.A.A. Mwakilembe (2013). Characterization of local chickens in selected districts of the Southern Highlands of Tanzania: II. Production and Morphometric traits. Livest. Res. Rur. Devel. 25: Article #190.

Khargharia, G., G. Kadirvel , S. Kumar, S. Doley, P. K. Bharti and Mukut Das (2016). Principal component analysis of morphological traits of Assam Hill goat in eastern Himalayan India. J. Anim. Plant Sci. 25 (5): 1251-1258.

Lukuyu, M.N., J.P. Gibson, D.B. Savage, A.J. Duncan, F.D.N. Mujibi and A.M. Okeyo (2016). Use of body linear measurements to estimate liveweight of crossbred dairy cattle in smallholder farms in Kenya. SpringerPlus 5: 63; DOI: 10.1186/s40064-016-1698-3.

Malomane, D.K., D. Norris, C.B. Banga and J.W. Ngambi (2014). Use of factor scores for predicting body weight from linear body measurements in three South African indigenous chicken breeds. Trop. Anim. Health Prod. 46: 331-335.

Mank, J.E. (2009). Sex chromosomes and the evolution of sexual dimorphism: lessons from the genome. Am. Nat. 173: 141-150.

Mendes, M. (2011). Multivariate multiple regression analysis based on principal component scores to study relationships between some pre- and post-slaughter traits of broilers. Tarım Bilimleri Dergisi – J. Agric. Sci. 17: 77-83.

Mwesigwa, M., J. Semakula, P. Lusembo, J. Ssenyonjo, R. Isabirye, R. Lumu and T. Namirimu (2015). Effect of pre-incubation and incubation conditions on hatchability and chick quality of Kuroiler chickens. Ugand. J. Agric. Sci. 16: 115 – 127.

N'dri A. L., N. Fofana, A.J.L. Okon and A.B. Adepo-Gourene (2016). Biometric characterization of local chicken "Gallus gallus domesticus" according to the sex and phenotype from traditional breedings of Dabakala (Côte d'Ivoire). Int. J. Environ. Agric. Res. 2: 1-6.

Osei-Amponsah, R., B.B. Kayang and A. Naazie (2012). Age, genotype and sex effects on growth performance of local chickens kept under

improved management in Ghana. Trop. Anim. Health Prod. 44: 29-34.

Padhi, M.K. (2016). Importance of indigenous breeds of chicken for rural economy and their improvements for higher production performance. Scientifica 2016: http://dx.doi.org/10.1155/2016/2604685.

Pinto, L.F.B., F.Q., Almeida, C.R. Quirino, P.C.N. Azevedo, G.C. Cabral, E.M. Santos and A. Corassa (2008). Evaluation of sexual size dimorphism in Mangalarga Marchador horses using discriminant analysis. Livest. Sci. 119: 161-166.

Ribeiro, J.C., L.P. da Silva, G.D.C. Caetano, A.C. Crispim, R.D.O. Pacheco and R.D.A. Torres (2016). Canonical correlation analysis applied to production and reproduction traits of meat type quails. Ciência Rural 46: 1289-1294.

Semakula, J., P. Lusembo, D.R. Kugonza, D. Mutetikka, J. Ssennyonjo and M. Mwesigwa (2011). Estimation of live body weight using zoometrical measurements for improved marketing of indigenous chicken in the Lake Victoria basin of Uganda. Livest. Res. Rur. Devel. 23: Article #170.

Sharma, J., J. Xie, M. Boggess, E. Galukande, D. Semambo and S. Sharma (2015). Higher weight gain by Kuroiler chickens than indigenous chickens raised under scavenging conditions by rural households in Uganda. Livest. Res. Rur. Devel. 27: Article #178.

Sharma, J. (2011). A new breed: Highly productive chickens help raise Ugandans from poverty researcher at the Center for Infectious Diseases and Vaccinology at ASU's Biodesign Institute. https://asunews.asu.edu/ node/21034.

Sonaiya, E.B. (2016). Science, technology and innovations for smallholder poultry development. 1st World Congress on Innovations for Livestock Development, Sentrim Elementaita Lodge, Nakuru, Kenya. www.ilinova.org.

SPSS (2010). Statistical Package for Social Sciences.SPSS Inc., 444 Michigan Avenue, Chicago, IL60611, 2010.

Tabachnick, B.G. and L.S. Fidell (2001). Using Multivariate Statistics. Allyn and Bacon, Boston, USA. 966 pp.

Yakubu, A. and M.M. Ari (2016). Multivariate analysis of body weight and other traits of Sasso, Kuroiler and indigenous Fulani chickens in a tropical environment of Nigeria. Proceedings of the 40th Annual Conference of Genetics Society of Nigeria (GSN), University of Jos, Nigeria, 30th October-2nd November, 2016. Abstract

Yakubu, A., D. Kuje and M. Okpeku (2009). Principal components as measures of size and shape in Nigerian indigenous chickens. Thai J. Agric. Sci. 42: 167–176.

Udeh, I. and Ogbu, C. I. (2011). Principal component analysis of body measurements in three strains of broiler chicken. Sci. World J. 6: 11–14.