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MULTIVARIATE PRINCIPAL COMPONENT ANALYSIS OF THE MORPHOMETRIC TRAITS OF SOME CATTLE BREEDS IN NIGERIA

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ABSTRACT

The conservation of Nigerian cattle is of increasing concern because of their historical and genetic value. Phenotypic characterization involves the differentiation of groups and/or breeds and provides support for conservation programmes. In this study, we reported quantitative examination of four Nigerian cattle breeds using multivariate technique. Data were collected from a total of 2,120 randomly selected trade cattle of both sexes (1,008 males and 1,112 females) comprising 859 Bunaji, 674 Sokoto Gudali, 409 Rahaji and 178 Kuri transported from the northern parts to the south western part of the country for sale. The animals were divided into four ages viz., 2-tooth, 4-tooth, 6-tooth and 8-tooth ages, respectively based on the eruption of permanent incisors. Eight biometric traits were taken on each animal namely height at withers (HTW), height at shoulders (HTS), body length (BDL), shoulder to tail drop (STD), heart girth (HTG), cannon circumference (CNC), ear length (ERL) and tail length (TLL). The fixed effects of breed, sex and age including their interactions on body traits were tested using General linear model (GLM). Pearson's coefficients of correlation among the various linear body measurements were computed. The multivariate approach involved the use of principal component (PC) analysis. Based on univariate analysis, the Kuri cattle had significantly (P<0.05) higher morphometric variables compared to other breeds. Sex and age also influenced (P<0.05) all the body parameters while there were breed and sex; breed and age; sex and age; and breed and sex and age interaction effects on the body traits. Phenotypic correlation Coefficients among the traits were positive and significant (P<0.01), ranging from 0.13-0.92. In the PC analysis, two parameters (STD and HTS) were sufficient for breed differentiation based on eigenvalue lower than 0.7. The present information may be useful for animal evaluation and when complemented with molecular diversity analysis, could be exploited in future efforts aimed at conserving the indigenous cattle.

Keywords: Morphological traits, multivariate analysis, diversity, cattle, Nigeria.

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INTRODUCTION

There are very diverse livestock breeds that are adapted to a wide variety of environments as a result of domestication, breed formation and selection schemes. Such locally adapted or indigenous breeds with special characteristics are usually owned by rural farmers (Rege *et al*., 2011). The indigenous livestock breeds are indispensable to rural farmers and produce a wider range of products. They could also be managed under low forage and health management and are more sustainable ecologically, especially in marginal environments (Kohler-Röllefson, 2000; Rege *et al*., 2011; Aksoy *et al*., 2018). There exists enormous intra- and inter-group variability in productive, morphological and adaptive traits of cattle breeds (The Bovine HapMap Consortium, 2009; Mustapha *et al*., 2018; Ladyka *et al*., 2020). Despite the identification of most indigenous African breeds of cattle, majority of them remain largely uncharacterized phenotypically and molecularly (Nyamushamba *et al*., 2017).

External appearance (morphology) is still commonly used by researchers and practitioners in the identification, characterization and selection of farm animals (Mwacharo *et al*., 2006; Sobczuk and Komosa, 2012; Houessou *et al*., 2019). Linear body measurements and indices are useful to assess type and function in cattle (Schwabe and Hall, 1989). Phenotypic and genetic relationships among biometric traits of animals have involved the use of analysis of variance and correlation (Dietl *et al*., 2005; Tolenkhomba *et al*., 2013; Vohra *et al*., 2015). However, there might be difference in biological relationship existing among the linear body variates if these body measurements are treated as bivariates rather than multivariates (Yakubu *et al*., 2011a and b; Kern *et al*., 2014). An alternative approach for data summarization involves multivariate analyses (Yiğit and Mendeş, 2018; Eyduran *et al*., 2019). Principal component (PC) analysis is an important tool in multivariate methodology used for correlated traits. PC functions mainly to reduce data dimensionality and to explore the relationship between traits (Parés-Casanova *et al*., 2012; Verma *et al*., 2015). This technique has been applied in cattle breeding to rank and group bulls (Lopes *et al*., 2013) and cows efficiently based on similarity. It has also been employed in studying the relationships among the estimated breeding values of various traits (Buzanskas *et al*., 2013; Boligon *et al*., 2015) including growth and carcass parameters (Brito *et al*., 2016).

Although previous attempts have been made to characterize phenotypically the Nigerian cattle (Yakubu *et al*., 2009; Raji *et al*., 2014), there is dearth of information on the morphometric differentiation of trade cattle using a classical statistical tool such as multivariate principal component. Therefore, the present study aimed at answering the question whether some trade cattle breeds (Bunaji, Sokoto Gudali, Rahaji and Kuri) in Nigeria are uniform groups in terms of biometry or demonstrate metric differences in body parts between individuals using principal component analysis.

MATERIALS AND METHODS

Linear body measurements were taken on a total of 2,120 randomly selected trade cattle of both sexes (1,008 males and 1,112 females) comprising 859 Bunaji, 674 Sokoto Gudali, 409 Rahaji and 178 Kuri. They were transported from the northern parts to the south western part (Bodija International Market, Ibadan, Oyo State) of Nigeria for sale. Bodija Market is a popular open-air market located in Bodija (Figure 1). Ibadan covers a total area of 3,080 square kilometres (1,190 sq mi), the largest in Nigeria (https://en.wikipedia.org/wiki/Ibadan). The Livestock Section of the market is populated by traders of Hausa and Yoruba extractions, which are the two dominant tribes in Nigeria.

Figure 1: Map of Bodija in Ibadan, Oyo State, Nigeria (Coordinates: 7°25'35"N 3°54'39"E)
Source: http://en.wikipedia.org/wiki/Bodija

In the market, the animals were left in the open during the day and in the night. They were fed mainly supplements such as cereal offal and crop residues. The animals were divided into four ages viz., 2-tooth, 4-tooth, 6-tooth and 8-tooth ages, respectively based on the eruption of permanent incisors. They were aged by dentition as indicated below, following the method of Carles and Lampkin (1977):

Permanent incisors	Age (months)
2-tooth (1 incisor pairs)	26-27
4-tooth (2 incisor pairs)	32-34
6-tooth (3 incisor pairs)	38-42
8-tooth (4 incisor pairs)	45-50

Eight morphometric traits were taken on each animal namely height at withers (HTW), height at shoulders (HTS), body length (BDL), shoulder to tail drop (STD), heart girth (HTG), cannon circumference (CNC), ear length (ERL) and tail length (TLL). The anatomical reference points are as described in Brown *et al.* (1983) and adopted by Raji *et al.* (2014). The height measurements were done with a calibrated measuring stick graduated in centimeters in (cm) while the girth, circumference and length measurements (cm) were carried out with a flexible tape. Only animals with features that conform to each breed standard were measured.

Statistical analysis: The analysis of the data was done using the general linear model (GLM) of IBM SPSS (2015) to test the effects of breed, sex and age including their interactions on HTW, HTS, BDL, STD, HTG, CNC, ERL and TLL. The separation of means was done using Duncan's Multiple Range Test (DMRT) at α = 0.05. The linear additive model employed was:

$Y_{ijkl} = \mu + B_i + S_j + A_k + (BS)_{ij} + (BA)_{ik} + (SA)_{jk} + (BSA)_{ijk} + e_{ijkl}$

Y_{ijkl} = observation per individual animal

μ = population mean

B_i = i^{th} breed fixed effect (i = Bunaji, Sokoto Gudali, Rahaji, Kuri).

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

A_k = k^{th} age fixed effect (k = 2-tooth, 4-tooth, 6-tooth, 8-tooth)

$(BS)_{ij}$ = breed and sex interaction effect

$(BA)_{ik}$ = breed and age interaction effect

$(SA)_{jk}$ = sex and age interaction effect

$(BSA)_{ijk}$ = breed, sex and age interaction effect

e_{ijkl} = random error

Pearson's coefficients of correlation were computed for all the traits. The multivariate technique applied was principal component (PC) analysis as earlier described (Yakubu *et al*., 2009; Vohra *et al*., 2015). The weights used to create the principal components are the eigenvectors of the characteristic equation:

$(S-\lambda_i I)a = 0$, or

$(R-\lambda_i I)a = 0$

where,

S =covariance matrix

R =correlation matrix.

The λ_i are the eigenvalues, the variances of the components which are obtained by solving $|S-\lambda_i I| = 0$ for λ_i.

Minimum explained variance equal to or less than 70% criterion for the retention of the main components was adopted as described by Ferreira *et al.* (2013). The rotation of the factor matrix was done using varimax criterion for easy interpretation of the PC. Anti-image correlations, The Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's Test of Sphericity were used to test the reliability of the PC analysis.

RESULTS

The biometric traits of Kuri cattle were significantly (P<0.05) higher than those of the three other genetic groups (Table 1). Rahaji had a comparative advantage (P<0.05) over Sokoto Gudali in all the morphometric traits with the exception of ERL (22.78±0.20 versus 22.68±0.12). However, Sokoto Gudali was superior (P<0.05) to Bunaji in all the body parameters estimated.

Sex effect on the morphometric traits was significant (P<0.05) (Table 2). Male cattle had higher HTW, HTS, BDL, STD, HTG, CNC, ERL and TLL than their female counterparts.

The body measurements were significantly (P<0.05) influenced by age (Table 3). There was progressive increase in body parameters with age. Although there was growth progression in HTW and HTS, this did not follow a similar trend. Full growth potential of BDL, STD and ERL appeared to have been reached at the 4-tooth age. Same pattern of growth was observed for HTG and CNC, where the peak was obtained at the 8-tooth age. However, there was no definite pattern of growth for TLL.

There were varying interaction effects on the body measurements of cattle (Table 4). Breed * Sex interaction effect (P<0.05) was on all the linear body traits except CNC and ERL. While Breed * Age and Breed * Sex * Age interaction effects significantly (P<0.05) influenced all the morphometric traits, only HTS was affected (P<0.05) by Sex * Age interaction.

Phenotypic correlations among the eight biometric traits are presented in Table 5. Positive and significant (P<0.01) correlations were recorded for all the linear body measurements. While the highest correlation coefficient was recorded between BDL and STD (r = 0.92), the lowest was obtained in HTS and ERL (r = 0.13).

The low Anti–image correlations showed that true factors existed in the data. This was consolidated by Kaiser-Meyer- Olkin (KMO) measure of sampling adequacy, which revealed the proportion of the variance in the morphometric traits caused by the underlying factor. The KMO value of 0.832 was found to be sufficiently high for all the morphometric traits. Bartlett's Test of Sphericity for the body traits (chi-square =1.910E4; P < 0.01) lent credence to the validity of the PC analysis. A summary of the PC analysis is shown in Table 6. Based on the criterion of minimum explained variance equal to or less than 70%, two principal components (PC1 and PC2) were retained. The first two components had eigenvalues of 5.564 and 0.906 (90.6%), respectively and explained about 81% of the generalized variance.

PC3, PC4, PC5, PC6, PC7 and PC8 were discarded because they had eigenvalues less than 0.7 (Table 7). The associated redundant variables for disposal in order of least importance to explain the total variation in this study were BDL, HTW, HTG, ERL, TLL and CNC.

STD and HTS were the two variables retained in the PC analysis (Table 8). While STD had the highest loading on PC1 (0.874), PC2 was more influenced by HTS (0.956).

Table 1. Effect of breed on the morphometric traits (Means±SE) of Nigerian cattle.

Traits	Breed			
	Bunaji	Sokoto Gudali	Rahaji	Kuri
HTW	115.94±0.38[d]	120.49± 0.47[c]	125.98±0.75[b]	133.47±0.81[a]
HTS	46.03±0.37[d]	47.76±0.46[c]	51.49±0.74[b]	60.87±0.79[a]
BDL	157.03±0.69[d]	163.02±0.85[c]	173.58±1.36[b]	188.41±1.45[a]
STD	111.00±0.58[d]	115.86±0.71[c]	122.09±1.14[b]	131.50±1.22[a]
HTG	139.71±0.67[d]	147.75±0.83[c]	151.35±1.33[b]	163.59±1.43[a]
CNC	21.52±0.10[d]	23.01±0.12[c]	23.52±0.20[b]	26.87±0.21[a]
ERL	20.69±0.10[c]	22.68±0.12[b]	22.78±0.20[b]	21.27±0.21[a]
TLL	91.28±0.47[d]	94.65±0.58[c]	100.90±0.93[b]	108.98±0.99[a]

HTW= height at withers; HTS=height at shoulders, BDL=body length; STD=shoulder to tail drop, HTG=heart girth, CNC=cannon circumference, ERL=ear length; TLL=tail length, SE=standard error
Means in the same row with different superscripts are significantly different (P<0.05)

Table 2. Effect of sex on the morphometric traits (Means±SE) of Nigerian cattle.

Traits	Sex	
	Female	Male
HTW	121.826±0.45[b]	126.12±0.45[a]
HTS	49.49±0.44[b]	53.58±0.43[a]
BDL	166.26±0.81[b]	174.76±0.80[a]
STD	117.39±0.68[b]	122.84±0.67[a]
HTG	146.21±0.79[b]	154.99±0.78[a]
CNC	23.33±0.12[b]	24.12±0.12[a]
ERL	21.51±0.12[b]	22.20±0.12[a]
TLL	96.97±0.55[b]	100.93±0.55[a]

SE=standard error
Means in the same row with different superscripts are significantly different (P<0.05)

Table 3. Effect of age on the morphometric traits (Means±SE) of Nigerian cattle.

Traits	Age			
	2-tooth	4-tooth	6-tooth	8-tooth
HTW	120.76±0.70[c]	124.44±0.66[b]	124.17±0.76[b]	126.52±0.31[a]
HTS	49.92±0.68[c]	49.92±0.64[c]	52.02±0.74[b]	54.28±0.30[a]
BDL	164.62±1.25[b]	170.89±1.18[a]	173.52±1.37[a]	173.01±0.56[a]
STD	116.21±1.05[b]	120.43±1.00[a]	121.89±1.15[a]	121.93±0.47[a]
HTG	146.16±1.23[c]	151.31±1.16[b]	150.31±1.34[b]	154.63±0.55[a]
CNC	23.01±0.18[c]	23.90±0.17[b]	23.64±0.20[b]	24.36±0.08[a]
ERL	21.38±0.18[b]	21.88±0.17[a]	21.98±0.20[a]	22.18±0.08[a]
TLL	96.45±0.86[c]	99.70±0.81[ab]	98.62±0.94[bc]	101.04±0.38[a]

SE=standard error
Means in the same row with different superscripts are significantly different (P<0.05)

Table 4. Analysis of variance showing the interaction effect of breed, sex and age on the morphometric traits of Nigerian cattle.

Source of variation	DF	Mean squares and level of significance							
		HTW	HTS	BDL	STD	HTG	CNC	ERL	TLL
Breed * Sex	3	579.52**	650.78**	2881.35**	2435.35**	1519.49**	3.83[ns]	3.80[ns]	621.96**
Breed * Age	9	746.44**	990.27**	2869.80**	2928.10**	1583.45**	24.83**	31.42**	722.74**
Sex * Age	3	88.67[ns]	539.00**	316.37[ns]	222.06[ns]	282.35[ns]	12.87[ns]	2.42[ns]	92.42[ns]
Breed * Sex * Age	9	403.92**	274.47**	690.80**	648.19**	869.10**	22.89**	16.50**	385.54**
Residual	2008	80.38	75.47	257.86	182.27	247.37	5.39	5.44	120.41

DF=degree of freedom; **Significant at P<0.01; [ns] Non-significant

Table 5. Phenotypic correlations of the morphometric traits of Nigerian cattle**

Trait	HTW	HTS	BDL	STD	HTG	CNC	ERL	TLL
HTW		0.52	0.88	0.85	0.91	0.80	0.53	0.76
HTS			0.62	0.35	0.51	0.51	0.13	0.34
BDL				0.92	0.85	0.73	0.47	0.72
STD					0.81	0.69	0.49	0.72
HTG						0.82	0.48	0.72
CNC							0.43	0.65
ERL								0.40

**Significant at P<0.01 for all correlation coefficients.

Table 6. Principal components, eigenvalues and percentage of variance explained by components (% VCP).

Principal components	Eigenvalues	% (VCP)	% (VCP) cumulative
1	5.564	69.544	69.544
2	0.906	11.327	80.871
3	0.584	7.306	88.177
4	0.360	4.504	92.681
5	0.323	4.041	96.721
6	0.148	1.854	98.575
7	0.087	1.085	99.660
8	0.027	0.340	100.000

Table 7. Weighting coefficients of morphological traits of cattle discarded with the principal components.

Variables	Principal Components					
	3	4	5	6	7	8
HTW	0.393	0.369	0.270	0.220	0.411	0.005
HTS	0.182	0.101	0.021	0.069	0.042	0.001
BDL	0.258	0.298	0.216	0.094	0.061	0.153
STD	0.258	0.298	0.228	0.102	0.037	-0.083
HTG	0.435	0.310	0.217	0.520	0.108	0.005
CNC	0.823	0.271	0.189	0.111	0.059	0.006
ERL	0.140	0.132	0.954	0.062	0.041	0.003
TLL	0.250	0.857	0.164	0.099	0.058	0.005

Table 8. Weighting coefficients of morphological traits of cattle retained with the principal components.

	Principal Components	
Variable	1	2
HTW	0.588	0.269
HTS	0.189	**0.956**
BDL	0.778	0.369
STD	**0.874**	0.103
HTG	0.565	0.258
CNC	0.355	0.268
ERL	0.217	0.028
TLL	0.381	0.129

DISCUSSION

The present findings revealed that Bunaji appeared to be the smallest, while Kuri exhibited more robustness among all the cattle breeds investigated. The values obtained for Kuri cattle in this study are close to the range 132.04+1.64-132.51+1.54 (height at withers), 160.88+2.01-166.91+2.21 (heart girth), 182.77+2.89-187.07+2.00 (body length), 133.24+1.74-133.51+1.54 (shoulder to tail drop), 21.07+0.44-21.93+0.49 (ear length) and 109.22+1.83-111.48+1.82 (tail length) reported by Raji *et al*. (2014) for the same breed. Breed influence on body traits has also been reported by Boujenane (2015). The present information may identify breeds potentially useful in breeding and conservation programmes in terms of meat production and may aid in understanding domestication in Nigerian cattle. According to Dossa *et al*. (2007), rapid selection of large size individuals for the establishment of elite flocks in the field may be possible using biometric measurements such as height at withers, body length and chest girth. In a similar fashion, Gizaw *et al*. (2007) reported that morphological description is an essential component of breed characterization for physical identification, description, and recognition of a breed, and also for livestock breeds classification into broad categories.

The superiority of the male over the female is as a result of sexual dimorphism (SD) (Yakubu and Akinyemi, 2010). Sex differences in most morphometric traits studied were also observed in cattle by Taiwo *et al*. (2010) and Yakubu *et al*. (2018). The higher morphometric measurements of male animals in this study is congruous to Polak and Frynta (2010) sexual selection hypothesis, providing the most intuitive explanation for male-larger sexual size dimorphism in cattle, whereby a male combat is a regular part of male-male competition for promiscuous oestrous females living frequently in mixed herds. SD may also be attributed to the delay in sexual maturation and males' prolonged growth.

The conformation traits of animals are greatly influenced by age. There were differential growth rates by each biometric trait at different age groups in the present study. Certain body parameters such as BDL, STD and ERL were mature early and also ceased growing before others. This, according to Yakubu (2011b), indicated that the essential body evolution of mammalian animals occurred before the maturity stage and there is a general pattern of growth till maturity stage. This was buttressed by the submission of Blackmore *et al*. (1995) that in skeletal development, there is faster growth in length than in width and circumference.

The four genotypes under the two sexes and four ages investigated were separately ranked in the present study. Breed * sex interaction showed that the breeds performed differently in both sexes for the traits that were influenced. The results obtained for interaction of breed * age suggest the sensitivity of the expressed forms of the four breeds to age differences while sex * age indicates that the performance of male and female cattle is different for HTS under the four ages investigated. Breed * age * sex interaction indicates that the performance of Bunaji, Sokoto Gudali, Rahaji and Kuri cattle may be different for male and female under 2 teeth, 4 teeth, 6 teeth and 8 teeth ages, respectively. Zulu (2008) reported breed * sex interaction effect on WH and BDL in Zambian native cattle breeds.

The body parameters, as observed in this study, were associated with one another. Similar estimates of correlation were reported in cattle by Raji *et al*. (2014). The strong relationship existing between most of the body parameters may be useful for selection purpose, considering similar gene action of positively correlated traits. This may be utilized in the genetic improvement of the indigenous stock especially in the rural areas where resources for large scale breeding programme are scarce.

Variation in breeds' characteristics permits animal identification within the breed standards. Size and conformation are parameters of high priority to most cattle herders and are strong selection presumably in most breeds. The PC analytic tool combines the morphometric variables to produce indices or components that are uncorrelated (Mavule *et al*., 2013). The importance of PC analysis in the present study was evident in the reduction of large number of explanatory variables (biometric traits) into two components (PC1 and PC2) that were able to describe size and shape better. This is in conformity with the submissions of Khargharia *et al*. (2015) and Shah *et al*. (2018). Since correlations between principal components are zero, the selection of animals for any principal component will produce independent response in terms of other principal components (Pinto *et al*., 2006).

The two selected variables (STD and HTS) in the present study showed lower simple correlation (Pearson's correlation) with each other, hence they are non-redundant. In this wise, the use of STD and HTS could be combined with other parameters of economic importance in classic evaluation of animals for characterization, racial discrimination, breeding and selection purposes. Height is a veritable trait used in determining the proper size of the animal, and its consistency with the breed standards presents high genetic correlations between growth traits (Pereira *et al*., 2010). Similarly, Mavule *et al*. (2013) reported that breeders could improve body shape to increase meat production traits and maintain an animal's body size suitable for walking longer distances and survival in harsh environmental conditions. Similarly, Verma *et al*. (2015) reported that PC could be used in breeding programmes with sufficient reduction in the number of recorded linear type traits to explain the body conformation of animals. The use of records on only STD and HTS corresponding to two PCs, instead of the original eight body parameters will ultimately lead to a reduction in the costs of labour and other resources used to evaluate animals. Similarly, Parés-Casanova *et al*.(2013) reported that first two PCs could be exploited in the evaluation and comparison of cattle; thus, it could provide an opportunity for the selection of animals based on a small group of traits rather than on isolated traits.

Conclusion: Kuri cattle had significantly higher morphometric variables compared to other breeds such as Rahaji, Sokoto Gudali and Bunaji. Sex and age also influenced all the body measurements while there were varying breed and sex, breed and age, sex and age and breed and sex and age interaction effects on the body parameters. The positive and significant correlations among different biometric traits suggested high predictability among the different traits, and also made them amenable for PC analysis. Two parameters (STD and HTS) which recorded the single highest loading on PC1 and PC2, respectively were sufficient to distinguish between the breeds. The present information may be exploited in phenotypic selection as a means to elucidate body conformation; and when complemented with molecular characterization, could be useful in future efforts geared towards conserving the indigenous cattle.

Authors' contributions: AY and AA conceived the study. AOR was instrumental to data collection. AY, AA and SOO did the statistical analysis. All authors wrote and proofread the manuscript.

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