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Original Contribution

PRINCIPAL COMPONENT ANALYSIS OF THE MORPHOSTRUCTURAL INDICES OF WHITE FULANI CATTLE

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ABSTRACT

A multivariate approach was adopted to provide an objective description of the body shape of 204 White Fulani cattle of two age groups: 1.5-2.4 and 2.5-3.6 years. Age group significantly influenced all the fourteen morphometric measurements investigated. Gender was only a significant source of variation for heart girth, head width, cannon circumference, shoulder width, rump width and rump length, with higher means recorded for male animals. The correlation coefficients of the body measurements ranged from 0.50-0.98 and 0.22-0.91 for 1.5-2.4 and 2.5-3.6 years old animals respectively. In factor solution of the principal component analysis, two factors with ratio of variance of 85.37 were identified in the first age group. In the second age group, four factors which explained 86.47% of the generalized variance were extracted. The first factor accounted for 78.99% and 67.05% in the first and second age group respectively, thus appearing as an index of general size. The subsequent factors in both age groups presented patterns of variation independent of general size. These results suggest that principal component analysis could be employed in breeding programmes with a drastic reduction in the number of body measurements to be considered in the improvement of body conformation.

Key Words: Body dimensions, age group, principal components, White Fulani cattle

INTRODUCTION

Characterization of a breed of livestock is the first approach to a sustainable use of its animal genetic resource (1) According to the Food and Agricultural Organisation (FAO), a global strategy involves identifying and understanding a unique genetic resource in a particular region and to develop the proper use of the associated diversity (2). Body measurements have been used in large animals to contrast variation in size and shape (3, 4). These body dimensions have also been used at various times for the estimation of weights when live weights are measured alongside these parameters (5-7).

Analysis of variance and correlations are widely used to characterise phenotypic and genetic relationships among body measurements of animals (8,9). However, principal component analysis is a valuable refinement. According to (10), the principal component analysis is a multivariate methodology that can be used with success when characteristics are correlated. This analysis transforms an original group of variables into another group, principal components, which are linear combinations of the original variables. The direct purpose of factor analysis is to reduce a set of data so that it may be described and used easily. From the viewpoint of animal genetics and improvement, principal components simultaneously consider a group of attributes which may be used for selection purposes.

(11) and (12) used factor analysis to study the interdependence among body measurements of young and adult sheep, and beef cattle respectively. In Nigeria, interrelationship among body dimensions of cattle treated as multivariate (simultaneously analysed) have not been widely exploited. Therefore, the present study was embarked upon to examine changes in the body measurements of White Fulani cattle of different age groups and to evaluate the relationship among their body

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dimensions in order to obtain fewer measurements for genetic and breeding purposes using principal component factor analysis.

MATERIALS AND METHODS

Location of study

The study was carried out in Lafia, Nasarawa State. The area falls within the guinea savanna zone of north central Nigeria and is located within latitude 08^0 35'N and longitude 08^0 33'E.

Experimental animals

Two hundred and four White Fulani cattle of both sexes reared through the extensive system of management were randomly measured. The animals were carefully observed to avoid measuring crossbreds, unhealthy and pregnant ones. The cattle were divided into 2 age groups namely, 1.5-2.4(age group 1) and 2.5-3.6 (age group 2) years old cattle respectively. Age group was determined primarily by dentition as described by (13).

Measured traits

Fourteen (14) morphometric traits were measured on each animal. The parts measured were, withers height (WH), distance from the highest point of the processus spinalis of the vertebra thoracica to the ground; rump height (RH), the distance from the highest point of rump to the ground; heart girth (HG), measured as body circumference just behind the forelegs; body length (BL), measured from distance between the horn site to tail drop; face length (FAL), distance from between the horn site to the lower lip; ear length (EL) distance from the point of attachment to the tip of the ear; head width (HW), measured as the widest point of the head; cannon circumference (CC), smallest circumference of the cannon bone of foreleg; tail length (TL), measured from the tail drop to the tip of the tail; foreleg length (FL), distance from the proximal extremity of the olecranon process to the ground; hind leg length (HL), measured up to the ground; shoulder width (SW), measured as the distance from left to right upper arm (pars cranialis of the tuberculum majus humeri); rump width (RW), width of hips (*Tuber coxae)* and rump length (RL), measured from hips (*Tuber coxae)* to pins (*Tuber ischii).*

A graduated measuring stick was used for the height measurements, the length and circumference measurements were done using a flexible tape and calibrated wooden caliper was used for the width measurements. Measurements were done by the same person to avoid between- individual variations.

Statistical analysis

Means, standard errors and coefficients of variation of the body measurements were calculated. General linear model (GLM) was used to analyze age group and sex effects. Pearson's coefficients of correlation (r) among the various morphometric traits were estimated. From the correlation matrix, data were generated for the principal component factor analysis. Anti-image correlations, Kaiser-Meyer-Olkin measures of sampling adequacy and Bartlett's Test of Sphericity were computed to test the validity of the factor analysis of the data sets. Principal component analysis according to (14), is a method for transforming the variables in a multivariate data set, X_1, X_2,..., X_P, into new variables, y_1, y_2---, y_p, which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables defined as:

$$y_1 = a_{11}x_1 + a_{12}x_2 + \text{---} + a_{1p}x_p$$
$$y_2 = a_{21}x_1 + a_{22}x_2 + \text{---} + a_{2p}x_p$$

$$y_p = a_{p1}x_1 + a_{p2}x_2 + \text{---} + a_{pp}x_p$$

With the coefficients being chosen so that y_1, y_2---, y_p account for decreasing proportions of the total variance of the original variables, x_1, x_2,---, x_p. The factor programme of (15) statistical package was used for the principal component analysis.

RESULTS AND DISCUSSION

Morphostructural traits

Table 1 shows the mean, standard error and coefficient of variation for each of the morphometric characters of the two age groups and sexes investigated. 2.5-3.6 years old cattle had significantly ($p<0.05$) higher mean values for all the body measurements estimated. The average withers height values of 83.44 and 111.84cm and rump height values of 89.51 and 120.34cm recorded for 1.5-2.4 and 2.5-3.6 years old animals respectively indicate that the White Fulani cattle are taller at the rump than at the withers. They were also wider at the rump than at the shoulder. The disproportionate values obtained in the two age groups might not be unconnected with the fact that the size and shape of an animal are expected to increase as the animal grows with age.

Table 1: Descriptive statistics of the quantitative traits of cattle according to age group and sex

Trait (cm)	1.5-2.4 years old cattle(n=80)		2.5-3.6 years old cattle(n=124)		Male animals (n=79)		Female animals (n=125)	
	Mean(±SE)	*CV*	*Mean(±SE)*	*CV*	*Mean(±SE)*	*CV*	*Mean(±SE)*	*CV*
WH	83.44±1.64[b]	17.57	111.84±0.98[a]	9.72	101.11±2.19[a]	19.29	100.48±2.70[a]	21.09
RH	89.51±1.81[b]	18.13	120.34±1.01[a]	9.31	109.13±2.42[a]	19.71	107.69±2.44[a]	11.36
HG	91.72±2.39[b]	23.30	141.94±1.62[a]	12.73	125.62±4.35[a]	30.77	113.71±3.04[b]	29.85
BL	109.96±3.15[b]	25.65	175.29±2.25[a]	14.28	152.29±4.63[a]	27.08	154.34±7.52[a]	20.38
FAL	34.51±0.93[b]	24.20	52.88±0.49[a]	10.36	47.19±1.26[a]	23.79	44.71±0.99[a]	24.96
EL	15.68±0.31[b]	27.10	18.66±0.20[a]	12.49	17.05±0.32[a]	16.89	17.57±0.27[a]	17.37
HW	12.70±1.83[b]	14.41	15.54±1.60[a]	10.29	15.64±0.17[a]	9.84	13.66±0.20[b]	15.97
CC	11.99±2.12[b]	17.68	14.56±1.86[a]	12.77	14.72±0.20[a]	12.29	12.81±0.21[b]	17.42
TL	48.62±1.53[b]	28.12	76.81±0.97[a]	14.06	66.35±2.01[a]	26.92	65.38±1.95[a]	33.35
FL	60.85±0.9[b]	13.76	77.99±0.65[a]	9.30	71.71±1.33[a]	16.44	70.90±1.97[a]	23.09
HL	67.76±0.95[b]	12.60	85.75±0.76[a]	9.85	79.56±1.47[a]	16.41	78.33±2.19[a]	16.42
SW	18.91±0.51[b]	24.06	28.94±0.43[a]	16.48	29.29±0.52[a]	15.78	22.31±0.59[b]	22.61
RW	20.75±0.57[b]	24.43	33.32±0.44[a]	14.86	32.89±0.63[a]	17.12	25.54±0.81[b]	25.86
RL	27.50±0.65[b]	19.67	39.06±0.42[a]	12.11	39.63±0.50[a]	11.30	31.29±0.85[b]	16.07

Means in the same row bearing the same superscripts do not differ significantly(p>0.05).
SE: Standard error.
CV: Coefficient of variation (%).

(16) reported wide variations in the body measurements of N'Dama cattle at different ages. The withers height, rump height, heart girth, ear length and face length estimates of White Fulani, which are the most prominent Nigerian cattle, are comparable to those reported by (17) for Maasai and Kamba Zebu in Kenya. The high coefficients of variation observed in shoulder width and rump width in both age groups are attributable to their environmental sensitivity. (18) reported that measures related to muscle and fat deposition, such as width and girth measurements are more affected by nutrition. Large variation within certain measurements suggest absence of selection. Sex- influenced (p<0.05) differences were observed in heart girth, head width, cannon circumference, shoulder width, rump width and rump length respectively, with superior values recorded for male animals. These apparent sex- related differences might be attributed to the usual between- sex differential hormonal effects on growth. Similarly, marked differences between the body measurements of males and females have been reported in African (17) and European breeds of cattle (3) respectively.

Phenotypic correlations

Pearson's coefficients of correlation among the various traits are shown on **Table 2**. Body measurements were positively and significantly inter-correlated (p<0.01) in both age groups. Correlations among conformation traits ranged from 0.50 – 0.98 and 0.22 – 0.91 for 1.5-2.4 and 2.5-3.6 years old animals respectively. In the first age group, the highest correlation was between withers height and rump height (r = 0.98) while the lowest was observed between shoulder width and rump height. Withers height and heart girth (r = 0.91) had the strongest association while the weakest was recorded for cannon circumference and ear length in the second age group (r = 0.22). The varying estimates of correlation in both age groups could be attributed to the fact that postnatal growth does not take place proportionally in all tissue categories and body regions. Instead, it gives preference in the different growth phases to particular tissue types or body regions within those tissue categories (19).

Principal component matrix

Anti – image correlations computed showed that partial correlations were low, indicating that true factors existed in the data. This was buttressed by Kaiser-Meyer- Olkin measure of sampling adequacy studied from the diagonal of partial correlation, revealing the proportion of the variance in the body measurements caused by the underlying factor. This was found to be sufficiently high for all the morphometric traits (0.90 and 0.92 for 1.5-2.4 and 2.5-3.6 years old animals respectively). The overall significance of the correlation matrices tested with Bartlett's Test of

Sphericity for the body dimensions of the first age group (chi-square = 1948.84 significant at p<0.01) and for the second age group (chi-square = 19 77.59 significant at p<0.01) provided enough support for the validity of the factor analysis of the data set.

After varimax rotation of the component matrix in age group 1, two factors with ratio of variance of 85.37 were extracted (**Table 3**). The factor pattern coefficients were used to assess the relative contributions of the various body measurements in determining the numerical value of the corresponding factor (principal component). Similarly, the variance of a variable was partitioned into a common portion 'communality' shared with some or all of the other variables. This showed that 55.3 – 95.2% of the variation in conformation traits were brought about by the principal components. The first factor was sufficient to explain 78.99% of the total variance among the fourteen body measurements estimated. The original variables most closely associated with factor 1 were withers height, rump height, heart girth, body length, face length, ear length, head width, cannon circumference and rump length. This tended to describe general size. In similar findings, (20) and (12) reported that the first principal component was a measure of overall size in Japanese black cattle sires and yearling performance in beef cattle respectively. (21) and (22) also reported that the first factor explained the highest variation. The second factor which accounted for 6.38% of the total variance had its loadings for tail length, foreleg length, hind leg length, shoulder width and rump width. In the second age group, four factors were identified which contributed to 86.47% of the generalized variance. The first factor which explained 67.05% of the total variance was determined by withers height, rump height, heart girth, body length, face length, rump width and rump length. The second factor was more closely related to cannon circumference, head width and shoulder width explaining about 8% of the variation. The third factor which was influenced by foreleg length and hind leg length accounted for only 6.70% of the total variance; while the fourth factor had its loading for ear length and tail length. The communalities in this case ranged from 0.79 to 0.93. Conformation traits are good traits for selection and genetic evaluation. The six factors obtained could be used to select animals based on a group of variables rather than on isolated traits. This is accentuated by the findings of (23) who predicted the effect of breeding programmes using a reduced data set on morphological traits that are sensitive to correlated responses to selection.

CONCLUSION

AND RECOMMENDATION

The principal component analysis technique was used to consolidate and describe the interdependence among the original fourteen conformation traits of White Fulani cattle. The aggregation of morphometric traits into factors was age dependent. In 1.5-2.4 years old cattle, two factors were obtained which contributed to 85.37% of the total variance. In the older animals (2.5-3.6 years old), four factors which accounted for 86.47% of the generalized variance were extracted. These factors could be exploited in breeding and selection programmes to acquire highly coordinated animal bodies using fewer measurements.

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***Table 2**: Coefficients of correlation of the morphometric characters of cattle*

	WH	RH	HG	BL	FAL	EL	HW	CC	TL	FL	HL	SW	RW	RL
WH		0.98	0.86	0.81	0.79	0.74	0.68	0.71	0.76	0.73	0.76	0.55	0.72	0.90
RH	0.81		0.86	0.81	0.80	0.78	0.63	0.74	0.75	0.72	0.75	0.50	0.70	0.90
HG	0.91	0.84		0.95	0.94	0.72	0.65	0.81	0.84	0.85	0.81	0.77	0.87	0.96
BL	0.90	0.81	0.90		0.91	0.74	0.65	0.84	0.86	0.80	0.74	0.73	0.80	0.94
FAL	0.82	0.74	0.86	0.80		0.77	0.58	0.82	0.82	0.82	0.77	0.69	0.79	0.92
EL	0.53	0.42	0.47	0.53	0.33		0.57	0.77	0.75	0.71	0.73	0.53	0.63	0.78
HW	0.73	0.68	0.74	0.78	0.70	0.36		0.69	0.67	0.63	0.60	0.63	0.62	0.72
CC	0.59	0.59	0.64	0.65	0.60	0.22	0.84		0.81	0.81	0.77	0.63	0.73	0.84
TL	0.82	0.77	0.84	0.82	0.65	0.64	0.69	0.56		0.87	0.84	0.79	0.82	0.85
FL	057	0.64	0.69	0.57	0.61	0.24	0.50	0.48	0.65		0.94	0.81	0.85	0.82
HL	0.62	0.65	0.70	0.59	0.62	0.28	0.44	0.42	0.57	0.81		0.79	0.89	0.79
SW	0.56	0.57	0.68	0.66	0.57	0.39	0.64	0.58	0.66	0.58	0.47		0.90	0.69
RW	0.77	0.73	0.81	0.71	0.80	0.32	0.62	0.57	0.67	0.58	0.57	0.49		0.81
RL	0.70	0.70	0.79	0.76	0.77	0.23	0.72	0.68	0.59	0.60	0.56	0.49	0.73	

Significant at P<0.01 for all correlation coefficients.
Upper matrix = 1.5-2.4 years old cattle.
Lower matrix = 2.5-3.6 years old cattle.

Table 3*: Eigenvalues and share of total variance along with factor loadings after rotation and communalities of the body measurements of cattle*

	1.5-2.4 years old cattle			**2.5-3.6 years old cattle**				
Traits(cm)	*Factor 1*	*Factor 2*	*Communality*	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*	*Communality*
Withers height	0.884	0.339	0.896	0.744	0.260	0.267	0.462	0.905
Rump height	0.919	0.293	0.931	0.658	0.285	0.404	0.335	0.791
Heart girth	0.734	0.617	0.919	0.705	0.346	0.423	0.369	0.932
Body length	0.739	0.573	0.874	0.673	0.410	0.258	0.454	0.893
Face length	0.739	0.558	0.857	0.786	0.285	0.331	0.174	0.838
Ear length	0.778	0.362	0.737	0.153	0.077	0.054	0.927	0.892
Head width	0.554	0.496	0.553	0.544	0.736	0.109	0.219	0.896
Cannon circumference	0.694	0.549	0.783	0.446	0.806	0.133	0.024	0.868
Tail length	0.599	0.709	0.861	0.450	0.361	0.381	0.624	0.868
Foreleg length	0.530	0.781	0.890	0.313	0.266	0.853	0.104	0.907
Hind leg length	0.522	0.763	0.855	0.405	0.089	0.826	0.136	0.872
Shoulder width	0.236	0.938	0.935	0.120	0.693	0.438	0.371	0.823
Rump width	0.445	0.843	0.908	0.802	0.215	0.289	0.162	0.799
Rump length	0.827	0.518	0.952	0.767	0.398	0.274	0.008	0.822
Eigenvalues	11.06	0.89		9.39	1.08	0.94	0.71	
% of total variance	78.99	6.38		67.05	7.68	6.70	5.04	