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Original Review Article

Genetic morphometry in Nigerian and South African Kalahari Red goat breeds

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Abstract

Genetic improvement of goat breeds in growth and other traits (e.g. milk production) is limited by the demographics of the goat herds, extensive production system and the seemingly long-term nature of improvement through traditional genetics and breeding methods. We studied the genetic morphometry in Nigerian goats and South African Kalahari Red goat breeds. A total of 192 goats belonging to three Nigerian breeds (Red Sokoto (RS), Sahel (SH) and West African Dwarf (WAD)) and one South African Kalahari Red (KR) goat breed were analysed. Animals were classified into four age groups: A group – less than 1 year, B group – between 1 and 2 years, C group – between 2 and 3 years and C group – older than 3 years based on dentition. Analysis of variance, correlation matrix, regression and discriminant analyses were used to evaluate morphological variability. Results revealed that the effect of breed on the measured morphometric traits was significant ($P < 0.05$). The best prediction equation for body weight (BW) with $R^2 = 0.84$ was obtained when body length (BL), withers height (WH) and chest depth (CD) were included in the model for KR goat. Growth traits were positively correlated with each other with the highest correlation coefficients found between BL and BW ($r = 0.877$, $P < 0.01$), WH and BW ($r = 0.541$, $P < 0.01$), WH and BW (0.661, $P < 0.01$) and CD and BW (0.738, $P < 0.01$) in KR, RS, SH and WAD goats, respectively, which are important for a conscious selection and breeding programme for desired traits. Stepwise discriminant procedure showed that WH, CD and BL were the most discriminating variables to separate KR, RS, SH and WAD goats. In accessing morphological diversity, efforts should be made to include phenotypic variables of at least ≥ 3 in order to minimize ambiguity in classification. Based on the pair-wise distances from the Discriminant function, the study provided informed decision, reference information on goat breeding and conservation strategy.

Keywords: Discriminant analysis; genetic; goat; morphology; Nigeria; South Africa.

INTRODUCTION

Genetic improvement of goat breeds in growth traits and other traits is desirable and hinged on certain beneficial genetic morphometry of forms and phenotypic structure leading to adaptation and fitness of these breeds in their production areas. The value of livestock increases in relation to its adaptation, capacity to contribute to the socio-economy and fulfill market opportunities potential for increasing productivity (Mamabolo and Webb, 2005). Nigerian goat breeds, namely Red Sokoto (RS), Sahel (SH) and West African Dwarf (WAD) and their South African counterpart, Kalahari Red (KR), are meat type breeds known for their good maternal abilities (Lomandra, 2013). The RS goat is probably the most widespread and well-known type in Nigeria (Bourn et al., 1994) and particularly predominant in the northern Nigeria. The WAD goat has a notable spread all across southern Nigeria and across 15 ECOWAS countries (Gall, 1996). The KR breed is differentiated from the Nigerian goat breeds for its rapid growth and produces more milk to support the growth of kids (Amie Marini et al., 2012; Stonehavenstud, 2013).

The RS goat is usually deep red and occasionally lighter or almost chestnut in colour. Both sexes are horned. Its ears are short with medium width and usually carried horizontally. Beards are present in males and absent in females. Its withers are not prominent and it possesses droopy long ears and well-developed udder (Otoikhian and Orheruata, 2010). The SH goat is an extant meat and dairy type goat in Nigeria (Otoikhian and Orheruata, 2010). It is large in size and having predominantly white colour pied with black or white and brown spots around the ear, nose and udder. The WAD goat is known to display a wide range of qualitative variations in coat colour (black, brown, white, pied, mottled, mixed, etc) (Ozoje and Mgbere, 2002), presence or absence of wattles (none, unilateral or bilateral) and super-numerary (extra) teats in adult females (which could be two, three or four extra teats; Oseni et al., 2006). Kalahari Red goats have dark coats and long ears, are innately hardy and naturally adaptable, much less susceptible to disease and parasite infestations than other breeds (Lomandra, 2013). The KR goat's background as desert animals has also given them unequalled ability to thrive in varied and poor conditions (Lomandra, 2013).

There is a considerable increase in interest in the assessment of African goat diversity. Economically-important growth traits in goats and their variations are predominantly attributed to possible association with different factors especially genetic factors. There is the need to improve the animal genetic resources (AnGR) of Nigeria facilitated by the meat production performance of Nigerian goat breeds and to select for improved meat goat breeds by evaluating the breed qualities. Selection of goats for improved growth and other traits of economic interest for example milk production are advantageous. This study is aimed at determining the morphological variability in Nigerian goats and South African Kalahari Red goat breeds.

MATERIALS AND METHODS

Experimental animals and sampling procedure

A total of 192 goats comprising of 55 Red Sokoto (RS), 44 Sahel (SH), 45 West African Dwarf (WAD) goats (Nigerian goat breeds) and 48 Kalahari Red (KR) goats of South African origin were sampled for the genetic

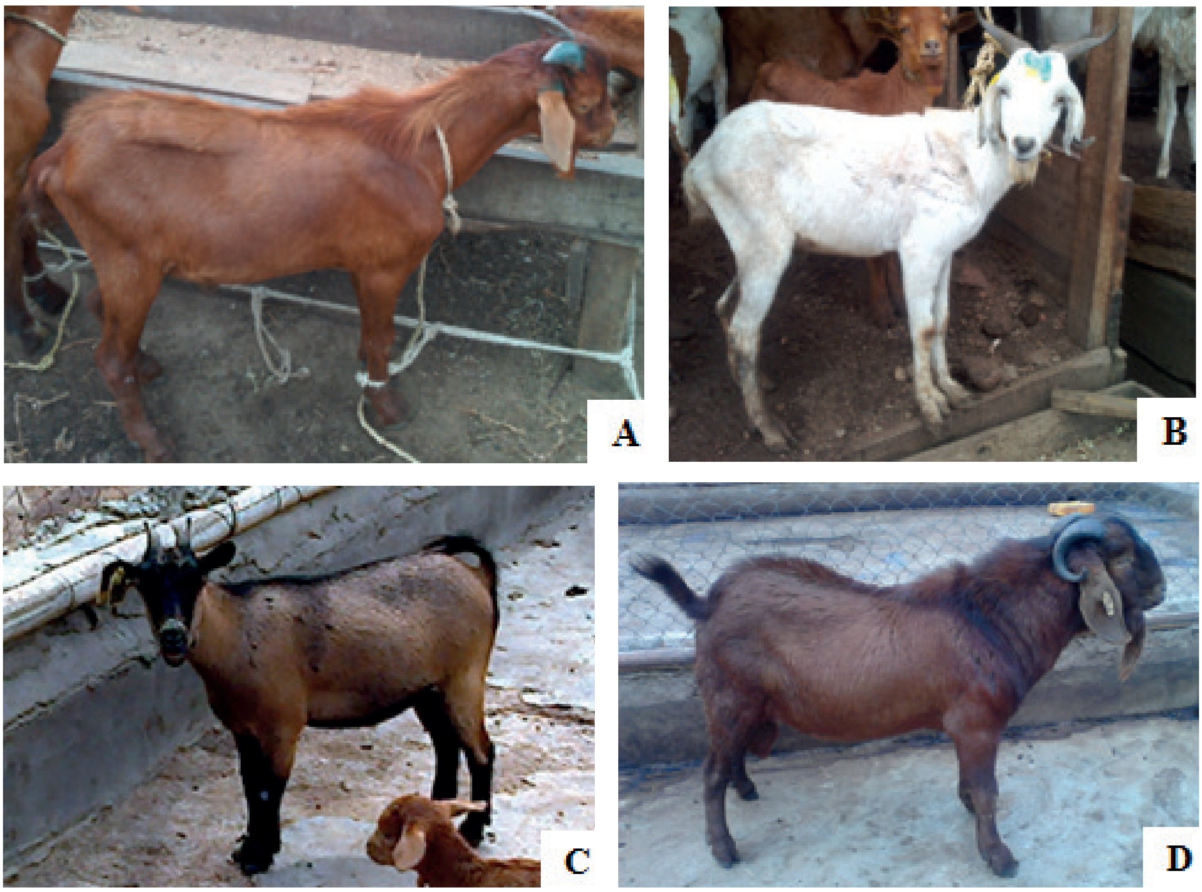

Figure 1. The experimental goat samples.
A Red Sokoto goat (♂), Nigeria; B Sahel goat (♂), Nigeria; C West African Dwarf goat (♀), Nigeria; D Kalahari Red goat (♂), South Africa

morphometry study (Figure 1). More bucks (116) were sampled than does (76). Animals were classified into four age groups: A group – less than 1 year (5), B group – between 1 and 2 years (38), C group – between 2 and 3 years (87) and D group – older than 3 years (62) using dentition. Each goat was identified visually by its morphological characteristics and its age was estimated using dentition as described for African indigenous goats (Wilson and Durkin, 1984; Steele, 1996). Goats were sampled from Institute of Food Security, Environmental Resources and Agricultural Research (IFSERAR, Abeokuta, Nigeria) and farmers' herds. Approval was secured from Institutional Animal Care Committee and prior informed consent was obtained from owners of animals before animal inclusion in the study.

The following growth traits were evaluated from three Nigerian goats (RS, SH and WAD) and South African goat (KR) using simple standard equipment, without compromising the animal's welfare: body weight (BW), withers height (WH), body length (BL) and chest depth (CD). The anatomical reference points followed standard zoometrical procedures (Teguia et al., 2008). Body index parameter for body length index (BLI) (%) as body length/withers height × 100, was calculated as described by Luo and Wang (1998). Body weight was taken using a weighing balance to a 0.1 kg minimum accuracy. (The weighing balance used was a 400 kg capacity Electronic WeighBridge Model with 0.050 kg sensitivity). Body length was taken using measuring tape in centimetres. Body length was measured as the distance from base of tail to the tip of the nose. Withers height was measured using a special measuring stick made with two arms; one of which was held vertical and the other, at right angle to it, sliding firmly up and down to record height as the distance from the surface of the platform on which the animal stands to the withers. Chest depth was measured using a metre rule as the distance from the backbone at the shoulder (standardized on one of the vertical processes of the thoracic vertebrae) to the brisket between the front legs. All the linear body measurements were recorded in centimetres.

Statistical Analysis

Analysis of variance and means estimates with standard errors and Tukey's Studentised Range (HSD) Test for different genotypes and growth traits were implemented using the R software (version 3.0.2). A $P < 0.05$ was considered to be statistically significant. The multi traits linear model established to analyse the fixed effects of the factors for the four goat breeds is given by:

$$Y_{ijklm} = \mu + B_i + A_j + S_k + (BA)_{ij} + (BS)_{ik} + e_{ijkl}$$

where:

Y_{ijklm} = trait measured on each animal

μ = overall population mean

B_i = fixed effect associated with i^{th} breed (1–4)

A_j = fixed effect associated with j^{th} age (1–4)

S_k = fixed effect associated with k^{th} sex (1–2)

$(BA)_{ij}$ = interaction between i^{th} breed and j^{th} age

$(BS)_{ik}$ = interaction between i^{th} breed and k^{th} sex

e_{ijkl} = random error

Multivariate statistical analyses using the SPSS 16 were applied to the morphological parameters utilising correlation matrix, regression and discriminant analyses to evaluate the genetic morphometry in Nigerian goats and KR goat breeds. Pearson Correlation Coefficient was used to assess inter-relationships among BW and linear body measurements. Stepwise multiple regression procedure was used in the prediction of the body weight from linear body measurements using the following model:

$$BW = a + B_iX_i + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + B_kX_k$$

Where:

BW = body weight, a = regression intercept, B_i = i^{th} partial regression coefficient of the i^{th} linear body measurement, X_i, B_k = k^{th} partial regression coefficient of the k^{th} linear body measurement, X_k.

A stepwise discriminant analysis method was used to select predictor variables in the model. Classification functions were used to assign cases to groups. Eigenvalues and Wilks' Lambda were used to determine how well the discriminant model as a whole fitted the data. The Tolerance was assessed as the proportion of a variable's variance not accounted for by other independent variables in the equation. The F to Remove values were used to describe what happens should a variable (for example WH) be removed from the current model (given that the other variables for instance CD and BL remain). An asterisk (*) was placed on each variable's largest absolute correlation where there is more than one discriminant function in the structure matrix. The asterisk indicates the largest absolute correlation between each of the variables and any discriminant function.

RESULTS AND DISCUSSION

The results of the genetic morphometry relative to the effects of breed and sex in Nigerian goats and South African KR goat breeds is shown (Table 1). The breed of the goat had significant ($P < 0.05$) effect on all the morphological variables. Kalahari Red goat had the highest BW compared to all the Nigerian goat breeds. The WAD goat breed had the lowest mean values for linear measurements and the highest BLI. Age of the goats had significant ($P < 0.05$) effects on all the morphological variables. The effect of sex was significant ($P < 0.05$) on the body weight and the BLI. It was found that the does weighed higher than the bucks.

Table 1. Body measurements and body length index of Nigerian goats and South African Kalahari Red goat breeds as affected by breed, age and sex (means ± standard errors)

Factor	n	Body Weight (Kg)	Body length (Cm)	Withers height (Cm)	Chest depth (Cm)	Body length index
Breed						
KR	48	32.99 ± 2.02^{a}	110.13 ± 2.39^{a}	60.04 ± 1.13^{b}	33.26 ± 0.70^{a}	183.64 ± 2.42^{b}
RS	55	18.09 ± 1.04^{bc}	100.81 ± 1.52^{b}	61.07 ± 0.86^{b}	28.67 ± 0.50^{b}	165.39 ± 1.71^{c}
SH	44	20.35 ± 0.95^{b}	106.11 ± 1.81^{a}	69.45 ± 0.96^{a}	28.79 ± 0.42^{b}	153.24 ± 2.31^{d}
WAD	45	15.89 ± 0.75^{c}	83.19 ± 1.41^{c}	40.97 ± 0.70^{c}	24.53 ± 0.51^{c}	203.77 ± 2.53^{a}
Age (year)						
<1	5	10.40 ± 0.75^{c}	70.10 ± 3.37^{c}	33.60 ± 1.47^{d}	18.60 ± 0.87^{c}	209.41 ± 9.37^{a}
1–2	38	14.90 ± 0.69^{bc}	85.32 ± 1.47^{b}	50.42 ± 1.87^{c}	25.26 ± 0.48^{b}	175.09 ± 4.98^{c}
2–3	87	26.43 ± 1.40^{a}	102.45 ± 1.75^{a}	55.97 ± 1.07^{b}	30.53 ± 0.53^{a}	185.19 ± 2.37^{b}
>3	62	20.516 ± 1.01^{b}	108.68 ± 1.18^{a}	67.53 ± 0.84^{a}	29.57 ± 0.43^{a}	161.47 ± 1.31^{d}
Sex						
Buck	116	18.82 ± 0.73^{b}	100.64 ± 1.30	62.14 ± 0.98	28.18 ± 0.37	163.95 ± 1.68^{b}
Doe	76	26.40 ± 1.57^{a}	99.60 ± 2.16	51.74 ± 1.30	29.93 ± 0.66	194.80 ± 2.28^{a}

^{abc}Means with different superscripts within the same column differed significantly ($P < 0.05$), KR = Kalahari Red goat, RS = Red Sokoto goat, SH = Sahel goat, WAD = West African Dwarf goat, n = Number of observations.

Table 2. Body measurements and body length index of Nigerian goats and South African Kalahari Red goat breeds as affected by the interaction effects of breed x age and breed x sex (means ± standard errors)

Breed	Age (year)	n	Body Weight (Kg)	Body length (Cm)	Withers height (Cm)	Chest depth (Cm)	Body length index
KR	1–2	8	17.83 ± 1.78	89.85 ± 2.36^{bc}	51.50 ± 1.38	28.38 ± 1.27	174.78 ± 3.81
KR	2–3	40	36.03 ± 2.09	114.19 ± 2.36^{a}	61.75 ± 1.15	34.24 ± 0.70	185.41 ± 2.73
RS	1–2	10	15.10 ± 1.75	88.88 ± 3.10^{bc}	56.40 ± 1.43	24.49 ± 0.67	157.66 ± 4.44
RS	2–3	18	18.22 ± 1.16	99.19 ± 1.88^{b}	59.56 ± 1.17	28.50 ± 0.51	167.26 ± 3.58
RS	> 3	27	19.11 ± 1.86	106.31 ± 1.93^{a}	63.81 ± 1.28	30.33 ± 0.72	166.99 ± 1.79
SH	1–2	5	13.90 ± 1.86	87.38 ± 4.44^{bc}	69.40 ± 5.10	26.80 ± 0.66	128.16 ± 10.46
SH	2–3	4	17.50 ± 1.32	91.12 ± 3.45^{b}	61.25 ± 2.39	29.25 ± 1.03	149.92 ± 10.25
SH	>3	35	21.60 ± 1.05	110.51 ± 1.40^{a}	70.40 ± 0.85	29.03 ± 0.50	157.20 ± 1.55
WAD	<1	5	10.40 ± 0.75	70.10 ± 3.37^{d}	33.60 ± 1.47	18.60 ± 0.87	209.41 ± 9.36
WAD	1–2	15	13.53 ± 0.52	79.84 ± 1.86^{c}	39.53 ± 0.82	23.60 ± 0.48	202.54 ± 4.76
WAD	2–3	25	18.40 ± 1.05	87.82 ± 1.54^{bc}	43.30 ± 0.76	26.28 ± 0.56	203.38 ± 3.16
Breed	**Sex**						
KR	Buck	6	31.10 ± 4.70	106.26 ± 5.29	62.00 ± 3.59	32.42 ± 1.53	171.79 ± 2.58
RS	Buck	53	17.75 ± 1.04	100.88 ± 1.58	61.21 ± 0.88	28.66 ± 0.50	165.09 ± 1.75
SH	Buck	44	20.35 ± 0.95	106.11 ± 1.81	69.45 ± 0.96	28.79 ± 0.43	153.24 ± 2.31
WAD	Buck	13	12.31 ± 0.62	78.53 ± 2.31	41.23 ± 1.61	22.23 ± 0.91	191.89 ± 4.69
KR	Doe	42	33.27 ± 2.22	110.68 ± 2.64	59.76 ± 1.20	33.38 ± 0.77	185.33 ± 2.65
RS	Doe	2	27.00 ± 6.00	99.06 ± 2.54	57.50 ± 4.50	29.00 ± 4.00	172.99 ± 9.12
WAD	Doe	32	17.34 ± 0.91	85.09 ± 1.65	40.86 ± 1.61	25.47 ± 0.54	208.59 ± 2.59

^{abc}Means with different superscripts within the same column differed significantly ($P < 0.05$, interaction effect of breed x age), Means within the same column do not differed significantly ($P > 0.05$, interaction effect of breed x sex), KR = Kalahari Red goat, RS = Red Sokoto goat, SH = Sahel goat, WAD = West African Dwarf goat, n=Number of observations

In a broad sense, the physiological status of the does was not ascertained. However, farmers were questioned about the state of their flock before they were included in the study. Since does with obvious signs of gestation were excluded from the study, it was therefore unlikely that some does might be in their early gestation and might have gained more weight due to foetal weight. Bucks (163.95 ± 1.68) exhibited lower BLI compared to does (194.80 ± 2.28). The interaction between breed and age had significant ($P < 0.05$) effect on the BL of the goats (Table 2). The mean BL values of the 2–3 years KR goat (114.19 ± 2.36 cm), the greater than 3 years SH

Table 3. Pearson correlation coefficients among body weight, linear body measurement and body length index of Nigerian and South African goats

Breed	Trait	BW	BL	WH	CD	BLI
KR	BW					
	BL	0.877**				
	WH	0.805**	0.717**			
	CD	0.806**	0.831**	0.743**		
	BLI	0.214	0.743**	–0.246	0.225	
RS	BW					
	BL	0.5**				
	WH	0.541**	0.754**			
	CD	0.279*	0.329*	0.538*		
	BLI	–0.106	0.251*	–0.443 **	–0.342**	
SH	BW					
	BL	0.635**				
	WH	0.661**	0.71**			
	CD	0.365*	0.34*	0.375*		
	BLI	0.041	0.485**	–0.27*	0.008	
WAD	BW					
	BL	0.587**				
	WH	0.241	0.577**			
	CD	0.738**	0.425*	0.208		
	BLI	0.39*	0.499*	–0.417**	0.249	

KR = Kalahari Red goat, RS = Red Sokoto goat, SH = Sahel goat, WAD = West African Dwarf goat, BW = Body weight, BL = Body length; WH = Withers height; CD = Chest depth; BLI = Body length index. * $P < 0.05$; ** $P < 0.01$

Table 4. Stepwise multiple regression of body weight on linear body measurements in Nigerian and South African Kalahari goat breeds

Variable	Model	S.E.	R^2
Kalahari Red goat			
Body length	BW = –52.66 + 0.78BL	6.43	0.77
Body length and chest depth	BW = –57.04 + 0.59BL + 0.74CD	6.24	0.79
Body length and withers height	BW = –66.77 + 0.55BL + 0.65WH	5.55	0.83
Body length, withers height and chest depth	BW = 0.67.30 + 0.50BL + 0.60WH + 0.27CD	5.59	0.84
Red Sokoto goat			
Body length and withers height	BW = –29.32 + 0.18BL + 0.48WH	6.84	0.31
Sahel goat			
Body length, withers height and chest depth	BW –35.46 + 0.19BL + 0.42WH + 0.23CD	4.45	0.50
WAD goat			
Body length and chest depth	BW = –31.17 + 0.23BL + 1.13CD	3.31	0.64
Body length, withers height and chest depth	BW = –28.20 + 0.27BL –0.16WH + 1.12CD	3.35	0.64

WAD = West African Dwarf goat; BW = Body weight; R^2 = Coefficient of determination; S.E. = Standard error

goat (110.51 ± 1.40 cm) and RS goats (106.31 ± 1.93 cm) were the longest. Meanwhile, the mean BL value of the less than 1 year WAD goat (70.10 ± 3.37 cm) was the shortest. The interaction between breed and sex had no significant ($P > 0.05$) effect on the measured variables.

Pearson correlations of morphometric variables in Nigerian goats and South African Kalahari Red goat breeds

The correlation coefficients (r) for BW, linear body measurements and BLI ranged from 0.214–0.877 for KR goat, –0.106–0.754 for RS goat, 0.008–0.71 for SH goat and 0.208–0.738 for WAD goat (Table 3). The highest correlation coefficients between BW and the other variables were observed between BL and BW (r = 0.877, $P < 0.01$), WH and BW (r = 0.541, $P < 0.01$), WH and

Table 5. Morphological characters selected by stepwise discriminant analysis to separate Nigerian goats and South African Kalahari Red goat breeds

Variable	F value	Pr > F	Wilk Lambda	Pr > Lambda	F to remove	Tolerance
Withers height	95.191	0.0001	0.478	0.0001	93.686	0.459
Chest depth	64.608	0 0001	0.223	0 0001	18.181	0.628
Body length	43.198	0.0001	0.182	0.0001	6.048	0.451

Table 6. Total canonical structure of the discriminant analysis of the four goat breeds

	CAN1	CAN2	CAN3
Withers height	0.814*	0.577	0.068
Chest depth	0.042	0.948*	-0.316
Body length	0.276	0.777*	0.566

* The largest absolute correlation between each of the variables and any discriminant function.

Table 7. Pair-wise distances for the four goat breeds

	Kalahari Red	Red Sokoto	Sahel	WAD
Kalahari Red	–	25.619	66.341	48.691
Red Sokoto		–	17.363	58.607
Sahel			–	117.024
WAD				–

WAD = West African Dwarf goat.

BW (0.661, $P < 0.01$) and CD and BW (0.738, $P < 0.01$) in KR, RS, SH and WAD goats, respectively. These inferences in breed differences are useful for selection purposes and breeding programme for desired traits in characterization studies.

Multiple regression of body weight on linear body measurements

Morphometric variables, given by the interdependent linear variables were used to predict BW (Table 4). Results revealed that BL alone accounted for 77% of the variation in BW of KR goat. The best prediction equation for BW with $R^2 = 0.84$ was obtained when BL, WH and CD were included in the model for KR goat. In SH goat, BL, WH and CD accounted for 50% of the variation in predicting BW. Body length and CD accounted for 64% of variability in predicting the BW of WAD goat. The R^2 in RS was low at the inclusion of BL and WH in the BW predicting model.

Stepwise discriminant procedure of the variables for the four goat breeds

The morphological characters selected by the stepwise discriminant procedure (Table 5) highlighting F values, Wilks Lambda, Tolerance and probability statistics of the variables for the four goat breeds were computed. Each variable in the discriminant model was significant. Wilks' Lambda measured the variable's potential at discriminating between groups. Smaller Wilks' lambda values for BL (0.182), CD (0.223) and WH (0.478) indicated that the variables were better at discriminating between groups. The Tolerance values were moderate to high and ranged from 0.451 – 0.628. The F to Remove values were 93.686, 18.181 and 6.048 for WH, CD and BL, respectively.

The stepwise discriminant procedure detailing the total canonical structure (Table 6) of the four goat breeds revealed that WH, CD and BL were the most discriminating variables to separate all goat breeds. Withers height was most strongly correlated ($r = 0.814$) with the first function, and it is the only variable most strongly correlated with this function. Chest depth and BL were most strongly correlated with the second function with $r = 0.948$ and 0.777, respectively; thus marking this function as a "stability" function.

The canonical discriminant analysis (Table 7) showed distinctive differences in the morphological characters of the pair-wise distances for the four goat breeds. The results of all pair-wise distances among the goat breeds were significant ($P < 0.0001$). The longest distance (117.024) was observed between WAD goats and SH goat breeds while the shortest (17.363) was observed between RS and SH goat breeds. This outcome is clearly represented in Figure 2 by the canonical discriminant function showing the relationship and distribution among the four goat breeds and Figure 3 by the territorial map of the four goat breeds. Two discriminant functions were plotted (the first and second), while the third function was found to be rather insignificant. The territorial map offers a comprehensive view of the discriminant model. Invariably, the closeness of the group centroids, indicated with asterisks (*) mark, to the territorial lines suggests that the separation between some groups is not very strong. The percentage of individual goats was

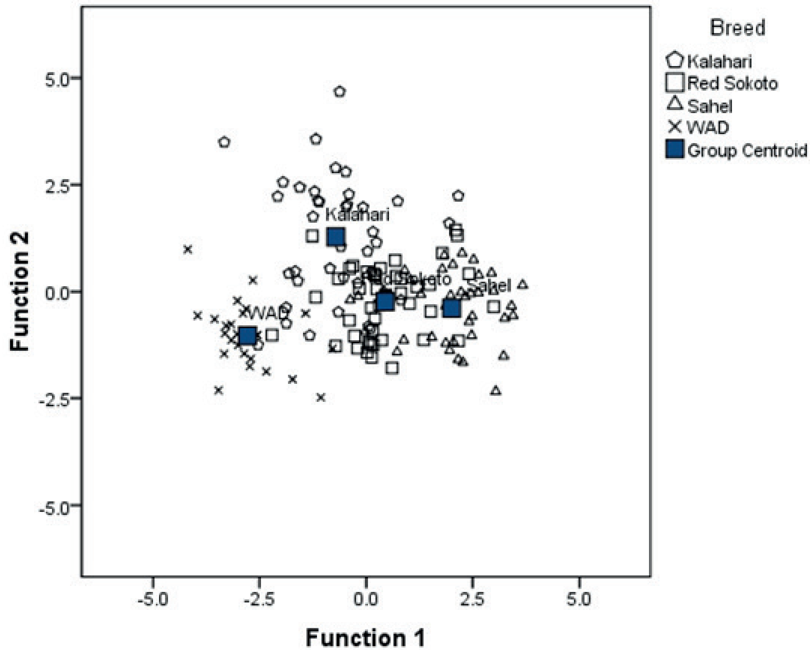

Figure 2. Canonical discriminant function showing the relationship and distribution among the goat breeds.

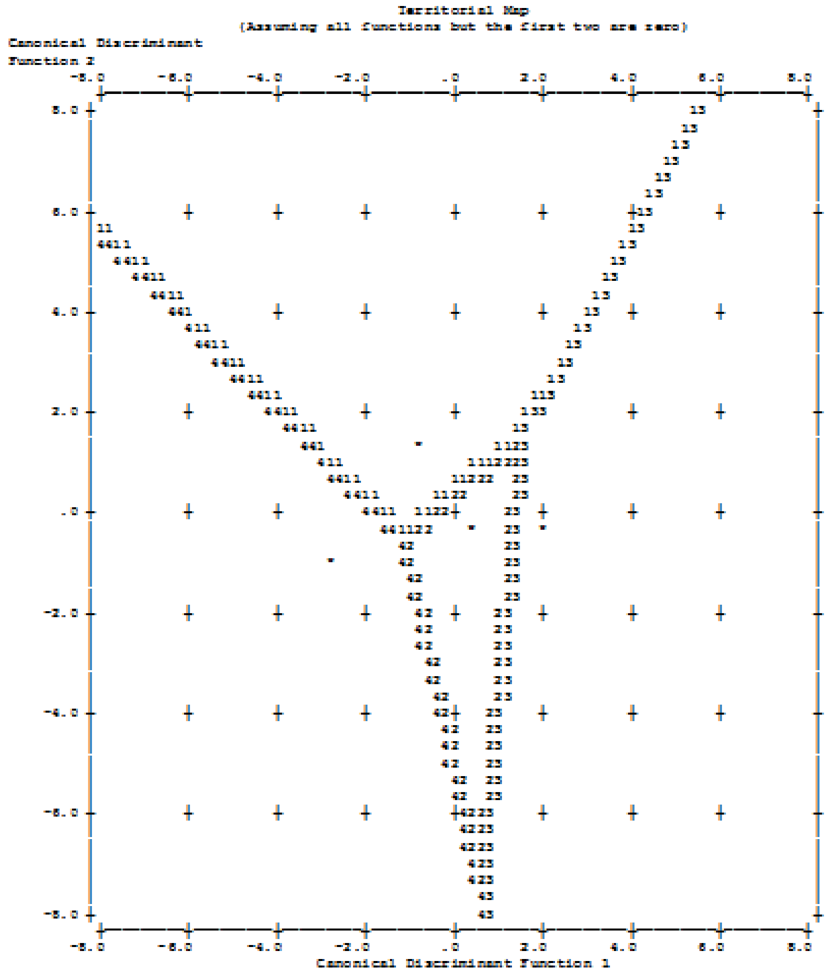

Figure 3. Canonical discriminant function showing the territorial map of the four goat breeds.
1 = Kalahari Red goat, 2 = Red Sokoto goat, 3 = Sahel goat, 4 = West African Dwarf goat

Table 8. Percentage of individuals classified into genetic groups after cross-validation

	Kalahari Red	Red Sokoto	Sahel	WAD	Total
Kalahari Red	70.0	15.0	5.0	10.0	100.0
Red Sokoto	11.1	68.9	17.8	2.2	100.0
Sahel	0.0	20.5	79.5	0.0	100.0
WAD	0.0	4.0	0.0	96.0	100.0

Original grouped cases correctly classified were 76.5%. Cross-validated grouped cases correctly classified were 75.8%. WAD = West African Dwarf goat.

classified into genetic groups (Table 8). The stepwise discriminant model excelled at classifying 96% of the WAD goats and least classified RS goat (68.9%) into source genetic group. However, 17.8% of the RS goats were misclassified as SH whereas 20.5% of SH were misclassified as RS goats.

The Red Sokoto, Sahel and West African Dwarf goat breeds have been famous for farming and meat-utility in Nigeria. The Nigerian goat breeds have proven characteristics of good meat quality, adaptability and genetic stability relative to the tropical environment (Fayemi, 2006). However, their notable and comparable smaller sizes can have some negative economic implications when compared to some foreign or exotic commercial meat type breeds, for example, Kalahari Red goat from South Africa.

Genetic morphometry could be useful in classifying animals by types and functions. Body weight, BL, WH and CDs are four growth traits which have important impacts on the production of chevon and skin. The body measurements in animals, along with growth and carcass traits have dominant difference in all breeds (Guifen et al., 2014). The breeding for optimal gains and for growth traits is a major consideration in goat breeding programmes. In this study, the KR goat had the highest measured values compared to the Nigerian goat breeds relative to the body measurement and growth traits considered. Although the growth and body measurements of Nigerian goat breeds seem to be lower when compared with the exotic KR goat from South Africa, they have good physical morphometric characteristics. The Nigerian goat breeds have been crossed with exotic breeds to improve their growth rate (Bemji et al., 2014). Among the Nigerian goat breeds, the SH goat is prominent for high-grade body measurements since its measured values were highest among all Nigerian goat breeds.

In a goat breeding programme, based on genetic correlations among two traits, selection for one trait may lead to a correlated response in the other trait (Falconer and Mackay, 1998). In this study, growth traits were positively correlated, with some pair of traits showing high correlation coefficients. It follows that as the BW of the goat increases, the linear body measurements (BL, WH and CD) will increase relative to the moderate to high positive correlations that exist between them. Conversely, as the WH increases, the BLI tends to decrease based on the negligible to low negative correlation existing between these variables. Obviously, this trend is consequential on selection practices in animal husbandry.

Discriminant analysis is used to model the value of a dependent categorical variable based on its relationship to one or more predictors. Discriminant analysis of morphometric traits is widely used in determining the relationships among different breeds of livestock (Carneiro et al., 2010; Ajayi et al., 2012b). An organism's phenotype is considered by most researchers as a set of variable whose covariation of traits is of important analytical consideration (Collyer and Adams, 2007). The result of some discriminating variables found in the present study are similar to the earlier work of Agaviezor et al. (2012) who reported that tail length, rump height, chest girth, ear length and chest depth were the most discriminating variables for classification from a stepwise discriminant analysis in WAD sheep, Yankasa, Uda and Balami sheep. This present study used three discriminating variables (BL, WH and CD) while the researchers used nine phenotypic variables in their study. Thus, in accessing morphological diversity, efforts should be made to include phenotypic variables at least ≥ 3 in order to minimize ambiguity in classification.

The Wilks' Lambda result from stepwise discriminant procedure shows that one, the variables contribute to the model; two, they are better at discriminating between groups; and three, the discriminant model as a whole fits the data. This study revealed that there is significant morphological variability among Nigerian goats and South African KR goat breeds. This morphological differentiation may be relative to the inherent genetic potential of each breed, alongside geographical isolation and ecological variation (Gizaw et al., 2007; Agaviezor et al., 2012). The pair-wise shortest distance observed between RS and SH goat breeds may be attributed to the close proximity due to location effect between these two breeds. The high morphometric variation (within the Nigerian context), between SH and WAD goat breeds suggests the possibility of obtaining heterotic gains (Zahraddeen et al., 2008). The SA goat is a promising goat breed in terms of its growth performance (Zahraddeen et al., 2008). The SH and RS goats of Nigeria are favourable options for improving WAD goat breed within the in-country context. There is also the possibility of obtaining higher heterotic gain between Nigerian SH goat and KR goat of Southern Africa than when compared between WAD and KR goat or between RS and KR goat. The pair-wise distances of the Discriminant function provide helpful information which could aid the breeding and conservation strategies of the studied goat species. Alternatively, the comparative assessment of the growth and carcass potentials of crossbreds obtained from crosses involving KR and Nigerian goat breeds would further clarify these hypotheses.

Canonical discriminant function showing the relationships and distribution among the goat breeds revealed that the first function on the horizontal axis separates the SH goats from the other goats. Since WH is strongly positively correlated with the first function, this suggests that the SH goats are distinctly classified from the other goats based on their WH. The second function separates WAD and KR goats. This study has shown that CD and BL are strongly positively correlated with the second function. Kalahari Red goats tend to have wider CD and longer BL than the WAD goats. RS goats are not separated well from the other goats in this study, although the territorial map of the four goat breeds suggests that they tend to be distinguished based on WH with a moderate BL.

The Canonical discriminant function that shows the relationship and distribution among the Nigerian goats and South African KR goat breeds reveals RS goat of Nigeria as a breed with genetic closeness with the SH, than with WAD. The RS goat has exemplified relatedness to the KR goats within the African context. The relatedness between the RS and KR goat may be as a result of the short pair-wise distance that was found between them alongside the misclassification of the KR goat in the RS genetic group. This probably suggests why the RS goat is a preferred choice for goat crossbreeding programmes in Nigeria. Systematic attempt has been made for the stability of the RS goat in Nigeria (Bourn et al., 1994). Sahel and WAD goat breeds were distinct from the KR goat. However, efforts should be made to tap the innate potentials, adaptability and survivability of each breed before embarking on a crossbreeding programme.

The three canonical functions obtained, which summarized differences among the four goat breeds used in the study, could be used for establishing phenotypic standards for Nigerian goats and their Southern African KR goat counterpart. The proper classification of WAD goat to its genetic group evidently highlights its morphological distinctness from the RS, SH and KR goats used in the study. Misclassification in the genetic group between RS and SH suggests a form of introgression which may possibly constitute a threat to the future of these Nigerian goats. The closeness between RS and SH goat compared to their WAD and KR counterparts might be due to near biometric convergence, possibly functioning as a guide to genetic and evolutionary relationships linking the two breeds. The observed level of intermingling between RS and SH goats could be partly attributed to indiscriminate crossbreeding due to their geographic proximity. Introgression among distinct genotypes or breeds could probably lead to the pollution of gene pool and erosion of between-breed diversity thereby resulting into more heterogenous populations with negative implications for utilizing inherent breed-specific genetic variation in future improvement programmes (Ajayi et al., 2012a). The WAD goats are found majorly in the trypanosome endemic humid zones of Southern Nigeria. The RS goat breed which occupies a central geographical position is more widely distributed in Nigeria than the other goat breeds (Bourn et al., 1994). The longer pair-wise distance between WAD goat and other goat breeds, especially SH and RS goats revealed that morphological differences are maintained in part by the reduction of gene flow amongst populations separated by large distances (Agaviezor et al., 2012) as well as physical and ecological barriers.

From the study, the WAD goats may have undergone a very weak form of gene flow based on the strongly separated position. It was reported that the similarity which existed between breeds from the same country rather than among the types of breeds used may have resulted from increasing crossbreeding due to increase in transhumance, indiscriminate mating and preference for larger animals by farmers (Missohou et al., 2006). The erosion of animal genetic diversity has been confirmed in other animal species studies from West Africa (Missohou and Adakal, 2004). A declining north-to-south gradient has been reported in male zebu introgression among taurine breeds of West Africa (MacHugh et al., 1997; Hanotte et al., 2000, 2002).

CONCLUSION

The Discriminant function is informative for morphological classification. The study provided informed decision (for instance relative to the pair-wise distances from the Discriminant function), reference information for policy direction on goat breeding, improvement and conservation strategy, which forms a basis for future management of the studied species. There is significant morphological variability among Nigerian goats and South African KR goat breeds. WAD goat demonstrated morphological distinctness from the RS, SH and KR goats used in the study. Comparative assessment of the growth and carcass potentials of crossbreds obtained from crosses involving South African KR and Nigerian goat breeds would further clarify expected heterotic gain hypotheses.

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