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COMPARATIVE BODY WEIGHT AND MORPHOMETRIC TRAITS OF WEST AFRICAN DWARF AND RED SOKOTO GOATS IN SOUTH WEST, NIGERIA

[1]Ajayi, Bababunmi Alaba, *[1]Babatunde, Olatunji, [2]Akintunde, Oye Akintunde, and [1]Atoyebi, Gbenga Oyewole

[1]Department of Animal Science, Faculty of Agricultural Production and Management, College of Agriculture and Renewable Natural Resources, Osun State university, Ejigbo Campus, Osun State, Nigeria.
[2]Animal Science Unit, Department of Agriculture and Industrial Technology Babcock University, Ilishan-Remo, Ogun State, Nigeria.

*Corresponding authors' email: olatunji.babatunde@pgc.uniosun.edu.ng

ABSTRACT

A total of 633 goats were sampled randomly across three states in Southwestern Nigeria for comparation of morphometric traits between West African Dwarf (WAD) and Red Sokoto (RS). Data collected were analysed using multivariate analyses of linear body measurements. The study aimed at confirming regional representation, intra- and inter-breed variations, and validating phenotypic indicators of genetic diversity. Twenty-two morphometric measurements were taken on each goat. RS goats were superior ($P < 0.05$) to the WAD in body weight and body proportions, except for ear width (male and female), ear length, canon circumference, and udder circumference (female only), where both breeds were comparable. The two breeds exhibited distinct morphometric profiles, as reflected in their respective loadings on the principal components. Five principal components (PCs) were similarly extracted for both breeds, but with different percentage contributions for each PC. In WAD the highest component loadings were Heart Girth, Body Depth and Chest Depth conversely it was Rump Height, Wither Height, Ear Length and Head Length in RS. The Mahalanobis distance between WAD and RS goats was 37.52 (overall), indicating a high level of breed divergence thus high heterotic potential from crossbreeding. These values reflect noticeable variations in physical features that are influenced by both sex and breed. Cluster analysis confirmed the relative importance of each morphometric trait across breed and sex. The backward stepwise Discriminant Function Analysis (DFA) highlighted the traits most relevant for differentiating between WAD and RS goats. There is significant difference between the two breeds to support crossbreeding gains.

Keywords: Morphometric traits, West African Dwarf, Red Sokoto, Discriminant Function Analysis, Principal Component Analysis

INTRODUCTION

Goats play a vital economic and cultural role in Nigeria, they provide income, meat, milk, hides, and social status, especially in rural communities (Hassan, 2024). In Nigeria, especially southwest, goats are integral to traditional ceremonies and serve as a financial fallback in low-income households. Goat production plays an important role in the economic improvement of poor farmers and contributing to poverty alleviation in Nigeria (Bashir, 2021). Population of goats in Nigeria was about 88 million in 2022 (USDA, 2025). This population is still increasing annually. Their economic and social significance extends beyond mere agricultural production, encompassing cultural, religious, and environmental dimensions.

The initial step involve in any animal genetic improvement program is to describe the important morphometric traits. Morphometric characteristics are essential in breed identification and classification (Adamu *et al*., 2020). Several studies have been carried out on multivariate analysis of linear body measurements, Yakubu *et al*. (2013) in sheep, Oseni and Ajayi (2014) in rabbits, Ajayi *et al*. (2017) on Nigerian indigenous chickens, Melak *et al.* (2019) on Egyptian Barki lambs, Adamu *et al*. (2020) on Red Sokoto and Sahel goats and Ajayi *et al*. (2024) on West African Dwarf goats.

Thorough comparison of the body size and shape of the two goat breeds in terms of multivariate statistical analyses such as principal components and cluster analyses is not adequate. Moreover there is no reported sex-specific morphometric comparisons between WAD and RS goats. The principal component technique reduces a large number of correlated variables into a smaller set of uncorrelated variables called principal components yet retaining as much of the original data's variation as possible. (Jolliffe, 2011). Morphological distance between the two goat breeds, which could serve as a basis for their genetic improvement, was reported by Yakubu *et al*. (2011); however, information on morphological distance between same sexes of the two breeds is scanty. This research examined the morphometric distinction between the two goat breeds using multivariate statistical analyses. The objectives of this work therefore were to evaluate the influence of breeds on live body weight and linear body measurements as well as to establish the morphometric differences between West African Dwarf and Red Sokoto.

MATERIALS AND METHODS

The experiment made use of a random sample of 394 WAD goats of both sexes (282 females and 112 males) and 239 RS goats (171 males and 68 females). While the WAD goats were measured in certain villages located in Oyo State, Osun and Ondo states of South-Western Nigeria, the RS goats were measured in the village markets in the same states of South-Western, Nigeria. The animals' ages which were adults of at least 12 months were determined by dentition (presence of two to eight permanent incisors) as described by Matika *et al*. (1992). Only physically healthy animals were included in the study. Live weights were measured using a calibrated spring balance. An apron was worn across the abdomen of the goats and hung on the spring balance suspended on a horizontal pole held at both ends by two upright poles. Two individuals restrain the goat while a third person observe and records the weight in kilograms. Morphometrical measurements were taken using a measuring tape by two individuals restraining the goat while a third person records the measurements. All measurements were taken by three trained individuals who took measurements of 20 goats in turns to check and ensure accurate and consistent measurement. This was done daily for 7 before the field work was undertaken. Linear body measurements were taken with a flexible tailor measuring tape (cm), in accordance with methods of Hassan and Ciroma (1992). Data were collected on live weight and 22 morphometric parameters.

Table 1: Selected Morphometric Traits and how they Were Measured

Trait	Abbrev-iation	Description and measurement procedure
Chest Width	CW	Horizontal distance across the chest, typically measured between the outermost points of the scapulae (shoulder blades)
Body Depth	BD	Distance from the top of the spine to the bottom of the body at its deepest point
Rump Length	RL	the distance measured along the back, from the point of hips to the point of pin bones;
Wither Height	WH	Vertical distance from the ground to the highest point of the withers (shoulders)
Rump Height	RH	Distance from the ground to the highest point of the rump (near the hip bone).
Body Length	BL	Measured from the point of the shoulder to the point of the pin bone
Heart Girth	HG	Circumference of the chest just behind the front legs
Chest Depth	CD	Vertical distance from the top of the withers to the brisket
Shoulder Width	SW	Distance across the shoulders, measured between the outermost points of the scapulae.
Rump Width	RW	Measured between the tuber coxae (hip bones) or tuber ischii (pin bones)
Neck Length	NL	Distance from the occipital bone (base of skull) to the point of the shoulder.
Neck Circumference	NC	Length of the circular measurement around the middle of the neck, typically taken just below the jaw and above the shoulders
Ear Length	EL	Measure from the base of the ear to the tip.
Ear Width	EW	Maximum width of the ear at its widest part
Face Length	FL	From the base of the horn or forehead to the tip of the nose
Head Length	HL	From the occipital ridge to the tip of the muzzle
Head Width	HW	Between the outer edges of the zygomatic arches (cheekbones).
Scrotal Length	SL	(Bucks only) Vertical length of the scrotum from top to bottom, measured while gently holding the scrotum.
Scrotal Circumference	SC	(Bucks only) Transverse distance round the scrotum;
Cannon Circumference	CC	Circumference of the foreleg just below the knee.
Tail Length	TL	Measured from the tail base to the tip.
Udder Length	UL	(Does only) Distance from the base of the udder to the tip of the teat at the lower end
Udder Circumference	UC	(Does) Females transverse distance round the udder.
Horn Length	HOL	Distance from the base of the horn to the tip of the distal end

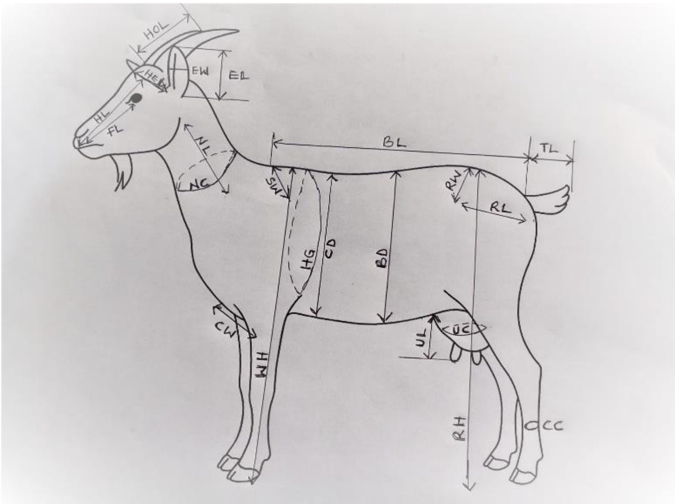

Figure 1: Illustration of morphometric parameters

Statistical Analysis

The analysis of morphological data was carried out using a combination of descriptive, inferential (Welch's test and Mahalanobis distance), and multivariate statistical techniques (Regression Analysis, Principal Component Analysis, Cluster Analysis and Discriminant Function Analysis). Mahalanobis distance measure how far the two breeds are from each other in terms of their measured traits, Welch test serve to investigate significance differences in the measured traits between the two breeds base on equal variances and unequal sample sizes and the multivariate statistics aimed at identifying significant patterns and relationships among traits across the two goat breeds. All statistical analyses were carried out with SPSS Statistics for Windows, Version 21.0.

RESULTS AND DISCUSSION

Morphometric analysis of indigenous goat breeds forms an essential foundation for their genetic improvement and conservation. In this study, clear and significant differences were observed between RS and WAD goats in the zoometric traits measured, and the results carry important implications for breed classification and assessment of genetic diversity.

Among bucks, RS goats were significantly ($p<0.05$) higher in all traits measured, except for Ear Width and Head Width, where the values were comparable to those of WAD bucks. WAD bucks, however, showed higher coefficients of variation in body weight, rump height, withers height, ear length, horn length, and tail length, indicating greater within-breed variability. For does, RS goats showed higher values ($p<0.05$) than WAD in most traits, although the differences were lower in heart girth, rump width, body length, body depth, ear dimensions, neck circumference, head and face lengths, rump length, chest depth, and canon circumference. Similarly, higher coefficient of variation was observed in WAD does for body weight, rump height, rump width, umbilical length, and umbilical circumference. This pattern agrees with Yakubu *et al*. (2011), who reported that RS goats generally have higher morphometric traits than WAD goats, with exceptions noted in ear width and head width; however, same-sex comparison across breeds was not reported. Abolusoro *et al.* (2020) also reported higher morphometric values for not only RS against WAD comparation but Sahelian goats were also higher than RS. The larger body size of RS goats compared to WAD goats is likely due to a combination of genetic and ecological factors, as well as the possibility that RS goats have been subjected to more selection pressure than their WAD counterparts, which may account for their generally lower coefficient of variation. This pattern needs to be confirmed by studies from other regions of Nigeria as well.

The Kaiser–Meyer–Olkin measure (Nkansah, 2018), Bartlett's Test of Sphericity (Azevedo, 2003), and Cronbach's Alpha (Cronbach, 1951). all confirmed that principal component factor analysis was appropriate and reliable for the data. In WAD goats, five principal components were extracted from 24 morphometric traits, explaining 68.93% of the total variance. The first component alone accounted for 42.18%, with strong loadings on traits like heart girth, body depth, chest depth, canon circumference, neck length, and face length. Subsequent components showed varying contributions from height, head, and scrotal related traits. Similarly, five components were also extracted in RS goats, accounting for 67.94% of total variance. The first principal component, with high loadings for general body size traits like withers height, rump height, body length, and canon circumference, explained 34.41% of the variance. The remaining components captured variation in traits such as chest width, ear width, and head width, indicating other sources of morphological variation. A backward stepwise selection procedure revealed 10 traits: RH, SL, BL, HL, HEW, SC, BW, CD, WH, and CC as the most discriminating variables. This aligns with Yakubu *et al*. (2010), who also retained 7 key traits in a similar study.

Mahalanobis distances were computed between the groups based on sex and then irrespective of sex. The pairwise distances were all significant ($P<0.0001$), showing a small distance (7.56) between RS and WAD does, a higher distance (18.95) between the bucks, and the largest distance (37.52) between the two breeds when sex was not considered. Yakubu *et al*. (2010) had earlier reported an even larger Mahalanobis distance of 72.28 between RS and WAD goats in a related study.

Multicollinearity checks showed all predictors had acceptable Variance Inflation Factor (VIF) values (typically < 5), indicating no serious collinearity, confirming model reliability. With an Adjusted R^2 of 0.725 and a highly significant ANOVA ($p < 0.001$), the model effectively predicts body weight (BW). Traits like HG, RW, BD, and others had strong positive effects on BW, while HL, SL, and RH showed significant negative associations. The negative link between SL and BW ($p < 0.01$) may reflect a trade-off between reproductive and somatic growth in bucks. Heart Girth and Rump Width emerge as reliable predictors of BW for selection and management in Red Sokoto goats. In WAD goats, the final regression model accounted for about 92.3% of the variation in body weight ($R^2 = 0.923$; Adjusted $R^2 = 0.921$) and was highly significant ($F = 414.875$, $p < 0.001$). Key predictors retained included WH, HG, BL, BD, NL, SW, HL, FL, SL, CD, and HEW, each contributing uniquely to body weight. Chest Depth (CD) stood out as the strongest predictor ($B = 0.531$, $p < 0.001$), reinforcing its reliability for estimating body mass where scales are unavailable. Body Depth (BD) and Withers Height (WH) also showed strong positive associations. Dakhlan *et al*, (2020) reported that Chest Girth and Body Length could be used as predictor for body weight and as indicator of indirect selection to improve genetic merit in body weight of Ettawa Grade goat.

Table 2: Summary of Descriptive Statistic for Bucks and does of RS and WAD

Trait	RS Buck			WAD Buck			RS Doe			WAD Doe		
	(Mean ± SEM)	SD	CV%	(Mean ± SEM)	SD	CV%	(Mean ± SEM)	SD	CV%	(Mean ± SEM)	SD	CV%
BW	17.64 ± 0.32^{a}	4.13	23.40	10.89 ± 0.33^{b}	3.52	32.34	20.98 ± 0.39^{a}	3.21	15.32	16.23 ± 0.28^{b}	4.74	29.22
RH	61.82 ± 0.34^{a}	4.45	7.20	44.17 ± 0.70^{b}	7.41	16.79	50.87 ± 0.56^{a}	4.60	9.04	48.91 ± 0.32^{b}	5.35	10.93
CW	17.10 ± 0.26^{a}	3.35	19.60	15.33 ± 0.19^{b}	1.99	12.94	17.92 ± 1.01^{a}	8.33	46.51	16.42 ± 0.32^{b}	5.29	32.22
WH	57.10 ± 0.30^{a}	3.96	6.94	41.94 ± 0.65^{b}	6.92	16.50	48.43 ± 0.54^{a}	4.48	9.25	46.97 ± 0.29^{b}	4.89	10.42
HG	61.11 ± 0.37^{a}	4.82	7.89	51.92 ± 0.48^{b}	5.11	9.84	59.29 ± 1.20^{a}	9.90	16.70	59.39 ± 0.48^{a}	8.11	13.65
RW	15.78 ± 0.21^{a}	2.73	17.31	14.71 ± 0.14^{b}	1.51	10.25	17.17 ± 0.29^{a}	2.36	13.74	17.26 ± 0.61^{a}	10.18	59.00
BL	52.88 ± 0.45^{a}	5.95	11.25	43.42 ± 0.58^{b}	6.09	14.02	49.70 ± 0.90^{a}	7.45	15.00	49.86 ± 0.49^{b}	8.24	16.52
BD	34.36 ± 0.30^{a}	3.94	11.47	28.75 ± 0.28^{b}	2.93	10.18	35.37 ± 0.52^{a}	4.29	12.14	34.42 ± 0.26^{a}	4.39	12.74
EL	13.13 ± 0.11^{a}	1.47	11.19	10.25 ± 0.17^{b}	1.78	17.38	11.32 ± 0.19^{a}	1.56	13.76	11.22 ± 0.08^{a}	1.34	11.95
NC	28.76 ± 0.33^{a}	4.27	14.85	24.09 ± 0.48^{b}	5.12	21.25	26.71 ± 0.47^{a}	3.83	14.34	26.52 ± 0.22^{a}	3.62	13.65
NL	18.93 ± 0.22^{a}	2.86	15.10	13.51 ± 0.24^{b}	2.56	18.96	16.52 ± 0.33^{a}	2.73	16.49	16.25 ± 0.18^{a}	3.05	18.75
SW	27.02 ± 0.42^{a}	5.52	20.43	21.75 ± 0.44^{b}	4.65	21.39	20.97 ± 0.59^{a}	4.86	23.16	23.17 ± 0.32^{b}	5.43	23.44
TL	11.46 ± 0.10^{a}	1.37	11.96	9.29 ± 0.15^{b}	1.58	17.00	10.01 ± 0.31^{a}	2.56	25.37	9.55 ± 0.11^{b}	1.81	18.98
HL	21.95 ± 0.14^{a}	1.81	8.25	17.28 ± 0.20^{b}	2.16	12.50	18.57 ± 0.24^{a}	2.00	10.75	18.62 ± 0.13^{a}	2.25	12.10
FL	11.90 ± 0.08^{a}	1.00	8.42	10.02 ± 0.09^{b}	0.99	9.89	11.48 ± 0.14^{a}	1.17	10.15	11.32 ± 0.08^{a}	1.35	11.92
EW	5.49 ± 0.05^{a}	0.67	12.24	5.08 ± 0.05^{b}	0.55	10.75	5.70 ± 0.11^{a}	0.88	15.48	5.33 ± 0.04^{a}	0.59	11.07
HOL	10.16 ± 0.24^{a}	3.10	30.52	6.41 ± 0.20^{b}	2.17	33.79	7.68 ± 0.27^{a}	2.23	29.05	6.77 ± 0.13^{b}	2.12	31.25
SL	15.38 ± 0.18^{a}	2.35	15.26	11.26 ± 0.12^{b}	1.30	11.56	—	—	—	—	—	—
SC/UC	19.56 ± 0.12^{a}	1.58	8.09	16.90 ± 0.16^{b}	1.69	10.00	20.12 ± 0.84^{a}	6.95	34.53	20.00 ± 0.51^{b}	8.49	42.47
RL	15.76 ± 0.17^{a}	2.16	13.71	13.69 ± 0.23^{b}	2.41	17.59	14.89 ± 0.30^{a}	2.44	16.41	14.18 ± 0.16^{a}	2.62	18.47
CD	30.84 ± 0.23^{a}	3.01	9.76	25.71 ± 0.20^{b}	2.09	8.12	30.39 ± 0.47^{a}	3.91	12.85	29.92 ± 0.20^{a}	3.29	10.98
CC	8.85 ± 0.07^{a}	0.90	10.18	7.38 ± 0.07^{b}	0.79	10.69	7.79 ± 0.10^{a}	0.78	10.05	7.69 ± 0.04^{a}	0.68	8.79
HEW	16.52 ± 0.25^{a}	3.28	19.83	15.94 ± 0.19^{b}	1.96	12.30	15.49 ± 0.31^{a}	2.52	16.28	16.63 ± 0.15^{b}	2.45	14.73
UL	—	—	—	—	—	—	9.74 ± 0.29^{a}	2.40	24.63	8.97 ± 0.23^{b}	3.92	43.67

^{a,b}Means in the same row with different superscripts are significantly different ($P<0.05$)

Table 3: Eigenvalues and Share of Total Variance Along with Factor Loadings After Rotation and Communalities for Comparing the Morphometric Traits of West African Dwarf and Red Sokoto Goats

Variables	West African Dwarf goats						Red Sokoto goats					
	PC1	PC2	PC3	PC4	PC5	Communality	PC1	PC2	PC3	PC4	PC5	Communality
RH	0.382	0.682	-0.232	0.165	-0.136	0.711	0.819	0.232	0.044	0.157	0.291	0.837
WH	0.000	0.875	-0.198	0.089	0.011	0.813	0.798	0.210	0.190	0.028	0.327	0.825
HG	0.934	-0.241	0.185	0.053	0.132	0.985	0.189	0.849	-0.214	0.050	0.025	0.805
BL	0.466	0.609	0.577	-0.037	0.005	0.923	0.562	0.541	0.033	-0.037	0.029	0.612
BD	0.776	0.124	0.009	0.042	0.108	0.632	0.097	0.851	0.216	-0.062	-0.054	0.788
EL	0.077	0.487	-0.024	0.005	0.105	0.255	0.762	-0.064	0.236	-0.113	-0.052	0.656
NL	0.564	0.403	0.180	0.320	0.030	0.617	0.634	0.422	-0.079	0.133	0.026	0.604
FL	0.607	0.265	0.178	-0.058	-0.057	0.477	0.209	0.432	-0.155	0.012	0.540	0.546
HOL	-0.014	0.561	-0.167	0.307	-0.045	0.438	0.426	0.338	0.205	0.080	0.384	0.492
CD	0.820	0.097	0.203	0.015	0.132	0.740	0.180	0.866	-0.005	0.035	0.091	0.563
CC	0.631	0.065	0.015	0.314	-0.031	0.502	0.583	0.308	-0.197	0.373	-0.067	0.768
Eigenvalue	9.28	1.71	1.66	1.35	1.16		7.57	2.81	1.98	1.53	1.06	
Percentage	42.18	7.79	7.53	6.14	5.29		34.41	12.78	8.98	6.94	4.83	

West African Dwarf goats: The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.809, and Bartlett's test of sphericity was significant ($\chi^2 = 2782.84$, $p < 0.001$)
Sokoto Red goats: The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was 0.824, and Bartlett's test of sphericity was significant ($\chi^2 = 3313.69$, $p < 0.001$. Cronbach's Alpha = 0.910

Table 4: Summary of Stepwise Selection of Traits[a]

Step	Variables Entered	Partial R^2	F Value	Pr > F	Wilks' Lambda	Pr < Lambda	Average Squared Canonical Correlation (ASCC)	Pr > ASCC
1	RH	0.690	625.47	0.000	0.310	0.000	0.821	0.000
2	SL	0.134	381.73	0.000	0.268	0.000	0.845	0.000
3	BL	0.132	306.17	0.000	0.233	0.000	0.865	0.000
4	HL	0.065	247.23	0.000	0.219	0.000	0.877	0.000
5	HEW	0.045	208.61	0.000	0.210	0.000	0.882	0.000
6	SC	0.042	182.83	0.000	0.201	0.000	0.887	0.000
7	BW	0.040	164.11	0.000	0.193	0.000	0.892	0.000
8	CD	0.034	149.30	0.000	0.187	0.000	0.896	0.000
9	WH	0.027	135.87	0.000	0.183	0.000	0.900	0.000
10	CC	0.022	124.11	0.000	0.180	0.000	0.906	0.000

[a]Only variables that were significant in the stepwise discriminant function procedure and that had partial R2 values≥0.01 were retained in the final model

Table 5: Mahalanobis Distance Between WAD and RS Goats

Breed	SR doe	SR buck	SR buck and doe
WAD doe	7.56	-	-
WAD buck	-	18.95	-
WAD buck and doe	-		37.52

Predictor Importance

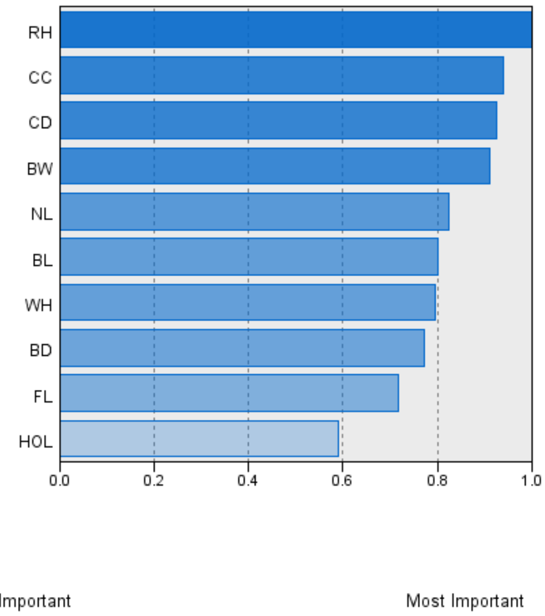

Figure 2: Predictor importance for Cluster analysis of SR and WAD does

Predictor Importance

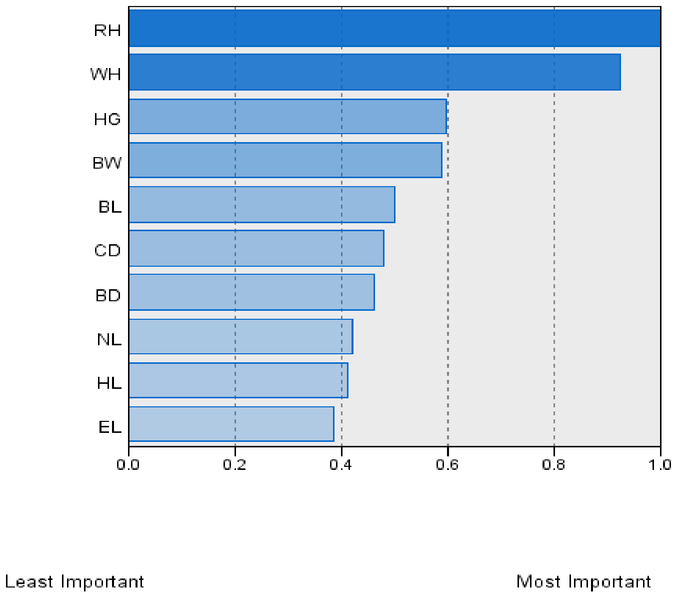

Figure 3: Predictor importance for Cluster analysis of SR and WAD buck

CONCLUSION

RS goats are morphologically and structurally larger than WAD goats across sexes. The higher coefficient of variation observed within WAD suggests greater within breed diversity which is valuable for good response to selective breeding. In contrast, the relatively lower variation in RS points to more uniformity, possibly due to past selection for commercial traits. PCA and discriminant analyses confirmed that a relatively small set of morphometric traits can effectively differentiate the two breeds with high accuracy. Mahalanobis distances further indicated clear breed separation by sex and when sexes are combined. These findings can guide breeding programs by identifying discriminating traits for selection, while also informing conservation strategies to maintain genetic diversity, especially in WAD goats. Longitudinal studies are recommended to monitor morphometric trends over time, enabling the tracking of genetic gains or losses and supporting sustainable improvement of indigenous goat populations.

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