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Effect of sexual dimorphism on phyenotypic traits in two-nigerian indigenous goat breeds at different ages

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ABSTRACT

This study investigated the effect of breed and sex on linear body morphometric traits of 2-Nigerian indigenous goats. Eighty goats averaging 150 days old were purchased and used for the study at the Goat Production Unit, Livestock Section of the Teaching and Research Farm, Federal University of Technology, Akure, Nigeria over a ten-week period. Two treatments of five replicates at 3 and 5 goats per replicate totalling 15 and 25 West African Dwarf (WAD) and Red Sokoto (RS) goat breeds respectively. The treatment was divided into equal number of bucks to doe ratio at 30 WAD and 50 RS goats. Factorial experiment in completely randomized design arrangement was used for the study. Data on linear body morphometry were collected at different ages to determine the growth performances of the goats. The pulled data were used to analyse the goat breeds for relationship between body weight and linear body morphometric traits using SAS (2008) statistical software. Significant differences ($p<0.05$) in morphometric traits were observed between the breeds, sexes and interaction. The WAD goats significantly ($p<0.05$) demonstrated superior body weight (18.13kg) by week 10 than the RS (15.70kg). Red Sokoto goats exhibited significantly ($p<0.01$) higher height at withers (59.51cm versus 45.66cm) than WAD goats. Does were observed heavier than their buck counterparts. Strong, positive and significant ($p<0.01$) correlation ($r=0.80$) existing between body phenotypic traits of goats in this study showed that genes controlling these traits have linkage/pleiotropic effect. Regression analyses showed linear body traits singly or jointly well described the body weight of the goats owing to their significant ($p<0.01$) coefficient of determination values mostly ≥74%. Heart

girth gave the best description of body weight in this study. The model becomes more accurate as more body parameters are included, indicating a better fit and higher accuracy of prediction. It is essential to prioritize the genes of both goat breeds for conservation and improvement through structured dietary, management and breeding programmes. Goat breeders can select heart girth to improve the body weight performance of their stocks.

Keywords: Morphometric, animal production, management systems, correlation and regression

INTRODUCTION

Goat farming has a rich history in Nigerian agriculture, contributing significantly to the nation's economy and food supply. Nigeria holds the distinction of having the largest goat population in West Africa, estimated to be around 76 million goats in 2019 (FAO, 2021). Goat farming in Nigeria is typically practiced on a small or subsistence level, often integrated with crop production in mixed farming systems (Ogundipe et al., 2020). These mixed crop-livestock systems are especially common in rural communities, where goats provide meat, milk and income through the sale of live animals and their by-products (Adebowale et al., 2019). Although, Nigeria is home to several goat breeds but two of the commonest indigenous breeds which are the Red Sokoto and West African Dwarf are particularly noteworthy for their adaptability and economic value. These breeds have adapted to local conditions and are essential to the livelihoods of many Nigerian farmers (Yakubu et al., 2018).

The Red Sokoto goat, also known as the Maradi goat is primarily found in the Northern region of Nigeria. It is renowned for its high-quality skin, which is prized in the leather industry for its unique grain pattern, often referred to as "Morocco leather" (Alphonsus et al., 2017). The goat breed is medium-sized, thrives in semi-arid climate of Northern Nigeria where it's also prized for its quality meat and milk production (Tsado et al., 2021). However, the West African Dwarf (WAD) goat is predominantly found in the Southern and Middle belt regions of Nigeria. This breed is characterized by its small stature which is believed to be an adaptive feature, allowing it to thrive in the tse-tse fly infested humid agro-ecological zones of West African countries (Odubote, 2019). Despite its small size, the WAD goat is highly regarded for its prolificacy, resistance to trypanosomosis and ability to thrive on low-quality feeds (Daramola et al., 2021). These indigenous goat breeds are valuable genetic resources, possessing traits developed over generations to thrive in local environments and resist prevalent diseases where their importance goes beyond immediate economic gain (Adjei et al., 2021).

There have been conflicting reports on the effects of sex on performance traits in goats. Ndlovu and Simela (1996) opined that sex had no significant effect on weight increase on weaned kids from smallholder East African goat flocks in North East Zimbabwe. However, this factor had significant effect on carcass composition where males had higher bone lengths, less intramuscular fat, less fat deposition channels and better carcass compactness than females (Teixeira et al., 2011). Also, sex in conjunction with some other factors such as age, season, parity, litter size and body condition score had significant effects on goats' daily weight gain where the male goats recorded daily weight gain than their female counterparts at early ages of 30 – 120 days (Zahraddeen et al., 2008).

Till date, many scholarly articles have reported positive, strong and significant correlation and regression coefficients in various animal species from body phenotypic measurements. Some of these researchers did not find any statistical difference in the correlation coefficients among linear body measurements with live weight using young male goat breeds during their experiment (Fonseca, et al. (2021). However, Almaguer et al. (2017) opined that all biometric measurements showed highly significant correlations with live body weights. Other researchers concluded that body weight and body morphometric measurements were positively correlated, indicating the possibility of correlated responses in field breeding programmes for specific goat breed (Costa Júnior et al., 2006; Ahmad et al., 2013; Rayanna et al., 2016). Observation that different models predict body weights differently from linear body measurements was reaffirmed using CART model which favours heart girth as the best predictor variable of body weight while MARS showed body length as it preferred variable Mathapo et al. (2025). Both models had strong coefficient of determination value that indicate a high prediction of accuracy (Mathapo et al., 2025).

Owing to the fore-going and increasing environmental pressures, the conservation and improvement of these breeds are crucial for sustainable livestock production and food security in Nigeria (Onzima et al., 2018). Therefore, this study investigated the sexual dimorphic effect of body morphometric traits on growth performances in two Nigerian indigenous goat breeds at different ages.

MATERIALS AND METHODS

Location of Study

The research was carried out at the Small Ruminant Unit of the Teaching and Research Farm of The Federal University of Technology, Akure. The area is located between 7o 18'5N and 5o 8'5E. The climatic condition of Akure follows the pattern of Southwest Nigeria where the climate is influenced mainly by the rain-bearing southwest monsoon winds from the ocean and the

dry northwest winds from the Sahara Desert. The rainy season lasts for about seven months (April to October). The temperature throughout the year ranges between 21 and 29oC while the relative humidity is high. The annual rainfall varies from 1,150mm to 2,000mm (Ogunrayi et al., 2016).

Pre-Experimental Operation

To ensure optimal animal welfare and bio-security, existing goat housing and pens were thoroughly inspected and repaired as needed. The facilities were cleaned and disinfected to minimize the risk of disease transmission. Appropriate feeding and watering systems were put in place, and essential equipment, including scales, thermometer, measuring tape was made readily available to facilitate smooth operations throughout the experimental period.

Animal procurement sample size and experimental layout

A total of 80 goats with average age of 150 days old were purchased from trusted local farmers proximal to the University community to reduce transportation-related stress. The animals were reared under controlled experiment and used for the study at the Goat Production Unit, Livestock Section of the Teaching and Research Farm, the Federal University of Technology, Akure, Nigeria over a ten-week period. There were two treatments (breeds) of five replicates at 3 and 5 goats per replicate, making a total of 15 and 25 respectively for WAD and RS goats. The treatment was divided into equal number of males (bucks) to females (does) ratio, totaling 30 WAD and 50 Red Sokoto goat breeds. Upon arrival on the farm, the goats underwent a quarantine period, during which they were isolated, screened for diseases and multivitamin administered thereafter. Following quarantine, the goats were gradually acclimatized to the farm environment, ensuring a smooth transition into the experimental conditions. Each goat was given a unique identification number, which helped in accurate tracking of their health and all relevant details throughout the experiment. This ensured that accurate records were taken and that the animals were well-prepared for the study.

Management Practices

An intensive farming system was employed to manage the goats during the study. The goats were housed in secure, well-ventilated pens, with regular cleaning and disinfection to maintain hygiene. Bedding was replaced frequently to prevent the buildup of waste and minimize disease risks. The goats were provided with a measured diet consisting of concentrates and forage (grasses) to meet their nutritional needs. Feed was allocated in controlled portions, ensuring precise intake, while water was supplied ad libitum to ensure constant availability. Dietary changes were introduced gradually to prevent digestive issues. The percentage composition of the

concentrates given to the goats is represented in Table 1. Health management was a top priority with routine deworming and drug administration carried out at appropriate time to ensure the animals remained in their optimal health condition. Immediate attention was given to any signs of illness to prevent outbreak of diseases.

Accurate records of all management activities, including feeding and health treatments, were maintained using the unique identification numbers assigned to each goat.

Data Collection

Morphometric measurements were taken regularly to track the growth and physical characteristic changes of the goats. The data generated were also analyzed for correlation to determine the extent of relationship among the measured phenotypic parameters and regression coefficients using simple linear growth prediction model. The simple equation used is $Y = a + bX + e$ while the multiple models is $Y= a + bX1 + bX2 + bX3 + Ɛ$.

Where: Y = Dependent variable (body weight), a = Constant associated with the model, b = coefficient of independent variables X1, X2 and X3 which are body length, heart girth and height at wither respectively and Ɛ = unexplained error associated with the model.

The parameters studied includes:

Bodyweight (BWT): Goats were weighed using a digital scale (kg) to monitor growth patterns during the experimental period.

Heart girth (HGT): This measurement was taken by wrapping a measuring tape (cm) around the chest, just behind the fore legs to assess the girth of the thoracic cavity. It provided an indicator of the overall body condition and growth.

Height at Withers (HWR): The vertical distance from the hoof to the highest point of the shoulders (withers) was measured using a measuring tape (cm). This parameter helped in assessing the skeletal development of the goats.

Body Length (BLT): The distance from the point of the shoulder (scapula) to the pin bone (ischium) was measured (cm) to determine the overall length of animal's body. This measurement is useful in estimating body conformation and growth patterns.

Leg Length (LLT): The length of the leg was measured (cm) from the point of the stifle joint (knee) to the ground, providing insight into limb development and proportionality in relation to the body.

Ear Length (ELT): This was measured (cm) from the base of the ear (where it attaches to the head) to the tip, which can be an indicator of breed characteristics.

Tail Length (TLT): The length of the tail was measured (cm) from its base (at the point of attachment to the body) to the tip. Tail length can sometimes be related to breed traits and overall body proportionality.

These morphometric measurements were critical for analysing growth rates, breed-specific characteristics and the overall physical development of the goats. For the purpose of this project, only the Body weight, Heart girth, Height at withers and Body length were analysed for linear body morphometric measurements because of their economic importance.

Statistical Analysis

All data collected were subjected to factorial analysis of variance using SAS (2008), Version 13 to determine the effects of breed, sex and their interaction. Where significant differences existed, the means were separated using Duncan Multiple Range Test of the same statistical package.

Table 1. Gross composition of concentrate feed (%)

Ingredients	Composition
Cassava Peel meal	50.00
Wheat Offal	34.00
PKC	13.00
Urea	1.00
Salt	0.5
Premix	0.5
DCP	1.00
Total	100.00

RESULTS

Effects of breed, sex and interaction on body morphometric traits at week one

The linear body morphometric parameters of the two experimental goat breeds via Sokoto Red (SR) and West African Dwarf (WAD) at week 1 revealed significant differences ($p<0.05$) between the two goat breeds as shown in Table 2. Sokoto Red goats had a significantly ($p<0.05$) longer body length (61.99 cm) than to WAD goats (54.16 cm) and were also taller at the withers (58.17 cm vs. 43.47 cm). The variation between these parameters (Body length and height at wither) for both breeds were statistically significant ($p<0.01$) and indicated distinct breed-specific growth patterns. The effect of sex on these breeds indicated that female goats weighed significantly ($p<0.05$) higher than their male (15.97 kg vs. 13.61 kg) counterpart. Similarly, female goats had significantly ($p<0.01$) larger heart girth measurements than the males (62.59 cm vs. 57.18 cm). This variability may likely due to differential in

the secretion of sex hormones. It was equally observed that there was no significant different ($p>0.05$) in the interaction between breed and sex for the parameters examined in this study except for height at wither (HWR).

Table 2: Effects of breed, sex and interaction on body morphometric at week one

Breed	Sex	BWT (kg)	BLT (cm)	HGT (cm)	HWR (cm)
Sokoto Red		14.38	61.99[a]	61.02	58.17[a]
WAD		15.20	54.16[b]	58.75	43.47[b]
±SEM		0.80	1.20	1.05	0.69
P-value		0.48	0.00	0.14	0.00
	Male	13.61[b]	56.63	57.18[b]	50.26
	Female	15.97[a]	59.52	62.59[a]	51.39
	±SEM	0.81	1.22	1.07	0.85
	P-value	0.05	0.10	0.01	0.35
Sokoto Red	Male	13.39	59.94	57.87	56.33[a]
	Female	15.37	64.03	64.18	60.02[a]
WAD	Male	13.83	53.31	56.50	44.19[b]
	Female	16.57	55.00	61.00	42.75[b]
	±SEM	1.13	1.69	1.48	1.18
	P-value	0.74	0.49	0.55	0.04

[a,b] Means with different superscripts on the same column for the same parameter are significantly different ($p<0.05$), SEM = Standard Error of Mean, BWT = Body weight, BLT = Body length, HGT = Heart girth and HWR = Height at withers

Effect of breed, sex and interaction on linear body measurements at week four

Table 3 represents the effect of breed, sex and the interaction of breed and sex on linear body measurements of experimental animals at fourth week of the study. The Sokoto Red goats continued with their impressive dominance in linear body morphometric parameters at week four compared to their West African Dwarf (WAD) counterparts. This inherent superiority indicated that Sokoto Red goats possessed highly significant ($p<0.01$) longer body lengths (62.18 cm) than the West African Dwarf (55.89 cm) goats. The Sokoto Red goats also maintained a greater height at the withers (58.82 cm vs. 44.98 cm), indicating they remained significantly ($p<0.01$) taller as they grew. In terms of sex differences, females had a significantly ($p<0.04$) longer body length (60.88 cm) than the males (57.19 cm). Also, the female goats showed significantly ($p<0.008$) larger heart girth measurements (62.77 cm vs. 58.34 cm) which reflect the persistence of sexual difference from the initial measurements. The phenotypic differences observed in the sex of the goat breeds could be attributed to the inherent sex influence inheritance. The interaction of breed and sex for all the phenotypic parameters studied were not seen to be different significantly ($p>0.05$).

Table 3: Effect of breeds, sex and interaction on linear body measurements at week four

Breed	Sex	BWT (kg)	BLT (cm)	HGT (cm)	HWR (cm)
Sokoto Red		15.06	62.18[a]	61.82	58.8[a]
WAD		15.68	55.89[b]	59.29	44.98[b]
±SEM		0.85	1.25	1.12	1.17
P-value		0.62	0.01	0.12	0.00
	Male	14.52	57.19[b]	58.34[b]	51.08
	Female	16.23	60.88[a]	62.77[a]	52.72
	±SEM	0.86	1.27	1.14	1.18
	P-value	0.17	0.04	0.01	0.33
Sokoto Red	Male	14.11	60.25	58.81	56.86
	Female	16.02	64.11	64.84	60.78
WAD	Male	14.93	54.13	57.88	45.31
	Female	16.44	57.65	60.70	44.65
	±SEM	1.20	1.29	1.58	1.65
	P-value	0.88	0.92	0.32	0.18

[a,b] Means with different superscripts on the same column for the same parameter are significantly different ($p<0.05$), SEM = Standard Error of Mean, BWT = Body weight, BLT = Body length, HGT = Heart girth and HWR = Height at withers

Effects of breed, sex and interaction on morphometric parameters at week ten

The morphometric performances of Sokoto Red and West African Dwarf (WAD) goats with the interaction based on their sexes at week ten of experimental period is shown in Table 4. The WAD goats were significantly ($p<0.05$) heavier (18.13 kg) than Sokoto Red goats (15.70 kg) at this age, suggesting a better growth rate in WAD goats over time. Despite this, Sokoto Red goats were observed to possess highly significantly ($p<0.001$) higher height at their withers than their WAD counterparts, valued at 59.51 cm compared to 45.66 cm for Sokoto Red and WAD goats respectively. This indicates that the sokoto red goats remained taller despite the variability in their weights. Regarding sex differences, females were significantly ($p<0.04$) heavier than males (18.20 kg vs. 15.64 kg) and had significantly ($p<0.01$) larger heart girth measurements (64.48 cm vs. 59.17 cm). This inherent phenotypic variability was consistent with the pattern of sexual differences observed in earlier measurements which could have being as a result of sex influence inheritance. The interaction of breed and sex for all the phenotypic parameters studied were not different significantly ($p>0.05$).

Correlation of body weight with linear body morphometric traits of experimental goats

The correlation of body weight with other linear body morphometric traits of experimental goats as presented in Table 5 showed that strong correlation existed between body weight and linear body morphometric traits of experimental goats in this study.

Table 4: Effects of breed, sex and interaction on morphometric parameters at week ten

Breed	Sex	BWT (kg)	BLT (cm)	HGT (cm)	HWR (cm)
Sokoto Red		15.70[b]	57.58	62.09	59.51[a]
WAD		18.13[a]	52.38	61.56	45.66[b]
±SEM		0.82	3.41	1.02	0.97
P-value		0.05	0.29	0.72	0.00
	Male	15.64[b]	55.05	59.17[b]	51.53
	Female	18.20[a]	54.91	64.48[a]	53.63
	±SEM	0.84	3.47	1.03	0.99
	P-value	0.04	0.98	0.01	0.14
Sokoto Red	Male	14.69	54.44	58.66	57.70
	Female	16.72	50.31	65.50	61.31
WAD	Male	16.59	55.66	59.66	45.36
	Female	19.68	59.50	63.46	45.95
	±SEM	1.16	4.82	1.43	1.38
	P-value	0.66	0.42	0.31	0.29

[a,b] Means with different superscripts on the same column for the same parameter are significantly different ($p<0.05$), SEM = Standard Error of Mean, BWT = Body weight, BLT = Body length, HGT = Heart girth and HWR = Height at withers

Table 5: Correlation of body weight with linear body morphometric traits of experimental goats

Parameter	BWT (kg)	BLT (cm)	HGT (cm)	HWR (cm)
BWT (kg)	1.00			
BLT (cm)	0. 65**	1.00		
HGT (cm)	0.80**	0.70**	1.00	
HWR (cm)	0.45**	0.68**	0.53**	1.00

** = Correlation is significant at $p< 0.01$ probability level, BWT = Body weight, BLT = Body length, HGT = Heart girth and HWR = Height wither

This suggests that the genes controlling these traits are somewhat linked together in their interactions to the production of body weight phenotype. The parameters studied were all highly significantly different ($p<0.01$) and

positively correlated. The strong correlation coefficients recorded in this study could have been inherently due to gene linkage or pleiotropic effect of genes. It follows from the result obtained that selection for improvement in one variable will lead to corresponding increment in the other variable. However, the strongest correlation coefficients (r=0.80) existed between body weight and heart girth. This signifies a strong association between chest size and heart girth and implies that selection of heart girth morphometric trait by goat breeders can efficiently optimize the body weight gain performance of their goats for greater profitability.

Regression analyses of morphometric parameters in goats

Table 6 below shows the regression analyses of morphometric traits in experimental goats using linear regression equations to determine the contribution of these parameters to body weight and their predictive power via their coefficient of determination (R^2) for each linear body trait over time. The models used three predictor variables via body length (X_1), heart girth (X_2) and height at withers (X_3) where the coefficient of determination (R^2) values and p-values were used to demonstrate the relationship between these variables and their predictive power for each trait.

Table 6: Regression analyses of morphometric parameters in experimental goats

Body Traits	Linear regression equation	R2	Adj. R2	±SEM	P-value
Body length	$Y= -6.48+0.36X_1$	0.38	0.37	3.24	0.001
Heart girth	$Y= -18.30+0.55X_2$	0.63	0.63	2.49	0.001
Height wither	$Y = -6.484+0.36X_3$	0.38	0.37	3.24	0.001
Body length	$Y= -18.88+0.07X1+0.49X_2$	0.64	0.63	2.49	0.001
Heart girth	$Y = -16.61+0.11X1+0.62X_2$	0.67	0.66	2.38	0.001
Height wither	$Y = -16.61+0.62X1-0.11X_2$	0.47	0.02	4.04	0.001
Body length	$Y= -17.26+0.27X1+0.47X2-0.22X_3$	0.75	0.72	2.14	0.001
Heart girth	$Y = -17.29+0.27X1+0.47X2-0.22X_3$	0.76	0.72	2.14	0.001
Height wither	$Y = -17.23+0.27X1+0.47X2-0.22X_3$	0.74	0.72	2.14	0.001

Y = Body weight, X_1 = Body length, X_2 = Heart girth, X_3 = Height at wither, R^2 = Coefficient of determination, Adj. R^2 = Adjusted R^2, SEM = Standard error of mean, P-value = Probability value, Regression coefficient is significant at $p< 0.01$

These equations with 38%, 63% and 38% R2 values for body length, heart girth and height at withers respectively, independently explained the variability in body weights which were accounted for by these variables. The R^2 values showed moderate to strong predictive power. It is important to note that the model becomes more accurate based on R^2 value (74 - 76%) as more

body parameters are included, indicating a better fit and higher accuracy of prediction. All the parameters either singly or in combination were significantly different ($p<0.01$).

DISSCUSION

Effects of breed, sex and interaction on body morphometric traits of goats at different ages

This study analyzed morphometric parameters to understand the growth dynamics and physical characteristics of Sokoto Red and West African Dwarf (WAD) goats. Over four weeks, the analysis revealed significant differences based on breed and sex, highlighting unique growth patterns and potential adaptations. At the start of the study (week one), Sokoto Red goats already showed significantly greater body length and height at withers compared to WAD goats. These initial differences suggest inherent breed-specific growth patterns, likely influenced by genetics and adaptation to their respective environments. (Ozoje and Kadri, 2001). Sex-based differences were also evident, with females showing significantly higher body weight and heart girth compared to males. This sexual difference in growth parameters was consistent with findings in other goat breeds and may be attributed to sexual dimorphism, hormonal differences and varying growth rates between sexes (Yakubu et al., 2010).

At week four, the breed-specific differences in body length and height at withers persisted, with Sokoto Red goats maintaining significantly higher values. This consistent pattern suggested that these morphological differences were inherent to the breeds and not merely a result of environmental factors (Okpeku et al., 2011). The sex-based differences became more pronounced, with females showing significantly greater body length and heart girth than to males. This trend indicates that sexual difference in these goat breeds becomes more evident as they grow, which is crucial information for breeding programs and management strategies (Akpa et al., 2013).

At week ten, WAD goats showed significantly higher body weight than to Sokoto Red goats. This shift suggested that WAD goats might have a higher growth rate or better feed conversion efficiency during this period, which could be advantageous in certain production systems (Obua et al., 2012).

Even though Sokoto Red goats were heavier, they also maintained a significantly greater height at withers throughout the study, demonstrating a consistent tendency to grow taller than WAD goats. This difference in height could be a factor in breed selection depending on specific production goals or adaptations to particular environments (Rotimi et al., 2017). The sexual difference in body weight and heart girth continued to be significant, with females showing higher values for both parameters. This consistent trend across the study period emphasizes the importance of considering sex-based

differences in goat management and breeding programs (Yakubu, 2010). The distinct morphometric differences between Sokoto Red and WAD goats reveal their unique growth characteristics. The consistently greater height and body length of the Sokoto Red suggest they are more suitable for meat production systems that prioritize larger carcasses. Conversely, the WAD goats' higher body weight gain by week four indicates their potential for efficient weight gain, which could be advantageous in different production scenarios (Oseni and Ajayi, 2014). The consistent sexual dimorphism observed throughout the study, with females exhibiting greater body weight and heart girth, has important implications for goat breeding and management. These sex-based differences should be taken into account when creating nutrition plans, selecting breeding animals, and making overall management decisions (Okpeku et al., 2011). Understanding these morphometric relationships can inform breeding and nutritional strategies aimed at optimizing growth and improving meat quality in goat production. Further research into the genetic basis of these morphometric differences and their correlation with production traits could provide valuable insights for the development of improved breeding programs for these indigenous Nigerian goat breeds.

Correlation of body weight with linear body morphometric traits in goats

Correlation indicates the extent of relationship between two traits which are under the influence of a gene and this concept is central to the understanding of evolutionary processes (Aruna and Chakravarty, 2020). The concept provides valuable insight into the association among body phenotypic measurements in living organisms. The result of correlation coefficients obtained in this study revealed significant relationships among the morphometric measurements of experimental goat breeds. The strong positive correlation between body length and height at withers suggested that taller goats tend to have longer bodies. This relationship reflects coherent growth patterns that are critical for meat production potential in these breeds (Okpeku et al., 2011). Also, the existing correlations between body weight with heart girth and body length were observed to range from moderate to strong and positive. These findings were consistent with Yakubu et al. (2011) who reported strong, positive and significant correlations among phenotypic parameters in Nigerian indigenous goat breeds. This indicated that as heart girth or body length increased, body weight tends to equally increase as well. However, a weak but positive and significant correlation may emerge between body weight and linear body morphometric traits as animal advances in age which might not be present in the initial record. This type of correlation suggests that the relationship between these parameters may change as the goats grow, highlighting the dynamic nature of body proportions during development (Rotimi et al., 2017). Also, correlation patterns may show notable changes as goats grow. Studies on WAD goats have shown that body

weight may maintain a strong and positive correlation with heart girth while it may change or weaken considerably with body length. This type of shift suggests that different body parts may have varying growth rates as the goats mature (Oseni and Ajayi, 2014). The weakening correlations among body parameters over time may highlight the importance of considering age-dependent changes in body measurement relationships in Nigerian goat breeds or developmental stage of the goats when using morphometric measurements for breed evaluation or weight estimation. (Akpa et al., 2017).

Regression of morphometric parameters in goat breeds using multiple linear model

The regression analysis performed on the morphometric parameters of Nigerian goats evaluated the relationships between body length, heart girth, and height at withers over time. Similar studies have shown that these parameters were interrelated and their combined analysis could lead to a better understanding of growth patterns and health in livestock (Khan et al., 2006; Yakubu et al., 2010).

For body length, the initial model showed moderate predictive power when analyzed alone. However, the inclusion of heart girth significantly improved the model's accuracy, which aligned with findings from previous research indicating that body measurements such as heart girth, were strong predictors of body size and overall health (Alade et al., 2008). When height at withers was added to the model, further improvement was observed which demonstrated the importance of combining multiple morphometric traits for more robust predictions (Yakubu et al., 2010). In the initial measurements, body length showed moderate predictive accuracy. However, the inclusion of heart girth and height at withers led to a significant improvement in the model, confirming findings from Yakubu et al. (2010) that suggested these traits were closely related. The stronger predictive power of the model when multiple traits were combined reinforced the idea that no single measurement should be relied upon to assess livestock growth (Brown et al., 1999). Body length alone showed poor predictive accuracy, but the addition of heart girth improved the model significantly. Adding height at withers further enhanced the model's performance, similar to studies that demonstrated how multiple body measurements, when combined, resulted in better predictions of growth and development (Khan et al., 2006). The same trend was observed for heart girth and height at withers, where their combination produced more accurate and reliable models.

In the case of heart girth, the model performed well from the outset, and adding height at withers and body length only strengthened the model. This reflected existing research that highlighted heart girth as a critical parameter in estimating body weight and overall animal productivity (Brown et al., 1999). The interdependence of these traits is essential for assessing the health

and growth potential of goats, especially in smallholder farming systems (Khan et al., 2006). For heart girth, the model performed well from the start, similar to findings by Alade et al. (2008), which showed that heart girth was a strong indicator of body condition. Adding other traits, such as body length and height at withers, resulted in even more accurate predictions. This echoed previous research on the importance of incorporating multiple morphometric measurements for a comprehensive analysis of livestock (Brown et al., 1999). For height at withers, the initial model is weak, as height at withers alone did not predict growth patterns as effectively. However, the model improved significantly when heart girth and body length were included, which aligned with previous studies that emphasized the use of combined body measurements to predict growth in goats (Alade et al., 2008). Height at withers became more relevant when viewed in conjunction with other morphometric traits, which contributed to a comprehensive understanding of the animal's growth and health status.

CONCLUSION

This study highlighted the importance of Red Sokoto and West African Dwarf (WAD) indigenous goat breeds to Nigerian livestock industry in meeting the protein need of the people at affordable rates. Red Sokoto goats demonstrated superior height at withers and body length, traits valuable for meat and skin production. The West African Dwarf (WAD) goats on the other hand showed a higher growth rate and weight gain, reflecting their adaptation to harsh and resource-limited situations prevalent in most tropical environments. The correlation and regression coefficients of the linear body traits well described the body weight performance of the goats. This showed that selection of one trait for improvement will lead to corresponding increment in the other trait that was not even selected showing that the two traits are under the control of a particular gene. The multiple linear regression model is better used in estimating the body weight of goats. The heart girth (HGT) gave the best relationship with body weight and could accurately predict the body weight owing to its goodness of fit. These findings suggest that Red Sokoto and WAD goats are well-suited for meat production in Nigeria and could be adapted for the entire sub-Sahara environment. The reason for this conclusion could be owing to the goats' superior adaptability to high temperature environment, resilience to commonest infectious and feed inadequacies. The two breeds offer these unique advantages and are thus suited to different agro-ecological zones and production systems, making their continued use a crucial purpose for sustainable goat farming in Nigeria.

RECOMMENDATIONS

Based on the distinct morphological and physiological advantages of both Red Sokoto and WAD goats, it is essential to prioritize their genes for conservation and improvement through structured breeding programs. Crossbreeding should be approached cautiously to ensuring that the unique genetic traits of these indigenous breeds are not diluted while selective breeding efforts should focus on enhancing desirable traits such as growth rates in the WAD and the superior size attributes of the Red Sokoto goats.

Farm management practices should be tailored to each breed's specific requirements. Red Sokoto goats would benefit from intensive systems where their larger body size and superior physical traits can be optimized for meat and skin production while the WAD goats' adaptability to a variety of environmental conditions make them suitable for both extensive and semi-intensive systems, particularly in areas with low-quality feed resources.

The two breeds displayed positive responses to structured feeding regimes which means optimizing their diets through strategic supplementation with protein and minerals concentrates could significantly enhance their productivity.

The heart girth can be selected to improve the body weight performance of the goats owing to their high correlation coefficient. The trait can also be used to accurately predict the body weight owing to its goodness of fit while the multiple linear regression model is better used in estimating the body weight of goats especially in rural population where weighing scales might not be available.

Further research on diet formulations that maximize both breeds' genetic potentials for improvement is recommended to optimize their growth performance, health status and reproductive efficiencies.

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