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The article entitled:

Influence of Haemoglobin Genotypes and Location on Morphometric Traits of West African Dwarf Goats in Zaria

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Influence of Haemoglobin Genotypes and Location on Morphometric Traits of West African Dwarf Goats in Zaria, Nigeria.

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ABSTRACT

Haemoglobin type, a useful marker for genomic selection, has been shown to influence the adaptability of animals to particular environments. This study evaluated the interaction of haemoglobin types with different locations on morphometric traits of West African Dwarf (WAD) goats in Zaria, Nigeria. A total of 384 goats of both sexes were sampled from three locations (Samaru, PZ and Chikaji). Morphometric traits measured included body length (BL), height at wither (HW), heart girth (HG), rump height (RH), body depth (BD) and body weight (BW). Five milliliters of blood were collected from each goat for electrophoretic analysis. Data obtained were subjected to a 2×3 factorial in a completely randomized design. Gene and genotypic frequencies were estimated, while chi-square was used to test for Hardy–Weinberg equilibrium. Two haemoglobin genotypes (HbAA and HbAB) were identified. HbAA showed higher frequencies across all locations and was superior in BL, HW and RH, while HbAB showed higher values for TL (tail length) and NC (neck circumference). The interaction of haemoglobin types with locations significantly influenced all morphometric traits, with HbAA generally superior to HbAB. Both HbAA and HbAB favoured body weight in PZ.

Keywords: West African Dwarf goats; haemoglobin types; morphometric traits; genotype-environment interaction.

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INTRODUCTION

Goat production is an important contributor to food security in Nigeria, particularly under resource-poor systems, due to their ability to thrive on crop residues and marginal feed resources (Shettima, Alade & Raji, 2019). West African Dwarf (WAD) goats are a dominant breed in the humid and sub-humid zones, known for their adaptability and genetic diversity (Okon *et al.*, 2023; Shoyombo *et al.*, 2018).

Haemoglobin polymorphism has been reported as a potential marker for selection due to its role in physiological adaptation (Peters *et al.*, 2004).Polymorphic markers linked to specific traits enable early selection of desirable genotypes. Hemoglobin, crucial for adapting to environmental changes, exhibits biochemical, biophysical, and physiological properties that influence morphological, performance, and adaptation traits (Tilahun *et al.* 2025). Hemoglobin polymorphisms play a significant role in understanding population relationships, environmental adaptability, and fitness. Notably, different hemoglobin genotypes confer advantages in specific environments, such as high-altitude or arid conditions (Egene & Alao 2014). Furthermore, hemoglobin variants have been associated with various productivity traits, including fertility (Vazic *et al* 2017), growth performance, wool quality, milk yield, and reproductive performance. These findings highlight the importance of hemoglobin polymorphisms in selective breeding programs aimed at improving productivity and adaptability in animals.

Studies have identified three haemoglobin genotypes (HbAA, HbAB, HbBB) in goats (Sam *et al.*, 2016; Shoyombo *et al.*, 2018), with additional HbAC reported in Red Sokoto goats (Alphonsus *et al.*, 2012).Such polymorphisms may influence morphometric and adaptive traits (Yakubu *et al*., 2014).While studies exist in humid areas of Nigeria such as Akwa Ibom (Okon*et al.*, 2023), little is known about haemoglobin polymorphism and its interaction with location in Northern Guinea Savannah environments like Zaria. This study, therefore, aimed to determine the interaction of haemoglobin genotype with morphometric traits of WAD goats in three locations of Zaria (Samaru, PZ and Chikaji).

MATERIALS AND METHODS

Study area

The study was conducted in Zaria, Kaduna State, Nigeria, covering three locations: Samaru, PZ, and Chikaji. Zaria lies in the Northern Guinea Savannah zone (11°07′–11°12′N; 07°41′–07°44′E), at an altitude of 550–700 m above sea level. The climate is tropical continental with a wet season (May–October) and dry season (November–April). Average annual rainfall ranges from 1,000–1,300 mm, with temperatures from 14°C in cool months to 36°C in hot periods. Vegetation consists of grasses with scattered trees and shrubs. Farming systems combine crops with livestock, with goats playing a key role in household livelihoods (Zaria Meteorological Data, 2020).

Animals and their management

A total of three hundred and eighty-four (384) goats between the ages of 1- 3years for males and 2- 5 years and above) for females were sampled. They were intensively managed in mud houses or tethered outside in pasture area to avoid damage that could be caused by goats to crops. They were fed on browses/grasses/legumes mixture Sometimes supplementary feed in form of cassava peel, yam peel and kitchen wastes were also given to them.

Samplesizeandsampling techniques

One hundred and twenty-eight (128) goats were sampled from each of the three senatorial districts, making it a total of three hundred and eighty-four (384) goats. Sample size was

determined using the formula for calculating sample size n = N x [Z^2 x p (1-p)/e^2] / [N – 1+(Z^2 x p x (1-p)/e^2] (Srivastav and Vaidya, 2023) from a population of 1,826,780 goats in Kaduna State reported by NBS/FMARD (2011). Maximum of two goats were sampled from each household using random sampling technique.

Measurement of morphometric traits

Animals selected for measurement were brought out with acceptance from the owner and restrained before measurement. The following measurements were taken using tailors' tape in centimeter (cm) except body weight in kilogram (kg) on each of the animals using the methods as described by Sam (2012).

Body length (BL): Body length was measured using tailor's tape as the distance from the occipital protuberance to the base of the tail.

Height at withers (HW): The height was measured as the distance from the ground to the withers using tailor's tape.

Heart girth (HG): The heart girth was measured by taking the measurement of the circumference of the chest using tailor's tape.

Rump height (RH): The rump height was measured as the distance from the ground to the rump using tailor's tape.

Body depth (BD): This was measured using tailor's tape as the circumference of the region immediately after the hind leg towards the abdomen.

Body weight (BW): This was measured using a hanging scale in kilograms.

Ear length (EL): ear length was measured from the base of the ear to the pinna of the ear.

Tail length (TL): tail length was measured from the base of the tail to the pinpoint of the tail.

Neck circumference (NC): this was measured as the distance around the neck.

Blood collection and preparation for analysis

Five milliliters (5ml) of blood were collected from each of the sampled animals by jugular venipuncture, using needle and syringe into test tube containing Ethylene Diamine Tetra Acetic acid (EDTA) as anticoagulant. The samples were properly labeled and sent to Haematology Laboratory, Ahmadu Bello University Teaching Hospital, Shika, Zaria for electrophoresis. The blood samples were washed with normal saline and haemolysed with distilled water to release the haemoglobin. The supernatant was removed after centrifuging at 3000 rpm for five minutes and the sample haemoglobin was stored until ready for electrophoresis. Cellulose acetate paper strip was used to separate the haemoglobin fractions. Electrophoresis was carried out in Shandon electrophoresis tank on cellulose acetate strips 34.5 x 150 with 0.26MTris buffer (pH 9.1) at the anode and cathode. The strips were run for five minutes at a constant voltage of 250v until a clear separation was observed. Interpretations were made based on the relative mobility of the haemoglobin bands toward the anode. The genotype that migrated faster was labeled HbAA, the double band, consisting of both fast and slow bands; was labeled HbAB as described by Das *et al*. (2004).

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Data analysis

Data collected on morphometric traits were subjected to a 2 x 3 factorial in a Completely Randomized Designed using General Linear Model procedure of Statistical Package for Social Science (SPSS). The significant different between means was separated using Duncan Multiple Range Test of the same package. The statistical model used was:

$Y_{ij}+ \mu+ H_i+ L_j+ (H \times L)_{ij}+ E_{ij}$

Where: Yij= Single observation, μ = Population mean, H_i= Effect of haemoglobin type (HbAA, HbAB)

L_j= Effect of locations (Samaru, PZ and Chikaji), $(H \times L)_{ij}$= Interaction effect of haemoglobin type and location, E_{ij} = Random error occurred during measurement.

Genotype and alleles frequencies were analyzed using Chi-square to test for goodness-of-fit for observed and expected frequencies under Hardy- Weinberg genetic equilibrium.

RESULTS AND DISCUSSION

The genotypic and allelic frequencies of West African Dwarf goats according to location is presented in Table 1. The results indicated that allele frequency of Hb A alleles was higher in Samaru (0.777), PZ (0.797) and Chikaji (0.773) than Hb B alleles 0.223, 0.203 and 0.227 respectively. This result strengthened the study of Dafur *et al*. (2019) who reported gene frequencies of 0.705 for Hb A and 0.295 for Hb B in male West African Dwarf goats.

Table 1. Gene and genotypic frequency of haemoglobin type based on location.

Location	Number of goats	Genotypic frequencies		Allelic frequencies	
		AA	AB	A	B
Samaru	128	(71) 0.555	(57) 0.445	0.777	0.223
PZ	128	(76) 0.594	(52) 0.406	0.797	0.203
Chikaji	128	(70) 0.547	(58) 0.453	0.773	0.227

However, gene frequency obtained in this study was higher than the values reported by Yakubu *et al* (2014) for West African Dwarf goats and Sam (2012) for Agropastoral goats. The predominance of Hb A over Hb B and the absent of Hb BB in this present study had been earlier reported by Yakubu *et al.* (2014) in West African Dwarf goats in north central Nigeria, Bindu and Raghavan (2010) in Malabari goats, Canatan and Boztepe (2000) in Turkish Hair goats and Tilahun *et al.* (2025) in Ethiopianindigenous goats. The high frequency of HbAA in the goat population studied suggested that the genotype is favoured by natural selection in the study area. Sam *et al*. (2016) noted that expression of Hb genotypes and adaptability of animals to a particular environmental condition are related. Guney *et al*. (2003) found out that gene frequency of haemoglobin types is related to breed and geographical location and may have influence on the performance of sheep and goats. Result of this study suggested that predominance of HbAA and absent of HbBB might be adaptive superiority of HbAA and its selective advantage over Hb BB.

Table 2. Observed and expected number of haemoglobin genotypes of West African Dwarf goats based on location.

Location	Number of goats	Hb	Observed (O)	Expected (E)	(χ 2) df = 1
Samaru	128	AA	71	72.33	**0.0563**
		AB	57	55.67	
PZ	128	AB	76	72.33	**0.1726**
		AB	52	55.67	
Chikaji	128	AA	70	72.33	**0.1726**
		AB	58	55.67	
Overall	384	AA	217	216.99	**0.657**
		AB	167	167.01	

Chi square test Table 2 showed that there were no significant (P>0.05) differences between the observed and expected frequencies of haemoglobin and alleles. Therefore, the population as a whole was in Hardy-Weinberg equilibrium. This suggested that there was no significant change in the gene frequency.The main effect of haemoglobin type on morphometric traits of West African Dwarf goats as presented in Table 3 showed that two haemoglobin genotypes were found in this present study. This finding corroborates the report of Yakubu *et al*. (2014), who also reported two haemoglobin genotypes (HbAA and HbAB) in West African Dwarf goat raised in north central. BL (50.75±0.52cm), height at wither (43.11±0.29cm) and RH (45.80±0.36cm) were significantly (p<0.05) higher in goats with HbAA than HbAB. The interaction of HbAA with locations showed significantly (p<0.05)BL inCHAA (52.06 ±5.89) and PZAA (51.65±4.86), while the least body length observed for CHAB (38.22±5.73). HW for SAAA (42.31±2.53), PZAA (43.22±3.10) and CHAA (43.78±3.05) were significantly higher than PZAB (40.54±0.88) and CHAB (40.17±2.55), suggesting that HbAA favours increased body size and height of West African Dwarf goats in all the locations. BW, HG, BD andEL were not significantly (P>0.05) influenced by haemoglobin genotype in the main effect.

Table 3. Main effect of haemoglobin genotype on morphometric traits (Mean ± SD) of West African Dwarf goats.

Parameters	Haemoglobin type		P-Value	LOS
	AA	AB		
Body weight (kg)	19.78±0.42	18.85±0.39	0.188	NS
Body length (cm)	50.75±0.52^{a}	44.73±0.99^{b}	0.000	*
Height at wither (cm)	43.11±0.29^{a}	41.33±0.37^{b}	0.003	*
Heart girth (cm)	59.34±0.47	60.16±0.45	0.289	NS
Rump height (cm)	45.80±0.36^{a}	42.61±0.43^{b}	0.000	*
Body depth (cm)	66.69±0.57	65.61±0.66	0.070	NS
Tail length (cm)	10.02±0.15^{b}	11.00±0.29^{a}	0.005	*
Ear length (cm)	9.72±0.11	9.69±0.20	0.516	NS
Neck circumference (cm)	28.15±0.39^{b}	33.43±0.82^{a}	0.000	*

*=p<0.05; LOS=level of significant, NS=no significant difference

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The effect of location on morphometric traits of West African Dwarf (WAD) goats is presented in Table 4. Significant ($p<0.05$) differences were observed for most traits, suggesting that the production environment in Samaru, PZ, and Chikaji plays an important role in shaping phenotypic expression.Goats sampled from PZ had the highest BW (20.71±4.43 kg), followed by Chikaji (19.45±3.22 kg), while Samaru goats had the least (18.26±3.26 kg). The heavier body weights in PZ may reflect better feed resources, less environmental stress, or more favourable management practices. This agrees with Odubote (1996), who noted that environmental differences can significantly influence body size in WAD goats.

PZ goats (50.74±4.94 cm) had significantly longer BL than those in Chikaji (47.08±8.86 cm), while Samaru goats were intermediate (48.54±4.39 cm). Longer BL is associated with better skeletal development and meat yield potential (Akinyemi & Salako, 2010). These results suggest that goats in PZ are better adapted for growth-related traits, possibly due to better grazing opportunities.

No significant differences were observed in HW among locations, indicating that this trait may be less sensitive to environmental variation. Similar findings were reported by Yakubu et al. (2014), who found that HW was not significantly influenced by location in WAD goats.

Goats from Chikaji had the largest HG (61.86±3.47 cm), followed by PZ (59.08±4.75 cm), while Samaru goats had the least (57.88±3.61 cm). HG is a strong predictor of body weight and overall robustness (Sam, 2012). The superior HG in Chikaji goats may indicate adaptive advantage in thoracic development despite lower BW compared to PZ goats.

Table 4. Main effect of location on morphometric traits (Mean ± SD) of West African Dwarf goats.

Parameters	**Location**			**P-value**
	Samaru (±SD)	**PZ (±SD)**	**Chikaji (±SD)**	
BW (kg)	$18.26±3.26^{b}$	$20.71±4.43^{a}$	$19.45±3.22^{ab}$	0.047
BL (cm)	$48.54±4.39^{ab}$	$50.74±4.94^{a}$	$47.08±8.86^{b}$	0.000
HW (cm)	42.58±2.59	42.52±2.94	42.48±3.34	0.321
HG (cm)	$57.88±3.61^{b}$	$59.08±4.75^{b}$	$61.86±3.47^{a}$	0.000
RH (cm)	$43.92±2.56^{b}$	$44.64±4.32^{ab}$	$45.72±3.91^{a}$	0.049
BD (cm)	$65.34±4.26^{b}$	$64.86±6.63^{b}$	$68.82±4.09^{a}$	0.000
TL (cm)	$10.42±1.62^{b}$	$9.50±1.14^{c}$	$11.10±2.08^{a}$	0.000
EL (cm)	$9.24±1.04^{b}$	$9.50±1.26^{b}$	$10.40±1.12^{a}$	0.000
NC	$28.64±3.37^{b}$	$28.44±3.68^{b}$	$32.54±6.91^{a}$	0.000

^{abc} means on the same row bearing different superscripts are significantly different ($p<0.05$);
BW=body weight; BL= body length; HW= height at wither; HG= heart girth; RH= rump height; BD= body depth; TL= tail length; EL= ear length; NC= neck circumference; SD=standard deviation.

Significant differences were observed (Table 4),with Chikaji goats having the highest RH (45.72±3.91 cm), PZ goats intermediate (44.64±4.32 cm), and Samaru goats the lowest (43.92±2.56 cm). Larger RH values suggest stronger skeletal frame, which could be beneficial for load-bearing and reproductive performance (Shettima *et al.*, 2019).

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Chikaji goats had significantly greater BD (68.82±4.09 cm) compared to PZ (64.86±6.63 cm) and Samaru (65.34±4.26 cm). Since BD is linked to abdominal capacity and feed intake potential, the higher values in Chikaji goats may reflect adaptation to higher forage consumption in their environment (Shoyombo *et al.,* 2018).

These traits also showed significant variation among locations. Chikaji goats consistently exhibited the highest values for TL (11.10±2.08 cm), EL (10.40±1.12 cm), and NC (32.54±6.91 cm), while PZ goats had the lowest TL (9.50±1.14 cm) and Samaru goats the lowest EL (9.24±1.04 cm). Extremity traits are often influenced by ecological adaptation, with longer appendages aiding thermoregulation in hotter climates (Hrinca, 2008).These findings highlight the significant role of location in shaping morphometric traits of WAD goats. The results agree with earlier reports (Yakubu *et al.,* 2014; Okon *et al.,* 2023), which emphasized that environmental variation across regions significantly influences the body size, skeletal development, and adaptive traits of Nigerian goats.

The interaction effect of haemoglobin genotype and location on morphometric traits of West African Dwarf (WAD) goats is presented in Table 5. The results revealed significant ($p<0.05$) differences across all measured traits, confirming that the phenotypic expression of morphometric characteristics in WAD goats is influenced by both genotype and production environment. Goats with HbAA (SAAA, PZAA, CHAA) generally exhibited higher BW (Table 5) compared to their HbAB counterparts (SAAB, CHAB). Notably, PZAB goats also recorded body weights comparable to HbAA genotypes, suggesting that PZ location provided favourable environmental conditions likely better feed availability and managementthat supported growth irrespective of genotype. This agrees with Guney *et al*. (2003), who emphasized the role of environment in modulating the expression of genetic potential in small ruminants.

Table 5. Interaction effect of location and haemoglobin type on morphometric traits of West African dwarf goats in

Parameters	Location						P.value
	Samaru		PZ		Chikaji		
	SAAA	SAAB	PZAA	PZAB	CHAA	CHAB	
BW (kg)	19.89±3.56^{a}	17.34±2.73^{b}	21.19±4.91^{a}	19.34±2.25^{a}	20.58±3.48^{a}	17.44±1.04^{b}	0.000
BL (cm)	48.41±4.26^{c}	48.78±4.71^{b}	51.65±4.86^{ab}	48.15±3.86^{c}	52.06±5.89^{a}	38.22±5.73^{d}	0.000
HW (cm)	42.31±2.53^{a}	43.05±2.71^{a}	43.22±3.10^{a}	40.54±0.88^{b}	43.78±3.05^{a}	40.17±2.55^{b}	0.001
HG (cm)	59.00±3.37^{ab}	57.25±3.65^{b}	59.34±2.44^{ab}	58.92±5.35^{b}	61.91±3.81^{a}	61.78±2.88^{a}	0.042
RH (cm)	43.63±2.56^{bc}	44.44±3.23^{b}	46.08±3.93^{ab}	43.54±1.27^{bc}	47.66±3.08^{a}	42.28±2.65^{c}	0.000
BD (cm)	67.22±4.88^{a}	64.28±3.52^{b}	66.35±7.05^{a}	60.62±2.10^{c}	69.50±4.55^{a}	67.61±2.87^{a}	0.000
TL (cm)	10.09±1.46^{bc}	11.00±1.74^{b}	9.73±1.15^{cd}	8.85±0.89^{d}	10.28±1.93^{bc}	12.56±1.46^{a}	0.000
EL (cm)	9.28±1.05^{c}	9.17±1.04^{c}	9.81±1.24^{bc}	8.62±0.86^{d}	10.06±1.10^{b}	11.00±0.91^{a}	0.000
NC (cm)	28.16±5.23^{c}	29.50±3.55^{bc}	27.32±3.56^{c}	31.61±1.61^{b}	29.09±4.90^{bc}	38.67±5.64^{a}	0.000

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[abcd] means on the same row bearing different superscripts are significantly different ($p<0.05$); SAAA=Samaru x HbAA; SAAB=Samaru x HbAB; PZAA=PZ x HbAA; PZAB=PZ x HbAB; CHAA=Chikaji x HbAA; CHAB=Chikaji x HbAB; BW= body weight; BL=body length; HW=height at wither; HG=heart girth; RH=rump height; BD=body depth; TL=tail length; EL=ear length; NC=neck circumference.

HbAA goats across all locations (PZAA, CHAA, SAAA) showed significantly higher BL and HW than HbAB goats (Table 5). The poorest performance was recorded in CHAB goats, which had the least BL (38.22±5.73 cm). This suggests poor adaptability of HbAB genotype in Chikaji. Similar findings were reported by Yakubu *et al.* (2014), who observed that HbAA genotype was superior in skeletal growth traits in WAD goats.

Both HG and BD followed a consistent trend, with HbAA goats outperforming HbAB across the three locations. These traits are critical indicators of thoracic and abdominal capacity, which are strongly correlated with meat yield (Akinyemi & Salako, 2010). The higher HG and BD observed in CHAA goats confirm the adaptability of HbAA genotype in Chikaji, even though HbAB goats performed poorly in the same location.

As shown in Table 5, CHAA goats had the highest RH (47.66±3.08 cm), while CHAB goats had the lowest (42.28±2.65 cm). This further demonstrates the superior skeletal frame of HbAA genotype under challenging environmental conditions. The predominance of HbAA in structural growth traits has also been documented in earlier studies (Yakubu *et al.,* 2014; Shoyombo *et al.*, 2018).

Interestingly, HbAB goats in Chikaji (CHAB) recorded the highest values (Table 5) for TL (12.56±1.46 cm), EL (11.00±0.91 cm), and NC (38.67±5.64 cm). This indicates that while HbAB is disadvantaged in body weight and skeletal development, it may confer some advantage in extremity-related traits. Similar observations were made by Shettima *et al.* (2019), who reported significant effects of haemoglobin polymorphism on traits such as ear length and neck circumference in Nigerian goats.The results suggest that HbAA genotype confers adaptability and growth advantage across locations, while HbAB genotype may thrive only under more favourable environments such as PZ. The consistent superiority of HbAA across most morphometric traits highlights its adaptive advantage and potential for selection in breeding programs aimed at improving WAD goats in the Northern Guinea Savannah. This aligns with earlier studies which emphasized the adaptive superiority of HbAA over other haemoglobin genotypes in goats (Hrinca, 2008; Yakubu *et al.,* 2014; Dafur *et al.*, 2019).

CONCLUSION

Two haemoglobin types, HbAA and HbAB were found in the studied location. This could be due to adaptive superiority of HbAA over HbBB in the studied area. Goats with HbAA had superior BL, HW and RH. The interaction of haemoglobin types with locations had significant influence on all the morphometric traits with HbAA being superior to HbAB but both HbAA and HbAB favoured BW in PZ. The present study highlights the significant role of location in shaping morphometric traits of WAD goats. Furthermore, our results suggest that HbAA genotype confers adaptability and growth advantage across locations, while HbAB genotype may thrive only under more favourable environments such as PZ. The consistent superiority of HbAA across most morphometric traits highlights its adaptive advantage and potential for selection in breeding programs aimed at improving WAD goats in the Northern Guinea Savannah. Haemoglobin polymorphism holds a potential as a genetic diversity, which could support informed decision making in selective breeding initiatives.

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