

Association Analysis of Morphometric, Haematological and Biochemical Profiles in Indigenous Nigerian Goat Breeds Raised in the Sudan-Sahel Zone

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ABSTRACT

This study evaluated the associations among morphometric, haematological, and serum biochemical parameters in indigenous Nigerian goat breeds (Sahel, Red Sokoto, and West African Dwarf) raised under the semi-arid conditions of the Sudan-Sahel zone. Pearson correlation analyses were performed on morphometric traits from 270 goats and on haematological and serum biochemical profiles from 120 goats. Among the morphometric traits, body weight demonstrated strong, highly significant positive correlations with heart girth ($r=0.99$, $P<0.01$), body length ($r=0.79$, $P<0.01$), head circumference ($r=0.71$, $P<0.01$), and horn length ($r=0.61$, $P<0.01$). Strong positive correlations were also established among body length, gonad circumference, udder dimensions, and teat length ($r=0.95$ to 0.99 , $P<0.01$). Haematological analysis showed strong positive associations among primary erythrocytic parameters, including red blood cell count with haemoglobin ($r=0.88$, $P<0.01$) and haematocrit ($r=0.81$, $P<0.01$), as well as haemoglobin with haematocrit ($r=0.89$, $P<0.01$). Mean corpuscular haemoglobin was positively linked to haemoglobin ($r=0.54$, $P<0.01$) and haematocrit ($r=0.57$, $P<0.01$), whereas neutrophils exhibited a strong negative relationship with lymphocytes ($r=-0.86$, $P<0.01$). Serum biochemical evaluation revealed significant positive correlations between aspartate aminotransferase and glucose ($r=0.71$, $P<0.01$), sodium and total protein ($r=0.43$, $P<0.01$), and urea and total cholesterol ($r=0.41$, $P<0.01$). Combined haematological-biochemical associations were generally weak, though minor significant relationships were noted, such as albumin with haemoglobin ($r=0.20$, $P<0.05$). These findings indicate that key morphometric dimensions, particularly heart girth and body length, serve as reliable indirect predictors of live body weight for selection. Furthermore, blood and biochemical interactions reflect essential physiological and metabolic interdependencies, providing critical baseline data for herd management, genetic improvement, and conservation of native goat resources in North-Eastern Nigeria.

Keywords: Morphometric, Haematological, Serum-Biochemical, Correlation, Breed

1.0 INTRODUCTION

Maintaining genetic diversity in livestock is crucial for their survival, adaptability, and performance in changing environments and warming climates (Kuthu *et al.*, 2022; Velado-Alonso *et al.*, 2020). It serves as the foundation for breeding programs and long-term climate resilience (Ganiyu *et al.*, 2018). Native livestock populations represent an irreplaceable genetic reserve, making their conservation and sustainable use vital (Velado-Alonso *et al.*, 2020; Maksimovic *et al.*, 2023). In native goats, physical and structural differences hold significant economic and cultural importance (Melesse *et al.*, 2022) while reflecting historical selection patterns (Mdladla *et al.*, 2017). Consequently, effective conservation and genetic management depend on thorough phenotypic and genetic evaluation (Okoro *et al.*, 2023). Nigeria's livestock sector relies heavily on three primary indigenous goat breeds the semi-arid northern Red Sokoto (a small-to-medium reddish-brown breed valued for meat, high reproduction, and premium hide used in leather), the arid Sahelian (a tall, long-legged breed adapted to heat and long-distance foraging for meat, milk, and hide production), and the humid southern West African Dwarf (a compact, short-legged breed prized for hardiness, trypanosomiasis resistance, household income, and food security) which collectively provide an essential reservoir of genetic diversity for conservation, selective breeding, and sustainable livestock production across the country (Adamu *et al.*, 2024; FAO, 2012; Rotimi *et al.*, 2021; Shoyombo *et al.*, 2024).

Complete livestock characterization integrates phenotypic, genetic, and historical data (FAO, 2012). Among these, phenotypic assessment is key to managing animal genetic resources across local and global scales (FAO, 2012). It encompasses both qualitative features and quantitative body measurements (Kitila *et al.*, 2025), serving as the primary tool to identify distinct traits and population

dynamics—particularly in resource-constrained regions lacking access to genomic technologies (Melesse *et al.*, 2022; Akounda *et al.*, 2023). Morphometric measurements are dependable indicators of breed identity and yield potential (Selvan *et al.*, 2023). Because these physical traits reflect body shape, growth, and structural balance, they correlate strongly with overall productivity (Kitila *et al.*, 2025).

Studies on diversity and variability amongst indigenous goat breeds on the basis of quantitative (Morphometrics) variables have been extensively carried out in many part of Nigeria (Ozoje and Mgbere, 2022). However, there is paucity of study especially on quantitative traits of goats found in the North eastern parts of the country (Yobe and Borno). This is despite the large production of indigenous small ruminant found in this location. Blood is an important and reliable medium for estimating the health status of individual animals (Okukpe *et al.*, 2021). Haematological tests have been widely used for the diagnosis of various livestock diseases (Tibbo *et al.*, 20014; Cetin *et al.*, 20019). Serum or plasma biochemical profile is known to complement haemogram. It provides information about internal organs (liver, kidney), electrolyte (sodium, chloride, potassium, calcium phosphate), proteins (globulin, albumin) and nutritional or metabolic parameter (cholesterol, glucose). The knowledge of normal blood changes in a particular region in relation to breed, age and sex is crucial. This is because without definite knowledge of what is normal, it will be difficult to determine the abnormal conditions. The objective of the study was to estimate the relationship among the morphometric traits, haematological and serum biochemical parameters of indigenous goat breeds.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the semi-arid Sudan-Sahel savanna zones of Borno (10°-13°N, 11°-14°E) and Yobe (10.578°-13.377°N, 9.654°-12.689°E) states in North-Eastern Nigeria (Figure 1), a region

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characterized by grass-and-shrub vegetation with scattered drought-resistant trees, year-round high temperatures (23–44°C), an average midday relative humidity of ~49%, and a short rainy season yielding 180–1,000 mm of annual rainfall alongside an extended 7–8-month dry period. Given that livestock production serves as a primary livelihood for the local population, this area provides an ideal setting to investigate the morphometric traits, hematology, and serum biochemistry of indigenous goats.

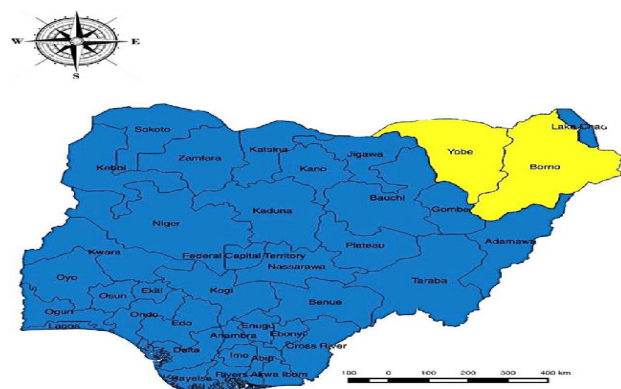


Figure-1: Map of Nigeria showing the Borno and Yobe state

2.2 Experimental Animals

A total of 270 goats aged 2–4 years determined by dentition examination (Sanni *et al.*, 2018) across Sahelian, Red Sokoto, and West African Dwarf (WAD) breeds were evaluated for morphometric traits. From this group, a subset of 120 goats (40 per breed) were selected for blood sampling to analyze haematological and serum biochemical parameters across five sites in Yobe and Borno States.

2.3 Animal Management

The goats were managed under a semi-intensive system, freely foraging for food and water alongside their offspring. Their housing consisted of corn stalk walls with thatched roofing to shelter them from extreme heat and rain. Standard veterinary care, including periodic vaccinations and deworming, was provided.

2.4 Morphometric Trait Measurements

Body measurements were taken using a standard weighing scale and a flexible measuring tape were used to measure morphometric traits according to the procedures of Issac & Ojukwu (2026). To minimize measurement discrepancies, animals were safely restrained while recording physical traits as follow;

Head circumference: This was measured as the circumference round of the head at its widest point.

Hip height: The vertical distance from the floor to the highest point in the hook region or pelvic girdle.

Neck length: The length of the cervical vertebrae.

Ear length: The length from the point of attachment of the ear to the tip.

Horn length: The length from the point of the attachment of the horn to the tip.

Tail length: The distance from the beginning of caudal vertebra to the tip.

Wither height: The vertical distance from the floor to the top of the shoulder.

Body length: The distance from shoulder point to the pin bone of the tail region.

Heart girth: The circumference slightly behind the shoulder and perpendicular to the body axis.

Face length: The length of the face from the poll region to tip of the muzzle.

Gonadal length: The length of the gonad from point of attachment to the body to the tip.

Gonadal circumference: The circumference of the gonads (Akpa *et al.*, 2023)

2.5 Sample Collection and Processing

Using hypodermic needles, 10 mL of blood was drawn from each goat's jugular vein. A 3 mL portion was immediately transferred into EDTA tubes for hematological analysis, while the remaining 7 mL was placed into sterile, labeled, screw-capped tubes positioned at an angle to encourage clotting. All samples were promptly moved to the hematology lab at the Specialist Hospital in Biu, Borno State.

The non-EDTA samples rested at room temperature for roughly two hours before being centrifuged at $4,060 \times g$ for 5 minutes to separate the serum. The isolated serum was decanted into clean, labeled vials and kept frozen at -20°C prior to biochemical testing.

2.6 Packed Cell Volume (PCV)

Packed Cell Volume (PCV): PCV was determined using the microhaematocrit capillary tube method. Blood was drawn into heparinized/EDTA microhaematocrit capillary tubes, sealed at one end and centrifuged, after which the packed red-cell column was read using a haematocrit reader. The PCV was expressed as a percentage of the total blood column (Oliva *et al.*, 2025).

2.7 Hemoglobin Concentration

Hemoglobin levels were measured via the cyanmethemoglobin technique. A total of 24 test tubes including a blank were placed in a rack. Each tube received 5 mL of cyanide solution, after which 0.02 mL of blood was added to every tube except the blank. The solutions were mixed well and incubated for a minimum of 3 minutes before measuring absorbance on an electronic colorimeter calibrated against the blank. Values were determined using an Hb reference chart (Buer & Moritz, 2008; Oliva *et al.*, 2025).

2.8 Red Blood Cell (RBC) Count

An automated pipette was used to transfer 4 mL of RBC diluting fluid into clean, dry tubes, followed by 0.2 µL of whole blood. The mixture was thoroughly blended, left to sit for 5 minutes, and then used to charge a clean Neubauer hemocytometer. After fitting a grease-free coverslip onto the chamber, an aliquot was carefully introduced along the edge to prevent air bubbles. The chamber was mounted on a microscope, and cells within the central primary, secondary, and tertiary grid squares were counted under low-power (10×) magnification.

2.9 White Blood Cell (WBC) Count

Using a hemocytometer WBC pipette, blood was aspirated to the 0.5 mark, the tip was wiped clean, and WBC diluting fluid was drawn up to the 11 mark (1.1). The contents were mixed gently to prevent air bubbles. A coverslip was fitted onto the hemocytometer chamber, which was then charged carefully without overflowing. After allowing the cells to settle for 2 minutes, the chamber was examined under low power (10×) magnification.

Leukocytes within the four corner primary squares were enumerated, applying standard exclusion rules for cells touching the outer borders.

2.10 Differential Leukocyte Count

Thin blood smears were prepared by placing a droplet of blood on a clean glass slide and spreading it rapidly with a second slide. Smears were fixed in methanol for 5 minutes and stained for 10 minutes using a diluted Giemsa solution (1:100 v/v in distilled water). Slides were rinsed with a gentle stream of water, air-dried, and stored in a slide carrier. Under an oil-immersion objective (100×), at least 100 leukocytes were identified and tallied using a manual cell counter across both central and peripheral fields to classify neutrophils, lymphocytes, monocytes, eosinophils, and basophils (Sood *et al.*, 2009).

2.11 Serum Biochemical Analysis

Serum levels of total protein, albumin, cholesterol, urea, creatinine, key liver enzymes (AST, ALT, ALP), and essential electrolytes (Na^+ , Cl^- , HCO_3^- , K^+) were quantified using commercial Randox assay kits in strict accordance with the manufacturer's protocol.

2.12 Determination of Blood Glucose

Blood glucose concentration was measured using a portable glucometer (Accu-Chek Active, S/N: GN 10023338). The device was powered on and allowed to calibrate automatically after a test strip was inserted. A single drop of whole blood was applied to the designated target area on the strip. The meter processed the reaction for several seconds, and the final reading was recorded once displayed on the digital screen.

2.13 Statistical Analysis

Relationships among morphometric traits, hematology, and serum biochemistry were evaluated using Pearson's Product-Moment Correlation Coefficient (PPMC)

3.0 RESULTS AND DISCUSSION

3.1 Pearson Correlation Coefficients Among Morphometric Traits

Significant relationships among various morphometric parameters in the 270 studied indigenous Nigerian goats are presented in Table 1. Body weight exhibited an exceptionally strong positive correlation with heart girth ($r=0.99$, $p<0.01$), highlighting heart girth as a highly reliable predictor of live body weight. This aligns with observations by Alemu *et al.* (2022), who identified heart girth as one of the most effective linear measurements for estimating live weight in indigenous goat populations. Additionally, body weight showed strong positive associations with body length ($r=0.79$) and head circumference ($r=0.71$), demonstrating that overall skeletal expansion

corresponds with increases in body weight a trend consistent with previous reports on native goat breeds (Getachew *et al.*, 2022).

Regarding reproductive and mammary morphology, correlation was observed between gonad length and gonad circumference ($r=0.95$). Similarly, strong interrelationships emerged among udder length, udder circumference, and teat length ($r=0.97-0.99$). These tight correlations underscore the structural co-development of reproductive and udder traits, offering valuable selection criteria since mammary dimensions serve as practical proxies for dairy yield potential in breeding programs (Bekele *et al.*, 2025; Guyo & Tareke, 2025).

Table 1: Pearson Correlation Coefficients among Morphometric Traits. N=270

Traits	Body Weight	Horn Length	Ear Length	Heart Girth	Neck Length	Head Circum.	Wither Height	Body Length	Tail Length	Gonad Length	Gonad Circum.	Udder Length	Udder Circum.	Average Teat Length
Body Weight														
Horn Length	0.61**													
Ear Length	-0.04	0.08												
Heart Girth	0.99**	0.59**	-0.06											
Neck Length	-0.03	-0.00	-0.07	-0.04										
Head Circum.	0.71**	0.57**	-0.17**	0.68**	-0.13*									
Wither Height	-0.30**	-0.07	0.08	-0.28**	-0.19**	-0.18**								
Body Length	0.79**	0.13*	0.00	0.17**	-0.05	0.10	0.12							
Tail Length	0.03	0.14*	0.15*	0.01	-0.09	-0.04	0.17**	-0.12*						
Gonad Length	0.27**	0.37**	-0.06	0.29**	-0.12	0.29**	0.10	0.03	0.19*					
Gonad Circum.	-0.06	0.24**	-0.03	-0.09	-0.15	0.03	0.38**	-0.12	0.95**	0.23**				
Udder Length	0.16	0.16	0.41**	0.12	-0.07	-0.04	0.06	0.02	0.97**	—	—			
Udder Circum.	0.18*	0.17*	0.31**	0.15	0.00	0.03	0.02	-0.03	0.96**	—	—	0.97**		
Average Teat Length.	0.15	0.17*	0.37**	0.11	-0.02	-0.02	0.03	0.02	0.97**	—	—	0.99**	0.98**	

* = significant correlation at $p < 0.05$; ** = highly significant correlation at $p < 0.01$; — = no valid paired observations (N = 270)

3.2 Pearson Correlation Coefficients Among Serum Biochemical Parameters

Table 2 outlines significant correlations among specific serum biochemical markers in the evaluated goats. Serum sodium demonstrated positive associations with both potassium ($r=0.38$, $p<0.01$) and total protein ($r=0.43$, $p<0.01$), whereas urea correlated positively with total cholesterol ($r=0.41$, $p<0.01$). These interrelationships point to underlying physiological links between electrolyte homeostasis, protein turnover, and energy metabolism. Correspondingly, Gebremariam *et al.* (2024) noted that blood proteins and metabolite markers often fluctuate in tandem depending on an animal's nutritional and physiological state.

Conversely, inverse relationships were detected between sodium and albumin ($r=-0.24$, $p<0.01$), as well as between aspartate aminotransferase (AST) and albumin ($r=-0.39$, $p<0.01$), reflecting divergent physiological responses among certain biochemical variables. Nevertheless, these statistical relationships reflect mutual associations rather than direct cause-and-effect mechanisms. These findings align with previous work demonstrating that serum albumin, liver enzymes like AST, and related metabolic indicators shift in response to metabolic demands and dietary intake in goats (Al-Mamun *et al.*, 2021).

Table: 2 Pearson Correlation Coefficients Among Serum Biochemical Parameters (N=120)

Parameter	Sodium (mmol/L)	Potassium (mmol/L)	Chloride (mmol/L)	Urea (mmol/L)	Creatinine (μmol/L)	Total Protein (g/L)	Albumin (g/L)	Alanine Aminotransferase (U/L)	Aspartate Aminotransferase (U/L)	Glucose (mmol/L)	Total Cholesterol (mmol/L)	Alkaline Phosphatase (U/L)
Sodium (mmol/L)												
Potassium (mmol/L)	0.38**											
Chloride (mmol/L)	0.38**	0.12										
Urea (mmol/L)	0.15	0.17	-0.04									
Creatinine (μmol/L)	0.17	0.07	0.17	0.10								
Total Protein(g/L)	0.43**	0.21*	0.24**	0.08	0.01							
Albumin (g/L)	-0.24**	-0.11	0.00	-0.13	-0.05	-0.15						
Alanine Aminotransferase (U/L)	0.03	0.11	-0.08	0.16	0.18*	-0.02	-0.21*					
Aspartate Aminotransferase (U/L)	-0.04	0.12	-0.15	0.26**	0.11	-0.09	-0.39**	0.71**				
Glucose (mmol/L)	0.31**	0.22*	-0.08	0.14	0.15	0.27**	-0.26**	0.15	0.19*			
Total Cholesterol (mmol/L)	0.13	0.19*	0.06	0.41**	-0.11	0.21*	-0.13	0.16	0.29**	0.14		

Alkaline	0.16	0.15	0.13	0.22*	-0.02	0.28**	0.06	-0.01	-0.05	0.09	0.09
Phosphatase(U/L)											

* P < 0.05; ** P < 0.01 (2-tailed). N = 120

3.3 Pearson Correlation Coefficients Among Hematological Parameters

Table 3 highlights strong, positive interrelationships among key erythrocytic indices. Red blood cell (RBC) count correlated strongly with both hemoglobin concentration ($r=0.88$, $p<0.01$) and hematocrit ($r=0.81$, $p<0.01$), while hemoglobin itself exhibited a high positive correlation with hematocrit ($r=0.89$, $p<0.01$). These parallel shifts are physiologically expected, as erythrocytes house hemoglobin and directly determine packed cell volume. Similar proportional relationships among RBCs, hemoglobin, and hematocrit are well-documented in goats across diverse health and physiological states (Alam *et al.*, 2021).

Conversely, mean corpuscular volume (MCV) shared an inverse relationship with RBC count ($r= -0.42$, $p<0.01$), whereas mean corpuscular hemoglobin (MCH) correlated positively with RBC count, hemoglobin, and hematocrit. Mean corpuscular hemoglobin concentration (MCHC) likewise aligned positively with RBCs and hemoglobin. These interconnected red cell indices collectively govern the oxygen-carrying capacity of the blood, mirroring patterns previously reported in goats experiencing varied dietary and environmental conditions (Al-Mamun *et al.*, 2021). Additionally, a pronounced negative correlation emerged between lymphocytes and neutrophils ($r= -0.86$, $p<0.01$), illustrating a trade-off within the primary leukocyte populations that likely reflects shifts in relative immune cell distribution.

Table 3: Pearson Correlation Coefficients Among Hematological Parameters (N = 120)

Parameters	WBC ($\times 10^9/L$)	RBC ($\times 10^{12}/L$)	Hemoglo bin (g/dL)	Hematoc rit (%)	MCV (fL)	MCH (pg)	MCHC (g/dL)	Platelet s ($\times 10^9/L$)	Lympho cytes (%)	Monocy tes (%)	Eosinoph ils (%)	Neutroph ils (%)
WBC ($\times 10^9/L$)												
RBC ($\times 10^{12}/L$)	-0.07											
Hemoglobin (g/dL)	-0.11	0.88**										
Hematocrit (%)	-0.09	0.81**	0.89**									
MCV (fL)	0.07	-0.42**	-0.18*	0.22*								
MCH (pg)	-0.05	0.18*	0.54**	0.57**	0.53**							
MCHC (g/dL)	-0.09	0.50**	0.54**	0.18*	-0.47**	0.47**						
Platelets ($\times 10^9/L$)	-0.08	0.14	0.11	0.12	-0.02	0.08	0.10					
Lymphocytes (%)	0.25**	0.03	0.01	0.04	0.03	0.02	-0.01	0.06				
Monocytes (%)	-0.08	-0.09	-0.08	-0.08	0.04	-0.02	-0.05	-0.07	-0.19*			
Eosinophils (%)	-0.09	0.06	0.07	0.09	0.05	0.07	0.03	0.05	-0.14	-0.08		
Neutrophils (%)	-0.27**	-0.02	-0.01	-0.04	-0.03	-0.03	0.02	-0.06	-0.86**	0.05	-0.12	

* $P < 0.05$; ** $P < 0.01$ (2-tailed). N = 120, MCH= Mean Corpuscular Hemoglobin, MCHC=Mean Corpuscular Hemoglobin Concentration, WBC= White Blood Cells, RBC= Red Blood Cells, MCV= Mean Corpuscular Volume

4.0 CONCLUSION AND RECOMMENDATION

The results from these findings indicate that indigenous Nigerian goat breeds show strong correlations among morphometric traits (notably heart girth as a precise predictor of live weight and mammary dimensions for dairy potential) alongside haematological and biochemical interdependencies demonstrate that field linear measurements and physiological profiles can be directly integrated into selection indices, veterinary diagnostic frameworks, and targeted conservation strategies. Furthermore, these findings establish foundational baseline data essential for the characterization, conservation, and sustainable genetic improvement of native Nigerian goat populations within the Sudan-Sahel zone.

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