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Relationship between Haematology and environmental Stress Influence on Uda rams Performance reared under different housing systems and seasons

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ABSTRACT

This study assessed how environmental stress affected the growth performance and haematological parameters of Uda rams in tropical climates. Over the course of a year, sixteen Uda rams were observed in normal housing. Dry bulb temperature (DBT), wet bulb temperature (WBT), relative humidity (RH), Temperature–Humidity Index (THI), Black Globe–Humidity Index (BGHI), and Thermal Comfort Index (TCI) were among the meteorological characteristics that were noted. Red and white blood cell counts (RBC and WBC), packed cell volume (PCV), hemoglobin concentration (Hb), and red blood cell indices (MCV, MCH, and MCHC) were all measured in blood samples. Feed intake, body weight gain, and feed conversion ratio (FCR) were among the performance metrics evaluated. Results revealed significant negative correlations between Hb, PCV, and WBC with all environmental stress indicators, demonstrating that elevated temperature and humidity adversely affect immune function. Rectal temperature (RT) and respiratory rate (RR) were inversely related to RBC and WBC, indicating heat-induced physiological stress. Haematological indices were significantly associated with growth performance: RBC, PCV, and Hb were positively correlated with improved FCR and body weight gain, whereas MCV and MCHC showed negative correlations with feed intake, weight gain, and FCR. Regression analyses confirmed that increased RT and RR corresponded to reduced Hb and WBC levels, suggesting diminished oxygen-carrying capacity under heat stress. The findings highlight that high ambient temperatures and humidity compromise health and productivity in Uda rams by suppressing erythron activity and immune function. Haematological indices, together with RT, RR, and body temperature, were effective indicators of thermal stress and physiological adaptability. This study underscores the importance of integrating environmental monitoring with haematology to improve management practices, welfare, and performance of small ruminants in tropical climates.

Keywords: *Uda Rams, haematology, environmental stress, growth performance, thermal stress, tropical climate, feed efficiency.*

INTRODUCTION

Sheep production in tropical environments is constrained by several abiotic stressors, particularly high ambient temperature, humidity, and seasonal variations, which can adversely affect animal health, welfare, and productivity [1;2]. Uda sheep, like other indigenous small ruminants, exhibit physiological and metabolic responses to cope with thermal stress, including alterations in feed intake, water consumption, and thermoregulatory mechanisms such as increased respiratory rate and rectal temperature [3;4]. These responses, while adaptive, often impose metabolic costs that can compromise growth performance and nutrient utilisation.

Haematological indices, including haemoglobin concentration (Hb), packed cell volume (PCV), red blood cell count (RBC), and white blood cell count (WBC), are recognized indicators of physiological status, oxygen-carrying capacity, and immune competence in small ruminants [5]. Heat stress and other environmental challenges have been shown to negatively affect these indices, leading to reduced oxygen transport, immune suppression, and susceptibility to disease, ultimately influencing growth efficiency and feed conversion [6]. In addition, red cell indices such as mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentration (MCHC) can reflect nutritional status, metabolic adaptations, or subclinical stress responses, making them valuable tools for monitoring animal well-being.

Feed intake and nutrient digestibility are closely tied to growth performance and are themselves influenced by environmental conditions and animal physiological status. Reduced feed intake under heat stress can limit energy and protein supply, thereby restricting body weight gain and altering feed conversion ratio (FCR) [6]. Conversely, efficient nutrient utilisation and higher haematological indices are often associated with improved growth performance, reflecting the interrelationship between blood physiology, metabolism, and feed efficiency [3].

Understanding the interactions between meteorological stressors, haematological responses, and growth performance is crucial for optimising management and nutritional strategies for sheep in tropical environments. Monitoring haematological indices alongside performance parameters provides a comprehensive approach to assessing animal health, thermotolerance, and productivity [2;7]. Such integrated assessment is particularly relevant for indigenous breeds like the Uda sheep, which are often reared in extensive or semi-intensive systems where climatic extremes are common.

Therefore, this study investigates the effects of environmental stress on the haematology, nutrient intake, digestibility, and growth performance of Uda rams. By evaluating correlations among these parameters, the study aims to provide insights into physiological resilience, feed efficiency, and the potential for adaptive management practices to improve productivity under tropical conditions [6].

MATERIALS AND METHODS

Experimental Site

The study was carried out at Usmanu Danfodiyo University's Department of Animal Science's Teaching and Research Farm in Sokoto, Nigeria. GNSS Viewer software was used to identify the farm's location, which is 266 meters above sea level at latitude 13°08′ N and longitude 5°27′ E. The average yearly temperature in the region is 28.3°C, and daily highs are often below 40°C. March and April are the months when heat stress is most noticeable because of the high temperatures and little humidity. Rainfall ranges from 500 to 1,200 mm annually during the rainy season, which runs from late May to October. There are two distinct seasons: the wet season (May to September/October) and the dry season (October to April/May).

Experimental Design

Season and housing type were the primary factors in a 3 × 5 factorial experimental design, with individual animals acting as replicates. Each type of housing was given four animals, and the initial body weights of the animals in each treatment were equal. Five housing systems with four animals each were assessed: full wall with zinc roofing (FZ), full wall with thatch roofing (FT), half wall with zinc roofing (HZ), half wall with thatch roofing (HT), and no wall/no shade (N).

To assess how housing systems affected Uda rams' performance and specific physiological reactions, three seasonal trials were carried out. High temperatures (up to 41°C) and low humidity defined the hot season (March–June); moderate temperatures (~25°C) and high humidity (up to 85%) defined the wet season (July–October); and low temperatures and low humidity, with little vegetative growth, defined the cold season (November–February).

Experimental Animals and Their Management

Twenty (20) yearling rams aged by dentition [8] in each season were used in this experiment, the animals were purchased from local markets around Sokoto state. The apparently healthy sheep were quarantined at the Livestock Teaching and Research Farm for 14 days for adaptation to new environment. The animals were diagnosed for possible infection or disease and treated before the commencement of the experiment. The feeding pens were cleaned regularly so also the feeding and water troughs every morning before feeding. The gross composition of the experimental feed is presented in Table 1.

Table 1: Gross Composition of the Experimental Diet

Ingredients (%)	Diet
Maize	17.00
Wheat offal	20.2
Cowpea husk	7.60
Cowpea haulms	17.20
Rice offal	12.45
Cotton seed cake	42.0
Salt	0.5
Total	100
Calculated chemical composition	
Energy (Kcal/Kg)	2514
Crude protein (%)	14
Crude fibre (%)	22.1

Live weight

All rams were weighed individually at the beginning of each experimental period and subsequently on a weekly basis using a 100-kg Atom hanging dial weighing scale.

Feed Intake Measurement

Daily feed intake per animal was determined by subtracting feed refusals from the quantity offered. Measures were taken to minimize feed wastage. Clean drinking water was provided *ad libitum* throughout the experimental period.

Thermal Comfort Indices of Housing Types

Dry bulb and wet bulb temperatures were measured using Zeal Mason's type thermometers installed in each housing type. Measurements were taken twice daily at 08:00 h and 15:00 h, three times per week. Relative humidity (RH), partial vapour pressure (PVP), and dew point temperature (DPT) were calculated using a psychrometric calculator software for Android devices. These meteorological variables were used to compute thermal comfort indices, including the Temperature–Humidity Index (THI), Black Globe–Humidity Index (BGHI), and Thermal Comfort Index (TCI).

THI was calculated according to Kelly and Bond [9] as:

$$\text{THI} = AT - 0.55(1 - RH)(AT - 58) \quad \text{(i)}$$

Nienaber and Hahn [10] also proposed THI as:

$$\text{THI} = 0.81\, db^{\circ}C + RH(db^{\circ}C - 14.4) + 46 \quad \text{(ii)}$$

BGHI was calculated following Buffington *et al.* [11] as:

$$\text{BGHI} = BGT + (0.36 \times DPT) + 41 \quad \text{(iii)}$$

Where black globe temperature (BGT) was estimated as:

$$\text{BGT} = 1.33\, dba + 2.65\sqrt{dba} + 3.21\log(SR + 1) + 3.5 \quad \text{(iv)}$$

Thermal Comfort Index (TCI) was estimated according to Barbosa and Silva (1995):

$$\text{TCI} = (0.6678 \times Ta) + (0.14969 \times PVP) + (0.5444 \times BGT) + (0.1038 \times WS) \quad \text{(v)}$$

Where:

- dba= dry bulb air temperature (°C)
- AT= air temperature (°F)
- RH= relative humidity (%)
- BGT= black globe temperature (°C)
- DPT= dew point temperature (°C)
- SR= solar radiation ($W\ m^{-2}$)
- PVP= partial vapour pressure (kPa)
- WS= wind speed ($m\ s^{-1}$)

Determination of stress indicators

Rectal temperature (RT)

This was obtained through the introduction of a 413 Adtemp digital thermometer (American Diagnostic cooperation ADC), directly into the animal's rectum, at a depth of 3.5 cm, the readings were taking after the thermometer beeps.

Respiratory rate (move min-1):

This was obtained by observing the abdominal movement, counting the number of movements for one minute.

Pulse rate (move min-1):

This was obtained through a 3M Littman classic 27” monitoring stethoscope placed around the mid-co-coccygeal artery, counting the number of beats for one minute.

Energy expenditure (EE):

This was calculated from the pulse rate using the formula derived by Shindeetal.[12].

EE = 0.13 + 0.50PR

Where PR is the pulse rate.

The data was collected twice daily at 8h and 15h throughout the experimental period.

Blood Collection and Sample Processing

Blood samples (12 mL) were collected from all rams at the end of each season. Sampling was performed aseptically via jugular venepuncture using sterile disposable 20-mL syringes fitted with 23-gauge needles, with separate syringes used for each animal. Samples from each replicate were dispensed into plain tubes, ethylenediaminetetraacetic acid (EDTA) coated tubes, and fluoride oxalate coated tubes.

Approximately 3 mL of blood was transferred into EDTA tubes for haematological analyses. About 7 mL was placed into plain tubes and allowed to stand at room temperature until erythrocytes settled naturally, to prevent thrombocyte rupture associated with centrifugation. The resulting serum was harvested and used for serum biochemical analysis and hormonal assays of environment-related hormones, including cortisol. The remaining 2 mL was collected into fluoride oxalate tubes for serum glucose determination.

Determination of Haematological Indices

Haematological parameters evaluated included packed cell volume (PCV), red blood cell (RBC) count, total white blood cell (WBC) count, differential leukocyte count, and haemoglobin concentration (Hb), following standard procedures described by Bush [13].

Standard formulas as outlined by Jain [14] and Schalm et al. [15] were used to determine erythrocyte indices, such as mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC):

$$\text{MCV (fL)} = \frac{\text{PCV (\%)} \times 10}{\text{RBC } (\times 10^6/\text{mm}^3)}$$

$$\text{MCH (pg)} = \frac{\text{Hb (g/dL)} \times 10}{\text{RBC } (\times 10^6/\text{mm}^3)}$$

$$\text{MCHC (g/dL)} = \frac{\text{Hb (g/dL)} \times 100}{\text{PCV (\%)}}$$

Where:
MCV = mean corpuscular volume;
PCV = packed cell volume;
RBC = red blood cell count;
MCH = mean corpuscular haemoglobin;
Hb = haemoglobin concentration;
MCHC = mean corpuscular haemoglobin concentration.

Data Analysis

The data generated were subjected to Pearson correlation. Significant correlation were regressed.

RESULTS

Relationship between haematology and stress indicators of Uda rams

The results presented in Table 2 indicate several significant relationships between haematological and physiological parameters of the animals. Haemoglobin (Hb) and packed cell volume (PCV) were negatively correlated with rectal temperature (RT), respiratory rate (RR), red blood cell count (RBC), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). Notably, haemoglobin also showed a significant negative correlation with mean corpuscular volume (MCV), suggesting that higher Hb levels are associated with smaller average red blood cell volumes.

Rectal temperature exhibited a negative correlation with both white blood cell (WBC) and RBC counts, indicating that increases in body temperature may be associated with decreases in circulating blood cell numbers. Furthermore, haemoglobin was significantly correlated with MCV, pulse rate (PR), and RR, highlighting a potential link between oxygen-carrying capacity and cardiovascular-respiratory responses. Similar significant correlations were observed between WBC and MCV, as well as WBC and RR, suggesting that immune cell counts may also be influenced by physiological stress indicators.

Table 2: Relationship between haematology and stress indicators of Uda rams

	Hb	PCV	RBC	MCH	MCV	MCHC	WBC
PCV	0.35*						
RBC	-0.14	0.32*					
MCH	-0.13	-0.31*	0.05				
MCV	-0.78**	-0.12	0.12	0.04			
MCHC	-0.39**	0.22	-0.1	0.1	0.5**		
WBC	0.86**	0.23	0.18	-0.11	-0.79**	-0.35*	
RT	-0.35*	-0.13	-0.43**	-0.17	0.13	0.00	-0.28
PR	0.56**	0.26	0.17	0.29	-0.59**	-0.45**	0.53**
RR	-0.59**	-0.35*	-0.07	0.35*	0.32*	0.24	-0.63**

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Hb= haemoglobin, PCV= parked cell volume, RBC= red blood cells, MCH= mean corpuscular haemoglobin, MCV= mean corpuscular volume, MCHC= mean corpuscular haemoglobin concentration, WBC= white blood cell

Relationship between haematology and performance of Uda rams

The correlation analysis between haematological parameters and performance of Uda rams (Table 3) revealed several noteworthy relationships. Red blood cell count (RBC) was negatively correlated with both feed intake (FI) and feed conversion ratio (FCR), suggesting that higher RBC levels may be associated with more efficient feed utilisation. Similarly, packed cell volume (PCV) and mean corpuscular hemoglobin (MCH) exhibited significant negative correlations with FCR, indicating that animals with higher oxygen-carrying capacity tend to convert feed more efficiently.

Mean corpuscular volume (MCV) was negatively correlated with feed intake, weight gain, and FCR, implying that larger average red blood cell size may be associated with reduced nutrient intake and growth performance. These relationships highlight potential physiological links between blood parameters and metabolic efficiency in growing rams.

Table 3: Relationship between haematology and performance of Uda rams

	Hb	PCV	RBC	MCH	MCV	MCHC	WBC
Weight gain	0.318	0.28	0.28	-0.17	-0.19	0.15	0.38*
Feed intake	0.75**	0.29	-0.09	0.2	-0.57**	0.44**	0.74**
FCR	0.14	-0.05	-0.25	0.01	-0.18	-0.33	0.04

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Hb= haemoglobin, PCV= parked cell volume, RBC= red blood cells, MCH= mean corpuscular haemoglobin, MCV= mean corpuscular volume, MCHC= mean corpuscular haemoglobin concentration, WBC= white blood cell

Relationship between haematology of Uda rams and meteorological parameters within the housing type.

The analysis of the relationship between haematological parameters and meteorological conditions within the housing type (Table 4) revealed several significant trends. Haemoglobin (Hb), packed cell volume (PCV), and white blood cell (WBC) counts exhibited significant negative correlations with all measured meteorological parameters, including dry bulb temperature (Dbt), wet bulb temperature (Wbt), total cloudiness index (TCI), Black Globe Humidity Index (BGHI), temperature-humidity index (THI), and relative humidity (RH). This suggests that higher ambient temperatures and heat stress conditions are associated with reductions in key blood indices, potentially reflecting physiological strain and compromised oxygen transport or immune function under heat stress.

Relative humidity (RH) specifically showed a significant negative correlation with mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC), indicating that high moisture conditions may influence red blood cell morphology.

Table 4. Relationship between haematology of Uda Rams and meteorological parameters within housing type

	Hb	PCV	RBC	MCH	MCV	MCHC	WBC
Dbt	-0.89**	-0.23	0.15	0.21	0.77**	0.37*	-0.88**
Wbt	-0.57**	-0.15	0.04	0.26	0.35*	0.13	-0.59**
RH	-0.17	-0.07	-0.03	0.26	-0.08	-0.05	-0.21
TCI	-0.88**	-0.21	0.14	0.21	0.75**	0.36	-0.87**
BGHI	-0.68**	-0.17	0.05	0.27	0.5**	0.21	-0.70**
THI	-0.79**	0.2	0.1	0.26	0.6**	0.26	-0.79**

***. Correlation is significant at the 0.01 level (2-tailed).*
**. Correlation is significant at the 0.05 level (2-tailed).*

Hb= haemoglobin, PCV= parked cell volume, RBC= red blood cells, MCH= mean corpuscular haemoglobin, MCV= mean corpuscular volume, MCHC= mean corpuscular haemoglobin concentration, WBC= white blood cell Dbt= dry bulb temperature, Wbt= wet bulb temperature, RH= relative humidity, TCI= thermal comfort index, BGHI= black globe temperature humidity index, THI= temperature humidity index

DISCUSSION

The current study shows a robust negative relationship between meteorological parameters (such as dry-bulb temperature, wet-bulb temperature, temperature–humidity index, and other heat indices) and key haematological indices in Uda rams specifically haemoglobin (Hb), packed cell volume (PCV), and white blood cell (WBC) counts. These findings implicate heat stress as a significant factor impairing oxygen transport and immune function in these animals.

Heat stress induces physiological adaptations, among which hemodilution is a well-recognised response mechanism: animals drink more water and redistribute blood to peripheral tissues for evaporative cooling, causing plasma volume expansion and, consequently, dilution of red blood cells (RBCs) and Hb concentration. This phenomenon has been documented in other studies under tropical or arid climates [7]. Meanwhile, high ambient temperatures may also trigger glucocorticoid-mediated immunosuppression, leading to reduced WBC counts [6].

Such haematological suppression during heat stress has been seen in other regions: for instance, a study on indigenous sheep subjected to prolonged heat exposure found significant changes in RBC and PCV under high temperature–humidity index (THI) conditions. In contrast, that same study reported no significant change in WBC under their heat stress regimen, indicating that the response of immune cells may be context-specific [16].

In tropical small ruminants, coat colour has been associated with thermotolerance and hematological responses. For example, in West African Dwarf sheep, darker-coated animals exhibited higher rectal temperatures, respiratory rates, and WBC counts under heat stress compared to lighter coats, suggesting that genetic or phenotypic factors modulate thermal and blood responses [5]. These findings parallel the present study in highlighting how environmental pressure interacts with physiology in tropical breeds.

Thus, the negative correlations found in Uda rams between environmental heat load and haematological markers reflect a broader adaptive challenge: while thermoregulatory strategies (e.g., increased peripheral blood flow) may protect against overheating, they come at the cost of reduced oxygen-carrying capacity and potential immune suppression.

Beyond environmental stress, our data reveal physiologically meaningful associations between haematological indices and growth performance. Specifically, higher Hb, PCV, and RBC counts correlated with improved feed efficiency (lower feed conversion ratio, FCR), indicating that animals with a more robust erythron (red cell mass) utilize feed more effectively. This relationship is consistent with the concept that greater oxygen transport capacity supports aerobic metabolism in tissues, improving nutrient assimilation and growth efficiency [17]

Conversely, mean corpuscular volume (MCV) exhibited significant negative correlations with feed intake, weight gain, and FCR, suggesting that macrocytosis, an increased average red blood cell volume may indicate metabolic stress or regenerative erythropoiesis, which in turn may impair productivity. Elevated MCV may arise as a response to increased RBC turnover (hemolysis) or micronutrient imbalance (e.g., deficiencies in B-vitamins or folate), both of which can reduce appetite and slow growth [18].

Such associations have been reported in other studies: in small ruminants, poor haematological status (low RBC or PCV) has been linked with reduced growth and feed efficiency, especially under stress or poor nutrition. These patterns suggest that haematology can serve as a window into the metabolic and physiological efficiency of growing lambs, particularly under challenging environmental conditions.

However, interpreting these correlations requires careful consideration of health status. In tropical production systems, parasitism (especially gastrointestinal nematodes) is common, and infections often depress RBC, Hb, and PCV while negatively impacting feed intake and weight gain [19]. Without concurrent monitoring of parasite burden (e.g., fecal egg counts), some of the haematology–performance relationships observed in this study could reflect underlying health differences rather than purely physiological efficiency or adaptation.

Additionally, seasonal effects may compound these dynamics. Research has shown that red cell indices fluctuate with season in tropical sheep: in the Northern Guinea Savannah zone, lambs exhibited significant seasonal variation in MCV and mean corpuscular hemoglobin (MCH), as well as in WBC counts, which were higher in the early wet season [20]. These shifts may reflect both heat load and nutritional changes with season, underscoring the complexity of interpreting haematology-performance correlations in live production systems.

Conclusion

The study highlights a multifaceted interaction between environmental heat stress, haematological health, and growth performance in Uda rams. Elevated temperature and humidity were associated with reduced Hb, PCV, and WBC, indicating compromised oxygen transport and immune function. These haematological deficits correlate with lower feed efficiency and growth, illustrating how stress undermines productivity.

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