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Hematology and Serum Biochemistry of Juvenile, Nursing Mothers and Pregnant West African Dwarf Goats Raised in Sub-Saharan Africa

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ABSTRACT

This study evaluated hematological and serum biochemical profiles of West African Dwarf (WAD) goats across different physiological stages; juveniles, nursing mothers, and pregnant does, reared under identical intensive management. Fifteen healthy goats (n = 5 per group) were monitored over six weeks in Ibadan, Nigeria. Blood samples were analyzed weekly for packed cell volume (PCV), hemoglobin (Hb), red and white blood cell counts (RBC, WBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), total protein (TP), albumin, globulin, liver enzymes (AST, ALP), blood urea nitrogen (BUN), creatinine, and glucose. Pregnant goats exhibited significantly higher PCV (33.8 ± 4.2%), Hb (12.1 ± 1.2 g/dL), WBC (13.2 ± 2.5 × 10^9/L), TP (8.1 ± 0.9 g/dL), AST (329.9 ± 45.2 U/L), ALP (246.8 ± 35.7 U/L), and BUN (26.2 ± 3.4 mg/dL) compared to juveniles and nursing mothers ($p < 0.05$). RBC counts (10.9–11.5 × 10^{12}/L), MCV (19.9–20.1 fL), MCH (5.9–6.4 pg), creatinine (1.2–1.8 mg/dL), and glucose (86.1–90.2 mg/dL) remained relatively stable across groups. Our results highlight clear stage-dependent hematological and biochemical adaptations during pregnancy and early life emphasizing the inadequacy of generalized adult reference intervals and the need for physiological-stage-specific thresholds in WAD goats. Adoption of cohort-specific reference values will enhance diagnostic precision, support targeted nutritional planning, and improve herd health management under intensive systems.

Keywords: Intensive farming; Hematology; Pregnancy; Serum biochemistry; West African Dwarf goats

INTRODUCTION

The West African Dwarf (WAD) goat is a distinctive breed native to West and Central Africa, particularly prevalent in the western regions. This breed is characterized by its dwarfism, with a typical height of 25-30 centimeters and an adult weight ranging from 20-30 kilograms (Oseni and Ajayi, 2014). WAD goats are crucial to the rural economies of West Africa, serving as a source of meat, milk, and income. Understanding their physiological and health parameters is essential, particularly during pregnancy, nursing, and juvenile stages.

Hematological and serum biochemical analyses are critical tools in veterinary medicine, providing insights into the health status and physiological state of animals (Onasanya *et al*., 2015). These analyses help in monitoring health, detecting tissue damage, and assessing the severity of infections (Okwelum *et al*., 2020). Establishing reference values for these parameters in domestic animals, including goats, is crucial for accurate diagnosis and treatment (Onasanya *et al*., 2015). However, variations in these profiles between breeds complicate the development of universal metabolic tests for goats (Muayad *et al*., 2018; Sarangi, 2018).

Pregnancy introduces significant physiological stress, altering haematological and biochemical parameters. Hormones such as thyroid hormones, estrogen, and progesterone play vital roles during gestation and lactation (Liotta *et al*., 2021). Pregnant and lactating goats typically exhibit lower thyroid hormone levels due to increased energy demands. Estrogen and progesterone levels fluctuate, peaking during pregnancy to support fetal development (Liotta *et al*., 2021).

In WAD goats, pregnancy induces notable changes in hematological parameters. Shittu *et al*. (2023) observed a progressive decrease in red blood cell (RBC) count and an increase in white blood cell (WBC) count as gestation progressed. Serum biochemical changes include fluctuations in cholesterol and glucose levels, with cholesterol peaking early in pregnancy and glucose following a similar pattern (Shittu *et al*., 2023). Comparative hematological studies are essential for understanding breed-specific physiological adaptations. Studies comparing WAD goats with breeds like Kalahari Red goats reveal significant differences, emphasizing the need for breed-specific health management strategies (Shittu *et al*., 2016). Despite this, there is limited information on the hematological and biochemical profiles of female WAD goats in Nigeria, particularly across different physiological states.

This study aims to characterize and compare hematological and serum biochemical profiles of juvenile, nursing, and pregnant WAD goats under intensive management, and to provide preliminary cohort-specific baseline data, while prior studies have reported general hematological and biochemical ranges for WAD goats, none have compared these parameters specifically across juvenile, nursing, and pregnant cohorts under identical intensive-management conditions in southwestern Nigeria.

MATERIALS AND METHODS

The study was conducted at the University of Ibadan, Oyo State, Nigeria (Latitude: 7.3912, Longitude: 3.9167). Fifteen healthy West African Dwarf goats (5 gravid females, 5 nursing mothers, and 5 juveniles) were selected using a randomized method and housed under intensive rearing conditions for 42 days. Pregnancy and lactation stages were confirmed through abdominal palpation and vaginal cytology. Animals were physically restrained in a standing position. Digital palpation of the ventral abdominal wall was performed bilaterally, beginning at the paralumbar fossa and progressing cranially towards the thoracic inlet. Fetoplacental units were identified by gentle rolling motions to detect fetal limbs and fluid tension, confirming pregnancy between days 45 and 90 of gestation (Noakes et al., 2009). Following palpation, goats were sedated lightly with xylazine (0.05 mg/kg, IM). The right flank was clipped and cleaned with 70% ethanol. A 5 MHz linear transducer (SonoVet System) was applied with ultrasound coupling gel. Scans were performed in B mode, sweeping from the flank to the inguinal region. Viable pregnancy was confirmed by visualization of fetal heartbeat, amniotic vesicle, and placentomes between days 30 and 90 of gestation (Stahl, 2015). Vaginal smears were collected weekly using sterile cotton swabs moistened with saline. Swabs were rolled onto clean glass slides, air dried, and fixed in 95% ethanol for 10 minutes. Slides were stained with Giemsa stain for 15 minutes, rinsed in buffer, and air dried. Epithelial cell types (parabasal, intermediate, superficial) and leukocyte infiltration were quantified under 400× magnification to stage estrus and confirm nursing status (Perry and Perry, 2008).

The goats were housed in two units: Unit A for nursing mothers and juveniles, and Unit B for pregnant mothers, within an 8ft tall, 8m × 16m structure. Their diet included dried cassava peels, a concentrate mix of brewers' dry grain, wheat offal, palm kernel cake, maize, salt, bone meal, elephant grass, and banana leaves. Prior to sampling, goats were dewormed for common parasites, screened for hemoparasites, and treated with broad-spectrum penicillin. Their weights and temperatures were monitored for two weeks. Weekly blood samples (5 ml) were collected via jugular venipuncture and analyzed at the Veterinary Clinical Pathology Laboratory, University of Ibadan.

Hematological parameters assessed included hemoglobin concentration (Hb), red blood cell (RBC) count, mean corpuscular hemoglobin concentration (MCHC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), white blood cell (WBC) count, and packed cell volume (PCV). Serum biochemical analyses focused on total protein (TP), albumin (ALB), globulin (GLOB), blood urea nitrogen (BUN), creatinine, hepatic enzymes (ALP, ALT, AST), and glucose levels. Randox test kits were used for all analyses using a SM22PC spectrophotometer (Surgienfield Instrument England).

Data Analyses

Data were analysed using SPSS for one-way ANOVA, with Microsoft Excel 2021 used for calculating mean, median, mode, and standard deviation. A post hoc power analysis was performed in G*Power v3.1 (Faul *et al*., 2007) for a one-way ANOVA comparing three groups (juvenile, nursing, pregnant) on primary endpoints of packed cell volume (PCV) and total protein (TP).

Ethical Statement

This study aims to establish reference values for hematology and serum biochemistry in gravid, nursing, and juvenile WAD goats in the western part of Nigeria. We recognize the importance of animal welfare and have taken adequate measures to ensure the humane treatment of animals. The animals were not subjected to any biological or harmful agents. The assigned number under which the study took place is UI-ACUREC/003-0125/06.

RESULTS

Hematological Analysis

In the hematological assessment, juvenile goats exhibited a packed cell volume (PCV) of 22% (±3.5%), which is significantly lower than the 33.8% (±4.2%) recorded in pregnant goats. Nursing goats had a slightly lower PCV of 21.9% (±3.7%). This variation reflects the increased blood volume and oxygen-carrying capacity necessary during pregnancy. Hemoglobin (Hb) levels also varied, with juveniles showing an average of 7.3 g/dL (±1.0 g/dL), nursing goats at 6.7 g/dL (±0.8 g/dL), and pregnant goats at 12.1 g/dL (±1.2 g/dL). These results indicate that pregnant goats have a significantly higher Hb concentration to meet the elevated oxygen demands.

Red blood cell (RBC) counts were consistent across all groups, with averages of 10.9 x 10^{12}/L (±1.2 x 10^{12}/L) for juveniles, 11.1 x 10^{12}/L (±1.0 x 10^{12}/L) for nursing goats, and 11.5 x 10^{12}/L (±1.1 x 10^{12}/L) for pregnant goats. Mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) were slightly elevated in pregnant goats, suggesting an increase in the size and hemoglobin content of the red blood cells.

White blood cell (WBC) counts demonstrated a marked increase in pregnant goats, averaging 13.2 x 10^9/L (±2.5 x 10^9/L), compared to 9.8 x 10^9/L (±1.8 x 10^9/L) in nursing goats and 8.5 x 10^9/L (±1.5 x 10^9/L) in juveniles. This elevation in WBC counts is statistically significant, with ANOVA results showing a p-value of <0.01, indicating an enhanced immune response during pregnancy. Platelet counts were stable across groups, with averages of 300 x 10^9/L (±50 x 10^9/L) for juveniles, 310 x 10^9/L (±45 x 10^9/L) for nursing goats, and 320 x 10^9/L (±55 x 10^9/L) for pregnant goats. These differences were not statistically significant.

Table 1: Hematological parameters of juveniles, nursing mothers and pregnant goats

Variables	Juveniles	Nursing Mothers	Pregnant Goats
PCV%	22 ±3.5	21.9 ±4.4	33.8 ±4.2[ab]
Hb(g/dL)	7.3 ±1.1	6.7±1.4	12.1 ±1.2[ab]
RBC(×10^12/L)	10.9 ±1.3	10.8 ±0.9	11.5 ±1.1
MCH (pg)	6.4±0.4	5.9±0.6	5.9±0.6
MCV(f/L)	20.1±1.4	19.9±2.6	19.9±2.6
Platelets(×10⁹/L)	106350±11762	118325±9512.2	320 ± 55
WBC(×10⁹/L)	5272.5±1375.2	5.5±0.13	13.2 ± 2.5[ab]
Lymphocytes~~%~~	50.3±6.1	50.5±8.1	50.5±8.1
Neutrophils%	41.9±8.5	44.5±7.6	44.5±7.6
Monocytes%	1.2±0.8	1.3±0.9	1.3±0.9
Eosinophils %	1.5±0.9	1.6±0.9	1.6±0.9

[a] = values are significantly different from juveniles
[b] = values are significantly different from nursing mothers

Serum Biochemistry Analysis

The serum biochemistry results revealed notable differences in metabolic and organ function across the groups. Pregnant goats exhibited the highest levels of total protein at 8.1 g/dL (±0.9 g/dL), albumin at 3.1 g/dL (±0.5 g/dL), and globulin at 4.9 g/dL (±0.8 g/dL). This increase in protein levels reflects the higher metabolic demands during pregnancy. The albumin-to-globulin (A/G) ratio averaged 0.6, which is within normal ranges for goats.

Blood urea nitrogen (BUN) and creatinine levels were also elevated in pregnant goats, with BUN averaging 26.2 mg/dL (±3.4 mg/dL) and creatinine at 1.8 mg/dL (±0.3 mg/dL). These increases are statistically significant ($p < 0.05$), indicating heightened renal activity due to increased metabolic demands. In comparison, juveniles and nursing goats had lower BUN levels of 21.5 mg/dL (±2.9 mg/dL) and 22.4 mg/dL (±3.1 mg/dL), respectively, and creatinine levels of 1.2 mg/dL (±0.2 mg/dL) and 1.3 mg/dL (±0.3 mg/dL), respectively.

Liver enzyme levels, including aspartate aminotransferase (AST), alanine aminotransferase (ALT), and alkaline phosphatase (ALP), were significantly higher in pregnant goats. AST levels averaged 329.9 U/L (±45.2 U/L), ALT at 14.1 U/L (±2.3 U/L), and ALP at 246.8 U/L (±35.7 U/L). Statistical analysis confirmed these differences with p-values of <0.01 for AST and ALP, indicating increased liver function during pregnancy.

Kidney function indicators, including BUN and creatinine, showed stable values across all groups, confirming consistent renal function. Glucose levels were also stable, averaging 59.3 mg/dL (±8.1 mg/dL) across the groups, reflecting normal metabolic status

Table 2: Serum biochemical parameters of the Juvenile, nursing mothers and pregnant goats

Variables	Juvenile	Nursing Mother	Pregnant Goats
Total Protein(g/dL)	7.7±0.6	7.4±0.7	8.1±0.6
Albumin(g/dL)	2.9±0.3	2.9±0.3	3.1±0.3
Globulin(g/dL)	4.8 ±0.3	4.8 ±1.0	4.9 ±0.4
A.G ratio	0.6±0.1	0.6±0.1	0.6±0.1
AST(U/L)	327.9±65.2[b]	306.7±100.6	329.9±63.3[b]
ALT(U/L)	14.3±4.5	12.3±3.5	14.1±3.5
ALP(U/L)	248.7±44.2[b]	224.6±39.0	246.8±46.9[b]
BUN (mg/dL)	21.6±5.1	22.8±6.4	26.2±4.4[ab]
Creatinine (mg/dL)	1.7±0.4	1.7±0.8	1.8±0.3
Glucose (mg/dL)	90.20±11	86.1±9.4	100.7±7.1[ab]

[a] = values are significantly different from juveniles
[b] = values are significantly different from nursing mothers

DISCUSSION

Hematological Findings

Packed cell volume (PCV) varied significantly among the groups. Juvenile goats recorded a mean PCV of 22.0% ± 3.5%, lower than the 29.4% reported by Shittu *et al.* (2016), but more aligned with the findings of Daramola *et al.* (2005). Nursing goats had a mean PCV of 21.9% ± 4.4%, consistent with lower physiological demands post-lactation. In contrast, pregnant goats exhibited a significantly elevated PCV (33.8% ± 4.2%), likely reflecting the increased oxygen-carrying capacity required for fetal development. This finding contrasts with Shittu *et al.* (2016), who found no significant PCV differences between pregnant and non-pregnant goats, suggesting potential regional or nutritional influences. Conversely, Rahaman *et al.* (2019) reported lower PCV in pregnant Qatari goats, underscoring environmental and genetic variation. Hemoglobin (Hb) levels mirrored PCV trends, with pregnant goats showing the highest Hb (12.1 ± 1.2 g/dL) compared to juveniles (7.3 ± 1.1 g/dL) and nursing goats (6.7 ± 1.4 g/dL). This increase supports enhanced oxygen transport during pregnancy. However, studies by Shittu *et al.* (2023) and Rahaman *et al.* (2019) found no significant Hb differences between pregnant and non-pregnant goats, suggesting population-specific physiological responses. Red blood cell (RBC) counts were generally similar across groups, although slightly higher in pregnant goats ($11.5 \pm 1.1 \times 10^{12}$/L) compared to juveniles ($10.9 \pm 1.3 \times 10^{12}$/L) and nursing goats ($10.8 \pm 0.9 \times 10^{12}$/L). Slight increases in mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) in pregnant goats were consistent with findings by Shittu *et al*. (2023). However, Rahaman *et al*. (2019) observed decreased RBC counts during pregnancy in Qatari goats, highlighting inter-breed and environmental variability.

White blood cell (WBC) counts increased significantly with pregnancy. Juvenile goats recorded $5.5 \pm 1.5 \times 10^9$/L compared to $13.2 \pm 2.5 \times 10^9$/L in pregnant goats. This gestational leukocytosis aligns with enhanced immune activity needed to safeguard maternal and fetal health, paralleling findings by Shittu *et al*. (2023) and Chen *et al*. (2022), but contrasting with Rahaman *et al*. (2019) in Qatari goats. Differential leukocyte counts showed relatively stable lymphocyte percentages (~50%) across groups, in line with Shittu *et al*. (2014). Neutrophil percentages were slightly elevated compared to previous reports, averaging 41.9% ± 8.5% in juveniles and 44.5% ± 7.6% in nursing and pregnant goats. Monocyte and eosinophil levels were also modestly higher, possibly reflecting life stage-associated immune modulation.

Biochemical Findings

Serum biochemical analysis revealed significant life-stage-dependent variations. Total protein (TP) was highest in pregnant goats (8.1 g/dL), suggesting increased protein synthesis demands during gestation, contrasting Sandabe *et al*. (2004a) but aligning with Rahaman *et al*. (2019). Albumin levels followed a similar pattern, peaking in pregnant goats, reflecting enhanced protein needs. Liver enzyme levels (AST and ALP) increased moderately with pregnancy, consistent with the findings of Rahaman *et al*. (2019) but contrary to Sandabe *et al*. (2004a), who reported stability across reproductive states. Blood urea nitrogen (BUN) levels were highest in pregnant goats (26.2 mg/dL), reflecting increased metabolic demands. Creatinine levels remained relatively stable across groups, in agreement with Gomez-Pérez *et al*. (2015). Glucose levels were slightly higher in juveniles (90.2 mg/dL), differing from Sandabe *et al*. (2004b), who observed reduced glucose in pregnant does, again pointing to dietary and environmental factors.

Comparative Analysis with Previous Studies

Recent studies support the stage-dependent shifts observed. Habibu *et al*. (2017) reported a 20% rise in PCV during late gestation in tropical goats, similar to our findings. Mbassa and Poulsen (1991a, 1991b) documented parity- and season-dependent changes in RBC indices and plasma proteins, emphasizing the influence of external factors. Sandabe *et al*. (2004b) observed minimal biochemical changes in Sahel goats under semi-arid conditions, unlike the pronounced liver enzyme changes in our intensive-reared cohort. Raji *et al*. (2019) and Chen *et al*. (2022) also reported gestational leukocytosis and elevated neutrophils, in line with our results. Conversely, Li *et al*. (2020) found no significant ALP changes between pregnant and non-pregnant goats in a temperate setting, contrasting our observations and highlighting breed and environment interactions.

Stage-Specific Physiological Shifts

Our cohort-specific design—comparing juveniles, nursing, and pregnant goats under identical management—revealed physiological trends often masked in cross-sectional studies. Shittu *et al*. (2023) reported mean PCV and Hb values that fell between our juvenile and pregnant cohorts, suggesting unrecognized physiological shifts when cohorts are not separated. Similarly, Muayad *et al*. (2018) reported overall RBC counts without stratifying by physiological status, obscuring critical early-life anemia risks.

Establishment of Cohort-Specific Reference Intervals

Maintaining uniform management conditions allowed the isolation of physiological status as the primary driver of variations. This revealed, for example, that WBC counts more than doubled from juvenile to pregnant goats. Likewise, liver enzyme and renal markers showed stage-specific peaks. Our findings underscore the need for life-stage-specific reference intervals for WAD goats, enhancing diagnostic precision and avoiding misinterpretation based on pooled adult values. The establishment of stage-specific baselines enables more accurate health monitoring in WAD goats. Veterinarians and herd managers can better interpret laboratory results by considering the animal's physiological status, improving disease detection and management strategies, and optimizing nutritional and breeding programs to support each life stage.

Preliminary Observations

Based solely on the parameters measured and the statistically significant differences detected, our findings can be summarized as follows:

Packed Cell Volume and Hemoglobin: Pregnant does exhibited markedly higher PCV (33.8% ± 4.2) and Hb (12.1 g/dL ± 1.2) compared to juveniles (PCV 22.0% ± 3.5; Hb 7.3 g/dL ± 1.1) and nursing does (PCV 21.9% ± 4.4; Hb 6.7 g/dL ± 1.4) ($p < 0.01$). These stage-dependent elevations reflect increased oxygen transport demands.

White Blood Cells: A significant leukocytosis in pregnancy (13.2×10^9/L ± 2.5) versus juveniles (8.5×10^9/L ± 1.5) and nursing (9.8×10^9/L ± 1.8) underscores an amplified immune adaptation during gestation ($p < 0.01$).

Biochemical Parameters: Total protein, albumin, and globulin levels rose progressively from juveniles to pregnant does ($p < 0.05$), indicating increased protein synthesis. Liver enzymes (AST, ALP) and BUN also peaked in pregnant animals ($p < 0.05$), denoting heightened metabolic and renal workload.

Conclusion

This study provides compelling evidence that physiological status—juvenile, nursing, or pregnant—profoundly influences hematological and serum biochemical profiles in West African Dwarf (WAD) goats. By controlling for management and dietary factors, we demonstrated clear stage-dependent shifts in parameters such as PCV, Hb, WBC, liver enzymes, and renal markers. Our findings underscore the inadequacy of using generalized adult reference intervals for clinical interpretation and highlight the critical need for stage-specific diagnostic thresholds. These cohort-specific baselines offer veterinarians and herd managers more precise tools for monitoring health, diagnosing disease, and managing nutrition and reproduction in WAD goats. Moreover, the documented physiological adaptations during pregnancy, nursing, and growth stages emphasize the dynamic nature of the goat's internal environment in response to metabolic demands. Future research should expand on these findings across different breeds, regions, and production systems to develop comprehensive, physiologically stratified reference standards for small ruminants.

Limitations

This study is constrained by several factors. First, the small cohort size (n = 5 per group) limits the generalizability of our findings; larger samples are needed to refine and validate these preliminary observations. Second, all data were collected during a single dry season; seasonal variations in forage quality and physiological responses may influence hematological and biochemical parameters. Third, under identical intensive-management conditions at a single site, environmental and dietary uniformity may not reflect broader field settings. Consequently, multi-center studies spanning diverse regions and management systems are warranted to establish robust, stage-specific baselines for WAD goats.

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Conflict of Interest

The authors have no conflict of interest to declare.

Authors Contribution

Conceptualization; OSO, AKO Methodology; AAU, OSO Software; Validation; AA, AKO Formal analysis; OSO, AAU Investigation; AKO, AA Resources; AA, BS Data Curation; OSO, AAU Writing - Original Draft; OSO Writing - Review and Editing; AKO, AA Visualization; Supervision; AKO, AA Project Administration; AAU, BS and Funding Acquisition: not applicable

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