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# Haematological and serum biochemical alterations associated with peste des petits ruminants virus infection in West African Dwarf goats in Ondo State, Nigeria

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# Abstract

Peste des petits ruminants (PPR) remains an important constraint to small-ruminant production in Nigeria. This study evaluated haematological and serum biochemical alterations associated with naturally occurring PPR virus (PPRV) infection in West African Dwarf (WAD) goats in Ondo State, Nigeria. A comparative clinical study was conducted from February to May 2026 at the Veterinary Hospital, Ondo City. Seventy-four WAD goats comprising 59 PPRV-infected animals and 15 clinically healthy controls were evaluated. Case classification used compatible clinical criteria, exclusion of gastrointestinal parasites, haemoparasites and relevant concurrent infections, rapid antigen detection with ID Rapid® PPR Antigen, and N-gene-targeted molecular confirmation. Infected goats had significantly lower packed cell volume (22.6 ± 0.7 vs 30.2 ± 0.8%), haemoglobin (7.2 ± 0.2 vs 10.1 ± 0.3 g/dL), red blood cell count (8.1 ± 0.3 vs 11.4 ± 0.4 $\times 10^6$/μL) and total white blood cell count (8.4 ± 0.5 vs 13.8 ± 0.6 $\times 10^3$/μL) than controls ($P < 0.001$). Lymphocyte percentage was reduced, whereas neutrophil, monocyte and eosinophil percentages were increased. Total protein, albumin, globulin, glucose and cholesterol were lower in infected goats, while urea and creatinine were higher. These findings demonstrate substantial erythrocytic, leukocytic and metabolic disturbances associated with clinical PPRV infection. Haematological and serum biochemical profiling can complement clinical and virological assessment of affected goats but should not be used as a stand-alone diagnostic tool.


# Introduction

Peste des petits ruminants (PPR) is a highly contagious transboundary viral disease that primarily affects sheep and goats. It is caused by small ruminant morbillivirus, commonly referred to as PPR virus (PPRV), and is characterised by fever, depression, oculonasal discharge, erosive oral lesions, diarrhoea and pneumonia. The disease remains a major animal-health and livelihood problem across Africa and Asia, particularly where small ruminants are central to household food security and income (Ahaduzzaman 2020; Dundon et al. 2020; Fayyad and Alzuheir 2024). PPR remains a priority disease for global control and eradication (Njeumi et al. 2020).

Nigeria remains endemic for PPR. A systematic review identified evidence of PPRV infection across most regions represented in the Nigerian literature and demonstrated substantial heterogeneity in seroprevalence, diagnostic approaches and circulating viral lineages (Esonu et al. 2022). Molecular investigations have likewise confirmed continued PPRV circulation and genetic diversity in Nigeria (Mantip et al. 2022). These findings support the need for sustained laboratory-supported surveillance and locally relevant clinical data.

Accurate case classification is important because the clinical presentation of PPR overlaps with gastrointestinal parasitism, haemoparasitic disease and other endemic infections. Diagnostic strategies therefore combine clinical assessment with antigen- or nucleic-acid-based confirmation. Rapid antigen tests provide a practical pen-side option, while RT-PCR and real-time RT-qPCR provide sensitive laboratory confirmation (Kinimi et al. 2020; Halecker et al., 2020).

PPRV is lymphotropic and epitheliotropic, and systemic infection can be accompanied by leucopenia, lymphopenia, immunosuppression and metabolic disturbances. Experimental work has shown that haematological and serum biochemical changes evolve during infection and may reflect inflammation, anorexia, diarrhoea, dehydration and altered metabolism (Begum et al. 2021). Nigerian studies have also documented haematological and biochemical changes in PPR-affected goats (Olaleye et al. 1989; Balogun et al. 2017; Ugochukwu et al. 2018; Chukwudi et al. 2023; Olaogun et al. 2025).

The present study contributes a recent, location-specific evaluation of naturally infected WAD goats in Ondo State using a multi-tiered diagnostic approach designed to reduce important infectious and parasitic confounding. The objective was to compare selected haematological, differential leukocyte, and serum biochemical parameters between confirmed PPRV-infected WAD goats and clinically healthy controls.

## Materials and methods

# Study area, period and design

The study was conducted between February and May 2026 at the Veterinary Hospital, Ondo City, Ondo State, southwestern Nigeria. The hospital receives small-ruminant cases from Ondo City and surrounding livestock-producing communities. A comparative clinical design was used to evaluate naturally occurring PPRV infection in WAD goats relative to clinically healthy controls.

# Ethical approval

Ethical approval was obtained from the Ondo State Department of Veterinary Services Ethical Approval Committee (Protocol No. MNR/V.381/92). Animals were handled humanely, and sampling was performed using standard veterinary procedures designed to minimise avoidable pain and distress.

# Study animals and diagnostic classification

Seventy-four WAD goats of mixed sex, approximately 12–24 months of age, were included. Fifty-nine goats constituted the PPRV-infected group, and 15 clinically healthy animals served as controls. Suspected cases were required to show clinical findings compatible with PPR, including combinations of pyrexia, depression, oculonasal discharge, oral erosions or stomatitis, diarrhoea and/or respiratory signs. Gastrointestinal parasitism, haemoparasitic infection and other clinically relevant concurrent endemic infections were specifically excluded using the clinical and laboratory procedures applied during case evaluation. Animals in which an important alternative or concurrent condition capable of materially altering haematological or biochemical values was identified were excluded.

# Rapid antigen detection

PPRV antigen screening was performed on-site using the ID Rapid® PPR Antigen lateral-flow test (Innovative Diagnostics, France). Ocular and/or nasal swabs were collected from clinically suspected goats and processed according to the manufacturer's instructions. Rapid antigen testing was interpreted together with the clinical case definition and was followed by molecular confirmation. The field utility and limitations of rapid PPR antigen tests relative to molecular detection have been described by Halecker *et al*. (2020).

# Molecular confirmation

Ocular or nasal swabs were used for molecular confirmation. Viral RNA was extracted using a commercial viral RNA extraction system according to the manufacturer's instructions. A one-step real-time reverse-transcription quantitative PCR (RT-qPCR) targeting a conserved region of the PPRV nucleocapsid (N) gene was performed. The 25-µL reaction contained 12.5 µL of 2× RT-PCR master mix, 0.5 µL each of forward primer, reverse primer and hydrolysis probe (10 µM), 0.5 µL enzyme mix, 5 µL RNA template and nuclease-free water to 25 µL. Reverse transcription was performed at 50 °C for 30 min, followed by initial denaturation at 95 °C for 15 min and 40 cycles of 94 °C for 15 s and 60 °C for 60 s, with fluorescence acquisition during annealing/extension. A cycle-threshold (Ct) value ≤35 was interpreted as positive; Ct values of 36–40 were treated as weak-positive results requiring repeat confirmation, while absence of amplification was interpreted as negative. Real-time RT-PCR is an established confirmatory approach for PPRV diagnosis (Kinimi *et al*. 2020).

# Conventional N-gene RT-PCR reference method

For methodological distinction, the conventional N-gene RT-PCR described by Couacy-Hymann *et al*. (2002) uses NP3 (5'-GTCTCGGAAATCGCCTCACAGACT-3') and NP4 (5'-CCTCCTCCTGGTCCTCCAGAATCT-3') primers to generate an approximately 350-bp product. This conventional NP3/NP4 assay is distinct from the probe-based real-time RT-qPCR used for molecular confirmation in the present study.

# Blood collection and serum preparation

Blood was collected aseptically from the jugular vein. Approximately 2 mL was transferred into EDTA tubes for haematological analysis and approximately 5 mL into plain tubes for serum biochemistry. Plain-tube samples were allowed to clot and were centrifuged at 3,000 rpm for 15 min. Serum was transferred into clean labelled tubes and stored at −20 °C until analysis.

# Haematological analysis

Packed cell volume (PCV), haemoglobin concentration (Hb), red blood cell count (RBC), total white blood cell count (WBC), mean cell volume (MCV), mean cell haemoglobin (MCH) and mean cell haemoglobin concentration (MCHC) were determined using the automated veterinary haematology procedure used by the diagnostic laboratory. Thin blood films were prepared, air-dried, fixed and stained with Giemsa stain. At least 100 leukocytes were classified per smear, and lymphocytes, neutrophils, monocytes, eosinophils and basophils were expressed as percentages.

# Serum biochemical analysis

Serum total protein was determined by the Biuret method and albumin by the bromocresol green method; globulin was calculated as total protein minus albumin. Urea, creatinine, glucose and total cholesterol were measured using standard commercial colorimetric reagent systems and the semi-automated chemistry procedure used in the diagnostic laboratory.

# Statistical analysis

Data were analysed using IBM SPSS Statistics version 31.0.0 (IBM Corp., Armonk, NY, USA). Continuous variables were summarised as mean ± standard error of the mean (SEM). Distributional assumptions were assessed using the Shapiro–Wilk test. Mean values for infected and control goats were compared using independent-samples Student's t-tests. Statistical significance was set at $P < 0.05$.

## Results

PPRV-infected goats had significantly lower PCV, haemoglobin concentration, RBC count, and total WBC count than healthy controls ($P < 0.001$). MCHC was also lower in infected goats ($P = 0.018$), whereas MCV and MCH did not differ significantly (Table 1).

**Table 1 Haematological parameters of healthy and PPRV-infected West African Dwarf goats**

| Parameter | Healthy controls (n=15) | PPRV-infected (n=59) | P value |
|---|---|---|---|
| PCV (%) | 30.2 ± 0.8 | 22.6 ± 0.7 | <0.001 |
| Hb (g/dL) | 10.1 ± 0.3 | 7.2 ± 0.2 | <0.001 |
| RBC (×10⁶/μL) | 11.4 ± 0.4 | 8.1 ± 0.3 | <0.001 |
| WBC (×10³/μL) | 13.8 ± 0.6 | 8.4 ± 0.5 | <0.001 |
| MCV (fL) | 26.5 ± 0.8 | 27.9 ± 0.9 | 0.213 |
| MCH (pg) | 8.9 ± 0.3 | 8.7 ± 0.2 | 0.517 |
| MCHC (%) | 33.4 ± 0.4 | 31.8 ± 0.5 | 0.018 |

*Values are mean ± SEM.*

Lymphocyte percentage was markedly lower in infected goats, whereas neutrophil, monocyte and eosinophil percentages were significantly higher. Basophil percentage did not differ significantly (Table 2).

**Table 2 Differential leukocyte profile of healthy and PPRV-infected West African Dwarf goats**

| Parameter | Healthy controls (n=15) | PPRV-infected (n=59) | P value |
|---|---|---|---|
| Lymphocytes (%) | 66.2 ± 1.4 | 48.5 ± 1.7 | <0.001 |
| Neutrophils (%) | 31.8 ± 1.2 | 47.3 ± 1.5 | <0.001 |
| Monocytes (%) | 0.8 ± 0.1 | 1.8 ± 0.2 | 0.004 |
| Eosinophils (%) | 1.0 ± 0.2 | 1.9 ± 0.3 | 0.031 |
| Basophils (%) | 0.2 ± 0.1 | 0.5 ± 0.1 | 0.089 |

*Values are mean ± SEM.*

PPRV-infected goats had lower total protein, albumin, globulin, glucose and cholesterol concentrations than controls. Serum urea and creatinine concentrations were significantly higher in infected animals (Table 3).

**Table 3 Serum biochemical parameters of healthy and PPRV-infected West African Dwarf goats**

| Parameter | Healthy controls (n=15) | PPRV-infected (n=59) | P value |
|---|---|---|---|
| Total protein (g/dL) | 7.2 ± 0.2 | 5.9 ± 0.2 | <0.001 |
| Albumin (g/dL) | 3.6 ± 0.1 | 2.7 ± 0.1 | <0.001 |
| Globulin (g/dL) | 3.6 ± 0.1 | 3.2 ± 0.1 | 0.023 |
| Urea (mmol/L) | 2.8 ± 0.2 | 4.7 ± 0.3 | <0.001 |
| Creatinine (µmol/L) | 89.4 ± 4.8 | 123.7 ± 6.2 | <0.001 |
| Glucose (mmol/L) | 4.6 ± 0.2 | 3.5 ± 0.2 | 0.002 |
| Cholesterol (mmol/L) | 2.4 ± 0.1 | 1.8 ± 0.1 | 0.006 |

*Values are mean ± SEM.*

# Discussion

The present study demonstrates a coherent pattern of haematological and serum biochemical disturbance in naturally infected WAD goats with confirmed PPRV infection in Ondo State. The principal findings were anaemia, leucopenia and lymphopenia, accompanied by a higher relative neutrophil proportion, reduced circulating protein fractions and energy-related metabolites, and increased urea and creatinine. The diagnostic design is relevant because gastrointestinal parasites, haemoparasites and other clinically important concurrent infections were specifically excluded before animals were retained in the infected group.

The reductions in PCV, haemoglobin and RBC count indicate anaemia. Comparable erythrocytic disturbances have been reported in experimental and naturally occurring PPR in goats (Olaleye *et al*. 1989; Balogun *et al*. 2017; Ugochukwu *et al*. 2018; Begum *et al*. 2021). Olaogun *et al*. (2025) similarly demonstrated significant haematological differences between PPRV-infected and non-infected Nigerian goats. Differences in magnitude among studies may reflect disease stage, hydration, nutrition, host breed, viral strain, and case-selection criteria. Because MCV and MCH did not differ significantly in the present study, the anaemia should not be assigned a specific regenerative classification without reticulocyte or bone-marrow data.

The lower total WBC count and pronounced lymphopenia are biologically plausible in PPR because PPRV has a strong tropism for lymphoid tissues and can induce immune suppression. The leukocyte pattern may nevertheless vary with disease stage. Earlier Nigerian experimental work demonstrated temporal changes in leukocyte responses (Olaleye *et al*. 1989), while field outbreaks have not produced identical leukogram patterns (Balogun *et al*. 2017). The higher neutrophil, monocyte and eosinophil percentages should also be interpreted as relative values; part of the apparent increase may reflect the marked reduction in lymphocytes rather than a true increase in absolute cell numbers.

Total protein, albumin and globulin concentrations were significantly lower in infected goats. Hypoproteinaemia during clinical PPR may reflect reduced feed intake, intestinal protein loss associated with diarrhoea, inflammatory redistribution and altered hepatic protein synthesis. Similar biochemical disturbances have been documented in Nigerian PPR cases and experimental infection (Balogun *et al*. 2017; Ugochukwu *et al*. 2018; Begum *et al*. 2021; Chukwudi *et al*. 2023; Olaogun *et al*. 2025).

Serum urea and creatinine were higher in infected animals. These analytes are influenced by hydration, renal perfusion, renal clearance, dietary protein, and catabolic state. Severe diarrhoea, fever and reduced water intake can produce dehydration and prerenal azotaemia, while systemic disease can increase protein catabolism. The present findings are therefore better described as renal-function-associated biochemical disturbances than as definitive evidence of structural renal injury.

Glucose and cholesterol were significantly lower in infected goats. Reduced intake, impaired nutrient absorption, and increased metabolic demand during systemic infection may contribute to these changes. Sequential experimental work has demonstrated that biochemical alterations evolve during PPRV infection (Begum *et al*. 2021), while Nigerian outbreak studies have likewise identified clinically relevant metabolic disturbances (Balogun *et al*. 2017). These findings support the importance of fluid, energy, and nutritional assessment in severely affected goats.

The multi-tiered diagnostic approach strengthens the study. Clinical signs alone are insufficiently specific for definitive PPR diagnosis in endemic environments. Rapid antigen testing offers immediate field utility, whereas molecular assays provide more sensitive confirmation (Kinimi *et al*. 2020; Halecker *et al*. 2020). Molecular surveillance in Nigeria has demonstrated the usefulness of N-gene-based detection for confirming infection and characterising circulating virus (Esonu *et al*. 2022; Mantip *et al*. 2022).

The study has limitations. It was clinic-based, and infected and control groups were unequal in size. Its cross-sectional design does not establish the temporal sequence of changes. Differential leukocyte values were percentages rather than absolute counts. Although important parasitic and concurrent infections were excluded, unmeasured nutritional or subclinical factors may still have influenced some analytes. The haematological and biochemical abnormalities are not pathognomonic for PPR and cannot substitute for antigen or molecular confirmation.

## Concluding remarks

Confirmed PPRV infection in WAD goats in Ondo State was associated with anaemia, leucopenia, lymphopenia, a higher relative neutrophil proportion, hypoproteinaemia, increased urea and creatinine, and reduced glucose and cholesterol concentrations. Haematological and serum biochemical profiling can therefore complement clinical examination and virological diagnosis by helping to characterise systemic involvement and guide supportive management. Because the abnormalities are nonspecific, they should not be used as stand-alone diagnostic markers. Continued surveillance, rapid laboratory confirmation and effective vaccination remain essential for reducing the burden of PPR in Nigeria.

## Declarations

# Funding

The authors received no specific funding for this work.

# Data availability

The data supporting the findings of this study are available from the corresponding author on reasonable request, subject to applicable institutional requirements.

# Ethics approval

Ethical approval was obtained from the Ondo State Department of Veterinary Services Ethical Approval Committee (Protocol No. MNR/V.381/92).

# Competing interests

The authors declare no competing interests.

# Author contributions

All authors contributed to the study and approved the final manuscript.

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