Turkish Journal of Agriculture - Food Science and Technology, 13(7): 1737-1744, 2025
DOI: https://doi.org/10.24925/turjaf.v13i7.1737-1744.7519

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Influence of Dietary Black Pepper Meal Supplementation on the Haemato-Serological Profile of West African Dwarf Goats

Oluwatosin Bode Omotoso[1,a], Kehinde Oluwatomisin Ogundeyibi[1,b], Teniola Samuel Oso[1,c,*]

[1]*Federal University of Technology Akure, School of Agriculture and Agricultural Technology, Department of Animal Production and Health, PMB. 704, Akure, Nigeria.*
[*]*Corresponding author*

ARTICLE INFO

Research Article

Received : 30.01.2025
Accepted : 02.05.2025

Keywords:
Blood
Health
Immunity
Phytogenic additives
Supplement

ABSTRACT

Phytogenic feed additives, such as black pepper meal (BPM), show promise for improving animal health and productivity. However, its application in ruminant nutrition remains underexplored. Thus, a 56-day study was conducted to assess the effect of BPM supplementation on nutrient intake, haematological, and serum biochemical indices in West African Dwarf (WAD) goats. A basal diet was formulated and divided into four equal portions. Each portion was supplemented with BPM at 0 (control), 250, 500, and 750 mg and designated as Diet A, B, C and D, respectively. Twenty WAD goats (average liveweight 5.00±0.23 kg) were assigned to the four dietary treatments. Blood samples were collected for haematological while serum harvested were used for serum biochemical analyses. Dietary DM, CP and NFE slightly decreased with increased BPM supplementation. DM intake significantly increased from 312.28±12.09 g/day (Diet A) to 316.88±14.74 g/day (Diet D) ($p<0.05$). Crude protein and fiber intake increased slightly. It is noteworthy that supplementation of BPM did not significantly influence the observed haematological parameters ($p>0.05$). Serum biochemical indices did not follow a particular trend. However, goats fed Diet B had significantly higher total protein (72.00±4.83 g/L) and globulin (34.00±3.09 g/L) compared to other treatments ($p<0.05$). The study revealed that use of BPM supplementation in goats' diets may not be essential, however, supplementation up to 750 mg/100 kg (Diet D) may support intake and thus, enhance immune functions, positioning BPM as additive to improve animal' health without adverse effect.

[a] obomotoso@futa.edu.ng https://orcid.org/0000-0002-6181-0467
[b] kentom762@gmail.com https://orcid.org/0009-0006-7461-0882
[c] osoaph146840@futa.edu.ng https://orcid.org/0000-0002-7255-979X

Introduction

Poor health condition is incontestably one of the major challenges militating small ruminant production in the humid tropics of West Africa (Oppong et al., 1988, Eke et al., 2019). Although indigenous breeds of these animals are said to be disease tolerant or poses some resistance traits against some endemic diseases (Jesuyon et al., 2023), albeit nutritional deficiencies and suboptimal feeding practices often compromise their immune systems, increasing their susceptibility to infections, hence reducing their overall productivity (Arilekolasi et al., 2020).

However, haemato-serological profiling has emerged as a reliable diagnostic tool for evaluating the health status of animals and assessing the effects of dietary interventions through the analysis of various blood components (Bermúdez et al., 2020). Key haematological parameters, such as red and white blood cell counts, haemoglobin concentration, and serum biochemical indices—including total protein, albumin, globulin, alanine aminotransferase, alkaline phosphatase, serum glutamic oxaloacetate transaminase, serum electrolytes, glucose, and cholesterol profiling could provide valuable insights into the functionality of organs, health status and physiological well-being of animals. As opined by Omotoso et al. (2019), the quality and quantity of nutrients play a crucial role in animals' health. Therefore, it is essential to ensure adequate provision of nutrients in diets, either through balanced formulations or supplementation with additives when necessary. This approach ensures that nutrients are readily available to support optimal blood production and functions, address potential health challenges, and enhance the overall performance of small ruminants (Omotoso et al., 2019; Alade et al., 2023).

The use of feed additives has emerged as an effective nutritional strategy to enhance livestock health and productivity. Among these, black pepper (*Piper nigrum*), its unique piperine content distinguish it from other spices and remains relatively under-explored in small ruminant nutrition. Studies by Abou-Elkhair et al. (2014) reported the positive impact of black pepper supplementation in broiler diets, it was found to enhance immune function by increasing serum globulin concentrations, a key marker of immune health. Similarly, it was found to reduce low density lipoproteins (LDL) cholesterol, triglycerides, and total cholesterol while mitigating oxidative stress, leading to improved cardiovascular health (Puvača et al., 2014). These could be linked to its richness in bioactive compounds, including piperine (2.1–8.9%), oleoresin (2.31–12%), essential oils (0.4–6.9%), and fatty acids (1.8–15%) (Garg, 2023). In addition, this spice (black pepper) is a nutrient-dense spice, with 10.4 g of protein, 251 kcal of energy, 64 g of carbohydrates, 26.5 g crude fiber, 4.49 g ash, and 3.26 g fat per 100 g on dry matter basis. It is also a rich source of minerals, including magnesium, copper, iron, calcium, phosphorus, potassium, selenium, and zinc, along with vitamins such as Vitamin C, E, D, (USDA, 2009). Its distinctive piperine content contributes to its strong antioxidative, antibacterial and anti-inflammatory properties while promoting good cholesterol in animals.

Thus, leveraging on BPM as a feed additive, the health status and growth of WAD goats could be significantly improved, translating into increase productivity helping to meet the growing demand for animal protein so to attain food security, particularly in developing African nations like Nigeria. Therefore, this study seeks to investigate and provides compelling information on the effects of dietary black pepper meal supplementation on nutrient intake and haemato-serological parameters in WAD goats.

Materials and Methods

Description of the Experimental Site

The experiment was carried out at the Small Ruminant Unit of the Teaching and Research Farm of the Department of Animal Production and Health, Federal University of Technology, Akure (FUTA), Ondo State, Nigeria. Laboratory analyses was done at the Nutrition Laboratory of the same Department and University. The University lies between longitude 4.94°E and 5.83°E and latitude 7.49°N and 6.96°N. This area is characterized by 6-7 months of annual rainfall between 1300 and 1650 mm and daily temperature ranges between 27 and 38°C (Daniel, 2015).

Sourcing of Feed Ingredients, Preparation and Formulation of Experimental Diets

Dried black pepper seeds were procured from local market in Akure, Ondo State which was further cleaned to remove dirt and stones, then air-dried before being milled into a fine powder to make black pepper meal (BPM). Dried cassava peels (energy and fibre source), crop residue from cassava (*Manihot esculenta*) and other conventional feed ingredients—including wheat offal, palm kernel cake, urea, bone meal, salt, and premix—were sourced from a reputable feed store in Akure. A basal diet (Table 1) was formulated, with all ingredients thoroughly mixed, then sub divided into four (4) portions where BPM was then supplemented in the diets at 0 mg, 250 mg, 500 mg, and 750 mg per 100 kg of the basal diet (mash form), thus designated as Diets A, B, C, and D, respectively.

Table 1. Gross Composition of Basal Diet Fed to West African Dwarf Goats

Ingredients	Quantity (kg)
Cassava peel meal	53.20
Wheat offal	22.00
Palm kernel cake	20.80
Urea	1.00
Bone meal	1.00
Salt	1.00
Premix	1.00
Total	100.00

Experimental Animal Management, Experimental Design and Ethical Approval

Twenty (20) West African Dwarf (WAD) goat-does, age range 6 – 12 months old, of multiple birth, with an average live weight of 5±0.23 kg was selected from the flock of goats available on the farm. Before the onset of this study, the goats were prophylactically treated and vaccinated against endemic diseases, as well as ectoparasites and endoparasites.

Thereafter, the goats were weighed, balanced for weight and randomly assigned to the dietary treatments (Diet A, B, C and D), with five (5) kids per treatment, following a Completely Randomized Design (CRD) arrangement. Each goat was housed individually in a pen with the dimension 1.8 x 1.2 meter in width and length. The goats were fed 5% of their bodyweight and increased feed given periodical as weight changes. Feeds were offered in wooden feeding troughs attached to each pen. The goats were given free access to fresh and potable drinking water while all other operations were carried out in accordance with animal research ethical guidelines as presented by Gross and Tolba (2015).

Feed intake by each goat was calculated by deducting leftover feed from feed offered while average daily feed intake was calculated as average feed intake by each animal over the experimental period. Nutrient intake per each goat was calculated as follows:

Nutrient intake (g/day) = $A \times B$

A: Av.feed intake per goat (g/day)
B: nutrient composition (%)

The study lasted 56-days and was carried out in compliance with the Research Ethical Committee guidelines of the Department of Animal Production and Health, Federal University of Technology Akure, Ondo State, Nigeria. The Ethical Approval Number given was FUTA/APH/PG/EA/23/07.

Chemical Analysis

Sub-samples of the experimental diets were bulked together and analyzed for chemical composition according to AOAC (2011) procedures. Fibre fractions (neutral detergent fibre, acid detergent fibre and lignin) were determined by the procedure described by Van Soest et al. (1991).

Blood Collection and Analysis

At the end of the 56-day feeding trial, 10 mL of blood sample were collected through the jugular vein from each (20 goats in total) experimental goats with subsamples of 5 mL placed into a well- labeled sample bottles containing Ethylene

Diamine Tetraacetic Acid (EDTA), an anticoagulant for haematological analysis while the other 5 mL were place in plain test tube used for serological analysis.

Haematological parameters such as red blood cell (RBC) count, white blood cell (WBC) count, packed cell volume (PCV), haemoglobin (Hb) and differential count were analyzed using the method of Dacie and Lewis (1991), while the serum biochemistry analyses such as serum total protein, serum albumin, globulin, alkaline phosphatase (ALP), alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were carried out using the method described by Reitman and Frankel (1957).

Statistical Analysis

Completely randomized design with the following model: Yij = μ + ai + eij was used. Where Yij – any of the response variables; μ – the overall mean; ai – effect of the black pepper meal, ith treatment (i = supplementation levels of black pepper meal - dietary treatment A, B, C, and D); eij – random error due to experimentation. Data generated were statistically analyzed using one-way analysis of variance (ANOVA) using SPSS version 26.0. The differences between treatment means were examined by Duncan multiple range test of the same package was used to separate the means and significance level was set at 95% confidence interval.

Results

Proximate composition of diets supplemented with black pepper meal fed to West African Dwarf goats

Table 2 presents the chemical composition of diets supplemented with black pepper meal (BPM) for West African Dwarf goats. The dry matter (DM) and crude protein (CP) were highest in Diet A (89.38±9.61 g/kg and 16.27±3.09 g/kg, respectively) but gradually decreased to 88.28±10.02 g/kg and 16.20±3.10 g/kg in Diet D. On the other hand, the crude fiber (CF), ash, and ether extract (EE) content increased with increased BPM supplementation, ranging from 25.54±3.53 g/kg to 26.36±3.28 g/kg, 6.03±0.98 g/kg to 6.29±0.77 g/kg, and 14.43±1.37 g/kg to 14.47±1.40 g/kg, respectively. The nitrogen-free extract (NFE) ranged from 37.23±5.23 g/kg to 37.73±5.56 g/kg, decreasing as BPM supplementation increased. In contrast, the neutral detergent fiber (NDF) increased from 58.39±6.90 g/kg to 60.07±7.34 g/kg, with acid detergent fiber (ADF) and acid detergent lignin (ADL) also showing increases, ranging from 38.24±2.39 g/kg to 39.58±2.48 g/kg for ADF and 31.21±2.18 g/kg to 31.81±2.23 g/kg for ADL.

Nutrient intake by West African Dwarf goats fed diets supplemented with black pepper meal

The nutrient intake of WAD goats fed diets supplemented with black pepper meal is shown in Table 3. Crude fiber intake, ash and ether extract intake increased with BPM supplementation, ranging from 79.76±3.09 g/day, 18.83±2.89 g/day and 45.06±5.00 g/day in goats placed on Diet A to 81.79±4.09 g/day, 19.93±3.67 g/day and 45.85±5.14 g/day respectively in those fed Diet D. Conversely, nitrogen-free extract (NFE) intakes decreased as BPM levels increased. The values ranged from 112.84±7.33 to 114.64±9.29 g/day ($p>0.05$). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and Acid detergent lignin (ADL) intakes increased with BPM supplementation, with NDF intake ranging from 182.34±13.64 to 190.35±12.85 g/day, 119.42±10.47 to 125.42±10.85 g/day and 97.46±6.32 g/day to 100.77±7.09 g/day from goats fed diet A to D respectively ($p<0.05$).

Haematological profile of West African Dwarf goats fed diets supplemented with black pepper meal

Table 4 presents the haematological indices of West African Dwarf goats fed diets supplemented with BPM. All parameters were not significantly influenced by the supplementation of BPM ($p>0.05$).

The packed cell volume (PCV) showed its highest value (31.67±3.34%) in goats fed Diet C, while goats fed other diets had similar values of 31.00%. The red blood cell (RBC) count ranged from 9.27±0.62% in Diet B to 9.67±0.67% in goats fed Diet A. The white blood cell (WBC) count numerically differs though not significantly influenced as values ranged from 12.30±1.21 × 10^3μl in goats fed Diet A to 13.02±1.37 × 10^3/μl in goats fed Diet D ($p>0.05$). Haemoglobin concentration (Hb) was highest in goats fed Diet A (11.73±1.09 g/dL) and lowest in goats fed Diet C (10.17±1.17 g/dL). Neutrophil and lymphocyte counts were numerically influenced as supplementation of BPM increased. The highest values (47.00±3.72% and 54.00±3.89%) were recorded in goats fed Diet D and lowest in Diet A (45.00±4.02% and 50.00±3.89%). The eosinophil count increased from 2.04±0.03% in goats fed Diet A to 2.33±0.11% in goats fed Diet C.

Table 2. Proximate and fibre fraction composition of diets supplemented with black pepper meal fed to West African Dwarf goats

Parameters (g/kg)	A	B	C	D	P-value
Dry matter	89.38±9.61	89.16±9.69	89.02±9.32	88.28±10.02	0.38
Crude protein	16.27±3.09	16.24±3.00	16.21±2.78	16.20±3.10	0.07
Crude fibre	25.54±3.53^{b}	25.62±3.30^{b}	26.24±3.09^{a}	26.36±3.28^{a}	0.01
Ash	6.03±0.98	6.09±0.67	6.14±0.76	6.29±0.77	0.13
Ether Extract	14.43±1.37	14.43±1.27	14.45±1.32	14.47±1.40	0.20
Nitrogen free extract	37.73±5.56^{a}	37.60±5.34^{a}	37.49±5.11^{ab}	37.23±5.23^{b}	0.03
Neutral detergent fibre	58.39±6.90^{b}	58.67±6.72^{ab}	59.22±7.02^{a}	60.07±7.34^{a}	0.01
Acid detergent fibre	38.24±2.39	38.49±2.48	38.91±2.57	39.58±2.48	0.07
Acid detergent lignin	31.21±2.18	31.34±2.09	31.28±2.19	31.81±2.23	0.09

n=5 values are presented as mean±SEM. ^{a,b,c,d}: means within the same row with different superscripts are significantly ($p<0.05$) different SEM: Standard Error of Mean. A: 100kg Basal diet + 0mg BPM, B: 100kg Basal diet + 250mg BPM, C: 100kg Basal diet + 500mg BPM, D: 100kg Basal diet + 750mg BPM

Table 3. Nutrient intake by growing West African Dwarf goats fed diets supplemented with black pepper meal

Parameters (g/day)	A	B	C	D	P-value
Dry matter	312.28±12.09^{ab}	313.58±11.23^{ab}	315.47±13.28^{a}	316.88±14.74^{a}	0.03
Crude protein	50.81±2.01	50.93±2.35	51.14±2.51	51.33±2.78	0.76
Crude fibre	79.76±3.09 ^{cd}	80.34±4.25 ^{c}	81.08±3.87 ^{b}	81.79±4.09 ^{a}	0.04
Ash	18.83±2.89^{b}	19.10±2.42^{ab}	19.37±2.52 ^{ab}	19.93±3.67 ^{a}	0.05
Ether Extract	45.06±5.00	45.31±5.05	45.59±4.89	45.85±5.14	0.23
NFE	114.64±9.29	114.08±9.10	113.51±7.55	112.84±7.33	0.27
NDF	182.34±13.64 ^{c}	183.98±13.00^{c}	186.82±12.58 ^{ab}	190.35±12.85 ^{a}	0.01
ADF	119.42±10.47^{c}	120.70±10.29^{c}	122.75±9.07 ^{b}	125.42±10.85 ^{a}	0.04
ADL	97.46±76.32^{c}	98.28±6.21 ^{b}	98.68±6.02^{b}	100.77±7.09 ^{a}	0.01

n=5 values are presented as mean±SEM. ^{a,b,c,d}: means within the same row with different superscripts are significantly (p<0.05) different SEM: Standard Error of Mean. A: 100kg Basal diet + 0mg BPM, B: 100kg Basal diet + 250mg BPM, C: 100kg Basal diet + 500mg BPM, D: 100kg Basal diet + 750mg BPM, NFE - Nitrogen free extract, NDF - Neutral detergent fibre, ADF - Acid detergent fibre, ADL - Acid detergent lignin.

Table 4. Haematological profile of West African Dwarf goats fed diets supplemented with black pepper meal

Parameters	A	B	C	D	p-value	Reference value
PCV (%)	31.00±3.59	31.00±3.08	31.67±3.34	31.00±3.65	0.38	22.00 - 38.00
RBC (%)	9.67±0.67	9.27±0.62	9.33±0.59	9.30±0.78	0.34	8.00 – 12.00
WBC (x10^{3}µl)	12.30±1.21	13.00±1.31	13.00±1.21	13.02±1.37	0.06	4.00 – 13.00
Hb (g/dl)	11.73±1.09	10.63±1.29	10.17±1.17	10.83±0.99	0.19	8.00 – 12.00
Neutrophils (%)	45.00±4.02	46.67±4.09	46.67±3.89	47.00±3.72	0.48	30.00 – 48.00
Lymphocytes (%)	50.00±3.89	50.33±3.16	53.00±3.28	54.00±3.89	0.74	50.00 – 70.00
Monocytes (%)	1.67±0.21	1.33±0.17	1.00±0.23	1.07±0.20	0.56	0.00 – 4.00
Eosinophils (%)	2.04±0.03	2.06±0.05	2.33±0.11	2.07±0.20	0.50	1.00 – 8.00
MCV (fL)	23.38±1.64	24.85±1.44	24.91±1.39	24.92±2.23	0.75	16.00 – 25.00
MCH (pg)	7.98±0.73	7.58±0.68	7.47±0.65	7.85±0.67	0.68	5.20 – 8.00
MCHC (g/dL)	33.53±2.99	31.24±2.70	32.12±2.88	31.79±3.01	0.82	30.00 – 36.00

n=5 values are presented as mean±SEM. ^{a,b,c,d}: means within the same row with different superscripts are significantly (p<0.05) different SEM: Standard Error of Mean. A: 100kg Basal diet + 0mg BPM, B: 100kg Basal diet + 250mg BPM, C: 100kg Basal diet + 500mg BPM, D: 100kg Basal diet + 750mg BPM, PCV - Packed Cell Volume, RBC - Red Blood Cell, WBC - White Blood Cell, Hb – Haemoglobin, MCV - Mean Cell Volume, MCH - Mean Cell Haemoglobin, MCHC - Mean Cell Haemoglobin Concentration. Reference value source: MSD Veterinary Manual (2022a).

Table 5. Serum biochemical profile of West African Dwarf goats fed diets supplemented with black pepper meal

Parameters (g/l)	A	B	C	D	p value	Ref. value
TP	70.00±4.59^{a}	72.00±4.83^{a}	65.00±4.74^{b}	68.00±4.78^{ab}	0.03	64 - 70
Albumin	40.00±3.67^{a}	38.00±3.24^{b}	35.00±3.09^{c}	36.00±3.45^{bc}	0.04	27 –39
Globulin	30.00±3.22^{b}	34.00±3.09^{a}	30.00±3.46^{b}	32.00±3.32^{ab}	0.04	27 – 41
Alb. : Glo.	1.33±0.07	1.12±0.05	1.17±0.07	1.13±0.07	0.18	NA
AST (U/L)	225.00±19.67	222.00±20.29	220.00±20.77	223.00±21.02	0.98	167 – 513
ALP (U/L)	245.00±25.66^{c}	250.00±24.09^{b}	255.00±23.56^{a}	248.00±23.94^{bc}	0.01	93 – 387
ALT (U/L)	50.00±5.50^{c}	55.00±5.45^{b}	58.00±6.02^{a}	53.00±5.43^{bc}	0.01	45 – 80
TB (g/dl)	0.80±0.07	0.70±0.03	1.10±0.08	0.90±0.03	0.11	NA
DB (g/dl)	0.20±0.02	0.15±0.03	0.25±0.03	0.18±0.03	0.06	NA

n=5 values are presented as mean±SEM. ^{a,b,c,d}: means within the same row with different superscripts are significantly (p<0.05) different SEM: Standard Error of Mean. A: 100kg Basal diet + 0mg BPM, B: 100kg Basal diet + 250mg BPM, C: 100kg Basal diet + 500mg BPM, D: 100kg Basal diet + 750mg BPM, TP - Total protein, AST - Aspartate aminotransferase, ALP - Alkaline phosphatase, ALT - Alanine aminotransferase, TB - Total bilirubin, DB - Direct bilirubin, NA: Not Available, Reference value source: MSD Veterinary Manual (2022b).

Mean cell volume (MCV) gradually increased from 23.38±1.64 fL in goats fed Diet A to 24.92±2.23 fL in goats fed Diet D. Mean cell haemoglobin (MCH) and mean cell haemoglobin concentration (MCHC) were highest in goats fed Diet A (7.98±0.73 pg and 33.53±2.99 g/dL, respectively) and lowest in goats fed Diet B (7.47±0.65 pg and 31.24±2.70 g/dL) in goats fed diet B respectively.

Serum biochemical profile of West African Dwarf goats fed diets supplemented with black pepper meal

The serum biochemical indices of WAD goats fed diets supplemented with BPM are presented in Table 5. Total protein and globulin concentration were significantly different with the highest value (72.00±4.83 g/L and 34.00±3.09 g/L) from goats fed Diet B and lowest (65.00±4.74 g/L and 30.00±3.46 g/L) in goats fed Diet C (p<0.05). Albumin concentration was highest in goats fed Diet A (40.00±3.67 g/L) and lowest in those fed Diet C (35.00±3.09 g/L). The albumin-to-globulin ratio was highest in goats fed Diet A (1.33±0.07) and lowest (1.12±0.005) in those fed Diet B.

Alkaline phosphatase and Alanine aminotransferase levels were significantly different with the highest values in goats fed Diet C (255.00±23.56 U/L and 58.00±6.02 U/L respectively) and the lowest in goats fed Diet A (245.00±25.66 U/L and 50.00±5.50 U/L) respectively (P<0.05).

Discussion

Proximate and fibre fraction composition of diets supplemented with black pepper meal fed to West African Dwarf goats

Dry matter content is a pivotal aspect of ruminant nutrition, significantly affecting feed intake, shelf life, and overall feed quality. In this study, a reduction in dry matter content was observed with increasing supplementation of BPM, likely due to the inherent characteristics of the feed ingredients used. Despite this, the dry matter values were sufficient to inhibit microbial growth and promote a stable shelf life, as reported by Ibhaze et al. (2024).

The CP in the diets exceeded 8.00 g/kg recommended by the NRC (2007) for optimal rumen functionality. This indicates that the diets provided adequate protein to meet metabolic demands, support microbial proliferation, and sustain rumen activity (Omotoso et al., 2017).

On the other hand, crude fiber (CF) levels surpassed the 12 g/kg minimum requirement for goats on maintenance ratio (Mamoon, 2008). The increase in CF content revealed that BPM supplementation can enhance fiber composition in animal feed, thereby promoting rumination, salivation, and improved rumen ecology in ruminant animal (USDA, 2009; Abou-Elkhair et al., 2014). Ash content with higher BPM supplementation was also observed, was consistent with the report of USDA (2009) that black pepper is a rich source of mineral and has the capacity to improve the mineral profile of diet. Meanwhile, these minerals play critical roles in supporting physiological functions such as nerve coordination, blood synthesis, and bone development (Omotoso et al., 2017). However, there availability may be hindered by phenolic compounds like tannins in feed material which has not been full degraded or acted upon by rumen microbes or enzymes which in turn form an insoluble complex with these minerals.

Interestingly, EE levels in the diets were considerably high, similar to the report of Garg, (2023) who emphasized that BPM contain essential oils of about 0.4–6.9% and fatty acids 1.8–15% which could help improve EE value of feed. Similarly, Abou-Elkhair et al. (2014) reported that BPM may contain oil but not adequate to significantly improve oil content in diets possibly due to the naturally low oil content in it.

Additionally, NDF, ADF, and ADL fractions increased with BPM supplementation. According to Soltan and Patra (2021), these structural carbohydrates are vital for ruminants, as rumen microbes can degrade and ferment them into short-chain fatty acids (SCFAs), which are crucial for energy supply and microbial growth.

Nutrient intake by Growing West African Dwarf goats fed diets supplemented with black pepper meal

High dry matter intake as observed could be attributed to the high crude protein content, feed palatability and acceptability of the diets, which have been recognized as key factors that influences dry matter intake. High dry matter consumption supports rumen microbial activity by supplying the energy and acting as substrates for microbial growth and proliferation (Oso et al., 2024).

The increase in crude protein intake underscores its critical role in meeting the nitrogen demands of rumen microbes. Nitrogen is essential for microbial protein synthesis, a process that supports rumen functionality and facilitates the breakdown of fiber fractions into volatile fatty acids (VFAs)—the primary energy source. This finding aligns with earlier reports emphasizing the importance of crude protein for maintaining rumen health and optimizing nutrient utilization (Ibhaze and Fajemisin, 2015). The secretion of digestive enzymes, bile acids, and pancreatic juices could be attributed to the effect of piperine (bio-active ingredient in black pepper) in the diet. Thus, this in turn, enhance nutrient' digestion and absorption (Abou-Elkhair et al., 2014). Abdelnour (2018) further highlighted piperine's ability to improve feed efficiency by promoting faster gastrointestinal transit and better digestive efficiency. According to Srinivasan, (2016) piperine is largely susceptible to microbial degradation in the rumen, which in turn reduces its availability in ruminant animal system, making it less effective in eliciting its functions as compared to other livestock, such as monogastric animals. These benefits, coupled with its phytogenic properties, make BPM a valuable feed additive in ruminant diets, particularly for enhancing nutrient quality and intake in goats.

Haematological profile of West African Dwarf goats fed diets supplemented with black pepper meal

Examining haematological parameters is a reliable approach for detecting blood disorders and assessing the overall health status of animals (Omotoso et al., 2019). In this study, the packed cell volume (PCV) fell within the recommended range of 21–37% for healthy growing goats, as reported by Kalio et al. (2014) and 22 – 38% as reported by MSD Veterinary Manual (2022a). This parameter is often use as an indirect measure of red blood cell (RBC) count, anemia, and dietary protein quality (Omotoso et al., 2019). The fact that PCV levels in this study were within the normal range and not significantly different across dietary treatments suggests that the basal diet had adequate and high-quality protein to support blood production without BPM supplementation.

RBC were within the range of 8 – 12% as recommended by MSD Veterinary Manual (2022a) for healthy goat. This reduction may be attributed to the presence of phenolic compounds in the feed ingredients and BPM, as they are known to inhibit iron absorption by forming insoluble complexes, thereby reducing iron bioavailability in the bloodstream, as iron is a critical mineral required for haematopoiesis (Hurrell et al., 1999). Despite this, there were no clinical signs of anemia, suggesting that the diets contained tolerable levels of anti-nutrients such as phenolics hence no detrimental impact.

White blood cell (WBC) count often reflects the immune status of an animal. Values above reference range is an indication of stress, infection, trauma, toxicities, or immune activation, while low counts may suggest chronic inflammation or diminished bone marrow function (Clement et al., 2010). In this study, the obtained WBC count suggests no immunostimulatory effect rather than a pathological condition.

Haemoglobin concentration showed a slight decrease with increasing BPM supplementation but remained within the range of 8– 12 g/dL recommended for healthy goats (MSD Veterinary Manual. (2022a). This reduction aligns with the established fact that phenolic compounds inhibit iron absorption (Hurrell et al., 1999). Similar findings were reported by Galib et al. (2011), where dietary pepper supplementation reduced haemoglobin concentration in broiler birds. Consequently, goats on the basal diet (control diet) were found to exhibited improved levels of circulating erythrocytes and haemoglobin when compared to those on BPM-supplemented diets, pointing to the fact that BPM may contain a substance capable of reducing haemoglobin production.

BPM supplementation did not induce allergic reactions and the animals are not suffering from any bacterial/viral infections that could trigger cellular immune responses as white blood cell differential counts were within the range recommended for healthy goats. Clinical indicators of anemia, such as pale mucous membranes, weakness, lethargy, or reduced appetite (Ryan, 2010), were not observed during the feeding trial. Moreso, the feed intake of the animals increased with BPM supplementation, further supporting the nutritional adequacy of the diets and no incidence of pathological condition, as red blood cell indices (MCV, MCH and MCHC) values were normal for healthy goats.

Serum biochemical profile of West African Dwarf goats fed diets supplemented with black pepper meal

Serum biochemical analysis provides critical insights into the functionality of organs and tissues by assessing serum proteins, enzymes, lipids, and hormones (Herdt and Hoff, 2011). Serum proteins, primarily synthesized in the liver, play essential roles in maintaining blood volume, buffering blood pH, transporting hormones and drugs, facilitating coagulation, regulating metabolic and biochemical reactions, and supporting immune defenses (Melillo, 2013, Ayeni et al., 20024). In this study, total protein levels in the experimental goats were influenced by BPM supplementation, though the values observed, ranging within the normal range of 64–70 g/L (MSD Veterinary Manual (2022b), but do not follow a fixed pattern.

Albumin, a key protein involved in molecule transport and maintaining oncotic pressure, also contributes to blood clotting during injury, reducing blood loss (Rezende et al., 2017). Albumin levels in this study were consistent with the normal range of 27–39 g/L for healthy goats MSD Veterinary Manual (2022b). Globulin, another crucial protein supporting immune function, remained within the standard range of 27–41 g/L required for goats, ensuring adequate immune defense (MSD Veterinary Manual (2022b). Enzyme activity levels, such as AST and ALT, were also within normal physiological ranges. AST, an enzyme vital for amino acid metabolism and predominantly found in the liver and heart, and ALT, primarily used as a marker for liver health, was within the 167 - 513 U/L and 45 – 80 U/L as reported for healthy goat by MSD Veterinary Manual (2022b). The observed values for total bilirubin and direct bilirubin suggests BPM supplementation did not pose hepatic dysfunction or excessive haemolysis. Bilirubin levels serve as biomarkers for liver function and the breakdown of haemoglobin; elevated levels could indicate liver damage, bile duct obstruction, or haemolytic anemia. The balance between total and direct bilirubin also suggests efficient conjugation and excretion of bilirubin by the liver, further reinforcing the safety of BPM as a dietary additive.

Conclusion

This study demonstrated that supplementation of black pepper meal in goats' diet had no significant impact on the haematological profile of the experimental animals. However, the findings concludes that while routine supplementation of BPM may not be essential in goats' nutrition, supplementation up to 750 mg/100 kg (Diet D) could enhance improved nutrient intake and would not exert detrimental effect on the liver and or kidney as the serum biomarkers were within the normal range for healthy goats. However, further studies may be advised on the use of black pepper meal to assess its effect on meat quality and carcass characteristics.

Declarations

Funding

This research was self-funded.

Data Availability

All data generated or analyzed during this study are available upon request.

Conflict of Interest

The authors declared no conflict of interest regarding the research, authorship, or publication of this article.

Author Contributions

Conceptualization, supervision, investigation, and methodology were carried out by O. B. Omotoso. Investigation, data collection, analysis, and manuscript drafting were performed by K. O. Ogundeyibi and T. S. Oso.

References

Abdelnour, S., Alagawany, M., Abd El-Hack, M. E., Sheiha, A. M., Saadeldin, I. M., & Swelum, A. A. (2018). Growth, carcass traits, blood hematology, serum metabolites, immunity, and oxidative indices of growing rabbits fed diets supplemented with red or black pepper oils. *Animals*, 8(10), 168. https://doi.org/10.3390/ani8100168

Abou-Elkhair, R., Ahmed, H. A., & Selim, S. (2014). Effects of black pepper (*Piper nigrum*), turmeric powder (*Curcuma longa*) and coriander seeds (*Coriandrum sativum*) and their combinations as feed additives on growth performance, carcass traits, some blood parameters and humoral immune response of broiler chickens. *Asian-Australasian Journal of Animal Sciences*, *27*(6), 847. https://doi.org/10.5713/ajas.2013.13644

Alade, C. T., Ibhaze, G. A., Osho, T. S., & Fajemisin, A. N. (2023). Impact of roasting on nutritional composition of some underutilized tropical seeds in ruminant nutrition. In *Agricultural revolution for sustainable livelihood. (Edited) Dr. OM Akinnagbe and Dr. LO Oparinde. Proceedings of 11th Annual Conference of FUTA AGRIC CONFERENCE* (pp. 8-11).

AOAC (2011) Official methods of analysis of AOAC International. 18th edn, Revision 4, In: Horwitz W, Latimer GW Jr (eds) AOAC International. Gaithersburg, Maryland, USA.

Arilekolasi, T. A., Omotoso, O. B., Faluyi, O. B., Fajemisin, A. N., & Alokan, J. A. (2020). Dietary effect of with or without molasses in rice husk based-diet on performance and health status of goats. *Archiva Zootechnica*, *23*(1), 22-33. https://doi.org/10.2478/azibna-2020-0003

Ayeni, A., Oso, T., Olowoyeye, J., & Popoola, O. (2024). Performance characteristics, haematology and serological properties of broiler chickens fed diets supplemented with *Talinum triangulare*. *Slovak Journal of Animal Science*, *57*(3). https://doi.org/10.36547/sjas.894

Bermúdez, J. H., Castellote, J. L. B., & Rodríguez, C. C. (2020). Relevance of the study of metabolic profiles in sheep and goat flock. Present and future: A review. *Spanish Journal of Agricultural Research*, *18*(3), 12. https://doi.org/10.5424/sjar/2020183-14627

Clement, B. A., Goff, J. M., & Forbes, J. A. (2010). Blood biochemical profiles and health indicators in poultry systems. *Journal of Veterinary Medicine*, 60(2), 52- 59.

Dacie, J.V. & Lewis, S.M. (1991). Practical Textbook of Haematology. 7th Edition, Church Livingstone, Edinburgh, United Kingdom.

Daniel, O. A. (2015). Urban extreme weather: a challenge for a healthy Living environment in Akure, Ondo State, Nigeria. *Climate*, *3*(4), 775-791. https://doi.org/10.3390/cli3040775

Eke, S. S., Omalu, I. C. J., Ochaguba, J. E., Urama, A. C., Hassan, S. C., Otuu, C. A., & Okafor, I. D. (2019). Prevalence of gastrointestinal parasites of sheep and goats slaughtered in Minna Modern Abattoir, Niger State, Nigeria. *Journal of Animal Science and Veterinary Medicine*, *4*(2), 65-70. https://doi.org/10.31248/jasvm2019.131

Galib, M. A., Ahmed, M. H., & Haroon, M. R. (2011). Dietary hot red pepper and its effect on white blood cell count in broilers. *Journal of Poultry Science*, 3(2), 120-127.

Garg, A. P. (2023). Biomedical Applications of Black Pepper, the King of Spices-A Review. *Biomedical Journal of Scientific and Technical Research*, *53*(1), 44364-44371. https://doi.org/10.26717/bjstr.2023.53.008353

Gross, D., & Tolba, R. H. (2015). Ethics in animal-based research. *European Surgical Research*, *55*(1-2), 43-57. https://doi.org/10.1159/000377721

Herdt, T. H., & Hoff, B. (2011). The use of blood analysis to evaluate trace mineral status in ruminant livestock. *Veterinary Clinics: Food Animal Practice*, *27*(2), 255-283. https://doi.org/10.1016/j.cvfa.2011.02.004

Hurrell, R. F., Reddy, M., & Cook, J. D. (1999). Inhibition of non-haem iron absorption in man by polyphenolic-containing beverages. *British Journal of Nutrition*, *81*(4), 289-295. https://doi.org/10.1017/s0007114599000537

Ibhaze, G. A., & Fajemisin, A. N. (2015). Feed intake and nitrogen metabolism by West African Dwarf does fed naturally fermented maize cob-based diets. *World Journal of Animal Science Research*, 3(2), 1-8. https://doi.org/10.1186/s42269-021-00519-9

Ibhaze, G. A., Osilaja, T. O., Oso, T. S., Alade, C. T., & Ogunjemite, G. E. (2024). Nutrient, antinutrient intake, and digestibility of West African Dwarf does fed sole diet containing wheat offal substituted with tiger nut. *Annals of Animal and Biological Research, 4*(1).

Jesuyon, O. M., Boluwaji, O., Orunmuyi, M., Aganga, A. A., & Ogunjimi, S. I. (2023). Assessment of Management and Breeding Practices among Indigenous Goat Farmers in a Tropical Humid Forest Zone. In *Goat Science-Environment, Health and Economy*. IntechOpen. https://doi.org/10.5772/intechopen.99141

Kalio, G. A., Ayuk, A. A., & Agwunobi, L. N. (2014). Performance of West African Dwarf (WAD) goats fed N-treated source and forage supplemented cassava peels in humid Cross River State, Nigeria. *American Journal of Experimental Agriculture*, *4*(6), 629-638. https://doi.org/10.9734/ajea/2014/6972

Mamoon, R. (2008). *Goats and their nutrition*. Manitoba Agriculture, Food and Rural Initiatives: Management of Smallholder-Owned Sheep and Goats by Utilizing Local Resources. Proceedings of the Second DFID Livestock Production Programme Link Project (R7798) Workshop for Small Stock Keepers, Sokoine University of Agriculture, pp. 69-75.

Melillo, A. (2013). Serum proteins and their role in avian health. *Journal of Veterinary Research*, 44(4), 303-315.

NRC (2007). Nutrient Requirement of Small Ruminants. National Academies Press, Washington DC, USA.

Omotoso, O. B., Noah, F. A., & Adebayo, A. J. (2019). Nitrogen Metabolism, Digestibility and blood profile of West African dwarf goats fed dietary levels of *Cajanus cajan* as supplement to cassava peels. *Journal of Rangeland Science*, *9*(1), 13-23.

Omotoso, O. B., Ogunshola, O. J., Omoleye, S. O., & Alokan, J. A. (2017). Haematological and Serum Biochemical responses of West African Dwarf Goats Fed Panicum maximum replaced with untreated cocoa pod husk meal. *Animal Research International*, *14*(3), 2826-2835. http://www.zoo-unn.org/index.php/ARI/article/view/574/pdf

Opara, M.N., Udevi, N. & Okoli, I.C. (2010). Hematological parameters and blood chemistry of apparently-healthy West African Dwarf (WAD) goats in Owerri, South Eastern Nigeria. *New York Science Journal*, 3: 68-72.

Oppong, E. N. V., sTimon, V. M., & Baber, R. P. (1988). Health control for sheep and goats in the humid tropics of West Africa.

Oso, T. S., Alade, C. T., Ibhaze, G. A., & Faluyi, O. B. (2024). Nutrient digestibility, Nitrogen utilization, and growth performance of West African Dwarf (WAD) does fed diets containing wheat offal replaced with Tiger nut seed meal. *Archiva Zootechnica* 27(2), 137-154. https://doi.org/10.2478/azibna-2024-0019

Plumb, D.C. (2018). Plumb's Veterinary Drug Handbook: Pocket. 9th Edition, John Wiley and Sons, USA. https://books.google.com.ng/books?hl=en&lr=&id=vshQDwAAQBAJ&oi=fnd&pg=PA1&ots=0gSbgsX3E4&sig=bq5uvnbGiC-pgSM52Ir517OOXtU&redir_esc=y#v=onepage&q&f=false

Puvača, N., Ljubojević, D., Lukač, D., Kostadinović, L., Stanaćev, V., Popović, S., Baloš, M.Ž. & Nikolova, N. (2014). Digestibility of fat in broiler chickens influenced by dietary addition of spice herbs. *Macedonian Journal of Animal Science*, *4*(2). https://doi.org/10.54865/mjas1442061p

Reitman, S. & Frankel, S. (1957). A colorimetric method for the determination of serum glutamic oxalacetic and glutamic pyruvic transaminases. *American Journal of Clinical Pathology*, 28(1): 56 – 63. https://doi.org/10.1093/ajcp/28.1.56

Rezende, M. M., Lemos, F. S., & Dourado, L. R. (2017). Serum protein levels as indicators of dietary protein utilization in poultry. Journal of Animal Science, 95(8), 3699- 3709

Ryan, K., Bain, B. J., Worthington, D., James, J., Plews, D., Mason, A., Roper, D., Rees, D. C., De La Salle, B., & Streetly, A. (2010). Significant haemoglobinopathies: Guidelines for screening and diagnosis. *British Journal of Haematology, 149*(1), 35–49. https://doi.org/10.1111/j.1365-2141.2009.08054.x

Soltan, Y. A., & Patra, A. K. (2021). Ruminal microbiome manipulation to improve fermentation efficiency in ruminants. *Animal Feed Science and Nutrition – Production, Health and Environment*, 1-20. DOI: 10.5772/intechopen.101582.

Srinivasan, K. (2016). 1034 Metabolic effects of dietary pungent spices on the gut in animal models. *Journal of Animal Science*, *94*(suppl_5), 495-496. https://doi.org/10.2527/jam2016-1034

MSD Veterinary Manual. (2022a). Hematology reference ranges. Retrieved January 25, 2025, from https://www.msdvetmanual.com/reference-values-and-conversion-tables/reference-guides/hematology-reference-ranges

MSD Veterinary Manual. (2022b). Serum biochemical analysis reference ranges. Retrieved January 25, 2025, from https://www.msdvetmanual.com/reference-values-and-conversion-tables/reference-guides/clinical-chemistry-si-conversion-factors

U.S. Department of Agriculture (2009). USDA Food Data Central Spices, Pepper, Black Available at https://fdc.nal.usda.gov/fdc-app.html#/food-details/170931/nutrients. Accessed December 27 2024.

Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597. https://doi.org/10.3168/jds.s0022-0302(91)78551-2