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Influence of *Allium sativum* on the hematology, serum chemistry, and oxidative stability biomarkers of West African Dwarf goats artificially infected with *Haemonchus contortus*

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ABSTRACT

This study was conducted to access the influence of *Allium sativum* extract on the hematology, serum chemistry and oxidative stability markers of West African Dwarf goats experimentally infected with *Haemonchus contortus*. Twenty-five growing WAD goats were used for the study. These animals were divided into five treatment groups, comprising of five animals each in a completely randomized design. Treatments comprised *A. sativum* extract at 7.5, 12.5, and 17.5 mg/mL, albendazole at 10 mg/mL, and water as positive and negative controls, respectively. The experiment lasted 56 days. Collection of blood samples was done at the commencement and termination of the study. The hematological indices, serum chemistry and oxidative stability biomarkers of the animals were determined. The data gathered were analyzed using one-way analysis of variance, and treatment means were separated using Tukey's significant difference test at $P < 0.05$. At the end of the experiment, *A. sativum* significantly affected packed cell volume, red blood cell count, hemoglobin, mean corpuscular volume, and mean corpuscular hemoglobin. The 12.5 mg/mL treatment recorded a PCV of 32.13% and the highest hemoglobin concentration of 11.20 g/dL, whereas 17.5 mg/mL produced a PCV of 32.63%, MCV of 22.40 fL, and MCH of 7.89 pg. Significant effects were also observed for serum total protein, globulin, cholesterol, urea, and alkaline phosphatase. Total protein and globulin were highest at 7.5 mg/mL, with values of 9.35 and 4.09 g/dL, respectively. The urea level decreased gradually as the extract concentration increases, till it reached 25.00 mg/dL in group treated with 17.5 mg/mL of the extract. Glutathione peroxidase activity at the onset was higher at 12.5 and 17.5 mg/mL, with values of 16.55 and 17.80 U/L, respectively. The total bilirubin obtained after the treatment reduced from 0.63 mg/dL in group treated with water to 0.18 mg/dL in group treated with 17.5 mg/mL of the extract. In conclusion, group treated with 12.5 mg/mL of the extract, produced the most favorable physiological and parasite-related responses. The outcomes further confirm the use of *A. sativum* extract as a potential

complementary intervention for the treatment of *H. contortus* infection in West African Dwarf goats.

Keywords: *Allium sativum*; anthelmintic activity; West African Dwarf goats; serum chemistry; oxidative biomakers; hematology.

1. INTRODUCTION

Goat production has proved to be a reliable means of food security, family proceeds, and source of revenue in developing countries (Okoro *et al*., 2023). West African Dwarf goats contributes greatly to the smallholder livestock systems, because of their adaptation to tropical environments, resilience, and ability to digest locally available feed resources. The optimal productivity of West African Dwarf goats is hindered by infectious diseases, inadequate nutrition, and gastrointestinal parasitism. Gastrointestinal nematodes are important causes of reduced health and productive performance in small ruminants. Among these parasites, *Haemonchus contortus* is particularly important because of its blood-feeding habit, high fecundity, and pathogenicity.

Haemonchus contortus is an abomasal nematode that infects sheep and goats, particularly in humid region. Infection of animals with *H. contortus* causes reduction in blood cells, hypoproteinaemia, loss of weight, reduced forage utilization, and death in severe condition (Ayankoso *et al*., 2025a). The main pathological signs showed by these animals are always caused by the blood-feeding activity of the adult worms. Goats have showed greater susceptibility to *H. contortus* infection than sheep under similar trial conditions (Risa *et al*., 2024). Infected goats showed higher fecal egg counts, greater worm establishment, and higher reduction in packed cell volume, which invariably reduce the health and performance of the animal.

H. contortus is conventionally controlled with the use of synthetic anthelmintic drugs. The repeated and inappropriate administration of these drugs has resulted in building resistance to the drugs. Reports had showed anthelmintic resistance to several drugs, which is associated with hereditary and biological changes in parasites. Qamar and Alkheraije (2023) reestablished resistance of *Haemonchus* to different anthelmintic drugs in sheep and goats. The increasing prevalence of resistance of this worm has lowered the efficiency of synthetic drugs and supported the need for unconventional parasite control approaches.

Medicinal plants are gaining continuous consideration as major sources of phytochemicals for controlling gastrointestinal nematode. Soliman *et al*. (2024) recognized numerous botanical products that are capable of preventing *H. contortus* infection in goats. *Allium sativum* L. was among the plant materials receiving research attention because of its ability to work against parasites (Ayankoso 2025). It also possesses health-promoting properties. Plant-based intervention offers prospects for incorporating natural products into parasite controlling programs, particularly where helminths have built resistance to conventional anthelmintic.

Allium sativum L., popularly called garlic, possesses many biological compounds. The compounds include allicin, alliin, diallyl disulfide, diallyl trisulfide, ajoenes, and S-allyl cysteine. These compounds display antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory activities (Verma *et al*. 2023; Okoro *et al*. 2023). Allicin has been reported to be an important bioactive compound in garlic, which possesses antimicrobial and antioxidant activities (Thakur *et al*., 2024).

Sulfur-containing compounds are considered important contributors to the biological activity of *A. sativum*. Allicin, diallyl disulfide, diallyl trisulfide, ajoenes, and S-allyl cysteine among the major sulfur compounds associated with the biological effects of garlic. Furdak and Bartosz (2024) also reported variation in the antioxidant activity of garlic constituents, including organosulfur and phenolic compounds. Such variation indicates the importance of extract preparation and chemical composition when evaluating the biological effects of garlic.

The properties of *A. sativum* in worm control has been examined. Its bioactive components have demonstrated anti-parasitic properties against gastrointestinal nematodes. Soliman *et al*. (2024) recognized *A. sativum* amongst plant materials examined for *H. contortus* management. Although, the reported responses varied with animal species, extract preparation, extraction method, dosage, and experimental conditions. The examination of the physiological responses of the host is very important when investigating plant-based interventions to ensure animal health and safety. Hematological parameters provide information on anemic condition, erythrocyte status, oxygen carrying capacity, and inflammatory responses. These indices are particularly important during *Haemonchus* infection because continuous blood loss affects packed cell volume, hemoglobin concentration, erythrocyte count, and related hematological parameters. Serum biochemical indices provide more information on protein metabolism, hepatic and renal function, energy metabolism, and tissue integrity.

Gastrointestinal nematode infection is also associated with changes in oxidative balance. Infection may disrupt the balance between oxidant production and endogenous antioxidant defense, leading to oxidative stress. Biomarkers such as superoxide dismutase, glutathione peroxidase, catalase, malondialdehyde, and bilirubin provide information on oxidative responses during

infection and treatment. Gu *et al*. (2025) reported oxidative stress and mitochondrial damage in *H. contortus* following ivermectin exposure. The findings of this study will indicate the relevance of oxidative processes in parasite biology and anthelmintic responses.

The antioxidant activity of *A. sativum* provides an additional basis for its evaluation in parasitized goats. Garlic-derived organosulfur compounds have been associated with antioxidant activity and modulation of oxidative processes (Verma *et al*. 2023). Assessment of oxidative stability alongside hematological and serum biochemical parameters is essential in providing a broader evaluation of the physiological response of infected goats to *A. sativum* treatment.

Despite increasing research on the biological activities of garlic, limited information is available on the combined effects of *A. sativum* extract on hematological status, serum biochemical characteristics, and oxidative stability of West African Dwarf goats infected with *H. contortus*. Information on responses to different concentrations of garlic extract is also limited.

Therefore, this study aims at determining the influence of *A. sativum* extract on the hematological profile, serum biochemical indices, and oxidative stability biomarkers of West African Dwarf goats experimentally challenged with *H. contortus*. The study further examined the response of infected goats to different levels of the extract. The outcomes offer information on the prospective use of *A. sativum* as an alternative plant-based approach for the treatment *H. contortus* infection and associated physiological disturbances in West African Dwarf goats.

2. METHODOLOGY

Experimental Site

The study was conducted using research facilities of the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria. The first and second phases were conducted at the Veterinary Teaching Hospital, College of Veterinary Medicine, and the Postgraduate Research Laboratory, Department of Animal Production and Health, College of Animal Science and Livestock Production. The third phase was conducted at the Small Ruminant Unit, Directorate of University Farms, FUNAAB.

The site of the study is located at approximately 7°10′N latitude and 3°20′E longitude. (Google Earth, 2025). The location has a tropical climate, with an average yearly rainfall of about 1,037 mm. Average ambient hotness varies from about 28°C in December to 36°C in February, with an annual average of about 34°C. Relative humidity averages approximately 83%. The plant cover of the area is intermediate between the tropical rainforest and derived savannah zones (Accuweather, 2025).

Collection and preparation of *Allium sativum* extract

Fresh garlic cloves (*Allium sativum*) were purchased from an open market in Abeokuta, Ogun State, Nigeria. The cloves were carefully cleaned to remove stones, soil particles, and other extraneous materials. Approximately 50 g of cleaned garlic cloves were weighed and homogenized after been mixed with 200 mL of distilled water using a laboratory blender. The resulting aqueous preparation was used as the garlic extract for the experiment. The exploration of garlic as a prospective natural anthelmintic was established on the recent findings showing that *A. sativum* possess bioactive compounds with curative potential against gastrointestinal nematodes. Recent research findings testified to the reduction of worm population after administering garlic-derived products to goats. However, the potency of this products may vary, depending on the method of preparation, dosage used, parasite load, and means of administration (Vargas-Bello-Pérez *et al*., 2024; Soliman *et al*., 2024).

Collection and identification of *Haemonchus contortus*

Adult *Haemonchus contortus* were obtained from heavily infected abomasa collected from goats slaughtered at a sheep and goat abattoir in Akinyele, Oyo State, Nigeria. Approximately twenty (20) abomasa, with visible *H. contortus* infections, were collected from the processing slabs. The worms were recovered from the abomasal contents and identified using established morphological characteristics. We washed the recovered parasites thoroughly in a nutritive medium prepared according to previously described procedures. The nutritive medium had amphotericin B which prevent the growth of fungi. The yeast added to the medium served as a source nutrient to help the growing larvae, while the Epsom salt solution assist in maintaining electrolyte conditions. The techniques explored in this research is in line with the procedures earlier described by Kaplan *et al*. (2023) and Rinaldi *et al*. (2023).

Preparation of infective *H. contortus* larvae

Two nine-month-old lambs with an average body weight of approximately 7.5 kg were obtained from the Small Ruminant Unit, Directorate of University Farms, FUNAAB. Before experimental infection, the lambs received albendazole at 1mL/kg body weight to

reduce pre-existing gastrointestinal worm infections. Approximately 200–250 adult *H. contortus* worms were transferred into the abomasum of each lamb through a left-sided celiotomy. Following the procedure, the lambs were housed in isolated pens to minimize exposure to external sources of gastrointestinal nematodes. The animals were fed cut forage harvested during dry and sunny periods to reduce the likelihood of contamination with infective larvae.

We then collected fecal samples from the donor lambs. The fecal material collected was carefully mixed with distilled water, which was allowed to pass through a 2-mm sieve to get rid of unwanted substances present in it. The suspension formed, containing *H. contortus* eggs, was dispensed into Petri dishes to allow the formation of the larvae. Amphotericin B was added to prevent the formation of fungi, while the yeast was added to provide nutrient for the developing larvae. Epsom salt solution was also added to maintain suitable electrolyte conditions.

The cultures were maintained at approximately room temperature for seven days to allow eggs to develop through the larval stages to the infective third-stage larva (L3). The resulting L3 larvae were used to infect the experimental goats by drenching.

Experimental animals and management

Twenty-five growing West African Dwarf (WAD) goats of both sexes, with initial body weights ranging from 7.18 to 8.54 kg, were purchased from an open market in Abeokuta, Ogun State, Nigeria. On arrival, the animals were placed in a quarantine facility that had previously been washed and disinfected with an iodophor solution.

During quarantine, the animals were treated against internal and external parasites with ivermectin administered subcutaneously at 0.5 mL/25 kg body weight. A wide-spectrum, long-acting antibiotic preparation (5% Tetranor®) was injected at 1 mL/10 kg body weight for three consecutive days as a positive control treatment. We also administered an injectable multivitamin preparation at 3 mL per animal. The quarantine period lasted 28 days. Following quarantine, the goats were housed individually in pens constructed with raised slatted floors and corrugated iron roofing. Each pen had separate feed and water troughs. The animals were offered clean drinking water on dally basis throughout the period of the experiment.

Artificial infection and experimental treatments

Following the quarantine period, the goats were artificially infected with infective third-stage larvae (L3) of *H. contortus* obtained from the donor lambs. The level of infection was monitored through fecal sampling and determination of fecal egg counts until a baseline of 2.000 eggs per gram (EPG) of feces was reached.

The 25 goats were randomly allocated to five groups containing five animals in each group, which was arranged in a completely randomized design. The treatment groups consisted of three garlic-extract concentrations, a positive control, and a negative control.
The treatments were:
T1: Water as the negative control
T2: Albendazole (ALBENOR®, 250-mg bolus; Jubaili Agrotec) at 10 mg/mL as the positive control.
T3: Garlic extract at 7.5 mg/mL.
T4: Garlic extract at 12.5 mg/mL
T5: Garlic extract at 17.5 mg/mL.

The garlic extract and water were administered orally by drenching daily throughout the experimental period. Albendazole was administered orally for three consecutive days at the commencement of treatment and repeated for three consecutive days from days 29 to 31. The *A. sativum* extract doses were administered based on the body weight of each experimental animal. The animals were maintained under intensive management throughout the study.

Experimental diet

The goats were maintained on an intensive feeding system and received a compounded concentrate diet daily. Cassava peels were obtained from a gari-processing facility in Abeokuta and sun-dried thoroughly before use. Wheat offal, palm kernel cake, bone meal, oyster shell, and common salt were obtained from a reputable feed mill within Abeokuta, Ogun State. The feed ingredients were milled separately and subsequently mixed to produce the experimental concentrate diet. The ingredient and determined compositions of the diet used for the study is presented in Table 1. The animals were fed at 4% of individual body weight on daily basis, which was adjusted on weekly basis throughout the period of the study. We provided clean drinking water to the animals throughout the experiment.

Table 1. Gross composition (%) of experimental concentrate diet

Ingredients	Composition (%)
Cassava peel	28.00
Maize	10.00
Wheat offal	32.00
Palm kernel cake	27.00
Bone meal	1.00
Salt	2.00
Total	100.00
Determined analysis (%)	
Dry matter	88.50
Crude protein	16.41
Ash	10.56
Ether extract	9.18
Carbohydrate	51.35
Crude fiber	12.50
Acid detergent fiber	22.40
Neutral detergent fiber	33.60
Acid detergent lignin	5.90

Data collection and analysis

Blood collection and laboratory analyses

About 10mL of blood sample was collected from each animal through jugular venipuncture on first and fifty-sixth day of the study. Out of the total volume collected, 5 mL was dispensed into well labeled sample bottles containing ethylenediaminetetraacetic acid (EDTA) as an anticoagulant. The sample bottles were gently mixed to ensure adequate anticoagulation and prevent clot formation. The remaining 5 mL was transferred into plain bottles without anticoagulant, so as to allow clotting for serum separation. An IDEXX LaserCyte Hematolgy Analyzer was used to determine the hematological parameters. Serum chemistry indices were analyzed with the help of a Catalyst Dx Chemistry Analyzer (IDEXX Laboratories). Impact of superoxide dismutase (SOD) was evaluated in line with Pisoschi *et al*. (2022). Activities of glutathione peroxidase (GSH-Px) were determined using the method described by Hadwan *et al*. (2025). Serum malondialdehyde (MDA) concentration was estimated using method stated by Frijhoff *et al.* (2022), while activity catalase was determined in line with Grilo *et al*. (2020). Serum creatinine concentration was determined according to Badiou *et al.* (2020).

Statistical analysis

Data gathered were analyzed by means of one-way analysis of variance (ANOVA) in a completely randomized design, and significant means effect were detected, they were separated using Tukey's honestly significant difference test at $P < 0.05$. Statistical analyses were performed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA).

3. RESULTS AND DISCUSSION

Results

Effects of *Allium sativum* extract on hematological indices of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The effects of *Allium sativum* extract on the hematological indices of West African Dwarf goats experimentally infected with *Haemonchus contortus* are presented in Table 2. At the onset of the experiment, significant treatment effects ($P < 0.05$) were noted in red blood cell (RBC) counts and mean corpuscular volume (MCV). In contrast, packed cell volume (PCV), hemoglobin (Hb), white blood cell (WBC) count, and mean corpuscular hemoglobin concentration (MCHC) were not significantly affected ($P > 0.05$). At the end of the experiment, significant treatment effects were observed for PCV, Hb, RBC, MCV, and mean corpuscular hemoglobin (MCH), whereas WBC and MCHC were not significantly affected ($P > 0.05$).

Table 2. Effect of *Allium sativum* extract on hematological status of experimentally infected West African Dwarf goats

Parameters		Saline (mL)	Albendazole 10 mg/mL	7.5 mg/mL	12.5 mg/mL	17.5 mg/mL	P-value
Packed cell volume (%)	Onset	29.13	28.58	25.33	29.51	29.87	0.309
	Final	29.63^{b}	29.00^{b}	28.25^{b}	32.13^{a}	32.63^{a}	0.040
Hemoglobin (g/dl)	Onset	10.68^{ab}	10.62^{ab}	9.43^{b}	10.49^{ab}	11.10^{a}	0.111
	Final	9.95^{b}	10.76^{ab}	9.80^{b}	11.20^{a}	10.33^{b}	0.040
Red blood cell (×10^{12}/L)	Onset	12.67^{b}	12.88^{b}	14.86^{ab}	16.45^{a}	15.94^{a}	0.008
	Final	16.44^{a}	15.69^{a}	15.98^{a}	15.21^{ab}	13.16^{b}	0.045
White blood cell (×10^{9}/L)	Onset	9.99	9.84	10.73	11.46	9.11	0.317
	Final	8.59	6.90	9.71	8.24	8.66	0.063
Mean Corpuscular Volume (fL)	Onset	22.85^{a}	22.51^{a}	16.96^{b}	17.96^{b}	18.79^{b}	0.000
	Final	20.12^{ab}	20.92^{ab}	17.79^{c}	19.12^{ab}	22.40^{a}	0.008
Mean Corpuscular Hemoglobin (pg)	Onset	8.40^{a}	8.36^{a}	6.36^{c}	6.43^{c}	7.03^{b}	0.000
	Final	6.91^{b}	7.01^{ab}	6.18^{b}	6.57^{b}	7.89^{a}	0.007
MCHC (g/dl)	Onset	37.07	37.17	37.64	35.80	37.42	0.604
	Final	34.33	33.49	33.58	34.29	35.39	0.224

^{a,b} Means across rows with different superscripts are significantly ($P < 0.05$) different; MCHC: mean corpuscular hemoglobin concentration

At the end of the experiment, PCV was significantly higher in goats administered 12.5 and 17.5 mg/mL of *A. sativum* extract, with values of 32.13 and 32.63%, respectively, compared with 29.63, 29.00 and 28.25% recorded for the saline, albendazole and 7.5 mg/mL groups, respectively. Hemoglobin concentration was highest in goats treated with 12.5 mg/mL of *A. sativum* (11.20 g/dL), which was comparable to the value recorded for the albendazole group (10.76 g/dL). The groups treated with saline, 7.5 and 17.5 mg/mL of the extract recorded 9.95, 9.80 and 10.33 g/dl, respectively. The RBC count at the end of the experiment was highest in the saline group (16.44 × 10^{12}/L) and was comparable with the albendazole (15.69 × 10^{12}/L) and 7.5 mg/mL *A. sativum* (15.98 × 10^{12}/L) groups. The lowest RBC count was recorded in goats administered 17.5 mg/mL of the extract (13.16 × 10^{12}/L), although this value was comparable with that of the 12.5 mg/mL group (15.21 × 10^{12}/L). Mean corpuscular volume differed significantly among treatments. The highest value was recorded in goats treated with 17.5 mg/mL *A. sativum* (22.40 fL), while the lowest value was observed in the 7.5 mg/mL group (17.79 fL). The MCH was also significantly highest in goats administered 17.5 mg/mL of the extract (7.89 pg) and was comparable with the albendazole group (7.01 pg). The saline, 7.5 and 12.5 mg/mL groups recorded 6.91, 6.18 and 6.57 pg, respectively.

White blood cell count was not significantly affected by treatment, although the 7.5 mg/mL group recorded the highest numerical value (9.71 × 10^{9}/L) at the end of the experiment. Similarly, MCHC did not differ significantly among treatments, with values ranging from 33.49 to 35.39 g/dL. Overall, administration of *A. sativum* extract, particularly at 12.5 mg/mL, improved PCV and Hb concentration, while the 17.5 mg/mL treatment produced the highest MCV and MCH values.

Effects of *Allium sativum* extract on the differential leucocyte counts of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The effects of *Allium sativum* extract on the differential leucocyte counts of West African Dwarf goats experimentally infected with *Haemonchus contortus* are presented in Table 3. At the onset of the experiment, significant treatment effects ($P < 0.05$) were observed for neutrophils, lymphocytes, eosinophils, and basophils. Monocyte count was not significantly affected ($P > 0.05$). At the final stage, significant differences ($P < 0.05$) were observed in neutrophils, lymphocytes, basophils, and monocytes, whereas eosinophils were not significantly affected ($P > 0.05$).

Table 3. Effect of *Allium sativum* extract on the differential leucocyte counts of West African Dwarf goats experimentally infected with *Haemonchus contortus*

Parameters		Water (mL)	Albendazole 10 mg/mL	7.5 mg/mL	12.5 mg/mL	17.5 mg/Ml	P-value
Neutrophils (%)	Onset	31.71^{b}	33.42^{b}	37.42^{a}	33.22^{b}	31.24^{b}	0.002
	Final	34.13^{a}	30.00^{c}	33.50 ^{ab}	32.00^{bc}	31.13^{bc}	0.016
Lymphocytes (%)	Onset	66.29^{a}	64.87^{ab}	61.87^{b}	64.84^{ab}	67.69^{a}	0.015
	Final	65.63^{b}	69.50^{a}	65.50^{b}	67.37^{ab}	67.50 ^{ab}	0.033
Eosinophils (%)	Onset	0.64^{a}	0.71^{a}	0.00^{b}	0.64^{a}	0.36^{ab}	0.002
	Final	0.25	0.25	0.38	0.00	0.38	0.530
Basinophil (%)	Onset	0.71^{a}	0.36^{ab}	0.00^{b}	0.64^{a}	0.36^{ab}	0.047
	Final	0.00^{b}	0.00^{b}	0.00^{b}	0.38^{a}	0.38^{a}	0.040
Monocytes (%)	Onset	0.64	0.64	0.71	0.64	0.71	0.997
	Final	0.00^{c}	0.25^{b}	0.63^{a}	0.63^{a}	0.63^{a}	0.031

^{abc} Means across rows with different superscripts are significantly ($P < 0.05$) different.

At onset, neutrophil count was highest in goats administered 7.5 mg/mL *A. sativum* extract (37.42%). It was significantly higher in the other treatment groups, which ranged from 31.24 to 33.42%. At the final stage, neutrophil count was highest in the saline group (34.13%) and lowest in the albendazole group (30.00%). The value recorded for the 7.5 mg/mL group (33.50%) was comparable with that of the saline group.

Lymphocyte count at onset was highest in goats treated with 17.5 mg/mL *A. sativum* extract (67.69%) and the saline group (66.29%), while the lowest value was recorded in the 7.5 mg/mL group (61.87%). At the final stage, the albendazole group had the highest lymphocyte count (69.50%), whereas the saline and 7.5 mg/mL groups had the lowest and comparable values of 65.63 and 65.50%, respectively. The 12.5 and 17.5 mg/mL groups recorded intermediate values of 67.37 and 67.50%, respectively.

Eosinophil count was significantly influence before the animals were treated with the extract. Albendazole group (0.71%) had the highest value, while eosinophil was not detected in goats treated with 7.5 mg/mL of *A. sativum* extract. After treating the animals, eosinophil values were between 0.00 to 0.38%, which were not significantly influenced among treatments.

Basophil counts were significantly affected by treatment at both stages. At onset, the highest value was recorded in the saline group (0.71%), while no basophils were detected in the 7.5 mg/mL group. At the final stage, basophil count was significantly higher in goats treated with 12.5 and 17.5 mg/mL *A. sativum* extract (0.38% each) than in the saline, albendazole, and 7.5 mg/mL groups, which recorded 0.00%.

Monocyte count was not significantly affected at onset, with values ranging from 0.64 to 0.71%. However, a significant treatment effect was observed at the final stage. The 7.5, 12.5, and 17.5 mg/mL *A. sativum* groups recorded the highest and comparable values of 0.63% each. The lowest value was recorded in the saline group (0.00%), while the albendazole group had an intermediate value of 0.25%.

Effects of *Allium sativum* extract on the Serum biochemical indices of West African Dwarf goats experimentally infected with *Haemonchus contortus.* The effects of *A. sativum* extract on the serum chemistry of WAD goats experimentally infected with *H. contortus* are presented in Table 4. At the onset of the experiment, significant treatment effects ($P < 0.05$) were observed for total protein, globulin, aspartate aminotransferase (AST), cholesterol, urea, alkaline phosphatase (ALP), and creatinine. Albumin, alanine aminotransferase (ALT), and glucose were not significantly affected ($P > 0.05$). At the final stage, significant differences were observed for total protein, globulin, cholesterol, urea, and ALP, whereas albumin, AST, ALT, creatinine, and glucose were not significantly affected.

At onset, total protein was highest in the albendazole group (7.89 g/dl) and lowest in goats administered 17.5 mg/mL *A. sativum* extract (6.49 g/dL). The values recorded for the saline, 7.5 mg/mL, and 12.5 mg/mL groups were 7.58, 7.24, and 7.07 g/dL, respectively.

Globulin was highest in the albendazole group (2.69 g/dL) and lowest in the 17.5 mg/mL group (1.46 g/dL). The 12.5 mg/mL group recorded an intermediate value of 1.98 g/dL.

Table 4. Effect of *Allium sativum* extract on serum biochemical status of experimentally infected West African Dwarf goats

Parameters		Water mL	Albendazole 10mg/Ml	7.5 mg/mL	12.5 mg/Ml	17.5 mg/mL	P-value
Total Protein (g/dl)	Onset	7.58^{ab}	7.89^{a}	7.24^{ab}	7.07^{b}	6.49^{c}	0.002
	Final	7.21^{b}	8.18^{b}	9.35^{a}	8.09^{b}	8.98^{b}	0.009
Albumin (g/dl)	Onset	5.21	5.20	5.01	5.80	5.03	0.067
	Final	4.46	5.21	5.26	5.04	5.04	0.250
Globulin (g/dl)	Onset	2.37^{b}	2.69^{a}	2.23^{b}	1.98^{ab}	1.46^{c}	0.006
	Final	2.75^{b}	2.96^{b}	4.09^{a}	3.05^{b}	3.05^{b}	0.007
Aspartate transferase (IU/L)	Onset	69.20^{a}	73.62^{a}	56.09^{b}	66.38^{ab}	41.62^{c}	0.000
	Final	48.38	50.63	55.13	53.63	62.13	0.071
Alanine transferase (IU/L)	Onset	11.50	9.11	8.65	7.50	11.13	0.224
	Final	14.50	15.00	15.75	16.50	16.13	0.234
Cholesterol (mg/dl)	Onset	300.16^{a}	158.69^{b}	124.31^{c}	119.55^{c}	250.16^{ab}	0.012
	Final	68.10^{b}	82.45^{a}	35.40^{c}	43.40^{c}	39.13^{c}	0.005
Urea (mg/dl)	Onset	41.74^{a}	33.94^{b}	40.03^{a}	40.83^{a}	44.45^{a}	0.003
	Final	59.29^{a}	54.13^{b}	42.67^{c}	39.16^{d}	25.00^{e}	0.024
Alkaline phosphate (U/L)	Onset	61.64^{ab}	64.15^{ab}	102.69^{a}	27.89^{b}	97.53^{a}	0.004
	Final	35.75^{c}	60.50^{b}	86.25^{a}	71.25^{ab}	72.25^{ab}	0.001
Creatinine (mg/dl)	Onset	0.76^{ab}	1.52^{a}	0.62^{b}	0.20^{b}	0.56^{b}	0.030
	Final	2.24	1.66	1.55	1.26	1.36	0.602
Glucose (mg/dl)	Onset	63.85^{a}	46.29^{b}	38.81^{b}	46.32^{b}	59.00^{ab}	0.111
	Final	34.54	56.31	42.28	43.28	51.05	0.349

^{abcd} Means across rows with different superscripts are significantly ($P<0.05$) different.

Aspartate transferase concentrations differed significantly across the treatments at the infective stage. Highest value (73.62 IU/L) was obtained in albendazole group, while the lowest value (41.62 IU/L) was observed in the 17.5 mg/mL *A. sativum* group. Meanwhile, saline group recorded 69.20 IU/L, while the 7.5 and 12.5 mg/mL groups recorded 56.09 and 66.38 IU/L, respectively.

Serum cholesterol was significantly affected at onset. The highest values were recorded in the saline (300.16 mg/dL) and 17.5 mg/mL (250.16 mg/dL) groups, whereas the lowest values were observed in the 12.5 mg/mL (119.55 mg/dL) and 7.5 mg/mL (124.31 mg/dl) groups. Urea concentration was highest in the 17.5 mg/mL group (44.45 mg/dL), followed by the saline group (41.74 mg/dL), while the lowest value was recorded in the albendazole group (33.94 mg/dL).

ALP was significantly affected at onset. The highest value was recorded in the 7.5 mg/ml group (102.69 U/L), followed by the 17.5 mg/mL group (97.53 U/L). The lowest value was recorded in the 12.5 mg/mL group (27.89 U/L). Creatinine also differed significantly, with the highest concentration recorded in the albendazole group (1.52 mg/dL). Lower values of 0.62, 0.20, and 0.56 mg/dL were recorded in the 7.5, 12.5, and 17.5 mg/mL groups, respectively. Glucose concentration was not significantly affected at onset, although values ranged from 38.81 mg/dL in the 7.5 mg/mL group to 63.85 mg/dL in the saline group.

At the final stage, total protein was significantly highest in the 7.5 mg/mL *A. sativum* group (9.35 g/dL). The saline, albendazole, 12.5 mg/mL, and 17.5 mg/mL groups recorded 7.21, 8.18, 8.09, and 8.98 g/dL, respectively. Globulin followed a similar pattern, with the highest value in the 7.5 mg/mL group (4.09 g/dl), while the other groups recorded values ranging from 2.75 to 3.05 g/dl.

Cholesterol concentration was significantly affected at the end of the study. The albendazole group recorded the highest value (82.45 mg/dL), followed by the saline group (68.10 mg/dL). The *A. sativum*-treated groups recorded lower values of 35.40, 43.40, and 39.13 mg/dL at 7.5, 12.5, and 17.5 mg/mL, respectively.

Urea content was observed to be significantly influenced among the treatments at the end of the study. Highest value (54.13 mg/dL) was noted in the saline group, this was followed by the albendazole group. Urea content reduced from 42.67, 39.16 to l.25.00 mg/dL as extract concentration was increasing at 7.5, 12.5 and 17.5 mg/mL. respectively.

Final ALP concentration was highest in the 7.5 mg/mL group (86.25 U/L) and lowest in the saline group (35.75 U/L). The albendazole, 12.5 mg/mL, and 17.5 mg/mL groups recorded 60.50, 71.25, and 72.25 U/L, respectively.

Oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The effects of *Allium sativum* extract on oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus* at the onset of the trial are presented in Table 5. Significant treatment effects ($P < 0.05$) were observed for total bilirubin and glutathione peroxidase (GPx). However, direct bilirubin, superoxide dismutase (SOD), malondialdehyde (MDA), and catalase were not significantly affected ($P > 0.05$). Total bilirubin concentration differed significantly among treatment groups and ranged from 0.24 to 0.80 mg/dL. The lowest value (0.24 mg/dL) was obtained in the saline group, while the highest values were recorded in the 12.5 and 17.5 mg/mL *A. sativum* groups, with concentrations of 0.80 and 0.72 mg/dL, respectively. The albendazole and 7.5 mg/mL groups had similar values of 0.50 and 0.62 mg/dL, respectively.

Glutathione peroxidase activity was also significantly affected by treatment. Values ranged from 6.01 to 17.80 U/L. The highest activities were recorded in goats administered 17.5 mg/mL (17.80 U/L) and 12.5 mg/mL (16.55 U/L) *A. sativum* extract. These values were significantly higher than those recorded in the saline, albendazole, and 7.5 mg/mL groups, which had values of 6.01, 10.16, and 8.86 U/L, respectively.

Table 5. Oxidative stability biomarkers of artificially infected West African Dwarf goats

Parameter/Treatment	Water mL	Albendazole mg/mL	7.5 mg/ml	12.5 mg/mL	17.5 mg/Ml	P-value
Total bilirubin (mg/dl)	0.24^{c}	0.50^{b}	0.62^{b}	0.80^{a}	0.72^{a}	0.037
Direct bilirubin (mg/dl)	0.11	0.15	0.17	0.16	0.19	0.426
Superoxide dismutase (U/L)	1.51	1.06	0.38	0.74	1.74	0.556
Malondialdehyde (UL x 10^{-09})	3.54	5.22	3.48	4.43	4.53	0.694
Glutathione peroxidase (U/L)	6.01^{b}	10.16^{b}	8.86^{b}	16.55^{a}	17.80^{a}	0.002
Catalase (U/L)	1.03	1.02	1.03	1.05	1.01	0.152

^{abc} Means across rows with different superscripts are significantly different ($P < 0.05$).

Effects of *Allium sativum* extract on oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The effects of *Allium sativum* extract on oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus* at the end of the experiment are presented in Table 6. Significant treatment effects ($P < 0.05$) were observed for total bilirubin and malondialdehyde (MDA). However, direct bilirubin, superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase were not significantly affected ($P > 0.05$).

Total bilirubin concentration varied significantly across the treatments. The highest comparable values were obtained in the saline (0.63 mg/dL) and albendazole (0.51 mg/dL) groups. Total bilirubin values were decreased as the *A. sativum* extract concentration increased from 0.32 mg/dL at 7.5 mg/mL to 0.25 mg/dl at 12.5 mg/mL and 0.18 mg/dl at 17.5 mg/mL.

Table 6. Effect of *Allium sativum* extract on oxidative stability biomarkers of West African Dwarf goats artificially infected with Haemonchus contortus

Parameter/Treatment	Water mL	Albendazole mg/Ml	7.5 mg/mL	12.5 mg/mL	17.5 mg/mL	P value
Total bilirubin (mg/d)	0.63[a]	0.51[a]	0.32[b]	0.25[b]	0.18[c]	0.000
Direct Bilirubin (mg/dl)	0.17[a]	0.19[a]	0.08[b]	0.07[b]	0.06[b]	0.070
Superoxide dismutase (U/L)	0.76[c]	0.63[c]	1.01[b]	1.90[a]	1.78[a]	0.070
Malondialdehyde (UL x 10^{-09})	2.96[b]	2.34[b]	3.74[ab]	5.92[a]	5.92[a]	0.018
Glutathione peroxidase (U/L)	6.79	8.10	7.86	7.25	7.20	0.882
Catalase (U/L)	0.06	0.05	0.24	0.24	0.05	0.207

[abc] Means across rows with different superscripts are significantly different ($P < 0.05$).

Direct bilirubin was not significantly affected by treatment ($P = 0.070$). Values ranged from 0.06 to 0.19 mg/dL. The highest concentrations were recorded in the albendazole (0.19 mg/dL) and saline (0.17 mg/dL) groups, while the *A. sativum*-treated groups recorded lower values of 0.08, 0.07, and 0.06 mg/dL at 7.5, 12.5, and 17.5 mg/mL, respectively.

Impact of superoxide dismutase was not significantly influenced by treatment ($P = 0.070$). The highest numerical values were recorded in goats administered 12.5 mg/mL (1.90 U/L) and 17.5 mg/mL (1.78 U/L) *A. sativum* extract. The lowest values were recorded in the albendazole and saline groups, with activities of 0.63 and 0.76 U/L, respectively.

Malondialdehyde concentration was significantly affected by treatment ($P = 0.018$). The highest value was recorded in the 12.5 and 17.5 mg/ml groups (5.92×10^{-9} UL each), and these values were comparable with those of the 7.5 mg/mL group (3.74×10^{-9} UL). The lowest values were recorded in the albendazole and saline groups, with concentrations of 2.34 and 2.96×10^{-9} UL, respectively.

Discussion

Hematological and serum biochemical assessments are the fastest means of predicting the performance and health status of the animals (Ogunbosoye *et al*., 2018). The hematological responses observed in this study indicated that *A. sativum* extract influenced selected blood indices of West African Dwarf goats experimentally infected with *H. contortus*. The significantly higher PCV recorded in goats administered 12.5 and 17.5 mg/mL of *A. sativum* extract suggests improved erythrocytic status following treatment. The inverse relationship observed between *Haemonchus contortus* and the increased PCV confirmed that *Haemonchus* is a hematophagus parasite that sucks host blood, thereby causing conditions like anemia, anorexia, depression, and death (Rongzhen *et al*., 2019). This response may be associated with reduced effects of *H. contortus* infection. *H. contortus* is a blood-feeding abomasal nematode capable of causing substantial blood loss and anemia in infected small ruminants. *A. sativum* drenched at higher doses might have assisted the animals in preventing microcytic hypochromic anemia that could have resulted from iron deficiency (Rongzhen *et al*., 2019). Risa *et al*. (2024) observed goats to be more vulnerable to *H. contortus* infestation than sheep in a closely related study conditions, which emphasized the significance of proper control of the parasite in goats. Likewise, Hassan *et al*. (2021) testified to the increases in hematological parameters after the treatment of *H. contortus*-infected sheep with plant-based materials.

Hemoglobin concentration was highest in goats administered 12.5 mg/mL *A. sativum* extract, which was comparable with the value recorded in the albendazole-treated group and higher than the value observed in the untreated control group. The increased Hb concentration may indicate reduced blood loss and improved erythropoietic recovery following suppression of the parasite burden. Because *H. contortus* feeds on blood, persistent infection can progressively reduce hemoglobin concentration and PCV. The higher values observed in the 12.5 mg/mL group may indicate improved physiological status following treatment (Ayankoso *et al*., 2025a). Hassan *et al*. (2021) similarly observed changes in hematological parameters in *H. contortus*-infected sheep following administration of plant extracts.

The significantly higher MCV observed in goats treated with 17.5 mg/mL *A. sativum* extract may indicate an increase in the average volume of circulating erythrocytes. The MCV value of 22.40 fL was higher than those recorded in the other treatment groups, while the lowest value was observed at 7.5 mg/mL. An increase in MCV may occur during regenerative erythropoiesis when immature, relatively

larger erythrocytes are released into circulation following blood loss. This is because *H. contortus* is associated with chronic blood loss; the increased MCV observed at the higher extract concentration may indicate a compensatory hematopoietic response (Ogunbosoye *et al*., 2018).

Mean corpuscular hemoglobin was significantly affected by treatment. The highest MCH value was observed in goats administered 17.5 mg/mL *A. sativum* extract, while the lowest value was recorded at 7.5 mg/mL. The increased MCH at 17.5 mg/mL, together with the increased MCV, indicates changes in erythrocyte size and hemoglobin content. Similar alterations in erythrocytic indices have been associated with recovery from parasitic anemia in small ruminants. However, the absence of a significant effect observed on MCHC suggests that the hemoglobin concentration within individual erythrocytes has improved and become relatively stable during the treatment period.

The observed hematological responses may also be related to the phytochemical composition of *A. sativum*. Garlic contains several organosulfur compounds, including alliin, allicin, ajoenes, and diallyl sulfides. These compounds are associated with antioxidant, antimicrobial, and anti-inflammatory activities (Yudhistira *et al*., 2022), which might have influenced hematological responses of the animals. The antioxidant properties of garlic may help to reduce oxidative stress associated with infection. At the same time, its biological activity against gastrointestinal parasites may contribute to a reduction in parasite-associated blood loss.

The response obtained in the group of animals treated with 12.5 mg/mL of the extract is of great importance. This group gave the highest concentration of Hb and PCV values, which might have resulted from the reduction in fecal egg count at the treatment (Ayankoso *et al.,* 2025a). This finding further supports the increasing interest in garlic, and other plant-derived products as potential complementary approaches for the management of *H. contortus* infection (Soliman *et al*., 2024; Ayankoso *et al.,* 2025b).

The response at 17.5 mg/mL requires more cautious interpretation. Although this concentration produced the highest PCV, MCV and MCH values, it also produced the lowest final RBC count. Therefore, the results did not demonstrate a consistent dose-dependent improvement in all hematological parameters. Instead, the intermediate concentration of 12.5 mg/mL appeared to provide the most favorable overall response based on PCV and Hb.

The outcomes of this study are relevant to the increasing worry on anthelmintic resistance in gastrointestinal helminths of goats. Baudinette *et al*. (2022) reported general anthelmintic resistance midst gastrointestinal parasite of goats, while Rodrigues *et al*. (2025) emphasized the complex structural mechanisms involved in resistance in *H. contortus*. These findings support the examination of plant products as possible materials that can be incorporated into parasite control programs. Soliman *et al*. (2024) also recognized garlic and other natural products as promising substances that need further research in the control of *H. contortus*. However, plant products should not be taken as direct substitutes for synthetic anthelmintics till their usefulness, potential, safety, quantity, and uniformity have been adequately established (Ayankoso, 2025).

Effect of *Allium sativum* extract on the differential leucocyte counts of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The differential leucocyte responses indicated that *A. sativum* extract influenced several components of the immune profile of *H. contortus*-infected WAD goats. Neutrophils are significant constituents of the distinctive protective response and are involved in the early response to tissue injury and infection. Neutrophils, which play a major role in host defense, had comparably lower values in the albendazole-treated group and in the groups treated with higher concentrations of the extract. This indicated that neutrophil activity may not have been strongly stimulated, possibly because the infection level had been reduced. The neutrophil values obtained were within the values recommended by Hassan *et al*. (2021) for healthy goats, which indicated that there was no occurrence of neutrophilia, which could occur when the animal is under trauma, or neutropenia, which could occur with very severe infections. The lower values in the extract and albendazole-treated goats may indicate reduced inflammatory stimulation following effective parasite control. Similar changes in leucocyte profiles have been reported in small ruminants infected with gastrointestinal nematodes, where the magnitude of the response was influenced by parasite burden and treatment (Hassan *et al*., 2021).

Lymphocytes, an indicator of infectivity, differed significantly among treatments. At the final stage, the highest lymphocyte count was recorded in the albendazole group, while the 12.5 and 17.5 mg/mL groups showed intermediate values. Lymphocytes are central to adaptive immune responses and help regulate antibody-mediated and cellular immunity. The relatively higher values observed in some *A. sativum*-treated groups may also indicate maintenance of immune competence during parasite challenge.

The significant effect observed for eosinophils at onset was particularly interesting because eosinophils are commonly associated with host responses to helminth infections. However, eosinophil counts were low across the treatment groups and became statistically similar at the final stage. The absence of a significant difference at the end of the experiment suggested that the albendazole and extract

treatments normalize the effect of circulating eosinophils; this agrees with Miter and Klion (2021), who reported that eosinophils discharge provocative mediators that suppress egg production, prevent infective larvae and adult worm establishment, paralyze worm motility, and possibly confound incoming larvae. Basophil counts were significantly affected at both stages. At the final stage, goats administered 12.5 and 17.5 mg/mL *A. sativum* extract had higher basophil counts than the saline, albendazole, and 7.5 mg/mL groups. Basophils participate in inflammatory and hypersensitivity responses and may contribute to host responses against parasites.

Monocyte count was not affected at onset but differed significantly at the final stage. The 7.5, 12.5, and 17.5 mg/mL groups recorded similar values of 0.63%, whereas the saline group recorded 0.00%. Monocytes contribute to innate immunity through phagocytosis and antigen presentation. The higher monocyte values in the extract-treated groups may indicate a mild alteration in innate immune activity during the later phase of treatment as a means to suppress the effect of the infestation. The observed changes may be related to the bioactive constituents of garlic. *A. sativum* possess organosulfur constituents, comprising allicin and many other sulfur-containing compounds, which have been reported to possess immunomodulatory, antioxidant, anti-inflammatory, and antimicrobial activities (Yudhistira *et al*., 2022). These properties might have possibly improved the physiological response detected in treated goats.

Effect of *Allium sativum* extract on serum biochemical status of experimentally infected West African Dwarf goats

The serum biochemical responses demonstrated that *A. sativum* extract influenced selected metabolic and biochemical indices of *H. contortus*-infected WAD goats. Total protein presented direct measurement of dietary protein quality, and could be used to predict proper protein metabolism and utilization by the goats. The reduced values obtained for total protein at the onset of the trial indicated that the body protein was directed towards the management of the worms. In contrast, the elevated values recorded at the end of the experiment could be due to the influence of diet and the drenched *A. sativum* effect, which showed efficient protein utilization and metabolism.

The increase in globulin concentration at 7.5 mg/mL may also have reflected the host response to persistent exposure to parasite antigens. Gastrointestinal nematode infection can stimulate immune responses and alter circulating protein fractions. The present finding is relevant because *A. sativum* contains several bioactive compounds with reported antioxidant and immunomodulatory properties. Tudu *et al*. (2022) reported that garlic contains organosulfur compounds such as allicin, diallyl disulfide, diallyl trisulfide, ajoenes, and S-allyl cysteine, which have been associated with antioxidant, antimicrobial, anti-inflammatory, and immunomodulatory activities. Reduced levels of globulin could suggest that more of it was used up as a mechanism put in place to combat and provide immunological responses to the activity of the worms (Makune *et al*., 2020),

Cholesterol showed a marked treatment response. At onset, the saline group had the highest cholesterol concentration, while the 7.5 and 12.5 mg/mL groups had substantially lower values. At the final stage, all *A. sativum*-treated groups had lower cholesterol concentrations than the saline and albendazole groups. The reduction observed may indicate effect of garlic constituents on metabolism of lipid. Garlic has been reported to possess hypolipidaemic activity and to influence lipid metabolic pathways (Tudu *et al*., 2022). The lower cholesterol values observed after treatment may therefore have been associated with the biological activity of garlic phytochemicals.

At onset, urea was observed to be high during the infectivity stage, whereas at the final stage, it decreased progressively as *A. sativum* concentration increased. Elevated serum urea can be associated with increased protein catabolism, dietary protein metabolism, dehydration, or altered renal handling. The progressive reduction in urea with increasing extract concentration at the final stage may suggest improved metabolic status or reduced protein catabolism (Jan, 2016).

Creatinine differed significantly at onset, with the highest value recorded in the albendazole group, indicating that *H. contortus* infestation can cause renal dysfunction. Considerably lower values obtained for creatinine in groups treated with the extract showed that *A. sativum* could be used to promote renal function in WAD goats. The activities of AST and ALT provide information relevant to hepatic and tissue integrity. AST was significantly affected at onset, with the highest value in the albendazole group and the lowest value at 17.5 mg/mL *A. sativum*. However, the difference was no longer significant at the final stage. ALT was not significantly affected at either stage. Transaminases do not show any significant influence at the final stage, this proposes that the extract did not stimulate a noticeable detrimental consequence on the enzyme indices under the circumstances of thi research. Garlic has been described as a plant product with antioxidant and liver-protective properties (Tudu *et al*., 2022).

Oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The oxidative stability profile showed that total bilirubin and glutathione peroxidase activity were affected at the onset of the trial. This indicates the early response of WAD goats to the effect of *H. contortus* infestation. GPx is a major enzymatic antioxidant that protects cells by reducing hydrogen peroxide and lipid hydroperoxides. The higher GPx activity observed in some treatment groups indicates an enhanced antioxidant response following the challenge imposed by *H. contortus* infection. The higher GPx activity may therefore represent an adaptive response to oxidative damage, this showed that parasitic infection can cause rise in GPx which increase metabolic and inflammatory stress and may stimulate endogenous antioxidant defense mechanisms. Total bilirubin also differed significantly among treatments. Bilirubin is majorly stimulated from the breakdown of hemoglobin which is processed in the liver. The higher levels noticed in some groups might have been due to erythrocyte production, hepatic processing and other physiological factors that prevent liver injury.

Effects of *Allium sativum* extract on oxidative stability biomarkers of West African Dwarf goats experimentally infected with *Haemonchus contortus*

The oxidative stability profile at the end of the experiment showed that *A. sativum* extract significantly influenced total bilirubin and MDA. In contrast, direct bilirubin, SOD, GPx, and catalase were not significantly affected. These findings indicated that the response to garlic supplementation can improve the antioxidant system in animals. Total bilirubin progressively decreased with increasing *A. sativum* concentration. Bilirubin is produced mainly from hemoglobin degradation and is subsequently processed and excreted through hepatic pathways. The reduction observed in total bilirubin values in the extract-treated groups might be a reflection of the potency of *A. sativum* extract in erythrocyte production, hemoglobin breakdown, or hepatic management of bilirubin.

Superoxide dismutase activity numerically increased at the higher extract concentrations, particularly at 12.5 and 17.5 mg/mL. However, the treatment effect was not statistically significant ($P = 0.070$). The numerical increase observed might confirm the stimulatory effect of *A. sativum* on SOD, which might serve as an important part of the enzymatic antioxidant defense system by converting superoxide radicals into hydrogen peroxide.

Malondialdehyde showed similar values across all the treatments during the infective stage. In contrast, after receiving the extract treatment, lowest values occurred in the albendazole and saline groups, meanwhile, higher values were recorded for animals in group 12.5 and 17.5 mg/mL. MDA is generally used as a pointer of lipid peroxidation and oxidative impairment. Thus, the higher increased malondialdehyde indicates the presence of oxidative instability which might have led into an increase in superoxide dismutase. This rise in superoxide dismutase could have been influenced by the *Allium sativum* treatment. This assists in harvesting the O^{2-} radicals leading to normal/similar glutathione peroxidase by mitigating the production of H_2O_2. Allicin in garlic has been reported to act as an antimicrobial, anticancer, and antioxidant. It also acts as a proficient healing agent. Allicin is hydrophobic in nature and also acts as a reactive sulfur species (RSS) within the cells, thereby oxidizing the thiol groups of glutathione and cysteine residues in proteins. Thus, it maintains oxidative stability within the system (Nadeem *et al*., 2021). The ameliorative effect of *A. sativum* might have helped in elevating the proportion of superoxide dismutase despite the abundance of malondialdehyde, thereby stabilizing the proportion of glutathione peroxidase that could have aided abundance of reactive oxygen species. The range of malondialdehyde in this study agrees with Dede *et al*. (2000), who reported significantly increased level of malondialdehyde in Akkaraman sheep infected with *Fasciola spp*., *Trichostrongylidae*, and *Eimeria spp*. The observed changes may be related to the complex phytochemical composition of *A. sativum*. Garlic comprises of numerous organosulfur compounds, comprising ajoenes, S-allyl cysteine, allicin, diallyl trisulfide, and diallyl disulfide. These compounds have been connected with antioxidant and redox-modulating actions (Yudhistira *et al*., 2022).

4. CONCLUSION

It could therefore be concluded from the findings of this study that *Allium sativum* extract improves the hematology, serum chemistry, and oxidative stability biomarkers of West African Dwarf goats artificially infected with *Haemonchus contortus*. It was revealed that the 12.5 mg/mL concentration appeared to provide the most balanced therapeutic response in terms of packed cell volume and hemoglobin responses. At the same time, the serum biochemical profile showed lower cholesterol and urea concentrations than the untreated infected group at the final stage. The enzymatic and oxidative biomarkers were maintained against the possible stress the challenge of *H. contortus* might cause. These combined responses suggest that the 12.5 mg/mL treatment may have supported physiological recovery during the experimental infection. The observed changes may be related to the abundance of phytochemical compounds in *A. sativum*, which are capable of providing antioxidant and redox-modulating activities.

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Author Contributions
This manuscript has been read and approved by all the authors. Each of the authors believes that this manuscript represents honest work done by us.

Informed consent
Not Applicable.

Conflicts of interests
The authors declare that they have no conflicts of interest, competing financial interests or personal relationships that could have influenced the work reported in this paper.

Ethical approval & declaration
In this article, the animal regulations are followed as per the ethical committee guidelines of Department of Animal Science, Faculty of Agriculture, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria; the authors observed the effect of *Allium sativum* on the hematology, serum chemistry, and oxidative stability biomarkers of West African Dwarf goats artificially infected with *Haemonchus contortus*. The Animal ethical guidelines are followed in the study for observation, identification & experimentation. Also, the ethical guidelines for plants & plant materials for *A. sativum* are followed in the study for observation, identification & experimentation.

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Data and materials availability
All data associated with this study will be available based on the reasonable request to corresponding author.

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