



THE EFFECT OF AQUEOUS EXTRACT OF *Ocimum gratissimum* LEAVES ON THE LIVER AND HAEMATOLOGICAL PARAMETERS OF *Salmonella typhi*-INDUCED ALBINO RATS

Jibril Hassan Liman and Esther Mayowa Pius*

Department of Biochemistry, University of Abuja, Nigeria

*Corresponding email: piusmayowaesther@gmail.com

ABSTRACT

This study investigates the effect of aqueous extract of *Ocimum gratissimum* on the liver function, kidney function, lipid profile, and hematological parameters of *Salmonella typhi*-infected Wistar albino rats. Experimental rats were grouped into six groups, induced with *S. typhi* via oral administration of an infective dose (1 ml of 1.5×10^8 cfu/ml) of cultured *S. typhi*. Group 1 served as the control, group 2 was untreated, group 3 was treated with the standard drug (ciprofloxacin), while groups 4, 5, and 6 were treated with (200, 250, and 300 mg/kg) body weight of the aqueous extract of *O. gratissimum*. The physical examination of rats in all the treated groups showed significant improvement. Groups treated with the plant extract had total clearance by the fourth day, while rats treated with the standard drug had a total clearance by the tenth day. Concentrations of alanine aminotransferase (GPT), aspartate aminotransferase (GOT) and albumin were higher ($p \leq 0.05$) in untreated rats than in treated rats. Also, a significant reduction ($p \leq 0.05$) in PCV, hemoglobin concentration, RBC count, and WBC count of the infected groups was observed as compared to the normal group, which were increased upon treatment with the extract. These results suggest that aqueous extract of *O. gratissimum* is a potent antimicrobial agent against *S. typhi* with hepatoameliorative potentials and a restorative effect on hematological parameter.

Keywords: Enzymes, Haematologic effects, *Ocimum gratissimum*, *Salmonella typhi*

INTRODUCTION

Enteric fever, primarily caused by *Salmonella enterica* serovar *typhi* (*S. typhi*), remains a major global public health concern, particularly in sub-Saharan Africa and South/Southeast Asia, where an estimated 11 to 21 million cases and 130,000 to 160,000 deaths occur annually (Akinduti *et al.*, 2026; Bassi *et al.*, 2026). *S. typhi* is a motile, Gram-negative rod and a strictly human pathogen with no known animal reservoir (Thye *et al.*, 2025; Oluwafemi *et al.*, 2026). In Nigeria, typhoid is highly endemic, representing the most commonly isolated *Salmonella* species in national surveillance. Stool culture surveys in Southern Benue reported a high *S. typhi* prevalence of 41.5 % among symptomatic patients, while retrospective hospital data in Nasarawa State showed case fatality rates peaking at 27.8 % among young adults. This hyperendemicity is driven by poor sanitation and limited access to potable water in many communities (Kehinde *et al.*, 2024; Adikwu *et al.*, 2025; Bassi *et al.*, 2026).

The clinical management of typhoid fever is severely challenged by the global emergence of multidrug-resistant (MDR) and extensively drug-resistant (XDR) *S. typhi* strains, particularly of the dominant H58 haplotype. *S. typhi* exhibits rising resistance to traditional first-line drugs like ampicillin, chloramphenicol, and trimethoprim-sulfamethoxazole, as well as fluoroquinolones and third-generation cephalosporins. In Nigeria, trimethoprim-sulfamethoxazole resistance regularly exceeds 90%, and regional MDR rates reach up to 61.1%, narrowing effective treatments and

highlighting the urgent need for natural plant-derived alternative therapeutics (Samuel, 2025; Thye *et al.*, 2025; Akinduti *et al.*, 2026). Upon ingestion, *S. typhi* translocates to some organs including the spleen, gallbladder, and liver, which serves as a critical target organ and a primary reservoir for chronic, persistent infection. Hepatic invasion often results in hepatomegaly, inflammation, and clinical liver damage. Concurrently, systemic *S. typhi* infection triggers profound haematological alterations, conventionally presenting as anaemia, leukopenia, and thrombocytopenia (Ehiremen *et al.*, 2025; Ekenna-Ohanenye *et al.*, 2026; Oluwafemi *et al.*, 2026).

In search of safe alternatives, *Ocimum gratissimum* (Lamiaceae), commonly known as scent leaf (efinrin in Yoruba, nchanwu in Igbo, and daidoya in Hausa), is widely utilized across Nigeria for culinary and ethnobotanical applications. This perennial herb is rich in bioactive secondary metabolites, including essential oils (predominantly eugenol and thymol), flavonoids, tannins, saponins, and alkaloids, which collaboratively mediate its broad-spectrum antibacterial, antioxidant, and anti-inflammatory properties (Ogundoju *et al.*, 2025; Ugwu *et al.*, 2025; Afolabi *et al.*, 2026; Maphetu *et al.*, 2026). Scientific validation indicates that *O. gratissimum* leaf extracts possess remarkable hepato-protective properties. In vivo studies demonstrate that its extracts protect the liver against chemical-induced injury, restoring tissue architecture and reducing elevated liver enzymes, such as alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline

phosphatase (ALP) (Ekenna-Ohanenye *et al.*, 2025; Banibella *et al.*, 2025). However, sub-chronic safety evaluations in healthy Wistar rats have shown a discordant biochemical-histological profile; while a 28-day oral administration of its ethanolic leaf extract lowered blood glucose without causing structural liver damage, it induced a dose-dependent elevation of AST, emphasizing the need for rigorous hepatic safety evaluations (Ekenna-Ohanenye *et al.*, 2025).

Furthermore, *O. gratissimum* has a significant impact on the serum lipid profile. Active compounds, such as magnesium, crude fibers, and specific fatty acids, are associated with lowering cholesterol levels, improving lipid metabolism, and protecting against cardiovascular diseases. In vivo studies confirm that its leaf extracts significantly reduce triglycerides and low-density lipoprotein (LDL) cholesterol in diseased models (Maphetu *et al.*, 2026). Finally, *O. gratissimum* acts as a potent modulator of haematological parameters. Sub-chronic and acute evaluations show that higher doses of its aqueous extracts significantly elevate packed cell volume (PCV), haemoglobin (Hb) concentration, red blood cell (RBC) count, and total white blood cell (WBC) count, promoting erythropoiesis and immunomodulatory responses. Conversely, some ethanolic leaf extract trials have reported selective reductions in PCV and platelet counts alongside an increase in neutrophil percentage, indicating complex plasma volume shifts or immunoregulatory signaling. Additionally, its bioactive compounds, such as ursolic acid, exhibit significant anti-sickling properties, further demonstrating its cellular protective value (Ehiremen, *et al.*, 2025; Ekenna-Ohanenye *et al.*, 2026). This research aims to dive into the antityphoid activity of *O. gratissimum* in wistar rats and its effect on the overall well-being of the animal.

MATERIALS AND METHODS

Experimental Design

Thirty Wistar albino rats (*Rattus norvegicus*) weighing (150-200 g) were purchased from the animal holding unit of the National Veterinary Research Institute (NVRI) VOM, Jos, Plateau state, Nigeria. The animals were acclimatized for two weeks at the animal house of the Department of Physiology, Federal University of Lafia, Nigeria, and were fed with rat normal pellet diet and water *ad libitum* throughout the experiment.

The rats were picked at random and grouped into six. A control group, while groups 2-6 were the experimental groups. The rats were sacrificed after four weeks of extract administration using cervical dislocation. Collection of serum for biochemical analysis was carried out as described by (Yakubu *et al.*, 2005). Twelve hours after the final treatment, the rats were anesthetized with chloroform. The rats were dissected laterally, and blood samples were collected by cardiac puncture using a sterile needle while the heart beats and pumps blood. The blood samples for kidney and liver function tests were collected into dry tubes and allowed to stand at room temperature for 15 min and then centrifuged at 1500 rpm/10 min. While the blood samples for the

hematological analysis were collected in K2 EDTA containers.

Preparation of Extracts

Fresh leaves of the plant *O. gratissimum* were collected and the botanical identification of the plant was done at the herbarium of the Botany Department of the Federal University of Lafia. They were washed properly in distilled water to remove soil, dust, and dirt. The *O. gratissimum* leaves were air-dried at room temperature for one week in a well-aerated atmosphere to prevent direct sunlight to avoid denaturation of vital phytoconstituents.

After the plants had been properly dried, they were pounded using a mortar and pestle and transferred into the electric blender to be blended. The blended plant material was thereafter subjected to cold extraction. 138 g of the powdered leaves were soaked in 1.38 liter of distilled water and allowed to stand in a dark conducive place for three days to avoid photoreactive contaminants. The samples were shaken several times for 72 h. The extract was filtered using Whatman filter paper No 1. The filtrate was poured into an evaporating dish and placed inside a water bath to evaporate at 45°C to get an extract. Giving a yield of 3.79 %, dilution to the desired concentration was done and preserved in the refrigerator using a universal bottle and used when needed.

Method of Administration

Administration of the aqueous extract was done orally through calibrated syringe with an attached rubber cannula. The animals received their doses daily for 10 days. The control group received a quantity of distilled water equivalent to the volume in group 4. Groups 3, 4 and 5 received the aqueous extract of *O. gratissimum* at doses of 200, 250 and 300mg/kg respectively.

Preparation of Standard Drug

A standard typhoid drug, ciprofloxacin, was purchased from Top 10 pharmacy in Lafia, Nasarawa state in a tablet form. The drug was dissolved in 1 ml distilled water at a dose of 12 mg/kg body weight for animals in group 6.

Test Bacteria

Stock culture of test bacteria (*S. typhi*) used in the study was obtained from Bafawat diagnostic laboratory, Lafia. *S. typhi* was confirmed by carrying out gram staining, culturing on appropriate selective media, and subjecting it to various biochemical tests. The collected bacterial samples were immediately taken to the microbiology laboratory of the Federal University of Lafia, where they were incubated within 2 to 3 h of collection at 37°C for 24 h. Emerged colonies were stripped from the plate and diluted with normal saline. The bacterial cell suspensions were standardized at 1.5×10^8 colony-forming units/ mL (CFU/mL) following McFarland turbidity standard N° 0.5. 1 ml of the standardized sample was administered orally to the animals to induce typhoid.

Induction and Confirmation of *S. typhi* Infection

Animals were screened bacteriologically for *S. typhi* infection and thereafter starved overnight before the bacterial inoculation. Rats in groups 2, 3, 4, 5, and 6 were orally administered 1 ml of 1.5×10^8 cfu/ml of the cultured *S. typhi* infective dose. After four days, some of the symptoms observed include unformed stool, loss of appetite, general body weakness, salivation, scattered fur, falling of hairs, stool with mucus, and weight loss. One rat from each group that was infected with *S. typhi* was picked at random and the stool samples were cultured using *Salmonella-Shigella* Agar (SSA) and incubated (24 h) for bacterial growth.

In vitro Antibiotics Sensitivity Test

2.8 g of nutrient agar powder was weighed and added to 100 ml of sterile water. The mixture was sterilized (using the autoclave) at 121°C for 15 mins. The sterile nutrient agar was allowed to cool to 45°C and then poured into sterile petri dishes containing the test organism. The petri dishes were rotated anti-clockwise to allow even distribution of the agar and then left to solidify. Thereafter, a ring of disks of each (Mast Diagnostics, UK) containing single concentrations of each antimicrobial agent was then placed onto the inoculated surface. After 24 h incubation at 37 °C, clear zones produced by antimicrobial inhibition of bacterial growth were measured in mm using a straight-line ruler.

Biochemical Analysis

Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) activities were determined with the Quimica Clinica Aplicada kit. Total serum protein levels were measured by the Biuret method and were analyzed using UV Shimadzu 120–02 spectrophotometer. Creatinine, alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase, total protein, and albumin using a semi-auto chemistry analyzer.

Hematological Analysis

Hematological parameters analyzed include hemoglobin concentration (Hb), Packed cell volume (PCV), Red blood cell (RBC) count, mean cell volume (MCV), mean cell hemoglobin concentration (MCHC), mean hemoglobin concentration (MCH), total white blood cell count (TWBC), lymphocyte, neutrophils, monocytes,

eosinophil, and basophils were determined using an automated blood analyzer (Accu cell DX 360 China).

Histological Analysis

The rats' liver and kidneys were removed for histological examination. The organs were immediately fixed in 10 % neutral buffered formalin, dehydrated with a graded series of ethyl alcohol, and embedded in paraffin. Sections (5 mm) were cut and stained with hematoxylin and eosin (Perls' Prussian blue method). Histological slides were photographed under a Zeiss Axioscope photomicroscope. The reading was performed using a light microscope (Olympus) at 300 X magnification. Histopathology was determined based on the severity of changes compared to control sections.

Statistical Analysis

Data are expressed as means standard errors of the mean (SEMs). Differences between groups were evaluated by analysis of variance (ANOVA) with the Bonferroni post hoc test or by calculation of Spearman's rank correlation coefficient, as appropriate, using Prism 5.03 (GraphPad Software Inc., San Diego, CA, USA). Statistical significance was at $p < 0.05$.

RESULTS AND DISCUSSION

The antioxidant and anti-inflammatory properties of *O. gratissimum* have been ascribed to its therapeutic benefits. Its leaf extracts have been shown to contain antioxidant vitamins, such as alpha-tocopherol and ascorbic acid (Ajiboye *et al.* 2024). The clinical signs observed upon the physical examination of the rats in each group (groups 1–6) in this study are shown in Table 1. The rats in the positive control group were observed to have loose stool with mucus, reduced activity, loss of appetite, fur scattering and falling contrary to the animals in the negative control group with none of these signs which agrees with the findings in literature. Most of these observations are signs of fever and diarrhea. This suggested that the bacteria proliferated in the organs after having invaded the system and challenged the non-specific defense mechanism of rats. Animals in the extract treated groups after two days of treatment had their symptoms ameliorating as treatment progressed for 4 days.

Table 1: Effect of aqueous extract of *O. gratissimum* on the physical parameters of *S. typhi* infected rats

Days	0	1	2	3	4	5	6	7	8	9	10
200 mg/kg	abde	abde	cfhj	Ghj	hij	hij	hij	hij	hij	hij	hij
250 mg/kg	abde	abdf	cghj	Hij	hij	hij	hij	hij	hij	hij	hij
300 mg/kg	abde	abdf	ghj	Hij	hij	hij	hij	hij	hij	hij	hij
NC	k	k	k	k	k	k	k	k	k	k	k
PC	abde	abde	abde	abdf	abdf	abdf	abdf	abdf	abdf	abdf	abdf
SC	abde	abde	abdf	abdf	abdf	cghj	cghj	chij	chij	hij	hij

a - reduced activity, **b** - reduced food intake, **c** - Scattered fur, **d** - Scattered and falling fur, **e** - Drooling, **f** - Loose stool, **g** - soft stool, **h** - active, **i** - formed stool, **j** - improved food intake, **k** – Normal

In vitro sensitivity tests in Table 2 showed that *S. typhi* was sensitive to only gentamycin, having the highest zone of inhibition (11.33 mm). Resistance of *S. typhi* to antibiotics could be because of the development of efflux pumps over time which is responsible for extruding and preventing the accumulation of antibiotics in the bacteria cell which results in antibiotic resistance.

Table 2: *In vitro* effect of antibiotics on *S. typhi* after 24 h

Antibiotic	Zone of inhibition (mm)
Gentamycin	11.33
Chloramphenicol	0.00
Sparfloxacin	0.00
Ciprofloxacin	0.00
Amoxicillin	0.00
Augmentin	0.00
Pefloxacin	0.00
Terivid	0.00
Streptomycin	0.00
Seprin	0.00

Treatment of infected rats with the plant extract and ciprofloxacin significantly decreased ($p < 0.05$) colony counts of *S. typhi* compared to the pretreatment values and the positive control group (PC) (Table 3). Groups treated with the plant extract recorded significantly lower ($p < 0.05$) colony counts than rats treated with ciprofloxacin. Rats treated with 200, 250 and 300 mg/kg of the plant extract had total clearance by the 4th day of treatment, while rats treated with ciprofloxacin had a total clearance by the 10th day of treatment. The decrease in the bacterial load observed during treatment may be due to free radical scavengers in the extracts, such as flavonoids and alkaloids, which have a wide range of antimicrobial and insecticidal properties elicited by inhibiting DNA topoisomerases of microbes. Other secondary metabolites found in substantial amounts in the extract and fraction, which could be responsible for their therapeutic effect on *S. typhi* infected rats are total phenols and saponins. Flavonoids and total phenols have been reported to complex with extracellular and soluble proteins as well as with bacterial cell walls while tannins are capable of inactivating microbial adhesions, enzymes, cell envelope of transport proteins and form complex with polysaccharide.

Table 3: Effect of aqueous extract of *O. gratissimum* on colony count of *S. typhi* (1×10^8 cfu) in the faeces of infected rats

Groups	Day 1	Day 4	Day 7	Day 10
200 mg/kg	7.50±0.28	0.00±0.00	0.00±0.00	0.00±0.00
250 mg/kg	3.80±0.34 ^a	0.00±0.99	0.00±0.00	0.00±0.00
300 mg/kg	8.10±0.63 ^b	0.00±0.00	0.00±0.00	0.00±0.00
NC	0.00±0.00 ^{abc}	0.00±0.00	0.00±0.00	0.00±0.00
PC	3.80±0.11 ^{acd}	4.10±0.23 ^{abcd}	3.50±0.17 ^{abcd}	7.20±6.70 ^{abcd}
SC	7.50±0.57 ^{bde}	3.50±0.28 ^{abcd}	2.90±0.05 ^{abcde}	0.00±0.00 ^e

Table 4: Effect of aqueous extract of *O. gratissimum* on liver enzymes of *S. typhi* infected rats

Group	PRO (g/L)	ALB (g/L)	GOT (u/L)	GPT (u/L)	ALP (u/L)
200 mg/kg	54.00±2.88	31.00±2.30	188.33±24.55	15.00±0.57	656.00±3.46
250 mg/kg	47.00±1.73	20.00±2.88	140.00±11.54	33.00±2.30 ^a	595.00±2.88
300 mg/kg	39.00±0.57 ^a	17.00±1.73 ^a	197.00±1.73	19.00±0.57 ^b	494.00±3.46 ^{ab}
NC	50.00±5.77	29.00±0.57 ^c	161.00±2.30	20.00±2.88 ^b	905.00±14.43 ^{abc}
PC	46.00±2.30	30.00±2.88 ^c	302.00±4.61 ^{abcd}	24.00±0.57 ^{a, b}	415.00±2.88 ^{abd}
SC	45.00±2.88	15.00±2.88 ^{ade}	150.00±14.43 ^e	11.00±0.57 ^{bcde}	673.00±42.14 ^{cde}

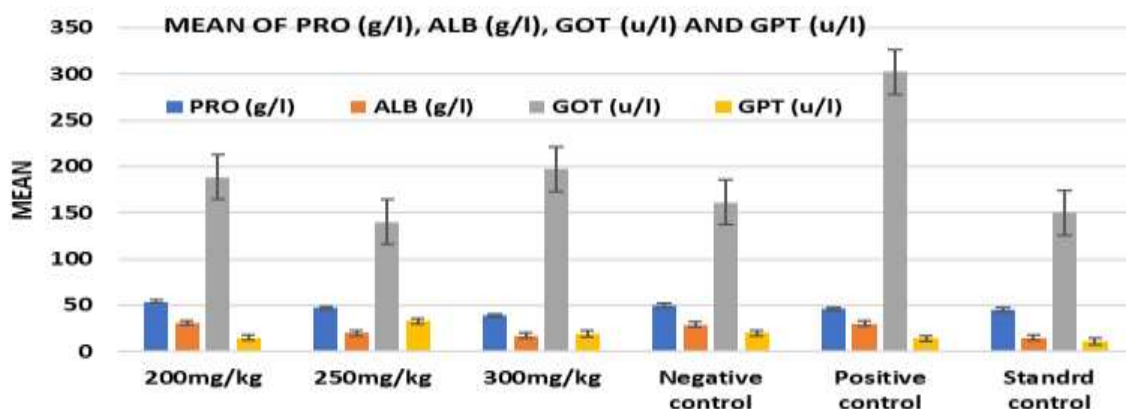
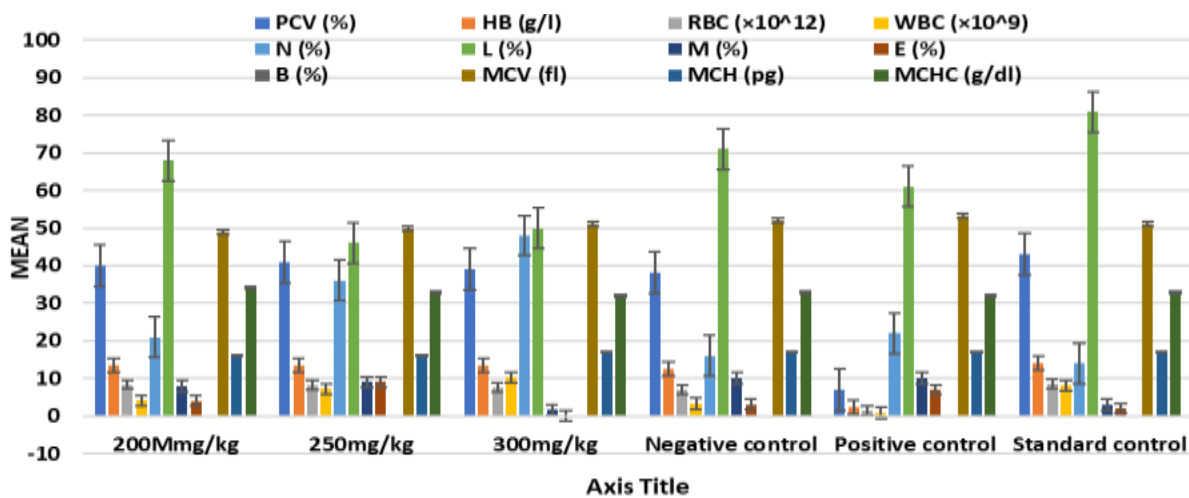


Figure 1: Effect of aqueous extract of *O. gratissimum* on Total protein (PRO), Albumin (ALB), Aspartate aminotransferase (GOT), and Alanine aminotransferase (GPT) of *S. typhi* infected rats

Table 5: Effect of aqueous extract of *O. gratissimum* on hematological parameters of *S. typhi* infected rats

parameter	200 mg/kg	250 mg/kg	300 mg/kg	NC	PC	SC
PCV (%)	40.00±0.57	41.00±1.15	39.00±1.15	38.00±1.15 ^e	7.00±1.15 ^{abc}	43.00±1.15 ^d
HB (g/dl)	13.60±0.75	13.40±0.17	13.50±0.11	12.40±0.34 ^e	2.40±0.17 ^{abc}	14.20±0.17 ^{dc}
RBC (×10 ¹²)	8.30±0.63	8.20±0.17	7.60±0.23	7.00±1.15 ^e	1.40±0.11 ^{abc}	8.50±0.57 ^d
WBC (×10 ⁹)	4.10±0.23	7.20±0.05 ^a	10.30±0.05 ^{ab}	3.30±0.51 ^{bce}	0.80±0.17 ^{abc}	8.10±0.51 ^{acde}
PLT (×10 ⁹)	500.00±28.86	676.00±26.55 ^a	485.00±8.66 ^b	382.00±10.39 ^{abce}	21.00±1.15 ^{ab}	512.00±4.61 ^{bd}
N (%)	21.00±0.57	36.00±0.57 ^a	48.00±1.15 ^{ab}	16.00±1.15 ^{abce}	22.00±0.57 ^{bc}	14.00±1.15 ^{abcd}
L (%)	68.00±1.15	46.00±1.15 ^a	50.00±0.57 ^a	71.00±1.15 ^{bce}	61.00±1.73 ^{abc}	81.00±2.30 ^{abcde}
M (%)	8.00±0.57	9.00±1.73	1.67±0.66 ^{ab}	10.00±1.15 ^c	10.00±0.57 ^c	3.00±0.28 ^{abde}
E (%)	4.00±0.57	9.00±0.57	-	3.00±0.57	7.00±0.57	2.00±0.28
B (%)	-	-	-	-	-	-
MCV (fl)	49.00± 1.15	50.00±2.88	51.00±0.57	52.00±0.57	53.33±2.96	51.00±2.30
MCH (pg)	16.00±0.15	16.00±0.57	17.00±0.57	17.00±0.57	17.00±0.57	17.00±0.57
MCHC (g/dl)	34.00±0.57	33.00±1.15	32.00±1.15	33.00±2.30	32.00±1.73	33.00±1.73



PC-Positive control, NC-Negative control, SC-Standard control, 200, 250, 300- aqueous *O. gratissimum* extract (Doses in mg/kg body weight), Packed cell volume (PCV), Hemoglobin (HB), Red blood cell (RBC) White blood cell (WBC) and Neutrophil (N), lymphocyte (L), Monocytes (M), Eosinophils (E), Basophil (B), Mean corpuscular volume (MCV), Mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC); Values are mean ± standard error of three replicates (n= 3). Values with different alphabets along a column are significantly different ($p < 0.05$). Values without alphabets are considered non-significantly different ($p < 0.05$)

Figure 2: Effect of aqueous extract of *O. gratissimum* on Hematological parameters of *S. typhi* infected rats

The activities of aspartate aminotransferase (GOT) in *Salmonella typhi* infected but not treated rats (PC) was significantly ($p < 0.05$) increased with a non-significant increase in Albumin (ALB) and Alanine aminotransferase (GPT) compared to the Negative control group (NC), as shown in Table 4. This may be a result of injury due to endotoxins released by the microorganism.

There was also a significant ($p < 0.05$) decrease in ALP levels and a non-significant decrease in PRO levels in the infected group compared to the Negative control group which is common in patients infected with *S. typhi* resulting in kidney malfunction (Fig. 1). We also relate our findings of decreased total protein levels to its reduced absorption following the disruption of the integrity of the stomach lining. Groups of rats that received treatment had total protein and albumin concentrations that compared favorably to that of the negative control group. Administration of the extract led to a dose-dependent significant ($p \leq 0.05$) reduction in GTP and GOT and a non-significant decrease in ALB. There was also a significant ($p \leq 0.05$) increase in ALP in treated groups treated with extract and the group treated with ciprofloxacin. These observations could be because of the extracts been able to prevent the excessive

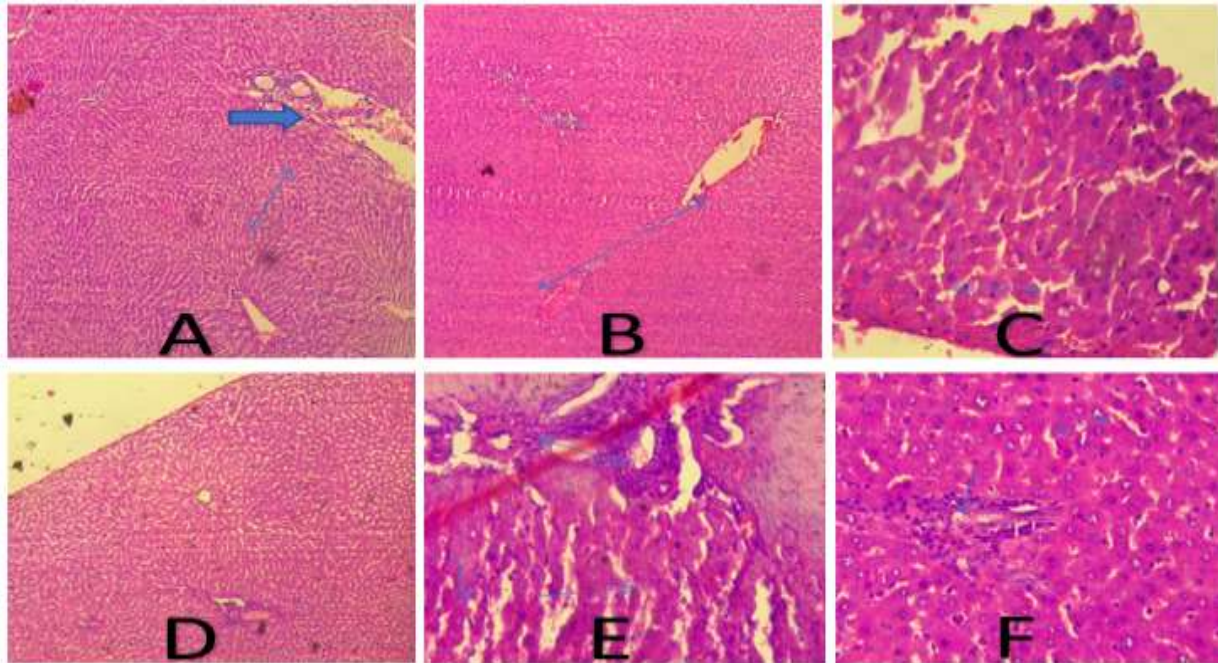
synthesis of the enzymes, inhibit their release from hepatocytes and therefore, ameliorating the injury.

The histological sections of the liver revealed histopathological changes in various groups. The liver of the Negative control rat shows the normal arrangement of the hepatocytes with no visible lesion. The liver of Positive control rats shows hepatocytes with reactive nuclear changes, inflammatory cells within the portal triad, congested capillaries (double thin arrow), and high vacuolation of the hepatocytes, which indicates the destruction of hepatocytes. liver of rats treated with ciprofloxacin shows a moderate increase in the size and color (darker) of nuclei of the hepatocytes (single arrow), an increase in size and color (more pinkish) of the cytoplasm, with a few exhibiting clear cell changes (double arrow). The liver of rats treated with 200 mg/kg of aqueous extract of *O. gratissimum* shows preservation of normal hepatic plate arrangement with individual hepatocytes having vesicular nuclei and moderate cytoplasm. The portal triad shows very few inflammatory cells. The liver of rats treated with 250 mg/kg of aqueous extract of *O. gratissimum* show hepatocytes still arranged in plates. The portal triad (top right) shows mild infiltration by inflammatory cells (thin arrow). The liver of rats treated with 300 mg/kg of

aqueous extract of *O. gratissimum* show the normal arrangement of hepatocytes with no vacuolation. Increase in the size and color (more pinkish/eosinophilic) of the cytoplasm of the hepatocytes which shows that our extract restored the histology of the infected liver.

As presented in Table 5, the induction of *S. typhi* infection resulted in a significant ($p < 0.05$) decrease in Packed cell volume (PCV), Hemoglobin (HB), Red blood cell (RBC), White blood cell (WBC), Platelet (PLT), and Lymphocyte (L) in the infected group compared to the negative control group, which is similar to the report of Kalia *et al.* (2016). The effect of *S. typhi*

infection may be because of the interaction between the bacteria toxins and the blood-forming tissues which in return inhibits the rate at which stem cells possessing hematopoietic specializations are synthesized. It is shown from literature that these toxins can interact with the red blood cell membrane proteins to accelerate the rate of red cell destruction. Thus, from the above, it can be inferred that the decrease observed in red blood cell count, hemoglobin concentration, and packed cell volume might be due to retardation of Hemopoiesis and increased hemolysis of red cells.



A: Liver of negative control rat; B: Liver of Positive control rats; C: Liver of rats treated with ciprofloxacin; D: Liver of rats treated with 200 mg/kg of aqueous extract of *O. gratissimum*; E: Liver of rats treated with 250 mg/kg of aqueous extract of *O. gratissimum*; F: Liver of rats treated with 300 mg/kg of aqueous extract of *O. gratissimum*; All panels were stained with H & E, magnification $\times 300$.

Plate 1: Effect of *O. gratissimum* on the histology of the liver of *S. typhi* infected rats

Aqueous extract of *O. gratissimum* elicited a dose-dependent significant increase in PCV, HB, RBC, PLT, and L in the treated groups compared to the infected groups (Fig. 2). This could be attributed to the ability of the extracts to reverse the damages prompted by the presence of the bacteria in the bloodstream viz; improving hemopoiesis of specialized stem cells and restoring membrane integrity. The significant ($p < 0.05$) increase in neutrophil (N) observed in the group infected with *S. typhi* when compared with the normal control group was consistent with the work of Kalia *et al.* (2016). Groups treated with extract and ciprofloxacin have a non-significant dose-dependent decrease in mean cell volume (MCV), mean cell hemoglobin (MCH), and mean cell hemoglobin concentration (MCHC).

CONCLUSION

The study indicated that aqueous extract of *O. gratissimum* contains potent antimicrobial agent(s) against *S. typhi* with restorative (and protective) influence against the biochemical and histological defects caused by the disease on the liver of the rats. It is

also revealed that aqueous extract of *O. gratissimum* restores hematological parameters.

Conflict of interest: The authors declare no conflict of interest.

Acknowledgements: We wish to acknowledge the Federal University of Lafia for providing us with the opportunity to use its lab and facilities for this experiment. We would also like to acknowledge the Lab. Technologists in the Biochemistry and Microbiology Departments at Federal University of Lafia for their support throughout this work.

REFERENCES

- Adikwu, P., David, O. S., Ameh, A. A., Oche, D. A., Akinibosun, O., Sonia, O. O., Ochela, E., Dominic, A. and Agbo, E. B. (2025). Determination of antibiotic susceptibility pattern of *Salmonella typhi* isolated from stool of patients in Southern Benue, Nigeria. *Tropical Journal of Medicine and Basic Sciences*, 1(2), 14–19.

- Afolabi, O. T., Agu, G. C., Sossou, I. T., Adeyemi, J. O., Olaleye, O. A. and Onabanjo, M. A. (2026). In-vivo and in-vitro efficacy of *Ocimum gratissimum* and *Vernonia amygdalina* on albino rats and some clinical isolates. *FUDMA J. of Sci.*, 10(4), 174–182. <https://doi.org/10.33003/fjs-2026-1004-4704>
- Ajiboye, B. O., Ajuwon, O. R., Jeje, T. O., Ijyemi, O. D., Ogunmilade, A. F., Okesola, M. A., Hosseinzadeh, H., Oyinloye, B. E., Ogedengbe, O. O. and Kowalski, R. (2024). Modulation of KIM-1/TGF- β 1 signaling pathway by *Ocimum gratissimum* leaf flavonoid-rich extracts in the kidneys of streptozotocin-induced diabetic rats. *Current Issues in Pharmacy and Medical Sciences*, 37(2), 142–165.
- Akinduti, P. A., Odoom, A., Aniweh, Y. and Donkor, E. S. (2026). Non-typhoidal *Salmonella* prevalence and antimicrobial resistance in Nigeria: A systematic review and meta-analysis. *International Health*. <https://doi.org/10.1093/inthealth/ihag044>
- Banibella, A., Saad, N., Eyad, J. and Chambuso, R. (2025). Laboratory epidemiology of *Salmonella* infections and multi-drug resistance profiles in Nigeria: Barriers, challenges and proposed solutions. *One Health*, 21, Article 101289. <https://doi.org/10.1016/j.onehlt.2025.101289>
- Bassi, I. G., Akpan, C. E., Saleh, I. M., Orole, O. and Abdulrasheed, I. S. (2026). Prevalence of typhoid fever among admitted patients of Federal University of Lafia Teaching Hospital, Lafia, Nasarawa State: A retrospective observational study. *Lafia J. of Scientific & Ind. Res.*, 4(1), 226–232. <https://doi.org/10.62050/ljsir2026.v4n1.819>
- Buzilă, E. R., Dorneanu, O. S., Trofin, F., Sima, C. M. and Iancu, L. S. (2025). Assessing *Salmonella* Typhi pathogenicity and prevention: The crucial role of vaccination in combating typhoid fever. *Int. Journal of Molecular Sciences*, 26(9), 3981. <https://doi.org/10.3390/ijms26093981>
- Ehiremen, S. E., Akanji, O. D., Okeoma, O. I., Nuhu, S. U., Alao, O. B., Kolawole, V. O., Dawodu, A. J., Uwagbai, I. and Agbolade, I. B. (2025). Antioxidative, haematological and histological assessment of sub-chronic administration of scent-leave (*Ocimum gratissimum*) on the cerebellum of adult Wistar rats. *Bayero Journal of Medical Laboratory Science*, 10(1), 93–108.
- Ekenna-Ohanenye, C. A., Nto-Ezimah, U. A., Nto, N. J., Irozulike, F. C. and Godson, P. K. (2026). Sub-chronic effects of ethanolic leaf extract of *Ocimum gratissimum* on glucose homeostasis, haematological indices, oxidative stress markers, and liver histology in adult Wistar rats. *J. of Medical Pharmac. and Allied Sci.*, 15(2), 35–48. <https://doi.org/10.55522/jmpas.V15I2.7010>
- Kalia, P., Kumar, N. R. and Harjai, K. (2016). Effect of propolis extract on hematotoxicity and histological changes induced by *Salmonella enterica* serovar Typhimurium in balb/C mice. *Archives of Biological Sci.*, 68(2), 385–391.
- Kehinde, A., Ogunleye, V., Popoola, O., Amadi, E., Coker, A., Rahman, M., Akintunde, Y., Adebisi, I., Ogundairo, J., Otunla, E., Davies, M., Udofia, P., Aderibigbe, A., Alaran, S., Taiwo, O., Uzzell, C., Troman, C., Gray, E., Rigby, J., Iqbal, T., Grassly, N., and Okeke, I. (2024). Seasonal patterns in typhoid environmental surveillance in Ibadan, Nigeria. *International Journal of Infectious Diseases*, Article 107386. <https://doi.org/10.1016/j.ijid.2024.107386>
- Maphetu, N., Unuofin, J. O., Oladipo, A. O. and Lebelo, S. L. (2026). *Ocimum gratissimum*: Chemical composition, phytochemical properties, antioxidants, and pharmacological activities: A review. *Plants*, 15, 1662. <https://doi.org/10.3390/plants15111662>
- Ogundaju, R. I., Oladunmoye, M. K., and Babatunde, O. J. (2025). GC-MS profiling and antibacterial efficacy of *Ocimum gratissimum* (Linn.) against bacteria associated with gastroenteritis. *Microbes and Infectious Diseases*, 6(2), 873–884. <https://doi.org/10.21608/MID.2023.216316.1538>
- Oluwafemi, E. O., Adegoke, R. A., Bello, M. O. and Onawole, A. T. (2026). Multi-target in silico screening of African natural products against *Salmonella* Typhi. *In Silico Research in Biomedicine*, 2, Article 100524. <https://doi.org/10.1016/j.insr.2026.100524>
- Samuel, E. (2025). Antimicrobial and antifungal potentials of *Ocimum gratissimum* leaf extracts against multidrug-resistant pathogens. *bioRxiv*. <https://doi.org/10.1101/2025.09.22.677875>
- Thye, T., Krumkamp, R., Lusingu, J. P. A., Ofori, L. A., Minja, D. T. R., Flieger, A., Gesase, S., Phillips, R., Simon, S., Obiri-Danso, K., ... and Dekker, D. (2025). Non-typhoidal *Salmonella* transmission reservoirs in sub-Saharan Africa: A genomic assessment from a One Health perspective. *Antimicrobial Resistance & Infection Control*, 14. <https://doi.org/10.1186/s13756-025-01561-2>
- Ugwu, C. H., Iheukwumere, I. H., Iheukwumere, C. M., Ike, V. E., Dim, C. N., Ezendianefo, J. N., Egbe, P. A., Oragwu, I. P., Orji, C. C., Ogbonnaya, O. C., Onwuasoanya, U. F., Okereke, F. O., Oduenyi, P. M. and Ochibulu, S. C. (2025). *Ocimum gratissimum* extract's effectiveness against *Vibrio cholerae* from Uli streams. *IPS J. of Phytochemistry and Medicinal Plant Res.*, 1(2), 15–19. <https://doi.org/10.54117/ijpmpr.v1i2.38>
- Yakubu, M. T., Akanji, M. A. and Oladiji, A. T. (2005). Aphrodisiac potentials of the aqueous extract of *Fadogia agrestis* (Schweinf. Ex Hiern) stem in male Albino rats. *Asian J. Androl.*, 7, 399–404.