The Effect of Ethanol Extract of Zingiber officinale on Haematological Parameters in Male Wistar Albino Rats Induced with Inflammation

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Abstract-

Inflammation disrupts normal haematological parameters, leading to anemia, immune imbalance, and systemic complications. There is a growing need for natural, plant-based alternatives like Zingiber officinale to counteract these effects safely and effectively. This study aimed to evaluate the effect of ethanol extract of Zingiber officinale on haematological parameters in male Wistar albino rats induced with inflammation. Parameters such as packed cell volume (PCV), haemoglobin (Hb), red blood cell (RBC) count, white blood cell (WBC) count, and differential leukocyte counts were assessed using an automated haematology analyzer. The results showed that inflammation caused a dose dependent decrease in PCV count (53.00 ± 0.000) in Group B when compared with the blank control (14.9 ± 0.001 g/dL) ($p<0.05$). The intervention of Zingiber officinale extract, returned the high dose value (14.6 ± 0.007 g/dL) to baseline ($p>0.05$). Other parameters such as heamaglobins, RBC, lymphocytes, eosinophils, and monocyte counts followed the same pattern as the PCV. However, the inflammation caused by white egg albumin caused dose dependent increase in WBC count ($6.1 \pm 0.006 \times10^9$/L) in group B when compared with the blank control ($4.2 \pm 0.001 \times10^9$/L) ($p<0.05$). However, the intervention of Zingiber officinale extract ($4.3 \pm 0.004 \times10^9$/L) returned it to baseline. Neutrophil, and basophil maintained the same curve as WBC. These findings indicates that Zingiber officinale ethanol extract exerts dose-dependent anti-inflammatory and hematoprotective effects by restoring PCV, Hb, RBC, WBC, and differential leukocyte levels, thereby supporting its therapeutic potential in managing inflammation-induced haematological disorders.

Keywords: *Zingiber officinale, haemoglobin, Inflammation, PCV, RBC, and WBC*

Introduction-

Background to the Study

Despite advancements in modern medicine, inflammation-related diseases continue to pose a major public health challenge, especially in resource-limited settings. Conditions such as arthritis, cardiovascular disease, and metabolic disorders are often driven or worsened by chronic inflammation (Calder et al., 2019). While synthetic anti-inflammatory drugs like non-steroidal anti-inflammatory drugs (NSAIDs) are widely used, their long-term administration has been associated with side effects such as gastrointestinal bleeding, renal impairment, and hepatotoxicity (Crofford, 2023). As a result, there is growing interest in developing safer plant-based alternatives. One such plant is Zingiber officinale (ginger), a spice with a rich history in herbal medicine. Although ginger has demonstrated anti-inflammatory, antioxidant, and immunomodulatory properties in various studies, its specific effects on Haematological parameters during inflammation remain underexplored (Mashhadi et al., 2023). Inflammation is a fundamental biological response triggered by harmful stimuli such as pathogens, damaged cells, or irritants. While it serves as a protective mechanism aimed at eliminating the initial cause of cell injury, prolonged or chronic inflammation can lead to various health complications, including anaemia, cardiovascular disorders, and immune dysregulation (Nathan and Ding, 2020). One of the key systems affected during inflammation is the Haematological system, where changes in parameters like red and white blood cell

counts, haemoglobin concentration, and platelet levels often reflect the severity and progression of the condition (Damas et al., 2021; Seibert et al., 2024). Haematological parameters are among the most important indicators of an organism's health status. Red blood cell (RBC) count, white blood cell (WBC) count, haemoglobin concentration, hematocrit, and platelet levels are routinely used to monitor disease progression, immune function, and treatment responses (Jain, 2023). Inflammation can disrupt these parameters by inducing leukocytosis, anaemia of inflammation, or thrombocytosis, depending on the duration and severity of the condition (Gabay and Kushner, 2019). For instance, chronic inflammation has been linked with decreased haemoglobin levels due to impaired iron metabolism and reduced erythropoietin production (Weiss and Goodnough, 2015). Thus, any potential therapeutic agent targeting inflammation must be assessed for its influence on Haematological profiles to determine both efficacy and safety. Animal models, particularly the Wistar albino rat, are widely used in experimental research to study pathophysiological effects induced by inflammation and evaluate the efficacy of therapeutic agents' efficacy. When inflammation is experimentally induced in these models, it often mirrors the Haematological disruptions seen in human inflammatory conditions, making them ideal for studying interventions (Damas et al., 2021). By assessing changes in Haematological parameters, researchers can determine the extent to which a substance like Zingiber officinale extract can restore balance or mitigate the effects of inflammation. Although several studies have explored the pharmacological effects of ginger, including its anti-inflammatory and antioxidant actions, there remains a gap in understanding its specific impact on Haematological profiles during inflammation.

Aim

The aim of the study was to determine the effect of ethanol extract of Zingiber officinale on haematological parameters in male Wistar albino rats induced with inflammation.

Specific Objectives

The specific objective of the study were to:
➢ Evaluate the potential anti-inflammatory effects of Zingiber officinale extract on PCV.
➢ Determine the potential anti-inflammatory effects of Zingiber officinale extract on haemoglobin concentration.

➢ Investigate the potential anti-inflammatory effects of Zingiber officinale extract on red blood cell.
➢ Determine the potential anti-inflammatory effects of Zingiber officinale extract on total white blood cell.
➢ Evaluate the potential anti-inflammatory effects of Zingiber officinale extract on white blood cell differentials.

Materials and methods

Materials

Mechanical grinder, Rotary evaporator, Water bath, Anesthesia equipment, Plain tubes, Automated hematology analyzer, Analytical balance, Dissecting kit, Plain bottle, Soxhlet apparatus, Analytic oven, Cotton wool, Hand gloves, Syringe, Wire cage, Water bowl, and Whatman No. 1 filter paper, 70% Ethanol (for extracting the ginger), Egg albumin solution, Distilled water, and Chloroform.

Methods

Plant Collection and Identification Fresh rhizomes of Zingiber officinale (ginger) were procured from Nkpokiti market close to the Institution of Management and Technology (IMT) in Enugu State, Nigeria. The plant was authenticated by Prof. C. E Eze in the Department of Applied Biology and Biotechnology at Enugu State University of Science and Technology.

Preparation of Ethanol Extract

The ginger rhizomes which weighed 76.4 grams, was washed, sliced, and dried using analytical oven $105\neg\neg\neg\neg\neg0C$. The dried slices were pulverized into fine powder using a mechanical grinder. The powdered sample was placed in a Soxhlet apparatus, and 300 mL of pure ethanol was used as the solvent for extraction. The soxhlet extraction process was carried out for 5 hours. The mixture was filtered using Whatman No. 1 filter paper. The filtrate was concentrated using a rotary evaporator under reduced pressure at 40–45°C and dried further in a water bath to obtain a semi-solid crude ethanol extract.

Experimental Animals

Thirty (30) healthy male Wistar albino rats weighing between 150–200g were obtained from the University of Nigeria Enugu Campus (UNEC) in Enugu state. The animals were acclimatized for 2 weeks under standard laboratory conditions (12-hour light/dark cycle, temperature 25 °C, and relative humidity 50–60%) with standard rat feed and clean water.

Experimental Design

The animals were sampled and grouped into 5 containing 6 rats. The experiment was laid on complete randomized experimental design (CRED).

• **Group A (Blank Control):** were neither induced or treated but received feed and water ad libitu.

• **Group B (Negative Control):** Induced with 0.5 ml of egg albumin, but received no treatment.

• **Group C (Standard Control):** Induced with 0.5 ml of egg albumin + treated with standard inflammatory drug (ibuprofen).

• **Group D (Low Dose Ginger Extract):** Induced with 0.5 ml of egg albumin + treated with 50 mg/kg body weight of Zingiber officinale extract.

• **Group E (High Dose Ginger Extract):** Induced with 0.5 ml of egg albumin + treated with 200 mg/kg body weight of Zingiber officinale extract. Treatments were administered orally (via intubation) for 3 consecutive weeks following egg albumin induction.

Induction of Inflammation

Inflammation was induced by intraperitoneal injection of 0.5 ml of egg albumin solution in the hind paw region. The inflammation peaked within 3-6 hours. The paw thickness was monitored using a Vernier caliper to confirm the presence and resolution of inflammation.

Collection of Blood Samples

At the end of the treatment period, rats were anesthetized using chloroform, and blood samples were collected via ocular puncture into plain bottles for

Haematological analysis. Haematological Analysis

The analyses were carried out according to the method described by Dacie and Lewis (2011). Blood samples were collected from each rat via the retro-orbital plexus into EDTA-containing tubes to prevent coagulation. Haematological parameters were determined within two hours of collection using an automated haematology analyser. The parameters measured included packed cell volume (PCV), haemoglobin concentration (Hb), red blood cell (RBC) count, white blood cell (WBC) count, and white blood cell differential (WBCD).

RESULT

Packed Cell Volume (PCV)

Table 1 shows the result of the effects of Zingiber officinale ethanol extract on the packed cell volume (PCV) levels of male Wistar albino rats induced with inflammation. Based on the data obtained, Group A (Blank Control) recorded the highest PCV value of $66.00 \pm 0.034\%$, reflecting a normal physiological state with no induced inflammation or treatment. Group B (Negative Control), which was subjected to inflammation without any treatment, exhibited a markedly reduced PCV of $53.00 \pm 0.00\%$, indicating that inflammation significantly impaired hematological status by reducing red blood cell volume. Group C (Standard Control), treated with a standard anti-inflammatory drug demonstrated a PCV of $65.00 \pm 0.021\%$, closely approaching the value observed in the blank control group. This finding suggests that the standard drug effectively counteracted the inflammatory effects on PCV. Group D (Low-Dose Treated Group), which received a low dose of Zingiber officinale extract showed a PCV of $55.00 \pm 0.043\%$, reflecting only a slight improvement over the negative control and indicating a limited hematological benefit at this dosage. However, Group E (High-Dose Treated Group), administered a higher dose of the extract, exhibited a significantly improved PCV of $60.00 \pm 0.002\%$. This result suggests a dose-dependent protective effect of the ethanol extract of Zingiber officinale on red blood cell volume under inflammatory conditions.

Table 1: Effect of Zingiber officinale ethanol extract on packed cell volume (PCV) of male wistar albino rats induced with inflammation.

GROUPS	PCV%
A (Blank Control)	$66.00 \pm 0.034a$
B (Negative Control)	$53.00 \pm 0.000b$
C (Standard Control)	$65.00 \pm 0.021a$
D (Low-Dose Treated Group)	$55.00 \pm 0.043b$
E (High-Dose Treated Group)	$60.00 \pm 0.002c$

The values are expressed as (mean ± SEM)
Mean values with different letters as superscript are significantly different ($p<0.05$)

Haemoglobin (Hb) g/dL

Table 2 reveals distinct effects of Zingiber officinale ethanol extract on the haemoglobin (Hb) levels of male Wistar albino rats induced with inflammation. Group A (Blank Control) recorded the highest Hb value of 14.9 ± 0.001 g/dL, representing a normal physiological status with no exposure to inflammation or treatment. Group B (Negative Control), which was subjected to inflammatory induction without any treatment, showed a significantly reduced Hb level of 10.8 ± 0.041 g/dL,

indicating that inflammation reduced the Hb level in the blood. Group C (Standard Control), treated with a standard anti-inflammatory drug, had an Hb level of 14.4 ± 0.000 g/dL, closely comparable to that of the blank control. This suggests that the standard drug effectively reduced the inflammatory impact on hemoglobin concentration. Group D (Low-Dose Treated Group), administered a low dose of Zingiber officinale extract recorded a moderate increase in Hb level to 12.6 ± 0.001 g/dL when compared to the negative control. Although this shows hematological improvement but the effect was limited at this dosage. Group E (High-Dose Treated Group), which received a higher dose of the extract, showed a significant restoration of Hb level to 14.6 ± 0.007 g/dL, a value similar to the blank and standard control groups. This outcome indicates a strong dose-dependent protective effect of Zingiber officinale ethanol extract on hemoglobin concentration in an inflammatory condition.

Table 2: Effect of Zingiber officinale ethanol extract on Haemoglobin (Hb) of male wistar albino rats induced with inflammation.

GROUPS	HB g/dL
A (Blank Control)	14.9 ± 0.001a
B (Negative Control)	10.8 ± 0.041b
C (Standard Control)	14.4 ± 0.000a
D (Low-Dose Treated Group)	12.6 ± 0.001c
E (High-Dose Treated Group)	14.6 ± 0.007a

The values are expressed as (mean ± SEM)
Mean values with different letters as superscript are significantly different (p<0.05)

Red Blood Cell (RBC)

The data presented in table 3 highlight the effects of Zingiber officinale ethanol extract on red blood cell (RBC) levels in male Wistar albino rats subjected to inflammation. Group A (Blank Control) exhibited an RBC count of $5.3 \pm 0.002 \times 10^{12}$/L, which is considered within the normal physiological range, indicating the absence of inflammation. Group B (Negative Control), which was induced with inflammation without treatment recorded a significant decrease in RBC count of $3.6 \pm 0.000 \times 10^{12}$/L. Group C (Standard Control), administered with a standard anti-inflammatory drug, showed a normalized RBC value of $5.2 \pm 0.041 \times 10^{12}$/L, similar to the blank control. This suggests that the standard treatment effectively modulated the inflammatory response. Group D (Low-Dose Treated

Group), which received a low dose of Zingiber officinale extract, had an RBC count of $4.8 \pm 0.139 \times 10^{12}$/L, indicating that even at a lower dosage, the extract was capable of maintaining RBC levels within the physiological range. Group E (High-Dose Treated Group), which was given a higher dose of the extract recorded a slightly lower RBC count of $5.0 \pm 0.001 \times 10^{12}$/L compared to the control and stardard. This observation further supports the anti-inflammatory efficacy of Zingiber officinale but in a dose-dependent manner.

Table 3: Red Blood Cell (RBC) of male wistar albino rats induced with inflammation.

GROUPS	RBC X1012/L
A (Blank Control)	5.3 ± 0.002a
B (Negative Control)	3.6 ± 0.000b
C (Standard Control)	5.2 ± 0.041a
D (Low-Dose Treated Group)	4.8 ± 0.139a
E (High-Dose Treated Group)	5.0 ± 0.001a

The values are expressed as (mean ± SEM)
Mean values with different letters as superscript are significantly different (p<0.05)

White blood cell (WBC)

The results in Table 4 show the effect of Zingiber officinale ethanol extract on White blood cell (WBC) levels in male Wistar albino rats subjected to inflammation. Group A (Blank Control) had a WBC count of $4.2 \pm 0.001 \times 10^{9}$/L in the absence of inflammation or treatment. Group B (Negative Control), which was induced with inflammation without treatment exhibited a significantly elevated WBC count of $6.1 \pm 0.006 \times 10^{9}$/L. Group C (Standard Control), treated with a standard anti-inflammatory drug recorded a WBC count of $4.3 \pm 0.003 \times 10^{9}$/L which closely similar to the value in the blank control group. This demonstrates the efficacy of the standard drug in suppressing the inflammatory response and normalizing leukocyte levels. Group D (Low-Dose Treated Group), which received a low dose of Zingiber officinale extract, had a moderately elevated WBC count of $5.1 \pm 0.017 \times 10^{9}$/L, showing a partial reduction of inflammation. Group E (High-Dose Treated Group), administered a higher dose of the extract exhibited a WBC count of $5.2 \pm 0.041 \times 10^{9}$/L. While this value remains elevated compared to the blank and standard controls, it is notably lower than the negative control, indicating a significant anti-inflammatory effect. These findings suggest that Zingiber officinale ethanol extract exerts a dose-

dependent modulatory effect on white blood cell levels during inflammation.

Table 4: Effect of Zingiber officinale ethanol extract on white blood cell (WBC) of male wistar albino rats induced with inflammation.

GROUPS	WBC X109/L
A (Blank Control)	4.2 ± 0.001a
B (Negative Control)	6.1 ± 0.006b
C (Standard Control)	4.3 ± 0.003a
D (Low-Dose Treated Group)	5.1 ± 0.017c
E (High-Dose Treated Group)	5.2 ± 0.041c

The values are expressed as (mean ± SEM)

Mean values with different letters as superscript are significantly different (p<0.05)

Neutrophils (N)

Table 5 presents the effects of Zingiber officinale ethanol extract on neutrophils (N) level in male Wistar albino rats induced with inflammation. Group A (Blank Control) recorded a neutrophil percentage of 19 ± 0.000%, indicating a stable neutrophil level in the absence of inflammation. Group B (Negative Control), which was subjected to inflammation without any treatment exhibited a significantly increased neutrophil level of 24 ± 0.001%, clearly indicating neutrophilia associated with acute inflammatory response. Group C (Standard Control), which received a standard anti-inflammatory drug recorded a neutrophil percentage of 20 ± 0.004%, which was statistically comparable to the blank control. Group D (Low-Dose Treated Group), treated with a low dose of Zingiber officinale extract showed an elevated neutrophil percentage of 25 ± 0.061%, a value similar to that of the negative control. This suggests that a lower dosage of the extract was ineffective in suppressing the neutrophil-mediated inflammatory response. Group E (High-Dose Treated Group), administered a higher dose of the extract, also recorded a neutrophil level of 25 ± 0.003%, indicating that even at increased concentration, the extract did not significantly reduce neutrophil percentage. These findings imply that although Zingiber officinale ethanol extract demonstrated notable anti-inflammatory effects on other hematological parameters, it had limited influence on neutrophil proliferation, regardless of dose.

Table 5: Effect of Zingiber officinale ethanol extract on neutrophils (N) of male wistar albino rats induced with inflammation.

GROUPS	N%
A (Blank Control)	19 ± 0.000a
B (Negative Control)	24 ± 0.001b
C (Standard Control)	20 ± 0.004a
D (Low-Dose Treated Group)	25 ± 0.061b
E (High-Dose Treated Group)	25 ± 0.003b

The values are expressed as (mean ± SEM)

Mean values with different letters as superscript are significantly different (p<0.05)

Lymphocytes (L)

The data presented in Table 6 highlight the effect of Zingiber officinale ethanol extract on lymphocytes (L) percentage in male Wistar albino rats induced with inflammation. Group A (Blank Control) recorded a lymphocyte percentage of 10 ± 0.000%, showing a normal lymphocyte level without inflammation. Group B (Negative Control), which was induced with inflammation but received no treatment showed a decreased lymphocyte percentage of 08 ± 0.002%. Group C (Standard Control), which received a standard anti-inflammatory drug exhibited a lymphocyte percentage of 12 ± 0.001%, reflecting an effective restoration of lymphocyte level. Group D (Low-Dose Treated Group), administered a low dose of Zingiber officinale extract showed elevated lymphocyte percentage of 17 ± 0.003%, the highest among all groups. This significant increase may suggest a stimulatory effect on lymphocyte level indicating an immunomodulatory response at lower doses of the extract. Group E (High-Dose Treated Group), which received a higher dose of the extract recorded a lymphocyte percentage of 12 ± 0.004%, consistent with the value observed in the standard control group. This suggests that at higher concentrations, Zingiber officinale extract is capable of restoring lymphocyte levels to normal, thus demonstrating anti-inflammatory efficacy without excessive immunostimulation.

Table 6: Effect of Zingiber officinale ethanol extract on lymphocytes (L) of male wistar albino rats induced with inflammation.

GROUPS	L%
A (Blank Control)	10 ± 0.000a
B (Negative Control)	08 ± 0.002b
C (Standard Control)	12 ± 0.001c
D (Low-Dose Treated Group)	17 ± 0.003d
E (High-Dose Treated Group)	12 ± 0.004c

The values are expressed as (mean ± SEM)

Mean values with different letters as superscript are significantly different (p<0.05)

Eosinophils (E)

Table 7 illustrates the effect of Zingiber officinale ethanol extract on eosinophils (E) percentage in male Wistar albino rats induced with inflammation. Group A (Blank Control) recorded an eosinophil percentage of 04 ± 0.001%, reflecting a normal eosinophil level under non-inflammatory conditions. Group B (Negative Control), which was induced with inflammation without receiving treatment showed a highly reduced eosinophil count of 01 ± 0.000%, indicating eosinopenia. Group C (Standard Control), treated with a standard anti-inflammatory drug maintained an eosinophil percentage of 01 ± 0.000%, suggesting that the anti-inflammatory intervention stabilized the eosinophil count but did not restore it to normal levels observed in the blank control. Group D (Low-Dose Treated Group), which received a low dose of Zingiber officinale extract recorded an eosinophil percentage of 00 ± 0.000%, representing complete eosinopenia. This could indicate a stronger suppressive or depleting effect on eosinophil activity at the lower dose, possibly due to a lack of sufficient anti-inflammatory or immunomodulatory support at that concentration. Group E (High-Dose Treated Group), administered a higher dose of the extract, showed an eosinophil percentage of 01 ± 0.000%, matching the levels observed in both the negative and standard control groups. This suggests that the higher dose of Zingiber officinale ethanol extract exerted a mild regulatory effect, helping to prevent further eosinophil depletion, though not significantly restoring levels to normal.

Table 7: Effect of Zingiber officinale ethanol extract on eosinophils (E) of male wistar albino rats induced with inflammation.

GROUPS	E%
A (Blank Control)	04 ± 0.001a
B (Negative Control)	01 ± 0.000b
C (Standard Control)	01 ± 0.000b
D (Low-Dose Treated Group)	00 ± 0.000c
E (High-Dose Treated Group)	01 ± 0.000b

The values are expressed as (mean ± SEM)

Mean values with different letters as superscript are significantly different (p<0.05)

Basophils

Table 8 presents the effect of Zingiber officinale ethanol extract on basophils (B) percentage in male Wistar albino rats induced with inflammation. Group A (Blank Control) recorded a basophil percentage of 00 ± 0.000%, indicating a stable condition without basophil activation. Group B (Negative Control), which was induced with inflammation but not treated, showed an elevated basophil percentage of 02 ± 0.000%, suggesting a basophilic response to the inflammatory stimulus. This increase may be attributed to the release of pro-inflammatory mediators that promote basophil recruitment during acute inflammation. Group C (Standard Control), treated with a standard anti-inflammatory drug had a basophil percentage of 00 ± 0.000% similar to the blank control. This suggests that the standard treatment was effective in suppressing the inflammatory response and preventing basophil elevation. Group D (Low-Dose Treated Group), which received a low dose of Zingiber officinale extract, showed a basophil percentage of 01 ± 0.000% showed a partial reduction compared to the negative control. While not as effective as the standard drug, this indicates some anti-inflammatory activity at the low dose with moderate control over basophil levels. Group E (High-Dose Treated Group), administered a higher dose of the extract, showed complete normalization of basophil percentage to 00 ± 0.000% when compared with the levels seen in the blank and standard control groups. This result demonstrates the efficacy of the high-dose Zingiber officinale extract in fully suppressing basophil elevation during inflammation.

Table 8: Effect of Zingiber officinale ethanol extract on basophils (B) of male wistar albino rats induced with inflammation.

GROUPS	B%
A (Blank Control)	00 ± 0.000a
B (Negative Control)	02 ± 0.000b
C (Standard Control)	00 ± 0.000a
D (Low-Dose Treated Group)	01 ± 0.000c
E (High-Dose Treated Group)	00 ± 0.000a

The values are expressed as (mean ± SEM)

Mean values with different letters as superscript are significantly different (p<0.05)

Monocytes (M)

Table 9 illustrates the effect of Zingiber officinale ethanol extract on monocytes (M) percentage in male Wistar albino rats induced with inflammation. Group A (Blank Control) showed a monocyte percentage of 01 ± 0.000%, which represents a normal monocyte

level in the blood. Group B (Negative Control), induced with inflammation without treatment exhibited a reduced monocyte count of $00 \pm 0.000\%$, suggesting a reduction in monocyte level. Group C (Standard Control), treated with a standard anti-inflammatory drug recorded a monocyte percentage of $01 \pm 0.000\%$, indicating effective restoration of monocyte levels to the normal level observed in the blank control. Group D (Low-Dose Treated Group) and Group E (High-Dose Treated Group), administered low and high doses of Zingiber officinale extract respectively, both showed monocyte levels of $01 \pm 0.000\%$, identical to the standard and blank control groups. These findings suggest that Zingiber officinale ethanol extract, at both tested doses, was capable of restoring normal monocyte level in inflammatory condition.

Table 9: Effect of Zingiber officinale ethanol extract on monocytes (M) of male wistar albino rats induced with inflammation.

GROUPS	M%
A (Blank Control)	01 ± 0.000^a
B (Negative Control)	00 ± 0.000^b
C (Standard Control)	01 ± 0.000^a
D (Low-Dose Treated Group)	01 ± 0.000^a
E (High-Dose Treated Group)	01 ± 0.000^a

The values are expressed as (mean ± SEM)
Mean values with different letters as superscript are significantly different ($p<0.05$)

Discussion, conclusion, and recommendation

Discussion

The present study showed a reduction in PCV upon induction of egg albumin inflammation. This is consistent with the work of (Ibrahim et al., 2017). They carried out research on clinical and haemtological evaluation of pneumonia in calves with special reference to oxidant/antioxidant indices. They reported a significant decrease in PCV following pneumonia injection indicating microcytic hypochromic anaemia associated with injections. A reduction in PCV is often observed during inflammatory states due to haemolysis. However, the administration of Zingiber officinale extract improved the PCV levels. This agreed with the work of Gounder and Lingamallu (2012) who reported that Zingiber officinale extract increase PCV in toxin challenged models. The study showed a significant

reduction in haemoglobin concentration. This is in line with the findings of Ali et al., (2018), who investigated the haematological alterations in inflammatory conditions and reported a marked decrease in haemoglobin levels due to haemolysis and suppressed erythropoiesis. A reduction in haemoglobin is often associated with impaired oxygen transport capacity of blood and anaemic conditions during inflammation. However, administration of Zingiber officinale extract markedly restored haemoglobin concentration to near-normal values. This observation is in agreement with the work of Prakash et al. (2015), who reported that Zingiber officinale extract improved haemoglobin and hematocrit in rat subjected to oxidative stress. The research revealed a relative decrease in RBC count in the negative control group following the induction of egg albumin inflammation. This result is comparable to the findings of Nworgu et al. (2016), who observed the same procedures as shown in our study. However, treatment with Zingiber officinale extract normalized the RBC count toward the normal range, indicating its role in maintaining red cell homeostasis. This is consistent with the findings of Ajayi et al. (2018), who documented that Zingiber officinale extract normalized RBC levels in anaemic rats. The present study showed a pronounced increase in WBC count following induction of inflammation, indicating leukocytosis. This is consistent with the work of Okonkwo et al. (2015), who reported elevated leukocyte levels in inflammatory states as part of the body's immune response. Increased WBC levels are a hallmark of acute inflammation and reflect excessive immune activation. However, administration of Zingiber officinale extract significantly reduced WBC count toward the normal value, suggesting an immunomodulatory effect. This finding agreed with the report of Okonkwo et al. (2015), who demonstrated that Zingiber officinale extract administration reduced WBC levels in rats with induced inflammation. The present research revealed an increase in neutrophil count in the negative control group after inflammation induction. This aligns with the findings of Obiefuna et al. (2012), who reported that neutrophil elevation is a key marker of acute inflammatory response. Neutrophilia is often associated with rapid recruitment of these cells to sites of tissue injury or infection. However, Zingiber officinale extract did not significantly reduce

neutrophil counts compared to the negative control, indicating limited efficacy in suppressing neutrophil proliferation. This observation agrees with the findings of Sharma et al. (2020), who also reported no significant reduction in neutrophil percentages after administration of Zingiber officinale extract in LPS-induced inflammation models. The study showed a decrease in lymphocyte count (lymphopenia). This finding is consistent with the work of Ismail et al. (2015), who documented reduced lymphocyte levels during inflammation due to immune suppression. Lymphopenia is commonly observed during acute inflammatory states and reflects reduced adaptive immune function. However, treatment with Zingiber officinale extract restored lymphocyte counts and, at low doses, even elevated them beyond baseline, suggesting an immune-stimulating potential. This is in line with the findings of Sharma et al. (2020), who reported that Zingiber officinale extract increased lymphocyte percentages in LPS-induced inflammation models. The present study revealed a reduction in eosinophil counts following induction of inflammation. This observation is comparable to the findings of Abubakar et al. (2017), who reported suppressed eosinophil levels in systemic inflammation, reflecting impaired allergic and modulatory functions. Reduced eosinophil levels often indicate suppression of allergic-type immune responses during systemic inflammatory states. Administration of Zingiber officinale extract, however, did not restore eosinophil counts, indicating minimal effect in modulating eosinophil activity. This finding is consistent with Kumar and Rao (2017), who reported that Zingiber officinale extract reduced eosinophil infiltration in murine allergic inflammation models. The study showed an increase in basophil counts following induction of inflammation. This agrees with the findings of Ejiofor et al. (2016), who reported elevated basophil activity in inflammatory conditions, particularly in hypersensitivity responses. Increased basophil levels may reflect enhanced histamine release and hypersensitivity in acute inflammation. However, treatment with Zingiber officinale extract restored basophil counts to normal, showing a modulatory effect on allergic and inflammatory pathways. This observation is in agreement with the findings of Desai and Mehta (2020), who reported that Zingiber officinale extract

normalized basophil activation in dermatitis models. The research revealed a reduction in monocyte counts following induction of inflammation. This is in line with the work of Osadebe et al. (2010), who reported reduced monocyte recruitment during acute inflammatory conditions. Low monocyte levels may indicate impaired phagocytic response and reduced immune clearance during inflammation. However, treatment with Zingiber officinale extract restored monocyte levels to the normal range, indicating its immune-restorative potential. This finding is consistent with the work of Mahassni and Al-Reemi, (2013), who documented that Zingiber officinale extract modulated monocyte levels, supporting balanced immune regulation.

Conclusions

The findings of this study inferred that Zingiber officinale ethanol extract exhibits significant anti-inflammatory effects by modulating hematological parameters in male Wistar albino rats induced with inflammation. The extract notably improved key indicators such as packed cell volume (PCV), hemoglobin concentration (Hb), and red blood cell (RBC) count, while also stabilizing white blood cell (WBC) levels and differentials. These improvements were more at the higher dose of the extract, indicating a dose-dependent therapeutic efficacy. The restoration of haematological parameters toward normal levels, comparable to those observed in the standard drug-treated group enhances the potential of Zingiber officinale as a natural alternative for managing inflammation and its hematological consequences.

Recommendations

Based on the outcomes of this study, it is recommended that Zingiber officinale ethanol extract be further investigated as a complementary therapeutic agent for inflammatory conditions, especially those that impact haematological health. Future research should include detailed phytochemical profiling to identify specific bioactive constituents responsible for the observed effects, as well as clinical trials to validate its efficacy and safety in humans. However, the dose-dependent response observed in this study suggests the need for standardized dosing protocols to optimize its therapeutic application.

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