Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 14, Issue 2, 2026

Lipid Profile and Hematological Modulation by *Curcuma longa* and *Zingiber officinale* in MSG-Induced Dyslipidemic Wistar Rats

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Accepted: *April 16, 2026.* **Published Online**: *April 21, 2026*

ABSTRACT

This study investigated the effects of *Curcuma longa* extract (CLE), *Zingiber officinale* extract (ZOE), and their combination on lipid profile parameters and hematological indices in monosodium glutamate (MSG)-induced dyslipidemic Wistar rats. Experimental dyslipidemia was induced using MSG. Animals were divided into six groups. Serum lipid profile, erythrocyte indices, and leukocyte parameters (TWBC and differential counts) were analyzed using standard biochemical and hematological methods. MSG administration significantly increased total cholesterol and triglycerides while decreasing HDL-C compared with normal controls ($p < 0.05$). *Curcuma longa* extracts significantly reduced total cholesterol and triglycerides and improved HDL-C levels. *Zingiber officinale* extract reduced LDL-C but elevated triglycerides. The combination therapy produced the most balanced lipid-modulating effect, restoring lipid parameters toward normal values comparable to ascorbic acid. *Curcuma longa* extracts alone reduced RBC count, PCV, and hemoglobin levels, whereas the combination therapy preserved near-normal hematological indices. *Zingiber officinale* extract treatment elevated TWBC and eosinophil counts, while *Zingiber officinale* extract and combination therapy-maintained leukocyte parameters comparable to controls. The combined administration demonstrated synergistic hypolipidemic activity with minimal hematological

disturbance in MSG-induced dyslipidemic rats. The findings suggest potential therapeutic value of combined extracts as adjunct agents in dyslipidemia management.

Keywords: *Curcuma longa*, *Zingiber officinale*, monosodium glutamate, dyslipidemia, hematology, Wistar rats

INTRODUCTION

Monosodium glutamate induces significant metabolic disturbances in experimental animals. These disturbances include elevated total cholesterol, triglycerides, and low-density lipoprotein cholesterol (LDL-C), alongside reduced high-density lipoprotein cholesterol (HDL-C), which collectively contribute to dyslipidemia and increased cardiovascular risk [1–2]. In addition, MSG has been associated with hematological toxicity, including reductions in red blood cell count, packed cell volume, and hemoglobin concentration, suggesting impaired oxygen-carrying capacity and systemic toxicity [1–2]. Plant-derived bioactive compounds have also been widely investigated for their therapeutic potential.

Curcuma longa (turmeric) has been reported to exhibit hypolipidemic and antioxidant properties by reducing total cholesterol, triglycerides, and LDL-C while increasing HDL-C levels [3–4]. These effects are largely attributed to curcumin, which influences lipid metabolism and reduces oxidative stress. Similarly, *Zingiber officinale* (ginger) has demonstrated lipid-lowering, antioxidant, and anti-inflammatory effects in experimental models. Studies have shown that ginger supplementation improves lipid profiles and enhances antioxidant defense mechanisms in high-fat diet and diabetic animal models [5–7]. Its bioactive constituents, including gingerol and shogaol, are responsible for these pharmacological activities.

Recent studies have suggested that combined turmeric and ginger therapy may produce synergistic metabolic effects, particularly in diabetic and dyslipidemic conditions, with improved lipid regulation and antioxidant status compared to single treatments [2]. However, most of these studies have focused on diabetes or high-fat diet-induced dyslipidemia models, with limited investigation into MSG-induced dyslipidemia.

Despite the available literature, several gaps still exist. First, most studies have focused on high-fat diet or streptozotocin-induced diabetes models, while MSG-induced dyslipidemia remains relatively underexplored. Second, although the lipid-modulating effects of turmeric and ginger are well documented, there is limited information on their combined effects on hematological parameters such as red blood cell indices, white blood cell counts, and

hemoglobin concentration. Third, few studies have directly compared the individual effects of *Curcuma longa* and *Zingiber officinale* with their combined administration to confirm possible synergistic interactions in a single experimental model. Finally, there is a lack of studies integrating both lipid profile and hematological parameters in MSG-induced metabolic disturbances, resulting in an incomplete understanding of their systemic effects.

This study addresses these limitations by using a monosodium glutamate-induced dyslipidemia model to investigate both metabolic and hematological alterations. It evaluates the effects of *Curcuma longa* extract, *Zingiber officinale* extract, and their combination on lipid profile and hematological indices in the same experimental setting. The study also compares single and combined treatments to determine possible synergistic interactions. In addition, a standard control group treated with ascorbic acid is included to provide a benchmark for antioxidant activity. This approach allows for a more comprehensive assessment of the protective effects of these plant extracts on both lipid metabolism and blood parameters in MSG-induced toxicity.

MATERIALS AND METHODS

Chemicals and Reagents

All chemicals and reagents used were of analytical grade and sourced from reputable manufacturers. These include 90% ethanol (BDH Chemicals Ltd., Poole, England), distilled water (Thermo Fisher Scientific, USA), monosodium glutamate (Ajinomoto Co. Inc., Tokyo, Japan), and ascorbic acid (Sigma-Aldrich, St. Louis, USA). Commercial reagent kits used for biochemical analysis included cholesterol esterase, cholesterol oxidase, and peroxidase for total cholesterol determination using the CHOD-PAP method (Randox Laboratories Ltd., Crumlin, UK). Lipoprotein lipase, glycerol kinase, and glycerol-3-phosphate oxidase used for triglyceride estimation by the GPO-PAP method were also obtained from Randox Laboratories Ltd. Precipitation reagents such as phosphotungstic acid and magnesium chloride ($MgCl_2$) were sourced from Sigma-Aldrich (USA), while phosphate buffer solutions were prepared using standard laboratory-grade reagents.

Experimental Animals

Adult male Wistar albino rats weighing between 150–200 g were used for this study. The animals were obtained from a standard animal breeding facility in Veterinary animal house of Michael Okpara University of agriculture Umudike and were acclimatized for a period of two weeks under controlled laboratory conditions, including a temperature of 25 ± 2°C and a 12-

hour light/dark cycle. The rats were fed standard pelletized feed and allowed free access to clean drinking water *ad libitum*.

Plant Collection

Fresh rhizomes of *Curcuma longa* and *Zingiber officinale* were harvested from the National Root Crops Research Institute, Umudike, Umuahia, Abia State, Nigeria. The plant materials were authenticated at the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike, and a voucher specimen was deposited in the departmental herbarium with voucher number MOUAU/PSB/2025/CL-ZO/014 for future reference.

Preparation of Plant Extracts

After collection, the rhizomes were thoroughly washed with tap water to remove soil and other contaminants, and then air-dried at room temperature under shade conditions to prevent degradation of active phytochemicals. The dried samples were subsequently milled into fine powder using an automated milling machine. The powdered samples were weighed using an analytical weighing balance, yielding a total weight of 200 g [11].

The dried rhizomes of *Curcuma longa* and *Zingiber officinale* were pulverized into fine powder using an automated milling machine. Ethanol extraction was carried out using 90% ethanol as the solvent in a maceration process. The mixture was allowed to stand with intermittent shaking for 72 hours at room temperature to ensure adequate extraction of bioactive constituents. After extraction, the mixture was filtered using Whatman No. 1 filter paper, and the filtrate was concentrated using a rotary evaporator (Model: RE-52A, Shanghai Yarong Biochemistry Instrument Company, China) under reduced pressure at controlled temperature. The concentrated extracts were further dried and stored in airtight containers at 4°C in a refrigerator (Haier Thermocool, China) until use [12].

Experimental Animals and Grouping

Adult Wistar rats (weighing 150–200 g) were procured and acclimatized under standard laboratory conditions (temperature 22 ± 2°C, 12-hour light/dark cycle) with free access to food and water. The animals were randomly divided into six groups (n = 6 per group) as follows:

Group 1: Normal control (received water and feed only)

Group 2: MSG-only group (received monosodium glutamate of 4 g/kg body weight dosage)

Group 3: MSG + Curcuma longa extract (CLE) 200 mg/kg

Group 4: MSG + Zingiber officinale extract (ZOE) 200 mg/kg

Group 5: MSG + CLE (200 mg/kg) + ZOE (200 mg/kg) combined treatment

Group 6: MSG + Ascorbic acid (100 mg/kg) as a positive control antioxidant

The treatment period lasted for 14 days, during which Monosodium glutamate (4 g/kg body weight) was administered orally once daily for 14 days to induce and the respective extracts or ascorbic acid by gavage [13].

Biochemical Analysis

Serum lipid profile parameters (total cholesterol, triglycerides, HDL-C, LDL-C, and VLDL-C) were determined using standard enzymatic methods [14].

Hematological Analysis

Blood samples were analyzed for hemoglobin (HB), packed cell volume (PCV), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), total white blood cell count (TWBC), and differential leukocyte counts [15].

Statistical Analysis

Data were expressed as mean ± standard deviation (SD). Statistical significance was determined using one-way analysis of variance (ANOVA), followed by appropriate post hoc testing. Values were considered statistically significant at $p < 0.05$ [16].

RESULTS AND DISCUSSION

Table 1 shows the effects of CLE and ZOE on lipid profile parameters, including total cholesterol, triglycerides, HDL-C, very low-density lipoprotein cholesterol (VLDL-C), and low-density lipoprotein cholesterol (LDL-C) in MSG-induced dyslipidemic rats.

Table 1: Effects of *Curcuma longa* Extract and *Zingiber officinale* Extract on Lipid Profile Parameters in MSG-Induced Dyslipidemic Wistar Rats

Group	Cholesterol (mg/dL)	Triglyceride (mg/dL)	HDL-C (mg/dL)	VLDL-C (mg/dL)	LDL-C (mg/dL)
Normal control	61.40 ± 4.25^{cd}	59.17 ± 0.48^{e}	35.47 ± 0.25^{a}	11.83 ± 0.10^{e}	14.10 ± 3.91^{cd}
MSG-only group	82.11 ± 0.41^{a}	114.17 ± 1.44^{b}	24.36 ± 0.25^{e}	22.83 ± 0.29^{b}	34.91 ± 0.36^{a}
MSG + CLE, 200 mg/kg	74.04 ± 0.61^{b}	86.67 ± 0.00^{c}	33.33 ± 0.98^{bc}	17.33 ± 0.00^{c}	23.37 ± 1.59^{b}

MSG + ZOE, 200 mg/kg	67.72 ± 3.44^{bc}	166.67 ± 15.40^{a}	23.50 ± 0.25^{e}	33.33 ± 3.08^{a}	10.88 ± 0.11^{de}
MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	63.16 ± 1.22^{cd}	69.17 ± 0.48^{de}	32.05 ± 0.25^{cd}	13.83 ± 0.10^{d}	17.27 ± 1.06^{c}
MSG + Ascorbic Acid, 100 mg/kg	57.19 ±0.20^{d}	85.00 ± 0.00^{c}	31.62 ± 0.49^{d}	17.00 ± 0.00^{c}	8.57 ± 0.29^{e}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$

Table 2 presents the effects of CLE and ZOE on hematological indices, including hemoglobin concentration (HB), PCV, RBC, MCV, MCH, and MCHC.

Table 2: Effects of *Curcuma longa* and *Zingiber officinale* Extracts on Hematological Indices in MSG-Induced Wistar Rats

Group	HB (g/dL)	PCV (%)	RBC ($\times10^{6}$mm^{3})	MCV (fL)	MCH (pg)	MCHC (dL/g)
Normal control	18.80±0.12^{a}	50.00±0.58^{a}	7.97±0.10^{a}	62.77±0.03^{bc}	23.61± .14^{c}	37.61±0.20^{bc}
MSG-only group	18.50±0.40^{abc}	49.00±1.73^{ab}	7.70±0.17^{abc}	63.58±0.82^{ab}	24.03±0.02^{c}	37.81±0.51^{bc}
MSG + CLE, 200 mg/kg	16.30±0.06^{f}	38.50±0.29^{c}	6.14±0.02^{e}	62.70±0.23^{bc}	26.55±0.01^{a}	42.34±0.17^{a}
MSG + ZOE, 200 mg/kg	17.80±0.12^{bcd}	48.50±0.86^{ab}	7.70±0.12^{abc}	62.98±0.18^{abc}	23.13±0.20^{c}	36.72±0.42^{c}
MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	17.70±0.75^{bcd}	45.50±3.75^{ab}	7.09±0.48^{cd}	64.03±0.94^{a}	25.11±0.6^{b}	39.29±1.59^{b}
MSG + Ascorbic Acid, 100 mg/kg	17.30±0.40^{de}	45.00±2.31^{b}	7.25±0.38^{bc}	62.07±0.03^{c}	23.97±0.68^{c}	38.61±1.08^{bc}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$

Table 3 illustrates the effects of CLE and ZOE on total white blood cell count (TWBC) and differential leukocyte parameters, including relative lymphocyte, neutrophil, monocyte, eosinophil, and basophil count in MSG-induced Wistar rats.

Table 3: Effects of *Curcuma longa* and *Zingiber officinale* Extracts on Total White Blood Cell Count and Differential Leukocyte Parameters in MSG-Induced Wistar Rats

Group	TWBC ($\times10^{3}$mm^{3})	RE lymphocyte (%)	RE neutrophil (%)	RE monocyte (%)	RE eosinophil (%)	RE basophil (%)
Normal control	9.98± 0.07^{d}	59.00±0.00^{b}	33.50±0.29^{bc}	5.50±0.29^{ab}	2.00±0.00^{bc}	0.00±0.00^{ab}
MSG-only group	10.23±0.13^{cd}	60.50±0.29^{a}	32.50±0.29^{c}	5.00±0.58^{ab}	2.00±0.00^{c}	0.00±0.00^{b}
MSG + CLE, 200 mg/kg	13.15±0.20^{a}	53.50±0.29^{d}	35.00±0.58^{a}	4.50±0.29^{b}	6.50 ± 0.29^{a}	0.50±0.29^{ab}
MSG + ZOE, 200 mg/kg	10.43±0.33^{cd}	58.50±0.29^{b}	33.50±0.29^{bc}	5.00±0.00^{ab}	3.00±0.00^{bc}	0.00±0.00^{b}

MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	10.80±0.23^{bcd}	56.50±0.29^{c}	34.50±0.29^{ab}	5.50±0.29^{ab}	2.50±0.29^{bc}	1.00±0.00^{a}
MSG + Ascorbic Acid, 100 mg/kg	10.08±0.04^{bc}	57.00±0.58^{c}	34.00±0.58^{ab}	6.00±0.00^{a}	2.50±0.29^{bc}	0.50±0.29^{ab}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$

Rats in the monosodium glutamate-only group (non-treated group) exhibited a significant increase in total cholesterol (82.11 ± 0.41 mg/dL compared with 61.40 ± 4.25 mg/dL in the control group) and triglycerides (114.17 ± 1.44 mg/dL compared with 59.17 ± 0.48 mg/dL), along with a marked reduction in HDL-C levels (24.36 ± 0.25 mg/dL compared with 35.47 ± 0.25 mg/dL in the control group). These findings confirm the dyslipidemic effect of MSG and are consistent with the report of Kayode et al. [1]. Similar observations were made by Onyema et al. [9], who demonstrated that MSG induces lipid abnormalities and oxidative stress, and by Nneli and Woyike [10], who reported disturbances in lipid metabolism associated with hepatic dysfunction.

CLE (200 mg/kg) significantly reduced cholesterol and triglycerides and improved HDL-C levels. This agrees with Kusuma et al. [23] and is further supported by Almatroodi et al. [18], who showed that curcumin improves lipid metabolism by reducing lipid peroxidation and enhancing antioxidant defense. Hewlings and Kalman [19] also reported that curcumin modulates key enzymes involved in cholesterol synthesis, contributing to its hypolipidemic effect.

ZOE alone showed the strongest LDL-C reduction (10.88 ± 0.11 mg/dL) but increased triglycerides (166.67 ± 15.40 mg/dL). This dual effect aligns with Harnafi et al. [5]. Similar observations were made by Mashhadi et al. [20] and Rahimlou et al. [21], who reported that ginger improves lipid profile but may produce variable triglyceride responses depending on dosage and metabolic conditions.

The combination therapy (CLE 20 mg/kg + ZOE 200 mg/kg) produced the most balanced lipid profile (cholesterol 63.16 ± 1.22 mg/dL, triglycerides 69.17 ± 0.48 mg/dL, HDL-C 32.05 ± 0.25 mg/dL, LDL-C 17.27 ± 1.06 mg/dL), comparable to the ascorbic acid control. This supports synergistic interaction between turmeric and ginger. Similar synergistic effects were reported by Abd El-Ghffar et al. [22] and Srinivasan [23], who showed that combined spice extracts enhance lipid metabolism and antioxidant status more effectively than single treatments.

CLE alone significantly reduced RBC count, PCV, and hemoglobin (Hb: 16.30 g/dL vs. control 18.80 g/dL), with increased MCH and MCHC, suggesting mild anemia or erythrocyte membrane instability. Comparable findings were reported by Chattopadhyay et al. [24] and Olayemi et al. [25], who indicated that high doses of turmeric may exert mild hematological alterations due to oxidative effects on red blood cells.

In contrast, ZOE-alone and combination groups maintained near-normal hematological parameters, indicating a protective role of ginger. This is consistent with Akinyemi et al. [26] and Elgazar et al. [27], who demonstrated that ginger improves hemoglobin levels and protects erythrocytes through antioxidant and membrane-stabilizing effects.

CLE alone elevated TWBC ($13.15 \times 10^3/mm^3$) and eosinophils (6.50%), suggesting an inflammatory response. However, ZOE and combination therapy normalized leukocyte profiles. Similar findings were reported by Mahmoud et al. [28] and Ezzat et al. [29], who showed that ginger exerts anti-inflammatory and immunomodulatory effects by reducing cytokine activity and stabilizing immune responses.

Overall, these findings corroborate earlier and recent reports on the hypolipidemic and antioxidant properties of turmeric and ginger, while also highlighting a novel observation that ginger may mitigate turmeric-associated hematological disturbances when used in combination therapy.

The present study demonstrates that monosodium glutamate administration induces significant dyslipidemia, characterized by elevated total cholesterol and triglycerides, reduced HDL-C, and increased LDL-C levels. These findings confirm the disruptive effect of MSG on lipid metabolism and validate the suitability of the MSG-induced dyslipidemia model for evaluating hypolipidemic interventions.

Administration of *Curcuma longa* extract at 200 mg/kg significantly improved lipid parameters by lowering total cholesterol and triglycerides while restoring HDL-C levels. This reinforces the well-established hypolipidemic potential of turmeric reported in metabolic disorder models. However, CLE alone was associated with notable hematological alterations, including reductions in RBC count, packed cell volume, and hemoglobin concentration, alongside elevated MCH and MCHC values. These findings suggest a possible mild anemia or hemolytic tendency at the administered dose, highlighting a dose-dependent hematologic concern that is less emphasized in previous turmeric studies.

Zingiber officinale extract demonstrated strong LDL-C-lowering activity and largely preserved hematological stability. Nevertheless, its unexpected elevation of triglycerides suggests that ginger's lipid-modulating effects may be dose-dependent and require careful optimization.

Importantly, the combined therapy (CLE 20 mg/kg + ZOE 200 mg/kg) produced the most balanced and favourable outcomes. [30-31] further demonstrated that both *Curcuma longa* and *Zingiber officinale*, individually and in combination, exert significant protective effects against metabolic disturbances, including hyperglycemia, thereby supporting their synergistic therapeutic potential. The combination normalized total cholesterol, triglycerides, HDL-C, and LDL-C to levels comparable with the ascorbic acid control, while also maintaining near-normal erythrocyte and leukocyte indices. These findings indicate a synergistic interaction between turmeric and ginger extracts, where ginger appears to mitigate the hematological disturbances associated with higher-dose turmeric while enhancing overall lipid regulation.

CONCLUSION

This study confirmed the hypolipidemic efficacy of turmeric and ginger, both individually and synergistically, in an MSG-induced dyslipidemia model. It also highlights the importance of concurrent hematological assessment, revealing that combination therapy not only optimizes lipid control but also improves hematologic safety. These findings support the potential development of combined *Curcuma longa* and *Zingiber officinale* formulations as a safer and more effective complementary strategy for managing dyslipidemia. Further studies are recommended to elucidate underlying molecular mechanisms and establish optimal dosing regimens for long-term use.

This study provides novel evidence that dyslipidemia induced by Monosodium glutamate can be effectively modulated using extracts of *Curcuma longa* and *Zingiber officinale*, thereby validating the MSG-induced model as a suitable alternative to high-fat diet and diabetic models for evaluating hypolipidemic interventions.

The research advances knowledge by demonstrating that while *Curcuma longa* extract possesses strong cholesterol- and triglyceride-lowering properties, it may produce dose-related hematological alterations, including reductions in RBC count, packed cell volume, and haemoglobin an effect rarely emphasized in previous turmeric studies. This highlights a previously underreported safety consideration in turmeric-based therapy.

Furthermore, the study establishes that *Zingiber officinale* extract exerts potent LDL-cholesterol–lowering activity and preserves hematological stability, although it may elevate triglycerides at higher doses, suggesting dose-dependent lipid modulation.

Most importantly, the work reveals a synergistic interaction between turmeric and ginger when administered in combination, producing balanced lipid normalization comparable to ascorbic acid while minimizing hematological disturbances. The finding that ginger mitigates turmeric-associated red cell and immune alterations represents a significant mechanistic insight into phytotherapeutic combination therapy.

By concurrently evaluating lipid profile and detailed hematological indices (erythrocyte and leukocyte parameters), this study uniquely integrates efficacy and safety assessment, thereby contributing a more comprehensive framework for phytotherapeutic evaluation. Overall, the research supports the development of combined turmeric–ginger formulations as a potentially safer and more effective complementary strategy for dyslipidemia management and provides a foundation for future mechanistic and clinical investigations.

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