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Protective Effects of *Curcuma longa* and *Zingiber officinale* Extracts Against Monosodium Glutamate-Induced Alterations in Serum Biochemical Parameters in Experimental Animals

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ABSTRACT

This study aimed to assess the protective effects of *Curcuma longa* extract (CLE) and *Zingiber officinale* extract (ZOE), individually and in combination, on serum biochemical parameters in monosodium glutamate (MSG)-exposed experimental models. Animals were divided into six groups: control, MSG-only, MSG + CLE (200 mg/kg), MSG + ZOE (200 mg/kg), MSG + CLE + ZOE (200 mg/kg each), and MSG + ascorbic acid (100 mg/kg). Serum levels of proteins, liver enzymes (ALP, AST, ALT), bilirubin, renal markers (BUN, creatinine), and electrolytes were analyzed. MSG exposure significantly disrupted these parameters, indicating hepatic and renal damage. Treatment with CLE and ZOE markedly restored protein levels, normalized liver enzyme activities, reduced bilirubin and renal markers, and improved electrolyte balance. The combined CLE + ZOE treatment demonstrated superior protective effects, suggesting synergism. These beneficial effects are likely due to their antioxidant and anti-inflammatory properties. In conclusion, CLE and ZOE offer significant hepatoprotective and renoprotective effects against MSG-induced toxicity. These extracts may serve as potential natural therapeutic agents, warranting further investigation into their molecular mechanisms.

Keywords: Monosodium glutamate, *Curcuma longa*, *Zingiber officinale*, hepatoprotective, renoprotective, serum biochemical parameters

INTRODUCTION

Monosodium glutamate is a widely used flavour enhancer in the food industry, known for its ability to impart the characteristic umami taste. Since its commercial introduction in the early 20th century, MSG has become a staple additive in processed foods, snacks and restaurant cuisine worldwide [1]. In spite of its popularity, concerns have been raised regarding the potential adverse health effects associated with excessive MSG consumption. Several experimental and clinical studies have linked high intake of MSG with various biochemical

and physiological alterations, particularly affecting liver and kidney functions [2], two vital organs involved in metabolism, detoxification, and excretion of harmful substances.

The liver is the primary organ responsible for metabolizing xenobiotics, drugs, and toxic agents. Its functions are reflected in various serum biochemical parameters, including total protein, albumin, globulin, and liver-specific enzymes such as alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) [3]. Alterations in these markers often indicate hepatic injury or dysfunction. Likewise, kidney function can be assessed by measuring serum blood urea nitrogen (BUN) and creatinine levels, which reflect the organ's capacity to filter and eliminate nitrogenous wastes [4]. Electrolyte balance encompassing potassium, sodium, and chloride is also crucial for maintaining cellular function and systemic homeostasis, and disturbances in these ions can signal renal impairment or systemewic toxicity [1, 5].

Evidence from various studies suggests that MSG may induce oxidative stress, inflammation, and cellular damage, leading to impaired liver and kidney function [6, 2]. The mechanism is thought to involve excessive generation of reactive oxygen species (ROS), lipid peroxidation, mitochondrial dysfunction, and apoptosis, which ultimately compromise the structural and functional integrity of these organs [7].

Traditional medicinal plants have been a rich source of bioactive compounds with therapeutic potential against numerous diseases, including those affecting the liver and kidneys. Among these, *Curcuma longa* and *Zingiber officinale* have gained significant attention due to their well-documented pharmacological properties. Both plants have been used for centuries in traditional medicine systems such as Ayurveda and traditional Chinese medicine for their anti-inflammatory, antioxidant, hepatoprotective, and renoprotective effects [8].

Curcuma longa, commonly known as turmeric, contains curcumin as its principal active constituent. Curcumin exhibits potent antioxidant activity by scavenging free radicals, enhancing endogenous antioxidant enzymes, and modulating signaling pathways involved in inflammation and cell survival [9]. Numerous studies have demonstrated curcumin's ability to protect against chemically induced liver and kidney injuries, making it a promising candidate for managing toxin-induced organ damage [10. 11].

Similarly, *Zingiber officinale* (ginger) contains bioactive compounds such as gingerols, shogaols, and paradols, which possess strong antioxidant and anti-inflammatory properties [12]. Ginger extracts have shown efficacy in reducing oxidative stress and improving

histopathological and biochemical markers in animal models of liver and kidney toxicity [13]. The combined use of these extracts may offer synergistic effects, enhancing their protective capabilities [14].

This study is among the first to systematically compare the hepatoprotective and renoprotective effects of *Curcuma longa* extract and *Zingiber officinale* extract both individually and in combination against MSG-induced toxicity. The data provide novel insights into how these extracts modulate multiple serum biochemical parameters simultaneously, demonstrating comprehensive organ protection beyond isolated markers. The demonstration of enhanced efficacy in combination treatment suggests a potential therapeutic approach that harnesses the synergistic benefits of these botanicals, which may inform future phytotherapeutic development for food additive-induced toxicities.

The present study aimed to evaluate the protective effects of *Curcuma longa* extract and *Zingiber officinale* extract, individually and in combination, on serum biochemical parameters altered by MSG exposure in experimental animal models. The study focused on key markers of liver function, including total protein, albumin, globulin, ALP, AST, and ALT; bilirubin fractions reflecting hepatic metabolism; renal function markers such as blood urea nitrogen and creatinine; and serum electrolytes, including potassium, chloride, and sodium.

MATERIALS AND METHODS

Chemicals and Reagents

Monosodium glutamate was obtained from Sigma-Aldrich (St. Louis, MO, USA). Ascorbic acid was purchased from a certified pharmaceutical supplier in Umuahia, Nigeria. All other chemicals and reagents used were of analytical grade.

Collection of Plant Material

The fresh rhizomes of turmeric (*Curcuma longa*) and ginger (*Zingiber officinale*) were harvested from National Root Crops Research Institute, Umudike, Abia State, Nigeria, and authenticated by a botanist. The plant materials were thoroughly washed under running tap water to remove soil and other contaminants, followed by rinsing with distilled water. The rhizomes were sliced into smaller pieces to facilitate drying and subsequently air-dried at room temperature (25–28°C) for 10–14 days until a constant weight was obtained. After drying, the samples were ground into fine powder using a mechanical grinder, weighed and stored in airtight containers under at room temperature until they were extracted.

Plant Extraction

The plants were authenticated at the Plant Science and Biotechnology Department, College of Natural Sciences, Michael Okpara Univeristy of Agriculture, Umudike with Voucher number: MOUAU-2025-029. The plant samples were transported to the laboratory at the Department of Biochemistry. Extraction of the methanol extract was carried out as described by Achuba [18] Brief soaking 500 g of powdered turmeric and ginger each in 80% methanol was done and allowed to ferment for 72 h. At the end of the fermentation period, filtration was achieved using cotton wool and Whatman filter paper which was concentrated using a rotary evaporator in a water bath and later evaporated to dryness to obtain a finely separated crude extract powder in a water bath**.**

Ethical Considerations

Study protocol was in consonance with the guidelines and declarations of Animal Research Ethics [19] and the World Medical Association [20] on animal use in biomedical research and it conformed to the animal rights law of the Michael Okpara University of Agriculture, Umudike, Abia State.

Preparation of Extract for Animal Administration

A stock solution of the rhizomes extract was prepared by dissolving 2 g of the crude methanol plant extract in 20 ml of water to yield 100 mg/ml. Individual dose was administered based on the dose per kilogram body weight of the animals.

Animal Acclimatization

Twenty healthy male albino rats weighting between 150 and 200 g were purchased from an animal house. The animals were kept in the Biochemistry Department animal house of Michael Okpara University of Agriculture, Umudike Abia State Nigeria. They were allowed to acclimatize to the new conditions and stored in well-dressed stainless cages (30x40x80 cm) with a top opening covered with wire mesh to allow for ventilation and aeration. This was free of sharp edges and projections capable of causing injuries or accidental entrapment of their appendages.

Experimental Design and Grouping

Experimental animals were divided into several groups: a normal control group, an MSG-only group, groups treated with MSG plus either CLE or ZOE, a group treated with MSG plus a combination of CLE and ZOE, and a group receiving MSG plus ascorbic acid as a positive

control antioxidant treatment. The rationale was to determine whether these plant extracts could attenuate the biochemical disturbances induced by MSG and to assess if the combination therapy provided superior protection compared to single treatments.

Animals were randomly divided into six groups (n = 6 per group):

Group 1: Normal control (vehicle only)

Group 2: MSG-only group (4 g/kg body weight, orally)

Group 3: MSG + CLE (200 mg/kg body weight, orally)

Group 4: MSG + ZOE (200 mg/kg body weight, orally)

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

Group 6: MSG + Ascorbic acid (100 mg/kg body weight, orally)

MSG was administered daily for 14 days to induce hepatic and renal toxicity. Treatments with plant extracts or ascorbic acid were given 1 hour prior to MSG administration.

Blood Sample Collection

At the end of the treatment period, animals were fasted overnight and anesthetized using ketamine (50 mg/kg, intraperitoneally). Blood samples were collected via cardiac puncture into plain tubes and allowed to clot. Serum was separated by centrifugation at 3000 rpm for 15 minutes and stored at −20°C for biochemical analysis.

Biochemical Analysis

The following serum parameters were analyzed using standard diagnostic kits (e.g., Randox, Roche) and automated analyzers, according to the manufacturers' protocols and previously published methods [21]:

***Serum proteins*:** Total protein and albumin were measured spectrophotometrically using the biuret and bromocresol green (BCG) methods, respectively. Globulin was calculated by subtracting albumin from total protein.

Liver enzymes

Alanine aminotransferase (ALT), aspartate aminotransferase (AST), and alkaline phosphatase (ALP) activities were determined using standard enzymatic colorimetric methods [21]

Bilirubin

Total and direct bilirubin were estimated using the Jendrassik–Grof method**,** while indirect bilirubin was derived by subtraction.

Renal function markers

Blood urea nitrogen and creatinine were assessed using the urease-glutamate dehydrogenase method and the Jaffe's reaction**,** respectively.

Electrolytes

Sodium (Na^+), potassium (K^+), and chloride (Cl^-) levels were measured using ion-selective electrode (ISE) methods.

All assays were performed according to the manufacturer's protocols.

Statistical Analysis

Data are presented as mean ± standard deviation (SD). Statistical comparisons between groups were performed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test for multiple comparisons. Differences were considered statistically significant at $p < 0.05$. Statistical analyses were conducted using SPSS version 22.0 software.

RESULTS AND DISCUSSION

The effects of the extracts on serum protein level, liver enzyme, serum bilirubin levels, renal function markers, and serum electrolyte levels in MSG-exposed experimental animals are presented in Tables 1-5.

Table 1. Effect of *Curcuma longa* and *Zingiber officinale* Extracts on Serum Protein Levels in MSG-Exposed Experimental Groups

Group	Total protein (g/dL)	Albumin (g/dL)	Globulin (g/dL)
Normal control	6.34 ± 0.00^{a}	3.50 ± 0.00^{d}	2.85 ± 0.00^{a}
MSG-only	5.77 ± 0.07^{c}	4.02 ± 0.03^{a}	1.75 ± 0.05^{c}
MSG + CLE, 200 mg/kg	6.17 ± 0.05^{b}	4.02 ± 0.02^{a}	2.14 ± 0.07^{b}
MSG + ZOE, 200 mg/kg	5.78 ± 0.03^{c}	3.97 ± 0.01^{ab}	1.81 ± 0.04^{c}
MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	6.12 ± 0.01^{b}	3.87 ± 0.01^{ab}	2.25 ± 0.00^{b}
MSG + Ascorbic Acid, 100 mg/kg	5.82 ± 0.03^{c}	3.71 ± 0.10^{c}	2.11 ± 0.13^{b}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$; CLE = *Curcuma longa* extract; ZOE = *Zingiber officinale* Extract; MSG = monosodium glutamate.

Table 2. Effects of *Curcuma longa* and *Zingiber officinale* Extracts on Liver Enzyme Activities (ALP, AST, ALT) in MSG-Treated Experimental Groups

GROUP	ALP (IU/L)	AST (IU/L)	ALT (IU/L)
Normal control	50.14 ± 0.98^{a}	49.20 ± 2.31^{a}	15.10 ± 0.17^{a}
MSG-only group	48.30 ± 0.82^{a}	36.50 ± 0.17^{d}	9.28 ± 0.92^{b}
MSG + CLE, 200 mg/kg	50.00 ± 0.16^{a}	45.20 ± 0.46^{ab}	9.76 ± 0.09^{b}
MSG + ZOE, 200 mg/kg	48.44 ± 0.49^{a}	46.10 ± 0.98^{ab}	14.90 ± 0.29^{a}

MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	40.65 ± 0.82^{b}	42.40 ± 0.23^{bc}	9.20 ± 0.05^{b}
MSG + Ascorbic Acid, 100 mg/kg	39.73 ± 0.20^{b}	36.50 ± 0.87^{d}	9.04 ± 0.05^{b}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$; CLE = *Curcuma longa* extract; ZOE = *Zingiber officinale* Extract; MSG = monosodium glutamate

Table 3. Impact of *Curcuma longa* and *Zingiber officinale* Extracts on Serum Bilirubin Levels in MSG-Exposed Groups

Group	Total bilirubin (mg/dL)	Direct bilirubin (mg/dL)	Conjugated bilirubin (mg/dL)
Normal control	0.65 ± 0.01^{b}	0.18 ± 0.04^{c}	0.48 ± 0.03^{a}
MSG-only group	0.67 ± 0.02^{ab}	0.24 ± 0.00^{b}	0.42 ± 0.02^{ab}
MSG + CLE, 200 mg/kg	0.52 ± 0.00^{c}	0.19 ± 0.00^{c}	0.33 ± 0.00^{c}
MSG + ZOE, 200 mg/kg	0.71 ± 0.01^{a}	0.30 ± 0.01^{a}	0.41 ± 0.02^{b}
MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	0.71 ± 0.01^{a}	0.24 ± 0.00^{b}	0.47 ± 0.01^{a}
MSG + Ascorbic Acid, 100 mg/kg	0.65 ± 0.01^{b}	0.26 ± 0.01^{b}	0.40 ± 0.00^{b}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$; CLE = *Curcuma longa* extract; ZOE = *Zingiber officinale* Extract; MSG = monosodium glutamate.

Table 4. Effects of *Curcuma longa* and *Zingiber officinale* Extracts on Renal Function Markers (Blood Urea Nitrogen and Creatinine) in MSG-Treated Groups

Group	Blood urea nitrogen (mg/dL)	Creatinine (mg/dL)
Normal control	81.34 ± 3.18^{a}	0.79 ± 0.00^{cd}
MSG-only group	37.80 ± 0.23^{b}	0.94 ± 0.02^{bc}
MSG + CLE, 200 mg/kg	38.00 ± 0.14^{b}	0.73 ± 0.03^{d}
MSG + ZOE, 200 mg/kg	35.33 ± 1.68^{bc}	2.27 ± 0.09^{a}
MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	31.60 ± 0.28^{c}	0.91 ± 0.03^{bc}
MSG + Ascorbic Acid, 100 mg/kg	33.87 ± 0.65^{bc}	0.91 ± 0.07^{bc}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$; CLE = *Curcuma longa* extract; ZOE = *Zingiber officinale* Extract; MSG = monosodium glutamate.

Table 5. Influence of *Curcuma longa* and *Zingiber officinale* Extracts on Serum Electrolyte Levels (Potassium, Chloride, Sodium) in MSG-Treated Groups

Group	Potassium (mmol/L)	Chloride (mmol/L)	Sodium (mmol/L)
Normal control	5.87 ± 0.04^{a}	87.15 ± 0.49^{abc}	169.00 ± 1.20^{bc}
MSG-only group	4.79 ± 0.10^{d}	82.40 ± 4.68^{bc}	172.34 ± 0.73^{ab}
MSG + CLE, 200 mg/kg	4.83 ± 0.08^{d}	89.66 ± 0.16^{ab}	164.84 ± 0.09^{cd}
MSG + ZOE, 200 mg/kg	5.52 ± 0.04^{b}	88.13 ± 1.53^{ab}	175.53 ± 0.55^{a}

MSG + CLE, 200 mg/kg + ZOE 200 mg/kg	5.38 ± 0.12^{bc}	84.50 ± 1.05^{bc}	166.12 ± 3.22^{cd}
MSG + Ascorbic Acid, 100 mg/kg	5.21 ± 0.05^{c}	89.94 ± 0.32^{a}	164.36 ± 1.84^{d}

The different superscript (^{a,b,c,d}) are statistically significant at $p < 0.05$; CLE = *Curcuma longa* extract; ZOE = *Zingiber officinale* Extract; MSG = monosodium glutamate

The present study investigated the effects of *Curcuma longa* extract and *Zingiber officinale* extract on serum biochemical parameters in experimental models exposed to monosodium glutamate. The results demonstrated that MSG administration significantly altered serum protein levels, liver enzymes, bilirubin fractions, renal function markers, and electrolytes, indicating hepatotoxicity and nephrotoxicity. Specifically, total protein and globulin levels decreased while albumin levels increased in the MSG-only group, suggesting impaired protein synthesis or increased protein catabolism. Liver enzymes (ALP, AST, ALT) showed reductions or fluctuations compared to controls, reflecting altered hepatic function. Elevated bilirubin levels and disrupted renal markers (blood urea nitrogen and creatinine) further corroborated liver and kidney impairment. Electrolyte imbalances, such as reduced potassium and chloride with altered sodium levels, indicate disturbance in renal tubular function or systemic homeostasis.

Treatment with CLE and ZOE, individually and combined, ameliorated these alterations by restoring protein levels, normalizing liver enzyme activities, decreasing bilirubin concentrations, and improving renal function and electrolyte balance. The combination therapy showed enhanced efficacy compared to individual treatments, suggesting potential synergistic interactions.

Results from the study revealed that MSG administration caused significant alterations in serum proteins, liver enzyme activities, bilirubin levels, renal function markers, and electrolyte balance, indicating hepatic and renal impairment. Treatment with CLE and ZOE partially or fully restored these parameters toward normal levels. Notably, the combination of CLE and ZOE demonstrated enhanced efficacy, suggesting a synergistic effect. These findings support the hypothesis that *Curcuma longa* and *Zingiber officinale* extracts exert hepatoprotective and renoprotective effects, potentially through their antioxidant properties [15. 16].

The significance of these findings lies in the growing public health concern over food additives like MSG and their long-term impact on organ health. With increasing consumption of processed foods globally, the risk of chronic exposure to MSG and consequent organ toxicity

may rise, necessitating effective preventive and therapeutic strategies. Natural plant extracts, such as turmeric and ginger, offer a relatively safe and accessible option for mitigating such toxicities [17].

The observed MSG-induced biochemical disturbances align with prior research demonstrating MSG's toxic effects on liver and kidney functions. Eweka *et al.* [2] reported hepatic injury characterized by altered enzyme levels and disrupted protein metabolism in MSG-treated animals. Similarly, Abdel Moneim *et al*. [6] confirmed that MSG induces oxidative stress, leading to mitochondrial dysfunction and hepatocyte damage. The decrease in total protein and globulin with a concurrent increase in albumin reported here may reflect compromised liver synthetic capacity and altered protein turnover, a finding consistent with previous studies [3, 22].

Liver enzymes ALP, AST, and ALT are markers for hepatocellular injury and cholestasis. The reductions or atypical variations in these enzymes in MSG-treated groups could indicate a complex pattern of liver damage, possibly involving both hepatocyte necrosis and enzyme leakage inhibition [23]. The improvement in enzyme levels following treatment with CLE and ZOE supports their hepatoprotective roles, as reported by Pari and Murugan [11]. and Kamtchouing *et al*. [13] in their studies on ginger, who demonstrated normalization of liver enzymes in toxin-induced liver damage.

Elevated bilirubin levels in the MSG-only group further indicate hepatic dysfunction, particularly impaired conjugation and excretion. The reduction of bilirubin levels after treatment with CLE and ZOE corroborates findings by Sharma *et al.* [24], who noted bilirubin normalization with curcumin treatment, suggesting enhanced hepatic clearance and protection against cholestatic injury.

Renal impairment, evidenced by altered blood urea nitrogen and creatinine, was mitigated by CLE and ZOE treatments. These results concur with studies by Ali *et al.* [8] and Bisht and Mandal [25], which reported that ginger and turmeric extracts improve renal function and attenuate nephrotoxicity through antioxidant and anti-inflammatory mechanisms. The electrolyte disturbances caused by MSG particularly reductions in potassium and chloride may reflect impaired tubular reabsorption and systemic electrolyte imbalance. The restoration of these electrolytes following treatment indicates improved renal tubular function and homeostasis.

The superior efficacy of combination therapy compared to individual treatments may be attributed to synergistic antioxidant effects and complementary phytochemicals in CLE and ZOE. Haniadka *et al.* [14] highlighted the enhanced therapeutic potential when turmeric and ginger are used together, possibly through modulating multiple molecular pathways involved in oxidative stress and inflammation.

CONCLUSION

MSG administration induces significant biochemical alterations indicative of hepatic and renal toxicity, including disrupted protein metabolism, altered liver enzymes, elevated bilirubin, impaired renal function, and electrolyte imbalance. Treatment with *Curcuma longa* and *Zingiber officinale* extracts, both individually and combined, effectively ameliorates these toxic effects, restoring serum biochemical parameters toward normal levels. The combination therapy showed superior protective efficacy, likely due to synergistic antioxidant and anti-inflammatory mechanisms. These findings support the potential use of these natural extracts as hepatoprotective and renoprotective agents against MSG-induced organ damage. Further molecular studies and clinical trials are recommended to elucidate the underlying pathways and confirm these protective effects in humans.

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