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EFFECT OF *CURCUMA LONGA* RHIZOME MEAL ON GROWTH AND HEALTH INDICES IN BROILERS FED MONOSODIUM GLUTAMATE

EFECTO DE LA HARINA DE RIZOMA DE *CURCUMA LONGA* EN EL CRECIMIENTO E ÍNDICES DE SALUD DE POLLOS DE CEBA ALIMENTADOS CON GLUTAMATO MONOSÓDICO

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The impact of *Curcuma longa* rhizome meal (CLRM) in ameliorating the adverse effects of dietary monosodium glutamate (MSG) on the growth and health of broilers fed dietary MSG was assessed. Two-hundred-day-old broilers were randomly distributed into four experimental diets: Control diet (CON): Basal diet without any supplementation; MSG diet (MSG): Basal diet supplemented with 1.25 g MSG per kg of feed; MSG + Low CLRM diet (MSG-LCLRM): Basal diet containing 1.25 g MSG and 1.25 g CLRM per kg of feed and MSG + High CLRM diet (MSG-HCLRM): Basal diet containing 1.25 g MSG and 2.50 g CLRM per kg of feed. The average weight gain (AWG) significantly increased in broilers fed diets MSG, MSG-LCLRM, and MSG-HCLRM, with the highest AWG ($p<0.05$) recorded among broilers fed diet MSG-HCLRM. The relative growth rate was not significantly influenced across all treatment groups ($p>0.05$). Broilers fed MSG had significantly lower vitality rates (VR) compared to other groups, while those on diet MSG-HCLRM exhibited the most significant VR ($p<0.05$). Most hematological and serum biochemical indices were negatively impacted in broilers on MSG ($p<0.05$). Serum antioxidant enzymes were significantly depressed in broilers on MSG ($p<0.05$). Serum potassium and sodium concentrations were unaffected by MSG ($p>0.05$), but serum chloride concentration increased significantly ($p<0.05$). In conclusion, supplementation of CLRM in the diets effectively mitigated adverse effects of MSG by enhancing growth without compromising the health status of the broilers.

Keywords: *blood electrolytes, chickens, MSG, performance, turmeric*

Se evaluó el impacto de la harina de rizoma de *Curcuma longa* en el mejoramiento de los efectos adversos del glutamato monosódico de la dieta en el crecimiento y salud de pollos de engorde, alimentados con este. Se distribuyeron al azar 200 pollos de un día de edad en cuatro dietas experimentales: dieta control (CON): dieta basal sin ningún suplemento, dieta con glutamato monosódico (GMS): dieta basal suplementada con 1.25 g de GMS por kg de alimento, dieta GMS + HRCL bajo (GMS-HRCLb): dieta basal que contiene 1.25 g de GMS y 1.25 g de HRCL por kg de alimento, y dieta GMS + HRCL alto (GMS- HRCLa): dieta basal que contiene 1.25 g de GMS y 2.50 g de HRCL por kg de alimento. La ganancia de peso promedio aumentó significativamente en los pollos alimentados con las dietas GMS, GMS-HRCLb y GMS-HRCLa, registrándose la mayor ganancia de peso promedio ($p<0.05$) en los pollos alimentados con la dieta GMS-HRCLa. La tasa de crecimiento relativo no tuvo influencia significativa en todos los grupos de tratamiento ($p>0.05$). Los pollos de engorde alimentados con GMS tuvieron tasas de vitalidad significativamente más bajas en comparación con otros grupos, mientras que aquellos con la dieta GMS-HRCLa mostraron la tasa de vitalidad más significativa ($p<0.05$). La mayoría de los índices hematológicos y bioquímicos séricos tuvieron afectación en los pollos de engorde alimentados con GMS ($p<0.05$). Las enzimas antioxidantes séricas se redujeron significativamente en los pollos de engorde con GMS ($p<0.05$). Las concentraciones séricas de potasio y sodio no se afectaron con el GMS ($p>0.05$), pero la concentración sérica de cloruro aumentó significativamente ($p<0.05$). Se puede concluir que la suplementación de HRCL en las dietas mitigó eficazmente los efectos adversos del GMS al mejorar el crecimiento sin comprometer el estado de salud de los pollos de engorde.

Palabras clave: *cúrcuma, electrolitos sanguíneos, GMS, pollos, rendimiento*

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Introduction

Monosodium glutamate (MSG) as a food additive has generally been used for decades in both human and livestock diets as taste enhancer (Olarotimi *et al.* 2023). Its use as flavouring agent in cooking to increase food palatability and acceptance has been severally stressed (Chung *et al.* 2022 and Yamamoto and Inui-Yamamoto 2023). Potentials of MSG in enhancing total diet consumption, weight increase, and efficiency of feed in various classes of animals have been previously reported (Olarotimi *et al.* 2023 and Soares *et al.* 2023). For example, broilers fed 1.00 g/kg MSG had increased weight and consumption of feed (Adetunji *et al.* 2019). In another report, feed palatability, growth performance, sperm production and efficiency were significantly enhanced in rabbits fed 0.25 g MSG/kg diet without causing any physiological imbalance (Adu *et al.* 2022). Similarly, the dietary inclusion of 2 % MSG was reported to have a beneficial effect on late gestating sows and their piglets as far as feed intake, growth and milk production are concerned (Li *et al.* 2024). The tendency of MSG to improve palatability of meals and feeds was directly linked to the ability of boosting taste sensory centres of the animal, thereby, resulting to increased weight (Banerjee *et al.* 2021). Furthermore, MSG has been reported as a veritable feed additive that could be used to harness the inherent potentials of non-conventional feed resources which are under-utilized as a result of their low palatability in animal nutrition (Alimi *et al.* 2024).

In another development, high dosage of MSG beyond 0.50 g/kg diet was reported to have an adverse consequence on the overall physiology of chickens such as causing kidney failure, heart dysfunction as well as generation of reactive oxygen species causing redox imbalance (Olarotimi 2020). The reproductive potentials of Wistar rats and roosters fed high MSG diets were reportedly affected by causing notable decrease in spermatogenesis and spermiogenesis (Oluwole *et al.* 2024 and Ruiz-Valderrama *et al.* 2025). Hence, indiscriminately high dietary MSG is implicated in conferring varying negative effects on animals (Afolabi and Olagoke 2020). Despite these perceived negative implications, the beneficial aspect of MSG can be explored through the use of herbs and spices such as *Curcuma longa* (turmeric) which could be capable of ameliorating the negative effects of MSG on the animals.

Curcuma longa has been used as a colouring, and flavouring agent as well as spice in many foods. *Curcuma longa* and its extracts have been reported to be an effective alternative to antimicrobial growth promoters in poultry production (Aderemi and Alabi 2023). Curcumin, an essential bioactive component, is abundantly inherent in *C. longa* and is responsible for its biological actions (El-Saadony *et al.* 2023). Significant increase in feed intake, weight gain and feed conversion ratio were recorded in broiler chickens receiving 0.9 % of Therapeutic Curcuma powder (Al-Muhammadawi and Jassim Hammoudi 2022). Jasim *et al.* (2024) documented that *C. longa* powder fed at 0.2 % in the diet of laying hens depressed blood lipid profiles. Fuloria *et al.* (2022) showed that *C. longa* is potent in the prevention of peptic ulcer due to the presence of flavonoid and other antioxidants. Due to the highlighted potentials of *C. longa* as a veritable natural antioxidant, it could have the ability to ameliorate the negative effect of MSG on broiler chickens. Therefore, this study investigated the ameliorative potential of *C. longa* rhizome meal on the effects of dietary MSG on growth and health indices of broilers.

Materials and Methods

Preparation of experimental materials: Fresh *C. longa* rhizomes were sourced from Adekunle Ajasin University (Nigeria) Teaching and Research Farm's herbs and spices section. They were cleaned and washed with fresh and cool water at room temperature. They were allowed to drain and then chopped into pieces to facilitate quick air drying for 14 days in a netted screen placed under a shade. The already dried chips were pulverized into powder to make *C. longa* rhizome meal (CLRM) using an electric blender [Bajaj, Model: Bravo Dlx Mixer Grinder (410175)] while MSG was sourced from a reputable store.

Animals and experimental design: A reputable hatchery was identified for supply of 200 Arbor-acre broiler chicks. The experiment was hosted by Adekunle Ajasin University Poultry Research Centre, Nigeria. The approval of the University's Research and Ethics Committee was secured. Chicks divided after weighing in a random manner over 4 experimental diets: Control diet (CON): Basal diet without any supplementation; MSG diet (MSG): Basal diet supplemented with 1.25 g MSG per kg of feed; MSG + Low CLRM diet (MSG-LCLRM): Basal diet containing 1.25 g MSG and 1.25 g CLRM per kg of feed and MSG + High CLRM diet (MSG-HCLRM): Basal diet containing 1.25 g MSG and 2.50 g CLRM per kg of feed in a completely randomized design (CRD). All the four treatment groups were in 5 repetitions; each repetition contains 10 broilers. Chicks received starter diets for first phase (3 weeks) and finisher diets for the second phase (3 weeks) of the study with fresh water *ad-libitum.* The experimental diets were shown in table 1.

Table 1. Gross composition of the basal diet for the experimental broilers

Ingredients (kg)	Starter (1 to 3 weeks)	Finisher (4 to 6 weeks)
Maize	50	56
Wheat offal	5	6
Rice bran	5	3
Soybean meal	30	27
Fish meal	5	3

Ingredients (kg)	Starter (1 to 3 weeks)	Finisher (4 to 6 weeks)
Soy oil	1	1.5
Bone meal	2.5	2
Limestone	0.5	0.5
Lysine	0.25	0.25
Methoinine	0.3	0.25
Salt	0.2	0.25
Vitamin-Mineral Premix	0.25	0.25
Total	**100**	**100**
Calculated Nutrients		
ME (MJ/kg)	12.50	12.79
Crude Protein (%)	22.68	20.4
Fat (%)	5.05	5.36
Calcium (%)	1.48	1.17
Phosphorus (%)	0.69	0.55
Lysine (%)	1.51	1.35
Methionine (%)	0.68	0.58
Crude Fibre (%)	4.40	4.18

Determination of average weight gain and relative growth rate of the broilers: On weekly basis, the average weight gains (AWG) of the broilers were captured by using a sensitive weighing balance. The weekly AWG was determined as the ratio of the addition of the differences in the weights at the beginning and end of each week to the number of live broilers per week as reported by Adebayo *et al.* (2020) and the relative growth rate (RGR) of the broiler was calculated as (Adebayo *et al.* 2020):

$$RGR\ (\%) = \frac{\Delta W \times 100}{½(\sum W)}$$

$$\Delta W = W_2 - W_1$$

$$\sum W = W_2 + W_1$$

W_1- initial live weight of broilers

W_2 - final live weight of broilers

The vitality/viability rate (VR) of the experimental broilers was calculated as 100 - the percentage mortality rate (MR) of the experimental broilers (Araujo *et al.* 2019). The MR was calculated thus:

$$MR(\%) = \frac{I - E}{I} \times 100$$

where:

I - Day 1 (commencement) population of live broilers

E - Day 56 (termination) population of live broilers.

Hence,

$$VR = (100 - MR)\ \%$$

Blood collection: On the experimental termination day, 5 broilers from each replication were isolated and fasted overnight. The broilers were bled from the jugular veins and blood samples collected into both heparinized and plain sample bottles.

Serum biochemical components analyses: The blood samples in the plain bottles were rested for 12 minutes under room atmospheric condition before spinning for ten minutes to harvest clear serum. The centrifuge speed was 3000 rpm. Serum cholesterol (Pesce and Bodourian 1976), electrolytes such as sodium cation (Na^+), potassium cation (K^+) and chloride anion (Cl^-) (Külpmann 1992), antioxidant enzymes activities such as catalase (CAT), superoxide dismutase (SOD), and glutathione peroxidase (GSH-Px) (Munteanu and Apetrei 2021) were all determined from the serum using commercially available assay kits. The serum liver enzymes such as aspartate aminotransferase (AST) and alanine aminotransferase (ALT) blood proteins and metabolites such as globulin (GLB), total protein (TP), albumin (ALB) and creatinine were assess as described by Tietz (1995).

Hematological parameters determination: The % PCV (packed cell volume) and Hb (haemoglobin concentration) were determined by the micro haematocrit and cyanmethaemoglobin methods respectively (Santos *et al.* 2025). Haemocytometer was used in the determination of RBC (red blood cells) and WBC (white blood cell counts) as previously described (Santos *et al.* 2025). The MCV (mean corpuscular volume), MCH (mean corpuscular hemoglobin) and MCHC (mean corpuscular hemoglobin concentration) were derived from the PCV, RBC, and Hb as postulated by Tazawa *et al.* (2011). The leucocyte differentials were also determined.

Statistical analysis: Data collected were subjected to One-Way Analysis of Variance (ANOVA) using SAS (2008). Significant differences between the treatment means were compared using the Honestly Significant Difference (HSD) test of Tukey, of the same software at 5 % level of significance.

Results and Discussion

Growth indices of broilers fed MSG and Curcuma longa rhizome meal: The weekly average weight gain (AWG), relative growth rate (RGR) and vitality rate (VR) of the broilers fed high inclusion of MSG and varying levels of *Curcuma longa* rhizome meal (CLRM) are shown in table 2. There was a statistical ($p<0.05$) improvement in the weekly AWG of broilers that received MSG and the two inclusion levels of CLRM as against the result recorded for broilers on CON. Furthermore, broilers fed MSG-HCLRM had better AWG ($p<0.05$) than their counterpart fed MSG. Though a slight increase in AWG was noted in MSG-LCLRM broilers as against those of MSG, however, this was not substantial ($p>0.05$). The RGR documented for chickens across all the diets were similar ($p>0.05$). There was a clear decrease ($p<0.05$) in the VR of broilers fed MSG as against the values recorded on CON. Furthermore, a non-significant increase was observed in the VR of broilers on MSG-LCLRM when compared with those on MSG. The VRs recorded for broilers on CON and MSG-LCLRM were statistically similar though the value was higher among broilers on CON. However, broilers fed MSG-HCLRM presented higher ($p<0.05$) VR when compared with those on all other diets respectively.

Table 2. Growth indices of broilers fed MSG and *Curcuma longa* rhizome meal

Indicators	CON	MSG	MSG-LCLRM	MSG-HCLRM	±SEM	P-value
AWWG (g)	214^{c}	296^{b}	335^{ab}	355^{a}	23.61	0.04
RGR (%)	194	190	193	194	0.73	1.12
VR (%)	77.8^{b}	44.4^{c}	67.8^{b}	94.4^{a}	9.36	0.01

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly (P<0.05). AWWG: Average Weekly Weight Gain, RGR: Relative Growth Rate, VR: Vitality Rate, Diets: CON (Control/Basal), MSG (Basal+1.25 g MSG/kg diet), MSG-LCLRM (1.25 g MSG + 1.25 g CLRM/kg diet), MSG-HCLRM (1.25 g MSG + 2.50 g CLRM/kg diet)

The significant gains in the weekly AWG recorded among the chickens on diets MSG, MSG-LCLRM and MSG-HCLRM were suggestive of weight gain enhancing ability of MSG in broiler chickens. Some previous studies had equally reported the weight gain enhancement potentials of dietary MSG in of farm animals especially the non-ruminant (Adu *et al.* 2022 and Li *et al.* 2024). The better weight gains observed among the broilers in diets MSG-LCLRM and MSG-HCLRM were indicators of complimentary effects of CLRM in MSG-treated diet. This present study as far as AWG enhancement ability of CLRM is concerned in agreement with some previously documented findings such as Al-Muhammadawi and Jassim Hammoudi (2022) who highlighted the significant feed intake and weight gain enhancement potentials of *C. longa* powder in broiler chickens fed diet containing up to 4 g/kg turmeric powder. Furthermore, Khodadadi *et al.* (2021) also reported that an inclusion of turmeric powder at 5 g/kg diet significantly improved body weight gains of broilers. The bioactive components in turmeric such as curcumin, demethoxycurcumin and bisdemethoxycurcumin have been identified to be responsible for its biological actions (El-Saadony *et al.* 2023). Hence, additions of CLRM at the rate used in this study brought about further enhancements in the weekly AWG and this could be linked with the action of the polyphenolic compounds inherent in CLRM which have played a modulatory role on the gastro intestinal enzymes of the broilers, and therefore, enhanced the digestion, nutrient availability and body weight gain of the broilers on diets containing CLRM.

However, the reduced vitality rate observed among the broilers on diet MSG is an indication of significant increase in the mortality percentage in MSG-treated broilers. This gave credence to previous reports that high inclusion of MSG could confer far reaching negative effects on farm animals such as kidney malfunction, heart problem, decreased spermatogenesis and increased sperm cells abnormalities as well as induction of oxidative stress and ultimately high mortality rate (Olarotimi 2020 and Ruiz-Valderrama *et al.* 2025). However, the elevation in the viability rate observed among broilers fed CLRM which translated to reduction in mortality percentage among the broilers on diets MSG-LCLRM and MSG-HCLRM highlighted the restorative potentials of CLRM on the adverse effects of high inclusion of MSG as a dietary flavour enhancer in broilers' diets. The present study has, therefore, pointed out that the right inclusion rate of CLRM as observed in diets C and D could eliminate negative concerns of using MSG as taste enhancer in non-conventional feed resources, considered not suitable for poultry diets due to their poor palatability, become generally useful and acceptable.

Haematological parameters of broilers fed MSG and Curcuma longa rhizome meal: There were depressions (p<0.05) in the haematological indices such as PCV, RBC and Hb (table 3) in diet MSG broilers as against the diets CON, MSG-LCLRM and MSG-HCLRM respectively. On the other hand, levels of MCV and MCH in diet CON broilers were elevated (p<0.05) while MCHC concentration across all the treatment diets remained unaffected. Among the studied differential white blood cell counts, the lymphocytes, heterophils, eosinophils and basophils in diet MSG broilers were substantially (p<0.05) reduced as against values recorded by broilers on all other experimental diets respectively. However, the monocytes concentrations were not influenced (p>0.05) in diet MSG broilers. Furthermore, all the haematological parameters were influenced in diets MSG-LCLRM and MSG-HCLRM broilers in comparison with diet MSG. In some cases, broilers on diet MSG-HCLRM had better results (RBC, Hb and lymphocytes) than diets CON and MSG-LCLRM respectively.

The main yardstick for the critical diagnosis of illnesses and health management of farm animals are the hematological and biochemical components of blood. The adverse health impacts of high inclusion of MSG were clearly indicated in the present study by the significant depressions recorded in the hematological parameters such as PCV, RBC, Hb, lymphocytes, heterophils, eosinophils and basophils. The reduction in the PCV could be as a result of MSG interference with the physiological processes. This might, however, culminate in cell damage, failure of bone marrow production or loss of blood. From this result, the broilers on diet MSG were anemic due to the reduced mean values of PCV, Hb and RBC recorded. The result of the current study did not vary from previous ones in which anemia and generation of reactive oxygen species were among the recorded negative

Table 3. Hematological indices of broilers fed MSG and *Curcuma longa* rhizome meal

Indicators	CON	MSG	MSG-LCLRM	MSG-HCLRM	±SEM	P-value
PCV (%)	29.20^{b}	20.40^{c}	30.40^{b}	32.40^{ab}	1.48	0.02
RBC (x10^{6} mm^{3})	2.14^{b}	1.24^{c}	2.03^{a}	1.95^{a}	0.09	0.02
MCHC (g/dL)	33.50	33.00	32.80	33.00	1.54	0.01
MCV (fL)	102.00^{b}	137.13^{a}	128.00^{ab}	110.00^{b}	7.45	0.00
MCH (pg)	37.22^{b}	47.71^{a}	36.18^{b}	34.10^{b}	2.48	0.04
Hemoglobin (g/dL)	9.72^{b}	5.12^{c}	10.10^{ab}	12.80^{a}	0.49	0.01
Lymphocytes (%)	28.2^{b}	24.5^{c}	34.6^{a}	34.8^{a}	1.81	0.01
Monocytes (%)	2.03	2.13	2.09	2.16	0.15	0.23
Heterophils (%)	28.30^{b}	21.30^{c}	31.15^{a}	29.30^{ab}	2.37	0.01
Eosinophils (%)	2.83^{a}	2.13^{c}	2.11^{b}	2.93^{a}	0.24	0.02
Basophils (%)	3.12^{a}	2.62^{b}	2.74^{b}	2.96^{a}	0.17	0.01

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly (P<0.05). PCV: Packed Cell Volume, RBC: Red Blood Cells, MCHC: Mean Corpuscular Hemoglobin Counts, MCV: Mean Corpuscular Volume, MCH: Mean Corpuscular Hemaglobin, Diets: CON (Control/Basal), MSG (Basal+1.25 g MSG/kg diet), MSG-LCLRM (1.25 g MSG + 1.25 g CLRM/kg diet), MSG-HCLRM (1.25 g MSG + 2.50 g CLRM/kg diet)

hematological effects of MSG on animals (Thongsepee *et al.* 2022). The functions of the heterophils and basophils in the defense mechanisms against micro-organisms, poisonous matters, and strange substances have been stressed (Poto *et al.* 2023). With the recorded depressions in the differential WBC among broilers on diet MSG, the immune system of the broilers to resist any invasion has been compromised.

In another development, Wistar rats fed high inclusion of MSG was also recorded significant elevations in the heterophil and lymphocyte counts (Ati *et al.* 2025). Furthermore, the case of macrocytic anemia was also noticed due to the elevated MCV and MCH among the broilers on diet MSG. It is evident that MSG in the diet had induced a folic acid deficiency in the broilers. However, restorative trends to normalcy in the negatively affected haematological parameters reported among the broilers on diet MSG were observed among broilers on diets MSG-LCLRM and MSG-HCLRM. This is a clear influence of the inclusion of CLRM in the feed. The authors of the present research could, therefore, infer that CLRM at these inclusions could play a restorative role on the haematological negative effects imposed by the inclusion of high MSG in broiler diets. The current results also gave credence to the findings of Hafez *et al.* (2025) where significant improvements in both red and white blood cells concentrations were recorded for broilers fed 200 mg/kg turmeric meal. Aderemi and Alabi (2023) equally observed that turmeric powder significantly increased the lymphocytes percentage of chickens. The bioactive component, curcumin, in turmeric rhizome has been linked to be responsible for this improvement (Peng *et al.* 2023). This could, therefore, suggests that herbal supplements are a viable solution to the negative effect of MSG in broiler chickens.

Serum biochemical indices of broilers fed MSG and Curcuma longa rhizome meal: In the current study, diet MSG significantly (p<0.05) decreased blood albumin, globulin with total protein levels in broiler chickens compared to those on the control diet (table 4). Conversely, serum creatinine, cholesterol, and aspartate aminotransferase concentrations were significantly (p<0.05) elevated in diet MSG broilers, while alanine aminotransferase concentration remained unaffected (p>0.05). Incorporating various levels of CLRM into MSG-treated diets significantly (p<0.05) increased serum albumin, globulin, and total protein concentrations in broilers on diets MSG-LCLRM and MSG-HCLRM compared to those on diet MSG without CLRM inclusion. Additionally, the increased serum creatinine, cholesterol, and AST concentrations observed in broilers fed 1.25 g MSG/kg diet were significantly (p<0.05) normalized in broilers fed high MSG diets with 1.25 and 2.50 g CLRM/kg inclusion.

Protein synthesis site is the liver. Any adverse effect on this organ will consequently affect the serum protein concentration. Therefore, the significant depressions recorded in the serum protein concentrations among broilers on diet MSG in the current study was suggestive of the negative impact of high inclusion of MSG as used on normal function the liver and protein synthesis. The results of this paper aligned with Abdulghani *et al.* (2022) and Olarotimi and Adu (2022) which reported reductions in the concentrations of blood proteins at high inclusion levels of MSG. The significant reductions observed in the serum proteins among the broilers on diet MSG was indicated an obstructed hepatic function, and essentially, disturbance of protein synthesis in the liver (Banerjee *et al.* 2020). Similarly, hepatic cell damage is also linked to a significant increase in serum enzymes

Table 4. Serum biochemical indices of broilers fed MSG and *Curcuma longa* rhizome meal

Indicators	CON	MSG	MSG-LCLRM	MSG-HCLRM	±SEM	P-value
Total Protein (g/dL)	55.60^{b}	51.59^{c}	59.91^{ab}	63.40^{a}	2.71	0.03
Albumin (g/dL)	13.02^{b}	10.79^{c}	13.30^{b}	14.60^{a}	0.68	0.01
Globulin (g/dL)	42.58^{b}	40.80^{c}	46.61^{a}	48.80^{a}	2.05	0.01
Creatinine (µmol/L)	22.30^{c}	33.90^{a}	27.60^{b}	22.90^{c}	1.83	0.02
Cholesterol (µmol/L)	3.02^{b}	4.90^{a}	3.41^{b}	2.77^{c}	0.16	0.01
Aspartate aminotransferase (IU/L)	121.00^{b}	146.00^{a}	82.80^{c}	116.00^{b}	5.41	0.01
Alanine aminotransferase (IU/L)	78.7	76.3	70.9	82.0	3.56	0.56

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly (P<0.05). Diets: CON (Control/Basal), MSG (Basal+1.25 g MSG/kg diet), MSG-LCLRM (1.25 g MSG + 1.25 g CLRM/kg diet), MSG-HCLRM (1.25 g MSG + 2.50 g CLRM/kg diet).

activities. The significant elevation in the AST concentration among the broilers on diet MSG indicated alterations in liver function (Abo Ghanima *et al.* 2023). The observed significant rise in the serum cholesterol level among the broilers on diet MSG concurred with the report of Moldovan *et al.* (2023). The elevated level of serum cholesterol was a sign of disturbance to cholesterol metabolism and could initiate coronary heart disease in broiler chickens (Kirkpatrick *et al.* 2023). Apart from the serum proteins, the significant elevations in creatinine, cholesterol, and aspartate aminotransferase recorded among the broilers fed diet MSG further strengthened the claim that MSG at the inclusion used in the present study could be detrimental to broiler chickens. One of the indicators used to ascertain the functionality of a healthy kidney is the serum concentration of creatinine. A failure in the ability of the kidney to filter fluid within the body was previously linked with an abnormal serum creatinine elevation (Gounden *et al.* 2022). Abdou *et al.* (2025) also observed and increase blood creatinine concentration of adult rats administered high MSG level. We could possibly infer a high inclusion of MSG as used in this study has the potential to predispose broiler chickens to renal impairment.

However, the restorative impacts of CLRM were noticeable among the broilers on diets MSG-LCLRM and MSG-HCLRM where the protein concentrations were significantly improved as compared with those on diet MSG. In fact, inclusion at 2.50 CLRM g/kg diet enhanced the process protein synthesis in the liver than it was observed in diet CON broilers. The present results gave more credence to Tuong *et al.* (2023) on the ameliorative effects of dietary turmeric powder on serum protein concentrations. Abdou *et al.* (2025), Kunnumakkara *et al.* (2023) as well as Olarotimi and Adu (2022) also previously reported the enhancement effects of turmeric on blood protein profiles. Furthermore, the inclusion levels of CLRM used in the study also reduced the negative effects of high MSG on the serum enzymes and cholesterol content among the broilers on diets MSG-LCLRM and MSG-HCLRM. The curcumin contents in turmeric which are a highly effective polyphenolic compounds are responsible for this. Curcumin is known to be capable of scavenging the MSG-induced free radicals already and shielding the cells from oxidative stress.

Serum antioxidant enzymes and electrolytes of broilers fed MSG and Curcuma longa rhizome meal: Table 5 presents the findings regarding serum antioxidant enzyme activities and electrolyte balance in broilers fed diets with high MSG inclusion, with and without CLRM. Broilers fed diet MSG showed significant ($p<0.05$) reductions in serum antioxidative enzyme activities (catalase, glutathione peroxidase, and superoxide dismutase) compared to those on the control diets. However, the additions of CLRM significantly ($p<0.05$) increased serum concentrations of all antioxidant enzymes compared to broilers on diet MSG. Among broilers on diets MSG-LCLRM and MSG-HCLRM, serum catalase and SOD enzyme concentrations were statistically ($p>0.05$) similar to those on diet MSG-LCLRM, except for GSH-Px, where concentrations on diet MSG-HCLRM were significantly ($p<0.05$) higher. Regarding electrolyte balance, diet MSG significantly ($p<0.05$) elevated serum chloride concentration, while there was no statistical ($p>0.05$) influence on blood Na^{+} and K^{+}. However, diets MSG-LCLRM and MSG-HCLRM significantly ($p<0.05$) decreased the elevated blood Cl^{-} level observed in broilers fed diet MSG.

The significant depressions in the serum anti-oxidant enzymes of the broilers on diet MSG clearly supported the claims that high inclusion of MSG in broiler diet could promote reactive oxygen species production, thereby, subjecting the broilers to oxidative stress. The results of the current research were also in agreement with Olarotimi (2020). The elevated anti-oxidant enzymes diets MSG-LCLRM and MSG-HCLRM further proved the free radicals scavenging ability of turmeric meal at the inclusion used in this study. This result agreed with Peng *et al.* (2021) who reported the anti-oxidant capacity of turmeric powder on serum anti-oxidant enzymes and opined that curcumin could be used as anti-inflammation agent.

Table 5. Antioxidant enzymes and electrolytes balance of broilers fed MSG and *Curcuma longa* rhizome meal

Indicators	CON	MSG	MSG-LCLRM	MSG-HCLRM	±SEM	P-value
Serum Antioxidant Enzymes						
Catalase (mM/mL/min)	12.5^{b}	7.24^{d}	19.57^{a}	20.69^{a}	0.54	0.01
Glutathione peroxidase (µg/g)	220^{b}	125^{c}	225^{b}	365^{a}	11.9	0.01
Superoxide dismutase (%)	67.51^{b}	50.50^{c}	80.22^{a}	86.00^{a}	3.58	0.01
Serum Electrolytes Balance						
Potassium (K^{+}) (mmol/L)	4.59	4.71	4.30	4.87	0.21	0.12
Chloride (Cl^{-}) (mmol/L)	97.20^{bc}	116.00^{a}	106.00^{b}	89.80^{c}	4.59	0.01
Sodium (Na^{+}) (mmol/L)	128	129	120	139	6.03	0.23

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly (P<0.05). Diets: CON (Control/Basal), MSG (Basal+1.25 g MSG/kg diet), MSG-LCLRM (1.25 g MSG + 1.25 g CLRM/kg diet), MSG-HCLRM (1.25 g MSG + 2.50 g CLRM/kg diet).

Furthermore, the elevation in serum Cl^{-} level among the broilers on diet MSG proved that MSG is potent enough to induce hyperchloremia. The outcomes of the present paper differed from Abdou *et al.* (2025) with higher serum potassium, and sodium concentrations reported in MSG-treated rats compared to the controls. In another development, Banerjee *et al.* (2021) recorded raised blood electrolytes in rats fed high MSG. However, the result of the present study was consistent with Macho *et al*. (2000) as well as Moldovan *et al.* (2023) because they opined that MSG does not alter the serum potassium and sodium concentrations. Chloride has been identified as one of the electrolytes used to monitor some health diseases. From this research, it could be said that broilers on MSG diet were greatly exposed to the incidence of an acid or fluid imbalance (metabolic acidosis). Some of the symptoms include: diarrhea, fatigue, weakness, dehydration and trouble breathing which were noted among the broilers on diet MSG. The health benefits of turmeric as an anti-inflammatory, antioxidant and anticancer agent (Shamsi-Goushki *et al.* 2020) were further strengthened with the outcome of this study, which clearly indicated the restorative effects of CLRM on the serum chloride concentrations of the broilers on diets MSG-LCLRM and MSG-HCLRM.

Conclusions

From the present study, we could therefore draw a conclusion that dietary inclusions of MSG with CLRM is a nutritional strategy to enhance feed palatability without compromising the growth and health status of broilers. Diet containing 2.50 g CLRM/kg diet provided better growth and viability rate when fed to animals. Therefore, to safeguard the health and support optimal growth of broilers against free radicals that may be generated by high dietary inclusions of MSG, the supplementation of 2.5 g/kg of *Curcuma longa* rhizome meal is recommended.

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