

Effects of turmeric meal supplementations on performance, carcass traits and meat antioxidant enzymes of broilers fed diets containing monosodium glutamate

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Abstract

The use of monosodium glutamate (MSG) as a potential taste enhancer in poultry nutrition is discouraged due to its perceived adverse effects. Hence, this study evaluated the impacts of turmeric powder (TP) on performance and some meat qualities of chickens fed MSG. Three hundred broilers were divided into four diets: T₁ (control), T₂ (1.25 g MSG/kg), T₃ (1.25 g MSG/kg and 1.25 g TP/kg), and T₄ (1.25 g MSG/kg and 2.50 g TP/kg). Results indicated increased ($P<0.05$) feed intake with a decrease ($P<0.05$) in weight gain resulting in poor feed conversion ratio ($P<0.05$) in T₂. However, inclusions of TP positively enhanced ($P<0.05$) these parameters in T₃ and T₄. Carcass characteristics did not differ significantly ($P>0.05$) between T₁ and T₂ but were improved ($P<0.05$) in T₃ and T₄. Organ weights were higher ($P<0.05$) in T₂ but were restored ($P<0.05$) in T₃ and T₄. While meat CAT and GSH-Px decreased ($P<0.05$), and MDA and cholesterol increased ($P<0.05$) in T₂, significant reversal of these trends was observed in T₃ and T₄. Hence, the inclusion of MSG without TP led to compromised performance, carcass, organ weights, and meat antioxidant enzymes in T₂ while they were ameliorated in T₃ and T₄.

Introduction

Several factors influence the feed consumption of broiler chickens, consequently impacting nutrient intake levels, production efficiency, and the profitability of the enterprise. While various factors affect feed intake, farmers often overlook the role of feed palatability. The palatability of feed largely depends on the ingredients used, with unappealing smells and tastes leading to reduced intake and diminished returns on investment ([Maroof et al., 2017](#)). Moreover, non-conventional feedstuffs, although cheaper and easily accessible, are generally less preferred by chickens ([Ababor et al., 2023](#)).

Factors like spoilage due to the rancidity of fats and oils, sugar molding, and protein putrefaction, commonly

found in long-term stored feed, can also adversely affect feed palatability. Deteriorating feed quality leads to the development of aversive flavors and odors for the birds ([Windisch et al., 2008](#)). To address these challenges and improve productivity, farmers may consider using feed additives like monosodium glutamate (MSG) to enhance feed palatability ([Khalil & Khedr, 2016](#)). MSG is renowned for intensifying the savory flavor of food, as natural glutamate does in various cuisines ([Ikeda, 2002](#)). Several studies have highlighted the positive impact of MSG on feed intake and animal performance. For instance, [Osman & Mohammed \(2021\)](#) observed a statistically significant increase in both feed consumption and body mass gain in broilers when

subjected to 5 g/L concentration of MSG. [Gbore et al. \(2016\)](#) observed that MSG had favorable effects on feed intake, body weight gains, and feed conversion ratio in female rabbits. Similarly, [Rezaei et al. \(2022\)](#) found a significant increase in piglet weight growth when gilts were fed a diet containing 1.15% MSG.

Nevertheless, it has been hypothesised that the overconsumption of MSG in livestock diets may have detrimental impacts on the overall health and welfare of farm animals ([Zanfirescu et al., 2019](#)). According to [Olarotimi \(2020\)](#), it was suggested that the excessive incorporation of MSG at levels exceeding 0.5g/kg in the diet of broilers resulted in the development of oxidative stress and a decline in overall antioxidant capacity. The use of excessive amounts of MSG has been associated with alterations in antioxidant systems and renal indicators, as suggested by [Paul et al. \(2012\)](#). According to [Sharma et al. \(2013\)](#), there was a considerable increase in the serum electrolyte levels of rats that were administered high quantities of MSG, as compared to the control group. According to the findings of [Olarotimi et al. \(2020\)](#), it was observed that the inclusion of MSG at a concentration of 1.00 g/kg diet and higher resulted in a decrease in both daily sperm production and efficiency in cocks. Consequently, the researchers concluded that a high level of MSG in the diets of male chickens has the potential to considerably diminish their reproductive capabilities.

To counteract the potential negative effects of MSG, incorporating antioxidants as feed additives has emerged as a promising strategy. The use of organic antioxidants, particularly phyto-additives like turmeric (*Curcuma longa*), has gained significant research attention ([Kermanshahi & Riasi, 2006](#); [Olarotimi, 2018](#)). Turmeric has been recognized for its various properties, including being an antimicrobial, anti-inflammatory, and antioxidant agent. It contains essential minerals and antioxidants, which contribute to its potential as a beneficial feed additive for broiler chickens ([Adegoke et al., 2018](#); [Youssef et al., 2014](#)). Thus, the aim of this study was to evaluate the effects of incorporating turmeric meals in the diets of broiler chickens fed high dietary MSG, focusing on their performance and meat antioxidative enzymes.

Materials and Methods

Experimental Materials, Site, Design and Animals

Turmeric powder was obtained by first sourcing fresh turmeric rhizomes from the local market, and they were thoroughly washed with clean water to remove any extraneous materials and then drained. Thereafter, the rhizomes were grated and air-dried under a shade for a week. After they were thoroughly dried, they were milled to produce turmeric powder (TP). The MSG used was procured from the nearest departmental store. The study was conducted at the Poultry Unit, Teaching and Research Farm of Adekunle Ajasin University, Akungba Akoko, Nigeria, after obtaining approval from the

University's Research and Ethics Committee for the ethical use and care of animals. Ethics Reference No: AAUA/FA/ANS/014/2024. Three hundred (300) day-old, mixed sex Arbor-acre broiler chicks were purchased from a dependable hatchery. Their weights were captured and documented before they were randomly assigned to four treatment groups labeled as T1, T2, T3, and T4. These groups received diets containing different quantities of MSG and TP per kilogram of food: (0.00 g MSG and TP), (1.25 g MSG), (1.25 g MSG and 1.25 g TP), and (1.25 g MSG and 2.50 g TP) respectively. Each of the four treatment groups was replicated five times, with each replication consisting of 15 birds. Throughout the six-week experiment, the chicks were provided with starter and finisher diets (Table 1) and had unrestricted access to fresh water for the whole experimental weeks.

Experimental Data Collection

The body weight gain (BWG) and feed intake (FI) were documented on a weekly basis. The weekly feed conversion ratio (FCR) was estimated as follows:

$$FCR = FI/BWG$$

At the end of the feeding trial, 25 birds per treatment (5 birds per replicate) were selected randomly and humanely sacrificed. The weights of the eviscerated organs such as the lungs, gizzard, heart, kidneys, and liver were captured and recorded using a sensitive laboratory weighing balance. The dressing percentage as the percentage ratio of the live weight to that of the dressed weight of the birds determined. The intestinal microflora population was determined according to [Engberg et al. \(2004\)](#) and [Tsiouris et al. \(2020\)](#). Briefly, the intestinal contents were extracted into a sterile 15-mL container and subsequently homogenized in 9 mL of sterile PBS (Phosphate Buffered Solution). Serial tenfold dilutions ranging from 10^3 to 10^7 were then prepared. Lactobacilli enumeration was conducted using De Man–Rogosa–Sharpe (MRS) agar, with plates incubated anaerobically at 37 °C for 48 h to calculate lactic acid bacteria counts. Total anaerobic bacteria were enumerated using Plate Count Agar (PCA) and anaerobic incubation at 37 °C for 48 h, with anaerobiosis achieved by placing the inoculated plates in a jar. The anaerobic environment was generated using Anaerocult® and confirmed using Anaerotest®. Lactose-negative bacteria were counted on MacConkey agar, with colonies appearing as red and colorless after aerobic incubation at 38°C for 24 h. Furthermore, breast meats were sampled after dressing and evisceration to determine the antioxidant enzymes of the meat. The meat catalase, glutathione peroxidase, and cholesterol activities were determined as described by [Farman & Hadwan \(2021\)](#) and reported by [Olarotimi et al. \(2022\)](#). Briefly, the samples were packaged aerobically in oxygen-permeable bags and stored in a freezer at -18°C for a duration of 20 days. Subsequently, the extent of lipid oxidation in the meat was assessed using the thiobarbituric acid (TBA) assay method. Catalase activity in the meat was determined by monitoring the

reduction in absorbance at 240 nm, indicative of hydrogen peroxide (H₂O₂) consumption. Glutathione peroxidase activity was determined by spectrophotometric monitoring of NADPH⁺ oxidation at a wavelength of 340 nm. The total cholesterol concentration of the meat was determined by colorimetric method and the values were read at the absorbance of 550 nm.

Statistical analysis

Data collected were subjected to One-Way Analysis of Variance (ANOVA) using SAS (2008, software version 9.2). Significant differences between the treatment means were compared using Tukey's Honestly Significant Difference (HSD) option of the same software at 5% level of significance.

Results and Discussion

Performance of broilers fed diets containing Monosodium Glutamate and turmeric powder

The outcomes from the evaluation of broilers that were provided with diets containing varying amounts of MSG and TP are shown in Table 2. Throughout the trial stages, notable decreases ($P < 0.05$) were observed in the body weight gains (BWG) of the birds on T₂ compared to those on the control diet (T₁). Conversely, the inclusion of 1.25 and 2.5 g TP/kg diet led to significant ($P < 0.05$) improvements in the BWG during both experimental phases and overall, in contrast to the broilers on T₁ and T₂. Notably, the birds on a diet T₄ exhibited the most favorable BWG. Similarly, the starter, finisher, and overall total feed intake (TFI) among the birds fed with 1.25 g MSG/kg diet alone (T₂) were significantly ($P < 0.05$) higher than the TFI recorded among the birds on the control diet. Conversely, the TFI observed among birds fed diets with varying amounts of TP were significantly ($P < 0.05$) lower than those on T₂. Birds on diet T₄ demonstrated lower TFI compared to those on T₃, although the difference was not statistically significant ($P > 0.05$). However, both diets T₃ and T₄ displayed significantly ($P < 0.05$) higher TFI when compared to the control diet.

Regarding the feed conversion ratio (FCR), broilers on diet T₂ showed the least significant ($P < 0.05$) values as against the FCR by birds on diets T₁, T₃ and T₄ respectively at the starter and finisher phases as well as the overall. The FCR values among the birds on diets T₃ and T₄ were statistically similar ($P > 0.05$) to those of the control diet during both the starter and finisher phases of the experiment. However, the FCR recorded among the birds on diet T₃ during the overall phase was significantly higher ($P < 0.05$) than the values obtained for the birds fed diet T₄ and the control diet.

Performance metrics, including BWG, TFI, and FCR, are commonly employed to assess the effectiveness and profitability of poultry farming. The noticeable increase in TFI among the birds fed MSG during all experimental stages suggested that the incorporation of MSG up to

1.25 g/kg in broiler diets, as implemented in this study, is an effective nutritional tactic for enhancing the taste of poultry feed. This finding further corroborated earlier research, which consistently highlighted the positive effects of MSG on the FI and BWG of livestock ([Gbore et al., 2016](#); [Olarotimi & Adu, 2022](#); [Osman & Mohammed, 2021](#); [Zhelyazkov, 2018](#)).

However, despite the increased TFI recorded in this study, the significant decrease observed in the BWG among the broilers on diet T₂ suggested that a high MSG inclusion in broiler diets might impede BWG. This is in line with the assertions of [Kondoh & Toril \(2008\)](#) that a high MSG inclusion rate in diets could induce stress, leading to heightened energy expenditure and subsequently reduced BWG in animals. Similarly, [Yamazaki et al. \(2011\)](#) observed diminished body weight in rats fed a high MSG diet, despite an increase in FI, attributing it to reduced growth and sex hormone activity or decreased fat content and deposition.

Furthermore, the inclusion of 1.25 and 2.50 g TP/kg diet proved to be effective in enhancing the BWG of broilers on diets T₃ and T₄, with a corresponding reduction in TFI compared to birds on diet T₂. Additionally, the FCR of birds on diets containing TP was better than those of birds fed a diet without TP. The positive impact of TP on broilers fed a high MSG inclusion could be attributed to its rich reservoir of bioactive compounds. Previous studies reported improved growth performance in broiler chickens fed a diet with 0.2 g/kg TP ([Rajput et al., 2013](#)). [Kafi et al. \(2017\)](#) also documented improved BWG, FI, and FCR in broilers supplemented with 0.75% turmeric. The results aligned with [Durrani et al. \(2006\)](#), who noted increased BWG and FCR with a significant reduction in FI in broilers fed 0.5% TP.

The significant enhancement in body weight observed throughout all experimental stages at the TP inclusion levels utilized in our study may be attributed to the antioxidant activity of turmeric, capable of stimulating protein synthesis by the animal's enzymatic system. The substantial reduction in FI among broilers fed MSG with TP, compared to those fed only MSG, concurred with [Emadi & Kermanshahi \(2007\)](#), who reported a significant reduction effect of turmeric on FI alongside corresponding BWG. Earlier reports also documented the best FCR among birds fed TP ([Durrani et al., 2006](#), [Raghdad & Al-Jaleel 2012](#)), attributing this to the enhanced dietary efficiency among broilers fed TP at the levels used in this study.

Carcass traits, relative organ weights and intestinal microflora of broilers fed MSG and TP

The data on carcass attributes, relative organ weights, and intestinal microflora of the birds fed MSG alongside varying amounts of TP are presented in Table 3. The results of the current study indicated no significant difference ($P > 0.05$) in the final live weights (FLW), dressed weights (DW), and dressed percentages (DP) of the birds on both T₁ and T₂. Nevertheless,

significant ($P < 0.05$) increases were noted in FLW, DW, and DP among the birds on diets T_3 and T_4 compared to birds on both T_1 and T_2 , with T_4 showing the most significant increase. The relative weights of the hearts, livers, bile, and lungs of the birds on T_2 were found to be notably ($P > 0.05$) higher than those recorded among the control birds, as well as T_3 and T_4 when compared. The gizzard, proventriculus, and spleen as well as intestinal microflora of the birds across all treatments were not significantly affected ($P > 0.05$).

The absence of significant differences recorded for FLW, DW, and DP among broilers fed diet T_2 indicated that the inclusion of MSG at 1.25 g/kg diet did not enhance the carcass characteristics of broiler chickens. Increased carcass breast meat quantity and decreased abdominal fat are among the critical factors used to assess the profitability of broiler production ([Adetunji et al., 2019](#)). However, the fortification of these MSG-treated diets with 1.25 and 2.5 g TP/kg diet demonstrated the potential of TP in enhancing the overall meat quality of broiler chickens, countering the limiting effects of MSG on carcass and meat quality. The significant increases observed in the FLW, DW, and DP was evidence of the positive effects of turmeric powder on enhancing carcass traits. Our findings were in complete agreement with the findings of [Raghdad & Al-Jaleel \(2012\)](#), who reported a substantial increase in the dressing yield of chickens fed diets supplemented with turmeric.

The observed elevation in the relative organ weights of the heart, lungs, liver, and bile among the broilers fed a diet containing 1.25 g MSG/kg diet indicated the hypertrophic effects of high MSG inclusion in broiler diets on the vital organs of broiler chickens, which could potentially lead to serious health challenges for the animals. For instance, the hypertrophy of the heart signifies an increased thickness of the heart muscle, which typically predisposes affected animals to cardiovascular damage. [El Malik & Sabahelkhier \(2019\)](#) and [Okon et al. \(2013\)](#) previously reported a significant increase in the tissue weight of the heart in rats fed elevated levels of MSG. Additionally, the hepatotoxic effects of MSG have been previously emphasized ([Dharita et al., 2023](#)). The enlarged liver and bile weights observed among broilers fed a diet containing 1.25 g MSG/kg diet confirmed the hepatotoxic potential of MSG, particularly when administered at high levels and for an extended duration. [Banerjee et al. \(2021\)](#) explained that liver hypertrophy occurs due to the dilatation of the central hepatic vein with lysed erythrocytes and distorted hepatocytes, caused by impaired membrane permeability resulting from high MSG inclusion.

However, the ameliorative effects of TP at the two inclusion levels used in the present study were clearly evident. The antioxidant and anti-inflammatory properties of turmeric may have been responsible for the significant reduction in the weights of the lungs, heart, liver, and bile among broilers on diets T_3 and T_4 ,

making them comparable to the values recorded for broilers on the control diet. The decreased lung, liver, and heart relative weights of birds fed TP indicated the nephroprotective, hepatoprotective, and anti-inflammatory properties of TP, demonstrating its restorative effects when used as dietary supplements in broilers fed diets containing MSG for improved palatability. MSG has been proven to generate reactive oxygen species (ROS), causing oxidative stress ([Olarotmi, 2020](#), [Olarotimi & Adu, 2022](#)). Turmeric, on the other hand, is a known phyto-additive that contains natural antioxidants ([Olarotimi, 2018](#)). It is capable of scavenging the ROS generated by high MSG inclusion, thus safeguarding the vital organs of the body against oxidative stress. Since the dietary incorporation of phytochemicals in broiler diets has been reported to reduce cholesterol levels in meat and liver ([Oloruntola et al., 2018](#)), the reduced cholesterol concentration in the liver of the broilers on diets T_3 and T_4 in this study may explain the lower weights of the liver compared to the liver weights of birds on diet T_2 . Consumers of meat from broilers fed TP would also benefit from its anti-cholesterolemic effects, resulting in the production of leaner meat and potentially protecting humans from the risks of hypercholesterolemia, atherosclerosis, and coronary heart diseases ([Shen et al., 2019](#)). The proper functioning of the gastrointestinal tract (GIT) and the composition of the gut microbial population are crucial for effective nutrient absorption, immune system development, and resilience against diseases in chickens. Changes in the composition of the GIT microbial community can negatively impact feed efficiency, productivity, and overall health outcomes for poultry ([Shang et al., 2018](#)). From this study, the gut integrity of the broilers was maintained, as the inclusions of MSG and TP did not individually or synergistically alter the intestinal microflora counts of the birds. The role of non-pathogenic intestinal bacteria in inhibiting pathogen proliferation, enhancing growth performance, and reducing morbidity and mortality in poultry cannot be overstated ([Abd El-Hack et al., 2022](#)).

Meat antioxidant status and cholesterol of broilers fed MSG and turmeric powder

Figures 1 to 4 depict the meat antioxidant enzymes and cholesterol levels of broilers fed diets with a high inclusion of MSG, both with and without the addition of turmeric powder. The current study revealed that the meat catalase (CAT) (Figure 1) and glutathione peroxidase (GSH-Px) (Figure 2) activities in the meat from broilers fed T_2 were significantly ($P < 0.05$) reduced compared to the values recorded among the control birds for the same parameters. However, the inclusion of both 1.25 and 2.50 g TP/kg diet significantly ($P < 0.05$) increased the antioxidant enzyme activities of the meat among broilers on diets T_3 and T_4 , respectively, when compared with birds on T_2 , with significantly higher values recorded among the broilers on diet T_4 for both parameters. Furthermore, the concentrations of meat

malondialdehyde (MDA) (Figure 3), and cholesterol (Figure 4) were found to be significantly ($P<0.05$) higher among the broilers on diet T₂ compared to birds from other diets, respectively. Although the inclusion of 1.25 g TP/kg diet significantly reduced the values of these parameters among broilers on T₃, it still remained higher ($P<0.05$) than the values recorded among the birds on the control diet for the same parameters. Notably, doubling the inclusion of TP in diet T₄ significantly ($P<0.05$) further decreased the meat MDA and cholesterol concentrations to a level comparable ($P>0.05$) with the values recorded on the control diet.

It is evident that the inclusion of MSG at 1.25 g/kg diet in broilers' diet compromised the oxidative stability of the meat as well as its cholesterol concentrations. The meat CAT and GSH-Px were noticeably depressed among the broilers fed diet T₂, while the MDA and meat cholesterol were significantly elevated. The primary function of antioxidative enzymes in meat is to preserve it against oxidative decomposition (Gbore et al., 2021). Cellular damage controlled by the absorption of superoxide and hydrogen peroxide occurs in meat whenever there is a reduction in the activities of antioxidative enzymes and an increase in MDA and meat cholesterol. This study suggests that the high inclusion of MSG promotes higher meat lipid peroxidation and cholesterol deposition due to the significantly higher meat MDA and cholesterol concentrations observed among broilers fed diet containing MSG. Adetunji et al. (2019) previously proposed that the inclusion of MSG up to 1.00 g/kg in broiler diets did not compromise meat quality parameters such MDA and antioxidative enzymes. The lipid peroxidation and antioxidant capacity of meat are typically indirectly linked (Gbore et al., 2021), highlighting the reason for an increase in lipid peroxidation of the breast meat in response to reduced antioxidative enzyme activities among the broilers fed MSG. Consequently, this implies a deterioration in meat quality among the birds fed MSG, posing significant health risks to humans as lipid peroxidation favors implies morbidity (Gbore et al., 2021).

Noteworthy is the ameliorative role of the inclusion of TP at 1.25 and 2.5 g/kg diet in this study, clearly restoring the quality of the meat from the broilers, as observed among the birds fed diets T₃ and T₄, respectively. The restorative effect of TP observed on meat antioxidative enzymes of broilers fed diets T₃ and T₄ suggests that turmeric has a complementary effect on the concentrations of catalase and glutathione peroxidase, resulting in improved meat antioxidant status of the birds. From this study, it can be deduced that the ameliorative effects of turmeric are quantity-dependent, as better enhancement of the meat antioxidant enzymes was recorded among the broilers on diet T₄. The results also confirmed the cholesterolemic potentials of MSG as well as the anticholesterolemic effects of turmeric. The presence of curcumins in turmeric is responsible for its antioxidant activities and its capability to stimulate superoxide

dismutase, catalase, and glutathione peroxidase activities, as well as its anticholesterolemic property (Olarotimi, 2018). Earlier studies have also reported the tendency of phytochemicals to mitigate meat lipid peroxidation (Gbore et al., 2021; Oloruntola et al., 2018). The apparent reduction in meat cholesterol concentration in response to an increasing level of TP further strengthens the anticholesterolemic effects of turmeric.

Overall, incorporating MSG at 1.25 g/kg diet in broilers' diets enhanced feed palatability, resulting in increased feed intake but without corresponding body weight gain and improvement in feed conversion ratio. There was no enhancement in the dressed weight and dressed weight percentage of the broilers. Furthermore, the inclusion of MSG appeared to potentially compromise the integrity of internal organs, including the heart, lungs, liver and bile. The study also indicated a significant reduction in meat catalase and glutathione peroxidase levels, accompanied by notable increases in lipid peroxidation and cholesterol. However, the incorporation of TP at 1.25 and 2.5 g/kg diet played a restorative role by enhancing the performance and carcass traits, along with the enhancement of the antioxidative enzymes of the meat.

Conclusion

In conclusion, the findings of this study shed light on the effects of incorporating MSG and TP in broiler diets. While MSG at 1.25 g/kg diet enhanced feed palatability, it did not translate into improvements in body weight gain or feed conversion ratio. Moreover, it appeared to have adverse effects on the integrity of internal organs and meat quality parameters. Conversely, the inclusion of TP at 1.25 and 2.5 g/kg diet showed promising results, enhancing performance, carcass traits, and antioxidative enzymes in meat. Of particular note, diets containing 2.50 g/kg TP demonstrated the most favorable outcomes. Based on these findings, it is recommended to feed broilers with a diet containing 1.25 g/kg MSG alongside 2.50 g/kg TP inclusion to optimize broiler production.

Ethical Statement

The entire procedure complied with the guidelines for the Care and Use of Laboratory Animals, and the experimental protocol was approved by institution's Animal Research Ethics Committee. Ethics Reference No: AAUA/FA/ANS/4759/2023.

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

Ingredients(kg)	Starter (1 to 3 weeks)	Finisher (4 to 6 weeks)
Maize	47	57
Corn bran	10	10
Rice bran	5	5
Soybean meal	15	15
Groundnut cake	15	5
Fish meal	5	5
Bone meal	1.2	1.1
Limestone	0.8	1.1
Lysine	0.3	0.2
Methionine	0.25	0.15
Salt	0.2	0.2
Vitamin-Mineral Premix	0.25	0.25
Total	100	100
Calculated Nutrients		
ME (Kcal/Kg)	2975.04	3054.24
Crude Protein (%)	23.01	19.31
Fat	5.34	5.16
Calcium (%)	1.1	1.15
Phosphorus (%)	0.49	0.46
Lysine (%)	1.35	1.12
Methionine (%)	0.62	0.49
Crude Fibre (%)	4.17	3.94

Table 2. Performance of Broilers Fed Diets Containing MSG and Turmeric Powder

Parameters	T ₁	T ₂	T ₃	T ₄	SEM	P-value
Starter Phase (1 to 21 days)						
Initial Body Weight (g/bird)	35.00	34.20	33.60	33.20	0.54	0.31
Body Weight Gain (g/bird)	650 ^b	619 ^c	668 ^a	673 ^a	38.7	0.02
Feed Intake (g/bird)	1510 ^c	1830 ^a	1620 ^b	1550 ^b	58.7	0.02
Feed Conversion Ratio	2.32 ^b	2.96 ^a	2.43 ^b	2.30 ^b	0.16	0.01
Finisher Phase (22 to 42 days)						
Body Weight Gain (g/bird)	1510 ^b	1480 ^c	1640 ^a	1670 ^a	111	0.03
Total Feed Intake (g/bird)	3220 ^c	3670 ^a	3580 ^b	3540 ^b	180	0.01
Feed Conversion Ratio	2.13 ^b	2.48 ^a	2.18 ^b	2.12 ^b	0.19	0.01
Overall (1 to 42 days)						
Body Weight Gain (g/bird)	2160 ^c	2099 ^d	2308 ^b	2343 ^a	106	0.01
Total Feed Intake (g/bird)	4730 ^d	5500 ^a	5200 ^b	5090 ^c	189	0.02
Feed Conversion Ratio	2.19 ^c	2.62 ^a	2.25 ^b	2.17 ^c	0.12	0.01

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly ($P < 0.05$). Diets: T₁ (control), T₂ (1.25 g MSG/kg), T₃ (1.25 g MSG/kg and 1.25 g TP/kg), and T₄ (1.25 g MSG/kg and 2.50 g TP/kg).

Table 3. Carcass Traits, Relative Organ Weights and Intestinal Microflora of Broilers Fed MSG and Turmeric Powder

Parameters	T ₁	T ₂	T ₃	T ₄	SEM	P-value
Carcass Characteristics						
Final Live Weight (g/bird)	2195.00 ^b	2133.30 ^b	2341.60 ^a	2376.2 ^a	122	0.01
Dressed Weight (g/bird)	1950 ^c	1907 ^c	2150 ^b	2200 ^a	109	0.01
Dressed Percentage (%)	88.84 ^b	89.39 ^b	91.82 ^a	92.58 ^a	4.18	0.02
Relative Organ Weights						
Heart	2.39 ^b	3.93 ^a	2.51 ^b	2.22 ^b	0.18	0.01
Liver and Bile	11.30 ^b	17.00 ^a	11.90 ^b	11.10 ^b	0.71	0.01
Gizzard and Proventriculus	16.80	16.70	16.57	16.30	0.83	0.11
Lungs	4.16 ^{ab}	4.54 ^a	3.70 ^b	4.11 ^{ab}	0.20	0.01
Spleen	0.87	0.76	0.78	0.76	0.03	0.34
Intestinal Microflora						
Aerobic Bacteria	7.57	7.78	7.30	7.74	0.37	0.28
Lactobacillus	7.44	7.59	7.56	8.37	0.37	0.13
Lactose Negative	6.90	6.39	6.87	7.30	0.23	0.30

Values are means and SEM (Standard Error of Means). Means in a row without a common superscript letter differ significantly ($P < 0.05$). Diets: T₁ (control), T₂ (1.25 g MSG/kg), T₃ (1.25 g MSG/kg and 1.25 g TP/kg), and T₄ (1.25 g MSG/kg and 2.50 g TP/kg).

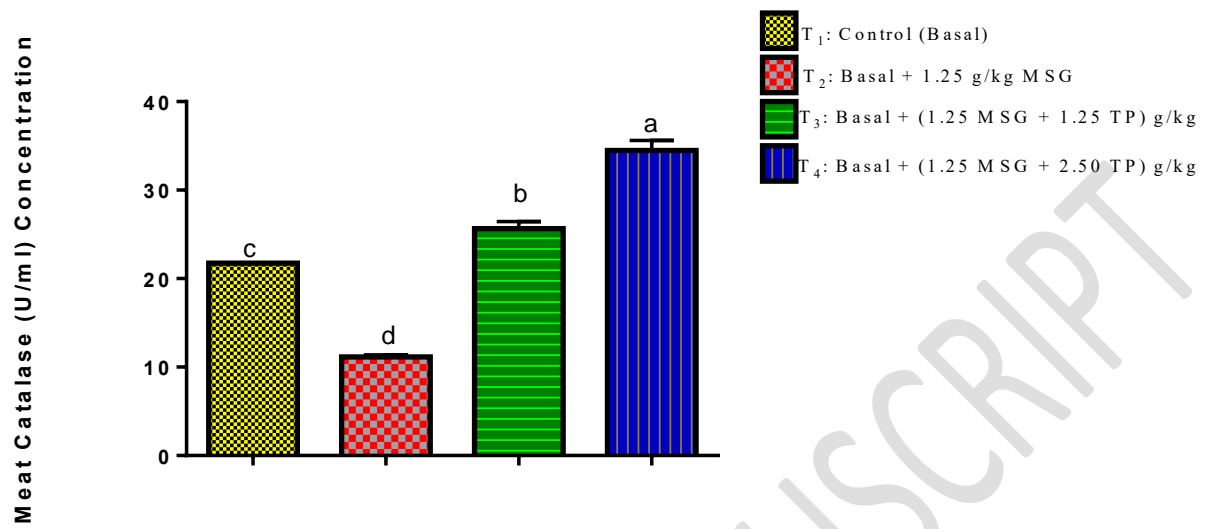


Figure 1. Meat catalase of broilers fed MSG and turmeric powder.

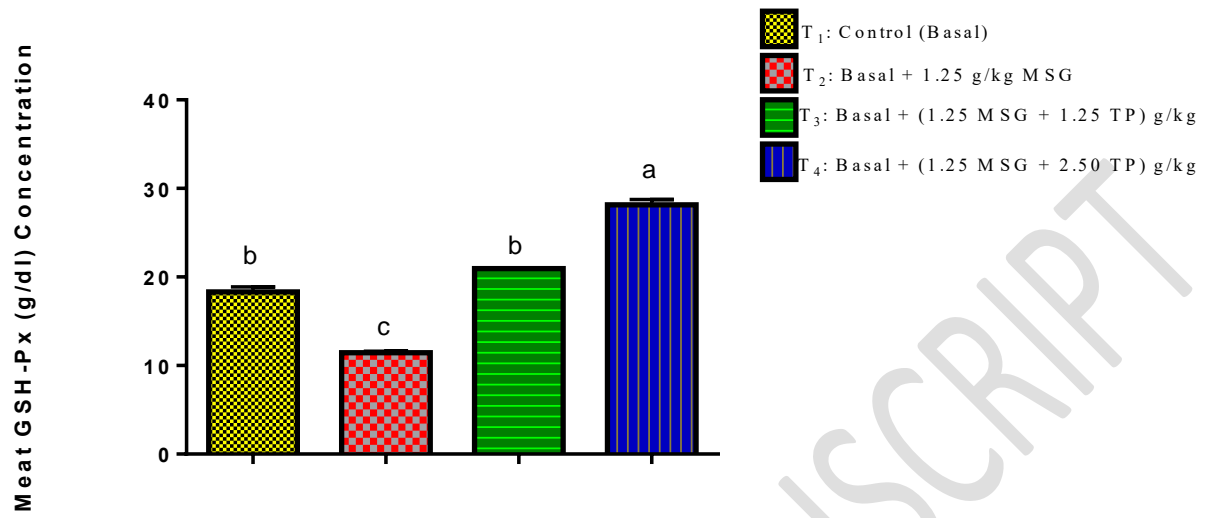


Figure 2. Meat glutathione peroxidase of broilers fed MSG and turmeric powder.

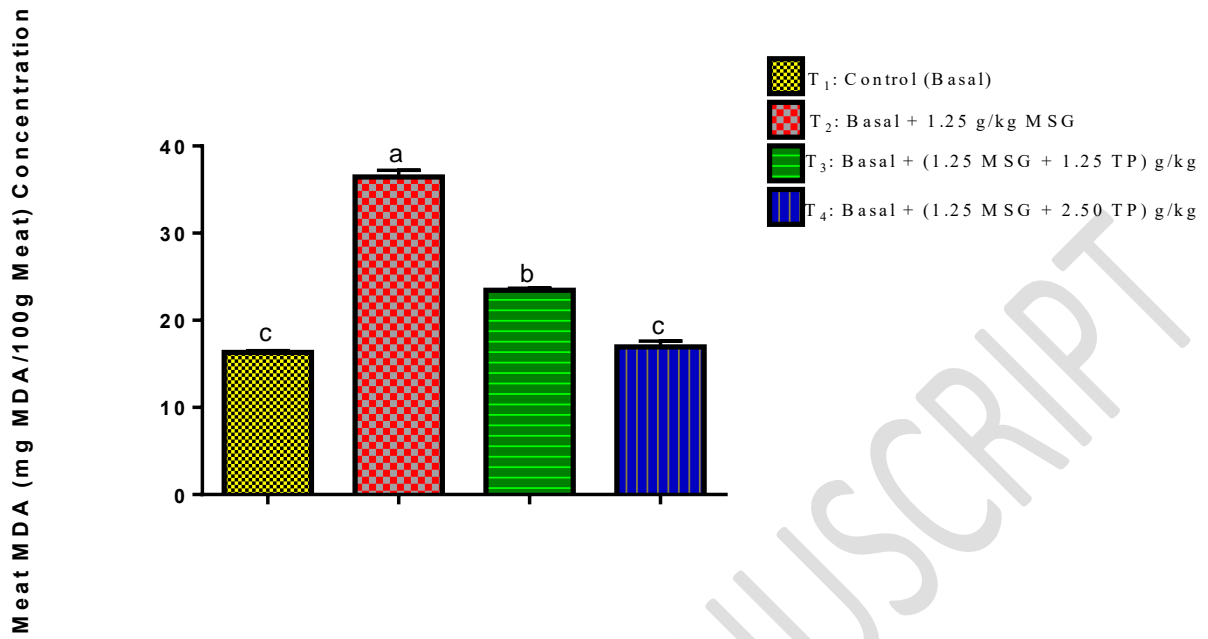


Figure 3. Meat malondialdehyde of broilers fed MSG and turmeric powder.

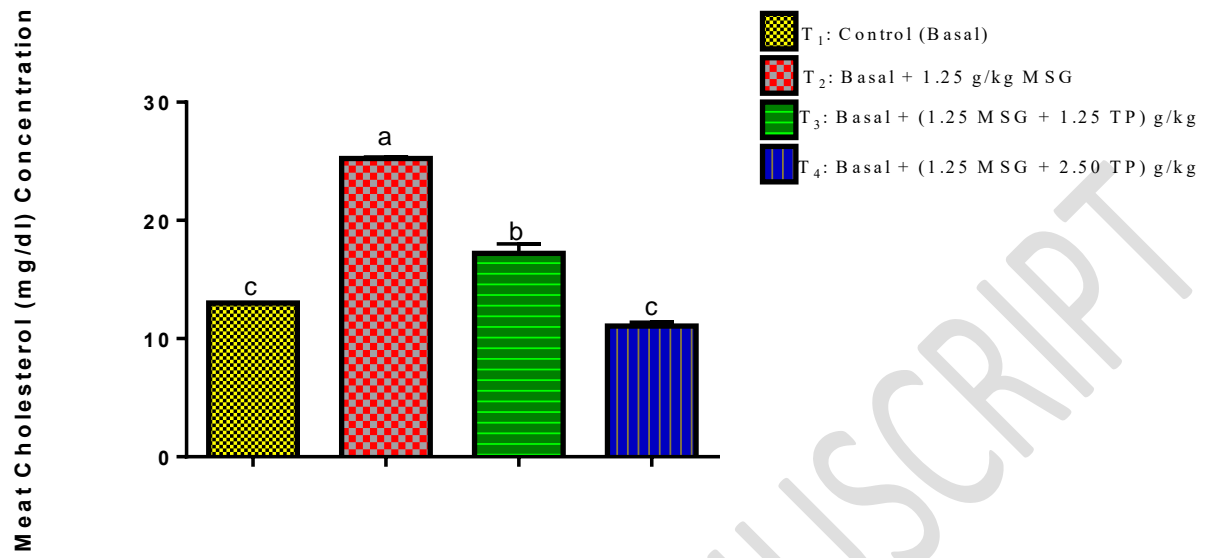


Figure 4. Meat cholesterol of broilers fed MSG and turmeric powder.